Dissertation Ref. No__________

EVALUATION OF DORPER SHEEP UNDER VILLAGE AND ON-STATION MANAGEMENT SYSTEMS IN ETHIOPIA

Ph.D. Dissertation

by
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College of Veterinary Medicine and Agriculture
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Ph.D. Program in Animal Production

August 2024
Bishoftu, Ethiopia

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EVALUATION OF DORPER SHEEP UNDER VILLAGE AND ON-STATION MANAGEMENT SYSTEMS IN ETHIOPIA

A dissertation submitted to the College of Veterinary Medicine and Agriculture, Addis Ababa University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Production

By

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August 2024
Bishoftu, Ethiopia

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Approval sheet

We, the members of the Examining Board of the final Ph.D. open defense have read and evaluated the dissertation prepared by Ayele Abebe Abiebie titled: **Evaluation of Dorper Sheep under Village and On-Station Management Systems in Ethiopia**, and recommend that as a partial fulfillment of the dissertation requirement for the degree of Philosophy in Animal Production.

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Statement of the author

I hereby declare that this dissertation represents my original and authentic work, and I have appropriately acknowledged all sources of materials used in its preparation. The submission of this dissertation fulfills the requirements for the attainment of a Ph.D. Degree at Addis Ababa University, College of Veterinary Medicine and Agriculture. It has been duly deposited at the University's Library, in accordance with the Library's regulations, to make it accessible to borrowers. I solemnly declare that this dissertation has not been previously presented, in whole or in part, to any other educational institution, with the intention of obtaining any academic degree, diploma, or certificate.

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Date of Submission: _____________*Aug. 16, 2024*____________________

`

Dedication

In profound honor and heartfelt remembrance, I dedicate this dissertation to my beloved wife, *Emebet Jemaneh*, whose enduring love, support, and encouragement have been the guiding light throughout my academic journey. To my sons, *Yemichael Ayele*, *Dagmawi Ayele*, and *Atnateyos Ayele,* you are the source of my inspiration, and the driving force behind my pursuit of knowledge. To *Leyouwork Tesfaye*, my dear daughter, your firm belief in my abilities has been instrumental in my success.

In loving memory, I pay tribute to my late parents, *Abebe Abiebie* and *Felekech Mitike*, who instilled in me the values of perseverance and determination. Though they are no longer with us, their persistent support, and sacrifices continue to shape my path.

To my sisters, *Alemnesh Abebe* and *Hiwot Abebe*, your reliable love and encouragement have been a constant source of strength. Your presence in my life has been a blessing beyond measure.

In gratitude to all those who have played a significant role in my academic journey, I extend my deepest appreciation. Your guidance, mentor-ship, and friendship have been invaluable, and I am forever grateful for your contributions.

While I received blessings beyond my wildest expectations, there are no words to express my gratitude and reverence for Saint Mary. Let this dissertation serve as a profound acknowledgment of the combined endeavors and steadfast encouragement provided by my cherished ones, both in the past and the present. I wholeheartedly dedicate this accomplishment to their memory, aspiring for it to be a heartfelt tribute, commemorating their everlasting impact on my journey.

`

Acknowledgement

Completing this work would not have been possible without the contribution of numerous institutions and individuals, to whom I am deeply grateful. I extend my sincere appreciation to the Debre-Birhan, Werer, Fafen, Yabello, Sirinka, and Areka Research Centers, as well as Haromaya and Hawassa Universities. I am also indebted to the Debre-Birhan and Amed-Guya Sheep Breeding and Multiplication Centers, the Ethiopian Dairy and Meat Technology Institute, ICARDA, Addis Ababa University and ESGPIP (Ethiopia Sheep and Goat Productivity Improvement Program). I am grateful for their support, including financial assistance and granting access to data and pertinent information regarding Dorper sheep. There are no words sufficient to express my gratitude to the farmers involved in the Dorper crossbreeding task, including enumerators and the extension workers.

I would like to express my profound gratitude to Professor Gebeyehu G., Dr. Gebreyohannes B., Dr. Solomon G., Dr. Tesfaye G., and Dr. Aynalem H. for their invaluable advice and the time they dedicated to critically supervise me and reading earlier versions of this dissertation and guiding the work. I am also thankful to Mr. Tesfaye Z., Mr. Kefyalew T., Mr. Asfaw B., Mr. Wondimagegn, Mr. Tadios, Mr. Shanbel, Mr. Leulseged, Mr. Amin M., Mr. Kebede H., Mr. Tsegaye G., Mr. Kenzemed K., Mr. Alemayehu H/M, Mr. Derbew B., Dr. Tefera M., W/rt Genet T., Dr. Fekede F., Dr. Solomon A., Dr. Abiyu T., Mr. Matios, Mr. Tamirat, Dr. Dereje, Mr. Hassen, Mr. Zeleke, Dr. Belay, Dr. Wondesen, W/ro Fitsum A., Dr. Haile, Mr. Nigatu, Dr. Berhe, Mr. Tedy, Mr. Dagne M., W/rt Hayat, Mr. Yasin, W/ro Worknesh, Mr. Anuar, Teacher Girma, Mr, Kura, Zelalem ("*Tele*"), Mr. Getu ("*Tele*"), Mr.Asefa, Dr. Fikru R., Mr. Yohannes M., W/ro Tsedale, Mr. Bedhasa and many others whose names I regrettably cannot mention. Their encouragement and unwavering support have been instrumental in the realization of this Ph.D. work.

My family holds a special place in my heart, and I am forever grateful for their continued support and prayers. My parents, in particular, have been instrumental in my career development, instilling in me the joy of intellectual pursuit. I extend my recognition to W/ro Kidan, Mr. Ameha, Mr. Netsanet, Tsegaab, Kaleab, Mena, W/ro Abaye, Mr. Endale, Mr. Tadesse, Mr. Alemzewed J., Mr, Naol M., Mr. Abreham, all those who have provided me with unimaginable support throughout this journey, even if their names may have slipped my mind.

I am deeply grateful to everyone who has contributed to this research endeavor, directly or indirectly. Your support, guidance, and encouragement have been invaluable, and I am honored to have had the opportunity to work with such exceptional individuals and institutions.

`

Biographical sketch

The author of this dissertation, born in October 1975 in Arsi, has extensive knowledge and experience in Animal production studies. He demonstrated exceptional dedication and enthusiasm for academic pursuits from an early age. After completing his primary and secondary education with the highest rank at Ras Darge and Assela Comprehensive High Schools, he pursued further studies at Awassa College of Agriculture. In 1989, he obtained a College Diploma in Animal Science and Technology. Recognizing his potential, he continued his academic journey at Hawassa University, earning a BSc Degree in Animal Production and Rangeland Management in 2006, followed by an MSc in Animal Production in 2012.

The author achieved remarkable success in the realm of agricultural research, having occupied diverse positions at both the Ethiopian Agricultural Research and Amhara Agricultural Research institutes. His invaluable contributions encompassed the identification of critical issues, the formulation of project proposals, and the effective execution of initiatives. His impact extended beyond individual projects, as he played a key part in developing research strategies that have contributed to Ethiopia's agricultural sector. Notably, he contributed to the formulation of the Ethiopian Sheep Research Strategy (EIAR) and the Ethiopian Small Ruminant Landscaping Project. His expertise in research and leadership led to positions such as Division Head for Sheep Research, Head for Sheep and Goat Research, and Head for Livestock Research at the Debre-Birhan Research Center. From 2012 to 2020, he served as the Ethiopian Sheep Research Coordinator.

The author's remarkable contributions have garnered recognition and acclaim. He received the prestigious Gold Medal at the 6th Annual Science and Technology Awards, along with his research team, for their exceptional work on "*Community-Based Selective Breeding Scheme Development*." The Ethiopian Government also honored him with an award, a laptop, and a certificate during the first National Livestock and Fisheries Week, acknowledging his outstanding achievements and contributions to the development of the Livestock and Fisheries sector.

In September 2019, driven by a firm thirst for knowledge and a desire to make further scholarly contributions, the author joined Addis Ababa University, College of Veterinary Medicine and Agriculture, to pursue a Ph.D. in Animal Production. This decision marked a significant milestone in his academic journey, enabling him to delve deeper into his field of expertise and push the boundaries of knowledge.

Throughout his academic pursuits, the author has established himself as a prolific researcher, writer and reviewer. He has authored/ co-authored over 25 articles in journals and contributed to more than 30 articles in conference proceedings. Notably, his current dissertation work has resulted in two journal publications, one book chapter, and an additional journal article currently under review.

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Table of Contents Page

Approval sheet .... Error! Bookmark not defined.

Statement of the author ii

Dedication iii

Acknowledgement iv

List of Tables xii

List of Figures xv

List of Appendices xvi

Abbreviations and acronyms xvii

Abstract xix

CHAPTER 1: INTRODUCTION 1

1.1. Statement of the problem 3

1.2. Objectives 4

1.2.1. General objective 4

1.2.2. Specific Objectives 4

CHAPTER 2: LITRATRE REVIEW 5

2.1. Sheep genetic resources of Ethiopia 5

2.2. Description of the sheep breeds under study 6

2.2.1. Menz sheep 6

2.2.2. Afar Sheep 7

2.2.3. Wollo Highland Sheep 7

2.2.4. Adilo Sheep 8

2.2.5. Blackhead Somali sheep 8

2.2.6. Tumele sheep population 9

2.2.7. Hararghe highland sheep 9

2.2.8. Dorper sheep 10

2.3. Strategies for genetic improvement program in sheep 11

2.4. Crossbreeding in sheep and its genetic basis 12

2.5. Crossbreeding and its benefits in sheep 13

2.6. Effort of sheep crossbreeding in Ethiopia. 14

2.7. Livestock composition, flock size and structure 16

2.8. Purpose of keeping sheep 18

2.9. Major constraints of sheep production 19

2.10. Reproductive performance and survival abilities 19

`

2.10.1. Age at first lambing 19
2.10.2. Lambing interval 21
2.10.3. Litter size 22
2.10.4. Annual reproductive rate 23
2.10.5. Productivity indices (90 days) 24
2.10.6. Survival of lambs 24
2.11. Growth performance of sheep 26
2.11.1. Body weight of sheep (breed influence) 26
2.11.2. Body weight of sheep (environmental influence) 27
2.11.2.1. Year and season of birth 27
2.11.2.2. Parity and age of dam 29
2.11.2.3. Sex of the lamb 29
2.11.2.4. Type of birth 30
2.11.3. Growth rate of lambs 31
2.12. Dorper crossbreeding system in Ethiopia 32
2.12.1. Dorper crossbreeding strategy and program in Ethiopia 32
2.12.2. Dissemination strategy 35
2.12.2.1. Dissemination of pure-bred stock 35
2.12.2.2. Dissemination of crossbred Dorper sheep to villages 35
CHAPPTER 3: METHODOLOGY 37
3.1. Description of the study area 37
3.1.1. On-farm study sites 37
3.1.2. On-station study sites 38
3.2. Study flock management practices followed 39
3.2.1. Farmers' flock management practices 39
3.2.2. On-station flock management practices 40
3.3. Data source and collection 41
3.3.1. On-station - data source and collection 41
3.3.2. Village monitoring data source and collection 41
3.4. Data collection methods 42
3.4.1. Questionnaire survey, focus group discussion, and on the spot observation and measurement 42
3.4.2. Growth, reproduction, and survival data collection (both on-station and on-farm) 43
3.4.3. Pedigree information from both on-station and on-farm evaluation works 44
3.4.4. Dorper crossbreeding scheme (on-farm) 44

`

3.4.5. Dorper crossbreeding scheme (on-station) 45

3.4.6. Dorper sheep multiplication and distribution (encompassing all stakeholders) 46

3.5. Data management and statistical analysis 47

3.5.1. Analysis of perception of farmers' on Dorper sheep production 47

3.5.2. Analysis of reproductive performance 48

3.5.3. Analysis of growth performance 51

3.5.4. Analysis of survival performance 53

3.5.5. Analysis of some indicators for effectiveness or failure of the Dorper crossbreeding strategy 53

CHAPTER 4: RESULTS 54

4.1. General household characteristics of the respondent households 54

4.2. Land holding and use pattern 54

4.3. Livestock holding and species composition 57

4.4. Sheep flock structure 59

4.5. Purpose of keeping sheep 60

4.6. Major constraints of sheep production 61

4.6.1. Feed resources, seasonal fluctuation and utilization 61

4.6.2. Prevalent health challenges impacting sheep production in the study areas 65

4.7. Breeding and selection criteria 65

4.7.1. Selection criteria for breeding ewe and ram 65

4.7.2. Dorper sheep breeding practice 67

4.7.2.1. Mating 67

4.7.2.2. Dorper ram sharing in the community 68

4.7.2.3. Access to Dorper rams 68

4.7.2.4. Special management to Dorper crossbred rams 69

4.7.3. Perceptions of farmers on production and adaptation of Dorper crossbred rams and lambs 69

4.7.3.1. Proportion of Dorper crossbred lambs over the local in the flock 69

4.7.3.2. Physical conformation of Dorper crossbred rams 70

4.7.3.3. Mating ability of Dorper crossbred rams 71

4.7.3.4. Testicle condition of Dorper crossbred rams (as assessed by researchers) 71

4.7.3.5. Scrotum circumference, service year and body measurements of disseminated Dorper crossbred rams 72

4.7.3.6. Off-take reasons and number in the past one year in the study areas 73

4.7.3.7. Constraints to Dorper sheep crossbreeding (weighted index rankings) 75

4.7.3.8. Farmers' perception on productive traits of Dorper crossbred lambs 76

4.7.3.9. Farmers' perception of adaptability traits of Dorper crossbred lambs 84

`

4.8. Reproductive performance of sheep **94**

4.8.1. Reproductive performance of sheep under village management system 94

4.8.1.1. Lambing distribution under village management system 94

4.8.1.2. Litter size at birth (LSB) under farmers' management 95

4.8.1.3. Litter size at weaning (LSW) under farmers' management 95

4.8.1.4. Age at first lambing (AFL) of ewes under village management system 96

4.8.1.5. Lambing interval (LI) of ewes under village management system 97

4.8.1.6. Annual reproductive rate (ARR) of ewes under village management system 97

4.8.1.7. Annual productive indices of ewes under village management system 98

4.8.2. Reproductive performance of sheep under on-station management 99

4.8.2.1. Mating and fertility traits of flocks managed under on-station management 99

4.8.2.2. Litter size and litter weight at birth and weaning of local, Dorper purebred and Dorper crossbred sheep under on-station management 104

4.8.2.3. Litter weight at birth and weaning of local, Dorper purebred and Dorper crossbred sheep under on-station management 107

4.8.2.4. AFL, LI and ARR of local, Dorper purebred and Dorper crossbred ewes under on-station management. 108

4.8.2.5. Annual production indices for the local, purebred Dorper and Dorper crossbred ewes under on-station management. 111

4.9. Growth performance of sheep **115**

4.9.1. Growth performances of lambs under village management system 115

4.9.1.1. Pre-weaning growth performances of lambs under farmers' management 115

4.9.1.2. Post-weaning growth performances of lambs under farmers' management 118

4.9.2. Growth performances of lambs under on-station management system 120

4.9.2.1. Pre-weaning growth performances of lambs under on-station management 120

4.9.2.2. Post-weaning growth performances of lambs under on-station management 123

4.10. Survival of lambs **128**

4.10.1. Survival of lambs under farmers management condition 128

4.10.2. Survival of lambs under on-station management condition 131

4.11. Dorper crossbreeding system in Ethiopia **136**

4.11.1. Dorper crossbreeding strategy and program in Ethiopia 136

4.11.1.1. Crossbreeding scheme 136

4.11.1.2. Importation 137

4.11.1.3. Purebred Dorper and Dorper crossbred lamb production (on-station) 138

4.11.1.4. Local and Dorper crossbred lamb production under farmers' condition 139

4.11.2. Dissemination strategy 143

4.11.2.1. Production and dissemination of purebred Dorper stock 143

4.11.2.2. Production and dissemination of crossbred Dorper sheep to stakeholders 145

`

4.11.2.3. Status of disseminated Dorper crossbred rams to farmers 147

4.11.2.4. Adaptation of disseminated Dorper crossbred rams to farmers 147

4.11.2.5. Number of Dorper crossbred lambs born within the flock and in the neighbors' flock 148

4.11.2.6. Body weight, body condition and body measurements of local and Dorper crossbred lambs under farmers' condition 149

4.11.2.7. Body weight, body condition of ewes, number of lambs born to ewe, estimated prices of local and Dorper crossbred ewes and their body linear measurements 151

4.11.2.8. Estimated prices for local and Dorper crossbred lambs under farmers' condition 151

4.11.2.9. Currently available number of Dorper and Dorper crossbred sheep at on-station and farmers' management condition 154

4.11.2.10. Future demand on crossbreeding using Dorper sheep 157

CHATER 5: DISCUSSION 158

5.1. Socio-economic characteristics of the respondent HHs 158

5.2. Land holding and use pattern in the study areas 160

5.3. Livestock holding and species composition in the study sites 161

5.4. Sheep flock structure within the study sites 162

5.5. Purpose of keeping sheep 163

5.6. Major constraints of sheep production 165

5.6.1. Feed resource, seasonal fluctuation and utilization 166

5.6.2. Prevalent health challenges impacting sheep production in the study areas 167

5.7. Breeding and selection criteria 168

5.7.1. Selection of ewes and rams and criteria for breeding ram and ewe 168

5.7.2. Sheep breeding practice 171

5.7.2.1. Mating Followed 171

5.7.2.2. Dorper crossbred ram sharing in the community 172

5.7.2.3. Access to Dorper crossbred rams 173

5.7.2.4. Special management to Dorper crossbred ram 173

5.7.3. Perceptions of farmers on production and adaptation of Dorper crossbred rams and lambs 174

5.7.3.1. Proportion of Dorper crossbred lambs born over the local in the farmers' flock 174

5.7.3.2. Physical conformation of disseminated Dorper crossbred rams 175

5.7.3.3. Mating ability of disseminated Dorper crossbred rams 176

5.7.3.4. Testicle condition of disseminated Dorper crossbred rams 177

5.7.3.5. Body weight, body condition, scrotal circumference, service year and body linear measurements of disseminated Dorper crossbred rams 178

5.7.3.6. Off-take reasons, and number in the past one year in the study areas 180

5.7.3.7. Constraints to Dorper sheep crossbreeding (weighted index rankings) 183

5.7.3.8. Farmers' perception of productive attributes and traits of Dorper crossbred lambs 184

5.7.3.9. Farmers' perception on adaptability traits of Dorper crossbred lambs 186

5.8. Reproductive performance 190

`

5.8.1. Lambing distribution under village management system 190
5.8.2. Mating and fertility traits of flocks managed under on-station management 191
5.8.3. Litter size at birth (LSB) under farmers' and on-station management 197
5.8.4. Litter size at weaning (LSW) under farmers' and on-station management 199
5.8.5. Litter weight at birth and at weaning under on-station management 201
5.8.6. Age at first lambing under farmers' and on-station management 204
5.8.7. Lambing interval under farmers' and on-station management 206
5.8.8. Annual reproductive rates under farmers' and on-station management 208
5.8.9. Annual productive indices of ewes under farmer' and on-station management 210
5.9. Growth performance of sheep 215
5.9.1. Growth performances of lambs under village and on-station management systems 215
5.9.1.1. Pre-weaning growth performances of lambs 215
5.9.1.2. Post-weaning growth performances of lambs 223
5.10. Survival of lambs 230
5.10.1. Survival of lambs under farmers' management condition 230
5.10.2. Survival of lambs under on-station management condition 237
5.11. Dorper crossbreeding system in Ethiopia 246
5.11.1. Dorper crossbreeding strategy and program in Ethiopia 246
5.11.1.1. Crossbreeding scheme 246
5.11.1.2. Importation 252
5.11.1.3. Purebred Dorper, and crossbred Dorper lamb production 253
5.11.2. Dissemination strategy 254
5.11.2.1. Dissemination of purebred Dorper stock 254
5.11.2.2. Dissemination of crossbred Dorper sheep to villages 256
5.11.2.3. Status of disseminated Dorper crossbred rams to farmers 257
5.11.2.4. Adaptation of disseminated Dorper crossbred rams to farmers 258
5.11.2.5. Number of Dorper crossbred lambs born within the flock & in the neighbors' flock 259
5.11.2.6. Body weight, body condition, and body measurements of local and Dorper crossbred lambs 260
5.11.2.7. Body weight, body condition of ewes, number of lambs born to ewe, estimated prices of local and Dorper crossbred ewes and their morphometric measurements 262
5.11.2.8. Estimated prices for local and Dorper crossbred lambs produced by farmers 263
5.11.2.9. Future demand on crossbreeding using Dorper sheep 263
5.11.3. Dorper crossbreeding coordination 265

CHAPTER 6: CONCLUSIONS AND RECOMMENDATION 267

REFERENCES 272

APPENDICES 290

`

List of Tables

Table 1 . Average age at first lambing, lambing interval, litter size, annual reproductive rate and post-partum body weight of some sheep breeds. 26

Table 2 . Birth weight, 3, 6 and 12-month weight of lambs born from different breeds (in kg) 27

Table 3 . Average weight gain of lambs at different age 32

Table 4 . Improved Dorper genotype delivered to ESGPIP BED sites, satellite nucleus sites, and producers by the end of September 2011 36

Table 5 . Location and environmental descriptors of on-station performance evaluation of purebred Dorper and crossbred sheep in Ethiopia (Nucleus and BED sites). 39

Table 6 . General Socioeconomic and Household Characteristics of the Study Areas 55

Table 7 . LSM±SE for land and livestock holding/household and land use pattern in the study sites 56

Table 8 . Percentage of livestock species composition in the study areas (excluding chicken) 58

Table 9 . Flock structure per household in the study sites (%) 60

Table 10 . Purposes of keeping sheep as was ranked by respondents (weighted index) 60

Table 11 . Major constraints to sheep production (weighted index) 61

Table 12 . Fluctuation in feed supply, feed shortage months, type of supplement, dry and wet season feed source for sheep per household in the study sites (%). 63

Table 13 . Major health challenges that affected sheep production in the study areas 65

Table 14 . Attributes considered while selecting female sheep for breeding purposes (weighted index). 66

Table 15 . Attributes considered while selecting ram for breeding purpose (weighted index). 67

Table 16 . Mating followed by the household in the study sites (%) 67

Table 17 . Proportion of farmers that exercise ram sharing within the community (%) 68

Table 18 . Proportion of farmers that access improved rams (Dorper crossbred rams) (%) 68

Table 19 . Farmers experience in managing Dorper crossbred ram used for breeding (%) 69

Table 20 . Farmers' assessment of the conformation of distributed Dorper crossbred rams (%). 70

Table 21 . Mating ability of distributed Dorper crossbred rams in the study sites (%). 71

Table 22 . Testicle condition of disseminated Dorper crossbred rams (%) 72

Table 23 . LSM±SE for body condition, body weight, dentition, testicle circumference, and body linear measurements of distributed Dorper crossbred rams in the study sites........ 73

Table 24 . LSM±SE for off-take reasons and estimated number of sheep out from the flock in the study sites 74

Table 25 . Constraints suggested to Dorper crossbreeding by farmers (index). 75

Table 26 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper rossbred and local sheep for (overall)........ 77

Table 27 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep-for Damot-pulasa and sore sites 78

`

Table 28 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for Kobo site 79

Table 29 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper rossbred and local sheep Minjar site 80

Table 30 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for Kewet site 81

Table 31 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for Merhabete site 82

Table 32 . Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for Baso site 83

Table 33 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep (overall, n=248) 87

Table 34 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Damot site 88

Table 35 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Kobo site 89

Table 36 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Minjar site 90

Table 37 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep or Kewet site 91

Table 38 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Merhabete site 92

Table 39 . Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Baso site 93

Table 40 . LSM±SE of the effects of dam genotype, location, lambing year, lambing season, lamb sex, and parity, on LSB and LSW for Local and Dorper crossbred sheep under farmers' management........ 96

Table 41 . LSM±SE of the effects of location, dam genotype, lambing year and season on average birth and weaning litter size of local and Dorper crossbred sheep. 97

Table 42 . LSM±SE of the effects of location, Dam genotype, Lambing season, Parity on subsequent productivity indices of Local and Dorper crossbred sheep........ 98

Table 43 . Number proportion of local, Dorper and Dorper crossbred ewes joined, conceived and lambed in the flocks managed at on-station........ 101

Table 44 . Number of local, Dorper purebred and Dorper crossbred ewes joined, and proportions of .... ewes

aborted, gave to still-birth and barren-ewe in the flocks managed at on-station. 103

Table 45 . LSM±SE of litter size and weight for the local, Dorper and Dorper crossbred sheep managed under on-station management in Ethiopia........ 106

Table 46 . LSM±SE of AFL, LI, and ARR for the local, Dorper purebred and Dorper x local crossbred sheep managed under on-station management........ 110

Table 47 . LSM±SE of annual production indices (I-III) for the local, Dorper and Dorper x local crossbred sheep managed under on-station management in Ethiopia. 114

`

Table 48 . LSM±SE of pre-weaning growth performance of Local and Dorper crossbred lambs under on-farm management......117

Table 49 . LSM±SE of post-weaning growth performance of Local and Dorper crossbred lambs under on-farm condition......119

Table 50 . LSM±SE of pre-weaning growth performance of Local, Dorper purebred and their different levels of crossbred lambs under on-station management......122

Table 51 . LSM±SE of post-weaning growth performance of Dorper purebred, Local and Dorper x Local crossbred lambs under on-station management. 125

Table 52 . Lambs' survival at 3, 6 and 12 months of age, under village management system. 130

Table 53 . Lambs' survival estimation at 3and 6 months of age, under on-station management. 134

Table 54 . Number of imported Dorper purebred sheep by sex and their destination in Ethiopia 138

Table 55 . Number of Dorper purebred and Dorper crossbred lambs produced by different stakeholders (under on-station) management 140

Table 56 . Number of Dorper crossbred and their contemporary local lambs born under farmers' condition 143

Table 57 . Source of distributed purebred Dorper and crossbreed sheep to different stakeholders in . Ethiopia 144

Table 58 . Destination of disseminated purebred Dorper and crossbred sheep for breeding purpose to different stakeholders in Ethiopia (n, %). 146

Table 59 . Status of disseminated Dorper crossbred rams to farmers in the study sites (%). 147

Table 60 . Adaptation of distributed Dorper crossbred rams in the study sites (%). 148

Table 61 . LSM±SE for estimated number of Dorper crossbred lambs born within the flock and neighboring flock (farmers recall basis estimate) 149

Table 62 . LSM±SE for estimated body weight, body condition, and body measurements of Local and Dorper crossbred lambs in the study sites (at the age of 5 months), at the spot measurement. 150

Table 63 . LSM±SE for estimated body weight, body condition, number of lambs born, estimated price of ewes and body measurements of Local and Dorper crossbred ewes in the study sites, at the spot measurement.152

Table 64 . LSM±SE for estimated market prices by farmers for local and Dorper crossbred lambs in the study sites 153

Table 65 . Number of Dorper purebred and different levels of Dorper inherited sheep currently available on-station (details). 155

Table 66 . Farmers' opinion and suggestion on the future demand on using Dorper sheep for crossbreeding. 157

`

List of Figures

Figure 1 . On-farm Dorper monitoring sites 38

Figure 2 . Proportion of Dorper crossbred lambs born over local lambs in the farmers' flock. 70

Figure 3 . Constraints to Dorper sheep crossbreeding over-all weighted index ranking. 76

Figure 4 . Lambing frequency by month for local and Dorper crossbred Lambs (on-farm). 94

Figure 5 . Seasonal distribution of lambing for local and Dorper crossbred lambs (on-farm) 95

Figure 6 . Comparative growth performances of local and Dorper x Local crossbred lambs managed by farmers .. 118

Figure 7 . Growth performances of local, pure Dorper and Dorper x local crossbred lambs under on-station management 127

Figure 8 . Number and proportion of (purebred Dorper and different levels of Dorper inherited crossbred lambs) born under on-station management (over all) 142

Figure 9 . Proportion of Dorper and crossbred sheep produced by different stakeholders and availed for ....

breeding in Ethiopia. 144

Figure 10 . Proportion of Dorper and crossbred sheep received by different stakeholders for breeding ....

purpose in Ethiopia 146

Figure 11 . Number and proportion of Dorper and Dorper crossbred sheep currently found under on- ....

station sites. 154

Figure 12 . Future demand for crossbreeding using Dorper sheep 157

`

List of Appendices

Appendix I: Questionnaire used to capture information from different stakeholders. 290

Appendix II: Statistical analysis results 306

Appendix-Figure 1: **Breeding scheme in nucleus center, multiplication center and at village level** 308

Appendix-Figure 2: Dorper ewes in quarantine at Brits (South Africa), adapted from ESGPIP 309

Appendix-Figure 3: Quarantine facility at Sebeta (Building #1), adapted from ESGPIP 309

Appendix-Figure 4: Photos from survey and at the spot measurement in the study sites 310

Appendix-Figure 5: Results of plagiarism test and lists of publications 311

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Abbreviations and acronyms

6-MWT	Six Month Weight
AFL	Age at First Lambing
ARR	Annual Reproductive Rate
BC	Body Condition
BED	Breeding Evaluation and Distribution
BHS	Blackhead Somali Sheep
BL	Body Length
BWT	Birth Weight
CBBP	Community Based Breeding Program
CG	Chest Girth
CI	Confidence Interval
CSA	Central Statistics Agency of Federal Republic of Ethiopia
CW	Chest Width
DAGRIS	Domestic Animal Genetic Resource Information System
DBARC	Debre-Birhan Agricultural Research Center
DBSBMC	Debre-Birhan Sheep Breeding and Multiplication Center
DM	Dry Matter
DxL	Dorper x Local
EMDTI	Ethiopian Meat and Dairy Technology Institute
EPA	Ethiopian Privatization Agency
ESGPIP	Ethiopia Sheep and Goat Productivity Improvement Program
F_1	First Generation Crossbred
FAO	Food and Agricultural Organization of the United Nations
FTC	Farmers Training Center
GLM	General Linear Model
HHs, hhs	House Holds
HW	Height at Wither
ICARDA	International Center for Agricultural Research in Dry areas
ILCA	International Livestock Center for Africa

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Abbreviations and acronyms continued

Kg	Kilogram
LI	Lambing Interval
LS	Litter size
LSB	Litter Size at Birth
LSM	Least Squares Means
LSW	Litter Size at Weaning
m.a.s.l.	Meters Above Sea Level
MoA	Ministry of Agriculture
NGO	Non-Government Organization
NLR	Number of Lambs Reared
OR	Odds ratio
POWADG	Post-Weaning Average Daily Gain
PRWADG	Pre-weaning Average Daily Gain
RW	Rump Width
SAPLING	Sustainable Animal Productivity for Livelihoods, Nutrition and Gender inclusion
SAS	Statistical Analysis System
SD	Standard Deviation
SE	Standard Error
SNNP	Southern Nations Nationalities and People
USA	United States of America
WWT	Weaning Weight
YWT	Yearling Weight

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Evaluation of Dorper Sheep under Village and On-Station Management Systems in Ethiopia.

Abstract

The study evaluated the performance of Dorper sheep and their crossbreds under both farmer-managed and semi-intensive systems across diverse regions of Ethiopia. On-farm flock monitoring of farmers' flock and extensive assessments of productive and reproductive traits were conducted on flocks managed semi-intensively at research centers and universities. Additionally, a survey of 248 households assessed the performance of distributed Dorper sires, Dorper crossbred lambs, ewes and farmers' perceptions of the breed's productive and adaptive traits. The data was analyzed using SAS and SPSS statistical software. The study found that sheep were the dominant livestock, accounting for 59% of holdings, with breeding ewes having the highest proportion (46%). Farmers kept sheep primarily for income, meat consumption, and savings. Farmers perceived Dorper crossbreds as superior to locals in conformation, growth, meat yield/quality (red meat), good mothering ability, and market readiness, but noted higher feed requirements. Both local and Dorper ewes lambed year-round, with peaks in Sep-Oct-Dec (35% of births), and more births (39%) in the dry season vs. 33% in the rainy season. Under semi-intensive system, conception and lambing rates were higher when using Dorper crossbred rams (90.5 and 98.5%) and local ewes (90.8 and 98.2%). Under both farmers' and semi-intensive management, local and Dorper crossbred ewes had similar litter sizes at birth (LSB) and weaning (LSW), though affected by environment. In semi-intensive systems, local and crossbred ewes had better litter sizes than Dorper purebreds. However, Dorper crossbred and Dorper purebred ewes had higher litter weights at birth (LWB), and weaning (LWW). Ewes sired by local sires had the lowest values for LWB and LWW. Under farmers' management, local ewes had lower age at first lambing (AFL) (14.7 vs 16.2 months) than Dorper crossbreds, but no differences in lambing interval (LI) (9.0 vs 9.6 months) or annual reproductive rate (ARR) (1.55 vs 1.42). Under semi-intensive management, AFL, LI, and ARR were affected by both genotype and environment. Ewes sired by pure bred Dorper and Dorper crossbred sires produced higher annual lamb weight per ewe (27.6 kg and 26.6 kg) in 90 days than local sires (23.4 kg) ($p < 0.0001$). Dorper crossbred ewes had the highest annual lamb weight (26.8 kg) compared to local (25.9 kg) and purebred Dorper (25.0 kg) ewes ($p = 0.0013$). No difference in annual lamb weight between local and Dorper crossbred ewes under farmers' management, indicating effects of management. Under farmers' management, Dorper crossbred lambs showed 39%, 31%, 34%, and 27% higher birth, 3-month, 6-month, and yearling weights, respectively, compared to local lambs. Dorper crossbreds also had 32% and 23% higher pre- and post-weaning gains. Under semi-intensive management, lamb-traits were influenced by both genetic and environmental factors, with lambs in low-mid to highland areas having higher values than those in cool-sub alpine areas. Lambs with 75% Dorper genes showed higher post-weaning trait-values. Under semi-intensive management, using 50% Dorper-F_1 and 75% Dorper inheritance improved lamb birth weights by 41-64%, weaning weights by 38-52%, and pre-weaning growth rates by 39-50%, six-month and yearling weights were improved by 36-56% and 55-64%, respectively. While lamb genotype did not influence survival under farmers' management, it affected survival at 3 and 6 months under semi-intensive systems due to genetic and environmental factors. In semi-intensive systems, lamb-traits were influenced by both genetics and environment,

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with higher Dorper inheritance (75%) improving post-weaning performance. Using 50-75% Dorper crossbreds significantly boosted lamb birth, weaning, and yearling weights compared to local sheep. Dorper purebred sheep (under a semi-intensive system) and their crossbreds under both systems demonstrated adaptability and productivity across low and high agro-ecologies. The study highlighted farmers' acceptance of Dorper sheep, but noted constraints around access to Dorper rams and improving production environments through feed development and healthcare. It emphasized the need for stakeholder coordination to ensure the success and sustainability of Dorper crossbreeding programs in Ethiopia. Indicators of Dorper crossbreed acceptance included ram distribution, rams' adaptation, lamb Dorper inheritance, and farmer interest. However, aspects of the breeding scheme, like upgrading units and farmer linkages, were still in early stages. Incorporating up to 25% Dorper genetics into indigenous sheep for traditional, farmer-managed systems (following the CBBP practice), use 50-75% Dorper genetics for semi-intensive production to maximize productivity, promote private commercial farmers and transform breeding centers, develop an Ethiopian synthetic Dorper crossbred population, and establishment of a consolidated national Dorper coordination body are recommended.

Keywords: Age at first lambing; Annual reproductive rate; Birth-weight; Crossbreeding; Gain; Dorper sheep; Growth; Litter size; Survival; Reproduction.

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CHAPTER 1: INTRODUCTION

Sheep and goats have long played a crucial role in livestock production in Sub-Saharan Africa (Kosgey *et al*., 2008). This is particularly true in Ethiopia, where they make significant contributions to the socio-economic development of the communities that raise them. According to the most recent data from Ethiopia's Central Statistical Agency (CSA, 2021), the country has an estimated population of 42.9 million sheep. This large and thriving sheep population is well suited to the diverse range of agro-ecological zones found across the vast Ethiopian landscape.

Indigenous sheep are typically raised under low-input, low-output management systems, primarily through extensive or semi-intensive traditional practices (Kosgey and Okeyo, 2007). Sheep and goats hold significant advantages for households led by women, as they provide a means of generating income and obtaining mutton, as well as non-food resources such as manure, skins, and coarse wool. Additionally, they help foster social connections among the rearers (Adane and Girma, 2008). Sheep are regarded as a form of living insurance against environmental challenges such as crop failure, drought, and flooding, and they hold significant socio-cultural value for various traditional communities (Zewedu *et al*., 2008; Alemseged and Hacker, 2014). According to a study by Zelalem and Fletcher (1991), sheep play a significant role at the farm-level economy, contributing up to 63% of the overall net cash income generated from livestock production within the crop-livestock production system. Furthermore, sheep play a role in generating foreign exchange earnings for the country through the export of carcasses, live animals, and skin products. In a study conducted by Solomon *et al*. (2013), it was elucidated that sheep comprise 34% of the live animal exports and hold a crucial role as valuable contributors to foreign currency earnings. Ameha (2008) also reported that sheep contribute 21% to the total ruminant livestock meat output in the country, with an estimated annual national mutton production of 77 thousand metric tons. In a similar vein, Hailemariam *et al*. (2009) discovered that sheep constitute 19% of the overall livestock population and account for a substantial (95%) of the live animal exports specifically within the small ruminant category in Ethiopia.

Despite the suitability of indigenous sheep breeds to the current production environments, their overall productivity, as highlighted by Solomon *et al*. (2010), significantly lags behind the existing population size. Studies have shown that the average net commercial off-take rates of sheep and goats in highland areas of Amhara, Oromia, and Tigray regions were 22% and 18%, respectively, in the year 1999/2000 (Asfaw and Jabbar, 2008). However, by 2004/05, these rates had dropped to 7% for sheep and 8% for goats. Reports from the Ethiopian Privatization Agency (EPA, 2002), and Adane and Girma (2008) indicate that the annual off-take rate for indigenous sheep and goats was only 33% and 35%, respectively. Another study by Legese and Fadiga (2014) reported average off-take rates from sheep and goats between 2008 and 2010 to be 30-38%.

According to a study by Sheriff and Alemayehu (2018), carcass yield from sheep and goats in Ethiopia has remained consistent over the years but is relatively low compared to other countries. The average carcass weight of yearling small ruminants in Ethiopia was reported to be 10 kg for mutton and 8 kg for chevon, which is one of the lowest compared to the world average (FAO, 2005). Similarly, FAO reports from 2009 indicate that the mean carcass production of indigenous sheep breeds in Ethiopia is estimated to be around 10 kg, which is low compared to other sub-Saharan countries.

The increasing demand for mutton in local and export markets presents opportunities for market-oriented productivity improvement, which can significantly improve the income of smallholder livestock rearers and meet the animal protein requirements of the growing population. However, the current production systems are unable to meet the rising demand for lamb meat and mutton. Therefore, there is a need to improve the overall productivity of indigenous sheep and implement efficient sheep genetic improvement programs to uplift the economic status of rearers (Kosgey and Okeyo, 2007). One suggested approach to improve carcass weight is to breed native genotypes with mutton breeds of sheep (Yimam *et al*., 2004; Mekonen *et al*., 2014).

Crossbreeding programs were initiated in Ethiopia in the early decades of the last century but yielded inconsistent results, likely due to various management and other factors (Tesfaye *et al*., 2016; Tadesse, 2018). To address these gaps and revitalize crossbreeding projects, the Sheep and Goat Productivity Improvement Program (ESGPIP) was initiated in collaboration with USAID and the University of Langston (USA). The program involved the importation of Dorper rams and ewes, their multiplication, crossbreeding with native Ethiopian ewes, and distribution of both

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crossbred and Dorper sheep to stakeholders. Dorper sheep, a synthetic breed developed specifically for mutton production, have had their germplasm widely distributed worldwide (Gavojdian *et al*., 2015). However, adaptation and productivity-related trials specific to Ethiopian conditions have been lacking, resulting in limited information on the performance and overall contribution of crossbred and exotic breeds (Scanlon *et al*., 2013; Alemseged and Hacker, 2014). In order to fully evaluate the adaptability and productivity potential of Dorper and its crosses with native Ethiopian breeds, comprehensive on-farm and on-station performance evaluations are necessary.

1.1. Statement of the problem

Efforts to enhance the growth and carcass yield of native sheep breeds in Ethiopia have been ongoing for decades, primarily through crossbreeding with improved genotypes. However, most of the crossbreeding experiments were conducted under controlled station conditions, without fully considering the animal productivity under on-farm management conditions. This oversight led to the assumption that the results obtained in on-station studies would hold true under on-farm conditions. Recently, the introduction of the Awassi breed from Israel and the Dorper breed from South Africa has provided new opportunities. However, like many developing countries, a major challenge in evaluating the impact of crossbreeding has been the lack of reliable data on farmers' perception, overall production, and reproductive performance of crossbred sheep, particularly in the specific areas and production systems where they are expected to perform. Furthermore, it is crucial to recognize that overall improvement in livestock breeding is not solely based on enhancing a single trait but on improving several correlated traits that collectively contribute to overall productivity. Therefore, assessing the performance levels of Dorper sheep and their crossbreds across different locations in Ethiopia and comparing them with native breeds is of paramount importance for designing effective and suitable crossbreeding programs. This evaluation should consider the distribution of crossbreds and their current presence in various locations throughout the country. Previous studies on Awassi crossbred sheep have revealed significant variations in productive performance across different locations and individual producers. Understanding the discrepancy between on-station and on-farm performance of crossbreds is also crucial, as it provides insights into the management practices that smallholder farmers and private commercial sheep breeders need to implement.

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1.2. Objectives

1.2.1. General objective

To evaluate the productivity of Dorper sheep and their crossbreeds across various geographic and ecological regions of Ethiopia under varied management conditions.

1.2.2. Specific Objectives

1. To assess the perceptions of smallholder farmers regarding the adaptability and productivity of Dorper sheep and their crossbred offspring.
2. To evaluate the productive and reproductive performances of Dorper crossbred sheep under smallholder management systems.
3. To evaluate the productive and reproductive performances of purebred Dorper sheep, their crossbreeds, and local sheep under on-station management systems and
4. To identify performance indicators for the effectiveness or failure of the Dorper crossbreeding system in Ethiopia.

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CHAPTER 2: LITRATRE REVIEW

2.1. Sheep genetic resources of Ethiopia

The identification, classification, and description of Ethiopian sheep genetic resources began in the 1970s with an initial categorization based on tail and fiber types (MoA, 1975). These early classifications, such as fat-tailed (Arsi-Bale sheep), thin-tailed (Horro sheep), and coarse-fleeced sheep (Menz and Tikur sheep), were limited in their ability to capture the full diversity of sheep populations. Later, Galal (1983) provided a more detailed description of four sheep types found in the country. However, these classifications were still not comprehensive enough, as they only considered sheep from a limited geographic area.

A study by Solomon (2008) offered a more recent and comprehensive classification and description of sheep resources at the national level. This study identified six breed groups (Short-fat-tailed, Washera, Thin-tailed, Long-fat-tailed, Bonga, and Fat-rumped sheep) and nine breeds (Simien, Short-fat-tailed, Washera, Gumuz, Horo, Arsi, Bonga, Afar, and Black Head Somali Sheep; BHS), as well as 14 populations (Simien, Sekota, Farta, Tikur, Wollo, Menz, Washera, Gumuz, Horro, Arsi-Bale, Adilo, Bonga, Afar, and BHS). Solomon's classification took into account the traditional recognition and naming of sheep types after the communities that maintain them, as well as their affiliations with specific ethnic communities, administrative locations, or phenotypic characteristics, Similarly, Domestic Animal Genetic Resource Information System (DAGRIS, 2014) reported that fourteen Ethiopian sheep populations have been traditionally acknowledged as distinct sheep breeds within the country.

In Ethiopia, the presence of exotic sheep breeds within the national flock is relatively limited. Among the exotic breeds that have been introduced to the country were Romney, Merino, Hampshire, Corriedale, Blue de Maine, Awassi, and Dorper (Tesfaye *et al*., 2015; Meseret, 2020), albeit in small numbers. According to the Central Statistical Agency (CSA, 2021), the hybrid sheep breeds make up only 0.41% of the sheep population, while exotic sheep breeds account for just 0.08%. These breeds are primarily found in research stations, universities, and have been selectively distributed to farmers (Sisay, 2009; Solomon and Tesfaye, 2009).

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2.2. Description of the sheep breeds under study

2.2.1. Menz sheep

The Menz sheep, native to central-northern Ethiopia, thrives at altitudes ranging from 2500 to 3200 meters above sea level and latitudes of 9-12°N. It is one of the few sheep breeds known for its coarse wool and fat tail, specifically adapted to the challenging high-altitude terrain characterized by limited feed resources and low crop production due to extremely low temperatures and drought in the cool highlands. According to Solomon (2008), Menz sheep breed falls under the sub-alpine short-fat-tailed group of Ethiopian sheep breeds and is also referred to as Legegora, Shoa, Abyssinian, or Ethiopian highland sheep. Its distribution is mainly concentrated in the North Shewa Zone of the Amhara region. The current estimated population of Menz sheep is 971,400.

Menz sheep possess distinct physical characteristics, including a short fat tail that curls up at the end, a small body size, short legs, and a long fleece with coarse wool. They are commonly black with white patches, white, brown, or white with brown patches. Males have horns, and both males and females have short semi-pendulous ears, with approximately 12% of the population having rudimentary ears. The Amhara community predominantly keeps these sheep. Traditionally, Menz sheep are raised on smallholder farms to meet subsistence needs and serve as a source of quick cash during times of financial need, as described by Yimam *et al*. (2004). While these sheep may not possess high productivity potential, they provide meat, skin, and manure, which can be used as fuel or fertilizer. The breed is highly adaptable to harsh conditions and effectively controls internal parasite infections, making it suitable for low-input production systems in degraded ecosystems (Tesfaye *et al*., 2010).

On average, adult rams and ewes of Menz sheep have shoulder heights of 64 cm and 58 cm, respectively (ESGPIP, 2008). Ewe lambs reach puberty at 10 months of age and weigh approximately 16.9 ± 0.1 kg, and they give birth for the first time at 15 months. The lambing interval is 8.4 months, with 65% of ewes lambing three times in two years. At birth, lambs from the Menz sheep breed have an average weight of 2.0 ± 0.1 kg, but they experience a pre-weaning mortality rate of 15% and exhibit slow growth, resulting in a weaning weight of 8.6 kg (Mukasa and Lahlou, 1995).

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2.2.2. Afar Sheep

The Afar sheep, also known as Adal or Danakil, is a small-sized breed with a mature weight ranging from 30 to 35 kilograms (kg). It is primarily found in arid lowland (<1000 m) and mid-highland (1200–1900 m) areas of the Afar state, bordering Tigray, Amhara, East and West Harerghe, and East Shoa of Oromia Zones in Ethiopia. The breed's habitat lies between 40° and 42° E longitudes and 9° and 11° N latitudes (ESGPIP, 2008). According to Solomon (2008), the estimated population of Afar sheep is 681,900. They are characterized by a wide fat tail, which can reach below the hock, hair fiber, medium size, a uniform creamy white coat, rudimentary ears, being polled, and having a dewlap. The Afar, Amhara and Tigray communities rear afar sheep.

The breeding tract of Afar sheep experiences erratic rainfall, with annual precipitation ranging from 300 to 700 millimeters (mm). The vegetation consists mainly of sub-desert range types, characterized by sparse coverage of low shrubs and bush, which is currently being invaded by the invasive tree species known as Prosopis. Afar sheep are highly adaptable and can withstand periods of drought, as they have evolved in harsh environmental conditions. They have small ears, often possess a dewlap, and develop thick layers of fat on the brisket. Adult rams have an average wither height of 66 centimeters (cm), whereas adult ewes measure around 61 cm in height. In terms of weight, Afar sheep typically weigh approximately 2.5 kg at birth, 13 kg at weaning (90 days), and 25.8 kg at one year of age. The mature weight of ewes is around 31.6 kg, and twin births are not common (ESGPIP, 2008).

2.2.3. Wollo Highland Sheep

The Wollo sheep, classified within the Sub-alpine short-fat-tailed group, inhabit the cool highlands (2000-3200 m) of the South Wollo zone in the Amhara state. According to Solomon (2008), notable physical characteristics of the Wollo sheep breed include a short-fat tail with a short twisted end, occasionally turned up at the end, small size, a well-developed wooly undercoat, and predominantly black, white, or brown coats, either plain or with patches of white, black, or brown. The breed has long hair with a wooly undercoat, and males have horns. The current estimated population of Wollo sheep is 1,395,900, and Amhara communities primarily

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raise them. These sheep play a crucial role in the livelihoods of smallholder farmers, serving as an important source of income, manure, meat, skin, and coarse wool (Solomon, 2008).

Wollo Highland sheep are managed within a traditional, low-input, and subsistence-oriented production system. In this system, sheep serve as the primary means of generating cash, as well as providing manure, meat, skin, and coarse wool (Solomon, 2008), while also playing a significant socio-cultural role. Natural pasture serves as the main source of feed throughout the year, and during the critical dry season, they are supplemented with crop residues. However, a major challenge faced by Wollo sheep production is feed shortage, as productive pasture lands are gradually being converted into crop fields and communal pasture lands are shrinking, which hampers the productivity of the Wollo sheep.

2.2.4. Adilo Sheep

The Adilo sheep is a recent addition to the sheep breeds in Ethiopia. It falls under the highland long-fat-tailed group and is widely distributed in wet, warmer mid-highland areas, specifically ranging from 1800 to 2000 meters above sea level (Solomon, 2008). The geographic distribution of Adilo sheep includes the North Omo, Derashie, Gedio, and Amaro zones of the Southern state, as well as some northern Borena districts, with elevations ranging from 1300 to 2400 meters. According to Solomon (2008), the estimated population of Adilo sheep is 407,700.

Key physical characteristics of Adilo sheep include a long fat tail, large size, short-haired coat, and male individuals typically have short horns, while approximately 18.4% of ewes are horned. The breed's coat color is predominantly brown (94.3%), with variations such as brown with white patches (32%), black (19%), and black with brown patches (9%). Adilo sheep are primarily reared by the southern nations and nationalities in Ethiopia.

2.2.5. Blackhead Somali sheep

The Blackhead Somali (BHS) sheep breed originates from the Ogaden area in the Somali Region of Ethiopia. It is also known by different names in eastern Africa and other countries, including Blackhead Persian and sometimes Blackhead Ogaden sheep. The breed has a wide distribution within the latitudes of 3-9° N and longitudes of 42-48° E.

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One of the distinguishing features of BHS is the black coloration of the head. While the majority of the body is white, other coat colors can also be observed. The majority of BHS sheep exhibit a prominent dewlap that stretches from the chin to the chest area, often characterized by notable accumulations of fat. Their tail is of the fat rump type, characterized by a distinct fat depot with a thin, straight backward-pointing tip that may occasionally hang down. Adult BHS ewes typically weigh between 30 and 35 kg.

ESGPIP (2008) notes that the Blackhead Somali sheep breed is well adapted to the dry and drought-prone environments of the Somali and Southern tip of Oromia regions in Ethiopia. They are commonly found at elevations below 1000 m, with many populations residing below 500 m above sea level. The breed's native habitat experiences dry and arid conditions, with erratic rainfall and average annual precipitation ranging between 200 and 400 mm.

2.2.6. Tumele sheep population

According to a study conducted by Belay *et al*. (2021b), Tumele sheep populations are classified as part of the fat-tailed sheep breeds. The research also revealed that the primary breeding tract for the Tumele breed is situated in the mid-altitude and lowland areas of North Wollo, extending towards the border of the Afar region. These areas, characterized by altitudes ranging from 1200 to 2200 meters above sea level, are predominantly associated with a mixed crop-production system.

The breed exhibited a relatively low litter size of 1.10 ± 0.03. Additionally, when compared to the Begait and Gumuz sheep breeds, the Tumele breed displayed lower values in terms of body weight, chest depth, wither height, and chest girth. Consequently, in order to enhance the performance of the Tumele breed within its breeding tract area, crossbreeding with Dorper sheep has been implemented.

2.2.7. Hararghe highland sheep

In a study conducted by Wossenie *et al*. (2014) in the highlands of Eastern Hararghe, indigenous sheep types were identified through on-farm phenotype characterization. The majority of males and females (74.9%) did not have wattles, with males more likely to have them. Most sheep (92.5%) did not possess a ruff, although it was more commonly observed in females. Regarding

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horns, the majority (67.5%) were not horned, with males more likely to have horns. The ear orientation varied, with semi-pendulous (35.7%) and erect (35.6%) being the most common. The back profile of the Hararghe highland sheep population typically sloped up at the rump (67.4%). The average body weight, chest girth, wither height, body length, and pelvic width of mature Hararghe highland sheep were 31.2 kg, 80.2 cm, 61.5 cm, 60.0 cm, and 19.7 cm, respectively. The dominant coat color pattern observed was plain, with light brown being the most common, followed by light brown with a white patch. Mature males were heavier and had larger measurements compared to females.

2.2.8. Dorper sheep

Dorper sheep is a superior meat-type breed that originated in South Africa through the long-term effort of crossbreeding Black-headed Persian and Dorset Horn sheep in 1930 (Gavojdian *et al*., 2013). This breed is widely distributed in African countries such as Botswana, Zimbabwe, Zambia, and Kenya. It has also been introduced to other regions around the world, including North America, Europe, and Australia (Gavojdian *et al*., 2013). In the late 1980s, Dorper sheep were introduced into Ethiopia, but due to political instability in 1991, the initial importation was lost (Kassahun and Gipson, 2009). However, in 2006, the Ethiopia Sheep and Goat Productivity Improvement Program re-imported Dorper sheep from South Africa with financial support from USAID (ESGPIP, 2006; Solomon *et al*., 2013).

In collaboration with local universities and research centers, the ESGPIP program successfully set up two nucleus sites and ten BED centers across the country (Solomon *et al*., 2013). Unfortunately, the program faced challenges after the termination of funding and phasing-out of the ESGPIP in 2011, leading to fragmented efforts to maintain and develop the Dorper sheep breed in Ethiopia (Tesfaye *et al*., 2016). Despite these challenges, there have been regional research and development projects focusing on Dorper sheep with rational crossbreeding schemes, which have shown promising results (Solomon *et al*., 2013). Dorper sheep have a distinctive appearance, with their body covered in a mixture of hair and coarse wool, except for the belly and face.

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A black head and neck with a white body characterize the imported Dorper sheep in Ethiopia, although solid white individuals also exist. Both rams and ewes of this breed are polled, meaning they do not have horns.

Birth weight is an economically important trait in sheep production as it affects pre-weaning growth rate and overall economic success, Al-Shorepy (2001). Various studies have reported the birth weight of purebred Dorper and crossbred Dorper to range from 3.5-3.9 kg and 3-3.3 kg, respectively (Neser *et al*., 2001; Gavojdian *et al*., 2013; Hinojosa-Cuéllar *et al*., 2013). However, Snyman and Olivier (2002) reported birth weights of 4.06 kg for purebred Dorper sheep under extensive management conditions. They also reported weaning weight (WWT) and yearling weight (YWT) of 30.0 kg and 64.4 kg, respectively. Cloete *et al*. (2000) estimated a mean WWT of 18.2 kg for purebred Dorper sheep. Adult Dorper ewes under favorable conditions weigh around 60 kg. According to DAGRIS (2005), average birth weight is 3.48 kg for male Dorper lambs and 3.37 kg for females. The average adult live weight is 74 kg for males and 44 kg for females. Dorper lambs have the capacity to attain a live weight of around 36 kg by the time they reach 34 months of age, with an average daily gain of 243g. This remarkable growth rate contributes to the production of a high-quality carcass weighing approximately 16 kg. The inherent growth potential of Dorper lambs, coupled with their ability to graze at an early age, makes them well suited for meat production. Their rapid growth and good conformation further establish Dorper sheep as a breed with excellent attributes for meat production, the breed is well adapted to dry environments and is well suited to a wide range of production systems like in the highlands of the Debre-Birhan area (Ayele *et al*., 2020).

2.3. Strategies for genetic improvement program in sheep

Genetic improvement in livestock involves intentionally modifying the genetic composition of animals to enhance their performance and meet the needs of the owners and the community (Simm, 1998). The choice of breeding strategy depends on the overall breeding objective and specific goals of the program. There are three main genetic improvement strategies: selection between breeds, selection within breeds or lines, and crossbreeding (Simm, 1998). Selection between breeds is a radical option where a genetically inferior breed is replaced by a superior one. This strategy involves identifying and acquiring animals from the superior breed and

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gradually phasing out the inferior breed. On the other hand, crossbreeding involves mating animals of different breeds to combine their desirable traits and capitalize on heterosis and complementarity between breed characteristics (Gregory and Cundiff, 1980). Conventional crossbreeding systems, such as rotational systems and terminal sire-based systems, have been widely discussed (Gregory and Cundiff, 1980). Another form of crossbreeding is the *inter se* mating of animals from newly developed composites (Dickerson, 1972).

Selection within breeds or lines is a slower method of genetic improvement, especially when the generation interval is long. However, the progress achieved through within-breed selection is permanent and cumulative (Simm, 1998). This strategy involves selecting superior individuals within a breed or line based on their performance and breeding them to propagate their desirable traits. In order to attain sustainable utilization and enhance genetic improvement, it is essential to have access to a diverse range of genetic resources (Nimbkar *et al*., 2008). This can be accomplished through various means, such as selecting from within local populations, employing crossbreeding with different breeds, or introducing improved breeds to either crossbreed with or replace the existing local breeds (Nimbkar *et al*., 2008). However, it is important to note that crossbreeding programs in developing regions have been criticized for their potential incompatibility with the conservation of indigenous adapted breeds (FAO, 2007). Nonetheless, many African countries still favor crossbreeding with exotic breeds as a faster means to enhance the productivity of sheep (FAO, 2007).

It is essential to consider that genetic improvement alone may have limited impact on overall productivity if feeding and management practices are not improved. Similarly, improvements in feeding and management with animals of low genetic potential will only result in limited response unless the animals are severely underfed or diseased. Therefore, a comprehensive approach that includes both genetic improvement and improvements in feeding and management practices is essential to achieve the desired benefits.

2.4. Crossbreeding in sheep and its genetic basis

Different sheep breeds exhibit variations in gene frequencies, allelic heterozygosity, and non-allelic gene combinations, which have developed over time due to evolutionary forces and artificial selection (Dickerson, 1973). Sheep have the highest number of breeds among all

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domestic animals (Masson, 1996; FAO, 2007). This wide range of sheep breeds globally provides an excellent opportunity for breed evaluation and crossbreeding experiments in many countries.

During crossbreeding, genes from different breeds interact with each other, resulting in changes in performance compared to the parental stocks. These changes occur due to a higher frequency of genes with favorable average effects, increased heterozygosity for dominant alleles (reducing inbreeding effects), and alterations in non-allelic interactions (Dickerson, 1973). It is generally assumed that there is a linear relationship between dominance and the degree of heterozygosity. In crossbred animals, certain genes may suppress the effects of other genes. Additionally, epistasis, which refers to the interaction between genes on different loci, can also contribute to changes in performance (Dickerson, 1973). Recombination loss, resulting from gene interactions on different loci, has been identified as one of the causes of significant performance deterioration in certain crossbred generations. However, the existing genetic diversity among mildly inbred breeds offers a valuable opportunity for rapid and cost-effective genetic adaptation to various production systems and market preferences.

2.5. Crossbreeding and its benefits in sheep

Crossbreeding involves mating rams and ewes of different breed compositions or types with the aim of producing crossbred progeny of a specific type. It is not a random mixing of breeds but a systematic approach that utilizes different breed resources. According to Rastogi *et al*. (1982), crossbreeding has long been practiced in livestock breeding to harness heterosis. Fathala *et al*. (2014) emphasized the use of crossbreeding systems to leverage breed diversity and increase productivity compared to purebred flocks. The degree of genetic divergence between parent breeds is an important factor in determining the success and benefits of crossbreeding programs. Mahmoud *et al*. (2009) highlighted the benefits of crossbreeding, including the exploitation of favorable combinations of breed characteristics and the utilization of hybrid vigor, leading to improvements in survival, fertility, growth, and disease resistance. Crossbreeding is not limited to meat breeds but is also applicable to meat-fat sheep breeds with high maturity, feed efficiency, and meat productivity (Fathala *et al*., 2014).

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The success of crossbreeding depends on the breeds used and their genetic distance. It is essential to consider combining ability, maternal and individual heterosis when selecting breeds for a crossbreeding system. In developed countries, crossbreeding has made significant contributions to productivity and product quality in sheep production, as income generation primarily relies on lamb production and sales. Structured crossbreeding systems, such as "terminal crossing" where first-generation crossbred (F_1) animals are slaughtered or specialized crossbred dam lines are used, are commonly employed (Nimbkar *et al*., 2008). Crossbreeding can also be used for gradual breed replacement or the controlled maintenance of various proportions of exotics, leading to the formation of composites. Farmers or commercial companies manage the need to maintain pure breeds for crossbred animals or commercial production. Farmers, with extensive support and training, understand the importance of maintaining a balance of breeds to ensure long-term sustainability (personal observation, such as in Choro village of South Wollo, Ethiopia).

While crossbreeding in sheep has faced criticism, successful crossbreeding programs have been implemented in developing countries. Carefully planned and executed crossbreeding programs have been effective in rapidly introducing desirable traits into locally adapted breeds. The creation of the Dorper sheep is recognized as a highly successful composite breed initiative tailored for low-input production environments (de Waal and Combrinck, 2000). Successful crossbreeding programs often involve rigorous selection processes with active participation from livestock owners and substantial public sector investment in technical support. Strategic crossbreeding is also important for addressing adverse trends in reproductive traits in commercial dairy cattle and preventing long-term reduction of genetic diversity (Nimbkar *et al*., 2008). In general, combining appropriate breeds in crossbreeding systems offers opportunities to enhance production efficiency through both additive and non-additive genetic effects.

2.6. Effort of sheep crossbreeding in Ethiopia.

According to DBSBMC (2007), and Tesaye *et al*. (2016), the introduction of exotic sheep breeds in Ethiopia can be traced back to 1944 when Merino sheep were brought from Italy by an American aid organization. Exotic breeds such as Blue De Maine, Merino, Corriedale, Hampshire, and Awassi were subsequently introduced to Ethiopia (Tesfaye *et al*., 2013).

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However, previous crossbreeding strategies were not successful in sustaining genetic improvement in village flocks (Markos, 2006; Tesfaye *et al*., 2013; Tadesse, 2018).

In a review by Tesfaye *et al.* (2016), the authors examined sheep crossbreeding practices in the tropics, with a focus on Ethiopia. Historically, the choice of breeds for crossbreeding overlooked the interests and preferences of farmers', who often valued physical appearance. More recently, the introduction of Awassi sheep considered farmers' preferences.

Performance evaluations showed that crossbred sheep often outperformed their local counterparts. Comparisons of pure local sheep and crossbreds indicated positive outcomes from this crossbreeding. However, crossbred performance varied by location and depended on management and exotic inheritance levels. According to Tesfaye *et al*. (2016), farmers who participated in crossbreeding programs often showed keen interest. This was primarily due to the faster growth and larger body size of the crossbred sheep, which resulted in higher market prices compared to the local breeds. However, the authors found that inefficient ram multiplication and dissemination from government farms undermined the crossbreeding efforts. This inefficiency diluted the intended benefits, preventing farmers from fully realizing the advantages of the crossbred sheep.

The authors cautioned that indiscriminate crossbreeding without proper analysis of suitability and clear breeding objectives could pose a threat to better-adapted indigenous breeds. They suggested that crossbreeding programs require strong research and development support from public and non-governmental institutions to ensure sustainable design, optimization, and implementation in defined production environments.

Recognizing the need to enhance the genetic potential of local sheep, Ethiopia has recently imported Dorper sheep for crossbreeding programs. The primary focus of these efforts has been on improving meat sheep productivity, as the country currently lacks a specialized mutton breed. Ethiopian farmers' breeding objectives are predominantly driven by market demands and the local agro-ecology, with a strong emphasis on meat production (Solomon *et al*., 2013). To address these objectives, the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) initiated national sheep-breeding program in 2006, introducing the Dorper sheep as a

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specialized meat breed. Compared to the previous breeding efforts in Ethiopia, the Dorper crossbreeding program (ESGPIP and '*Dorper-valley project*') implemented a more comprehensive approach that included the importation of Dorper sheep from South Africa, evaluation of the pure and crossbred animals' performance, development of distribution mechanisms to get the crossbred animals to farmers, organization of farmers into crossbreeding groups, provision of training to farmers on breeding and management, establishment of market linkages for the crossbred animals, follow-up on the implementation of the developed crossbreeding scheme, and promotion of the development of suitable forage resources, with purebred Dorper animals being bred at research centers in Fafen, Werer, Debre-Birhan, and Areka to serve as nucleus sites for multiplication and crossbreeding programs.

The integration of the high-yielding exotic Dorper sheep breed through crossbreeding is regarded as a valuable approach to enhance the productivity of indigenous sheep in Ethiopia, with a specific focus on market-oriented meat production and maximizing the advantages derived from local sheep (Desalgn, 2019). The ongoing crossbreeding program at various breeding, evaluation, and distribution sites implemented by the ESGPIP requires a comprehensive evaluation at the national level to assess its outcomes and impact on sheep breeding in Ethiopia.

2.7. Livestock composition, flock size and structure

Variations in the distribution of livestock species within households, known as livestock composition, have been documented in different regions of Ethiopia, as highlighted by various scholars. Agyemang *et al*. (1985) conducted a study in Debre Birhan and found that sheep were the predominant livestock species, accounting for 67.7% of the total, followed by cattle (22.4%), donkeys (6.5%), horses (4.5%), goats (1.2%), and mules (0.7%). In contrast, Berhanu (1998) conducted research in the southern part of Ethiopia and reported a different composition. According to his study, cattle constituted 47.4% of the livestock, followed by sheep at 45.95%, goats at 3.8%, and equines at 3.9%. Another study conducted by Tesfaye G. (2008a) in the Menz area revealed yet another pattern of livestock composition, with sheep dominating at 84.81%, followed by cattle at 9.85%, goats at 1.54%, donkeys at 2.75%, mules at 0.38%, and horses at 0.67%. Tesfaye G. (2008a) also conducted a study in the pastoral areas of Afar and found a

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distinct composition, with cattle accounting for 21.55%, sheep 23.92%, goats 41.26%, camels 12.19%, donkeys 1.08%, and no mules.

These studies underscore the diverse livestock composition in different areas of Ethiopia, reflecting the specific economic and environmental conditions unique to each region. Understanding these variations is crucial for developing targeted interventions and policies to support livestock management and improve the livelihoods of local communities. According to Tadesse (2018), flock structure refers to the distribution of different age and sex classes of sheep within a sheep flock. The composition of a flock is influenced by the sheep production strategies of the communities. Large flock sizes often indicate extensive sheep breeding and the production of a significant number of lambs for sale. This strategy is driven by the high reliance on sheep production for food security (Solomon *et al*., 2010). Large flock sizes are characteristic of sub-alpine sheep-barley and pastoral systems, which adopt an extensive mode of production. In contrast, high-potential cropping areas like Bonga maintain small flocks and focus on producing lambs for fattening (Solomon *et al*., 2010).

Tadesse (2018) noted that the flock sizes of smallholder sheep producers in developing countries tend to be small but vary and are highly complex. Zelalem and Fletcher (1991) found that in the central highlands of Ethiopia, sheep flock size increases with higher altitudes. Tesfaye G. (2008a) reported an average sheep flock size of 31 sheep per household in the Menz area and 23 sheep in the pastoral Afar area. In contrast, smaller flock sizes of 2.9 (Takele, 2005) and 6.9 (Aden, 2003) were reported in the humid Bench Maji zone and around Dire Dawa, respectively, which are regions with lower altitudes. Flock structures reflect the objectives of sheep production and breeding practices. For example, the maintenance of castrated males and a larger number of intact males, particularly in Menz, is related to the objective of meat production (Tadesse, 2018). The predominance of males in traditional flocks reflects the primary objectives of meat, wool or hair, production (Wilson, 1986). In Menz, there is a lower proportion of ram lambs compared to other locations in the crop-livestock system, indicating the tradition of marketing young ram lambs due to the greater reliance on sheep production. Tesfaye G. (2008a) reported that breeding ewes constitute a major portion (47%) of the flock in Menz, followed by lambs (19%) and ewe lambs (14%). In the Afar pastoral system, breeding ewes were dominant (49%), followed by lambs (24%) and ewe lambs (18%). A recent report by the Central Statistical Agency (CSA,

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2021) revealed that the national flock composition includes 22% sheep under 6 months of age, 12% sheep between 6 months and a year old, 16% sheep between 1 and 2 years old, and 51% sheep aged 2 years and older. Understanding the flock composition is important for designing tailored breeding programs for the community.

Sheep have various ways of exiting from the flocks, as they are small in size and sometimes seen as a secondary option to cattle and food grains (Deribe, 2009). The main exit routes reported include sale, slaughter, deaths, shareholding, and gifts/exchanges. Getahun (2008) reported that 104% of the exits were through commercial sales, 3% through slaughter, and 7% as gifts. Another flock monitoring study by Belete (2009) found that the total exits were through sale (69%), slaughter (29%), death (46%), predation (33%), theft (6%), and share arrangements (3%) in Western Ethiopia. A study conducted in Alaba, Southern Ethiopia, by Tsedeke (2007) revealed that 22% of sheep left the flock due to mortality, mainly associated with diseases and predation.

2.8. Purpose of keeping sheep

Understanding the motivations behind keeping animals is essential for establishing effective breeding objectives (Jaitner *et al*., 2001). According to Tesfaye G. (2008a), Menz sheep owners primarily keep sheep for income generation, followed by meat consumption, manure utilization, obtaining hair, and as a means of saving, in that order, with respective index values of 0.47, 0.22, 0.13, 0.09, and 0.07. However, the same author highlighted that the primary reason for keeping Afar sheep breed is to obtain milk, followed by meat consumption and income generation, with index values of 0.45, 0.24, and 0.23, respectively.

The purpose of keeping sheep for Afar pastoralists differs from that of Kenyan pastoralists, as Kenyan pastoral farmers prioritize regular cash income over milk and meat (Kosgey *et al*., 2008). Sheep production's significant contribution to the diets of Ethiopian Somali pastoralists has been documented (Solomon, 2008). Based on the motivations for keeping sheep, the primary breeding goal for Menz sheep is to increase meat production by enhancing growth rate and body conformation, as well as improving fleece yield. For Afar pastoralists, the main breeding objectives are to increase milk yield and meat production.

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2.9. Major constraints of sheep production

According to Markos (2006) and CSA (2021), sheep production in Ethiopia primarily relies on indigenous sheep breeds, with less than 1% consisting of exotic sheep breeds. These indigenous breeds have adapted to various agro ecologies and are capable of year-round breeding. However, the present off-take rate, which refers to the number of animals taken out of the population for slaughter or other purposes, is very low. Baker and Gary (2003) emphasized that identifying the constraints impeding sheep production and implementing effective genetic improvement programs is crucial.

In a study conducted in the Southern part of Ethiopia, several constraints were identified that hindered sheep production, including disease outbreaks, limited market access and information, feed shortages exacerbated by frequent droughts and water scarcity (Ermias 2014). Similarly, Zewedu (2008) investigated the Horro and Bonga areas and found that disease, feed shortages, predation, and labor shortage were the most prominent challenges affecting sheep production. Eyayu (2020) conducted a comprehensive review and identified key problems in Ethiopian sheep production, including feed shortage, disease and parasite burdens, poor animal management practices, genotype and genetics limitations, and socio-economic and institutional constraints. Tadesse (2018) revealed that farmers prioritized growth traits, indicating their recognition of the need for improved genotypes. To address the current low level of sheep productivity, meet the growing demand for meat within the human population, ensure household consumption of high-quality protein and nutrient-dense food, and boost export potential, a concerted effort should be made to address the major constraints and focus on their improvement.

2.10. Reproductive performance and survival abilities

2.10.1. Age at first lambing

Profitability in sheep production is heavily reliant on lamb output, and there are various genetic and management methods available to enhance lamb production. This output is influenced by factors such as fertility, fecundity, lamb survival, and the number of lambing’s per ewe's lifetime.

One crucial trait that significantly affects the reproductive performance of sheep is the age at which a ewe lamb gives birth to its first lamb. In small ruminants, the age at first lambing (AFL)

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holds economic importance as it determines the rate of genetic progress and population turnover rate (Zewedu, 2008). Several factors that influence pubertal development can also influence AFL. Ulfina *et al*. (2003) highlighted the influence of nutrition on the age at puberty and parturition in male and female Horro sheep lambs.

AFL is influenced by a combination of genetic and non-genetic factors. Genetic factors, such as post-weaning growth, as well as non-genetic factors like nutrition, disease, and parasite infestation, contribute to notable variations observed within and across different breeds and production systems. Marufa *et al*. (2017) suggested that improving age at puberty through better management and plane of nutrition could help reduce the age at first lambing. They reported that the Abera sheep breed found in the southern part of Ethiopia had an AFL of 12.9 ± 0.26 months. Yilmaz *et al*. (2007) also indicated an AFL of 12.7 months for the Norduz breed. On average, Assaf ewe lambs gave birth for the first time at 14.6 ± 2.4 months (Pollott and Gootwine, 2004). According to FAO (2002), age at first lambing ranges between 16.2 and 16.9 months in mixed farming systems of sub-Saharan African countries. Galina *et al*. (1996) reported that the age at first lambing for the traditional tropical production system ranged between 446 and 572 days, while improved conditions in Africa showed a range of 431 to 572 days. Mukasa-Mugerawa *et al*. (1994) reported an AFL of 253 days for Menz sheep in Ethiopia. Improving the timing of puberty in female lambs and enabling them to have their first lamb at one year of age, instead of the conventional two years, can significantly enhance the overall reproductive efficiency of the entire sheep flock (Augusto, 2013).

Ewes bred for the first time at an early age (7-9 months) demonstrate greater lifetime productivity compared to those bred later in life (18 months) (Dickerson and Glimp, 1975). Fourie *et al*. (2009) reported an AFL of 346 days (11.5 months) for Dorper ewes in South Africa, while well-managed ewes can lamb at the age of 13-15 months (Gavojdian *et al*., 2013). Budai *et al*. (2013) reported an AFL of 12 months for pure Dorper sheep breed, whereas Fourie *et al*. (2009) reported AFLs of 12 and 13 months for pure Dorper and Dorper crossbreds in South Africa, respectively.

A preliminary report by Mesfin *et al*. (2014) indicated an AFL of 469 ± 8.45 days for local Wollo sheep and 555 ± 6.25 days for Dorper x Wollo crosses at Sirinka Research Center.

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However, Ermias *et al*. (2015) observed that under extensive management, the AFL for 50% Dorper x Adillo and 25% Dorper x Adillo was 11.07 ± 0.53 and 12.50 ± 0.63 months, respectively. It's important to note that the results of Ermias *et al*. (2015) may be limited due to the small number of ewes assessed from both blood groups. Therefore, for a more robust conclusion, it is recommended to consider a larger sample size representing different genetic backgrounds. Furthermore, the AFL reported by Ermias *et al*. (2015) aligns with the findings of Fourie *et al*. (2009), which reported an AFL of 12 months for pure Dorper sheep, but differs from the AFL's reported by Mesfin *et al*. (2014), which were 16.63 months for local-Wollo and 18.50 months for local-Wollo x Dorper, respectively, Table 1 presents compiled data from various studies, focusing on reproductive performance and showcasing values specific to different breeds.

2.10.2. Lambing interval

According to Ibrahim (1998), the reproductive efficiency in small ruminant production is determined by the interval between two parturitions, known as the lambing-kidding interval. The author also identified three phases within the lambing interval: the gestation period, the post-partum anoestrus period, and the service interval. Extended lambing intervals often occur due to prolonged post-partum anoestrus intervals, repeated cycles of service intervals without conception, embryo death, or abortion. To optimize reproductive outcomes, it is important for farmers to remove breeding ewes with such issues from the flock. Unfortunately, some farmers tend to keep these ewes in the hope that the situation may improve, resulting in wasted resources in terms of feed and a lower flock production index.

Several factors have been reported to affect reproductive performance, such as the breed (Deribe, 2009), season (Mengiste, 2008), type of management, nutrition, and type of mating (Gbangboche *et al*., 2006). In their studies, Shigdaf *et al*. (2013) found that lambing interval in Washera sheep is influenced by the level of management, lambing year, lambing season, and parity.

Lambing intervals in Africa have been observed to range from 230 to 437 days (Wilson, 1989). Tesfaye *et al*. (2013) reported that the lambing interval for local, Awassi x Local, and Corriedale x Local crossbred ewes ranged from 228 to 252 days. Mesfin *et al*. (2014) observed lambing intervals of 287 ± 2.38 days (n=175) and 306 ± 4.62 days (n=12) for Local Wollo and Dorper X

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Wollo crossbred ewes, respectively. The Mexican Black belly and Pelibuey breeds were found to have lambing intervals ranging from 230 to 254 days (Galina *et al*., 1996). Mukasa-Mugerawa *et al*. (1994) reported that approximately 65% of Menz sheep in the Ethiopian highlands have an eight-month lambing interval and are capable of three lambings in two years, except when mating is managed. Solomon (2007) and Girma (2008) also mentioned in their studies that under normal circumstances, at least three lambings are expected every two years, and the lambing interval should not exceed 8 months (245 days). Shigdaf *et al*. (2013) reported lambing intervals of 263 days and 303 days for Washera sheep under on-station and on-farm management, respectively (Table 1).

In general, several authors have reported the possibility of achieving three parturitions from indigenous small ruminants in two years (Belete, 2009; Fsahastion *et al*., 2013). Similarly, a lambing interval of 8 months was reported for the Dorper sheep breed (Budai *et al*., 2013).

2.10.3. Litter size

The reproductive performance (RP) of a flock plays a vital role in determining its overall productivity. Various factors, including breed, nutrition level, season, and age, can influence the ovulation rate (Haresign, 1985). Another significant factor in sheep productivity is litter size (LS), as it is closely associated with the number of animals successfully weaned (Buxadera *et al*., 2004). In lamb meat production, LS is considered the most economically significant trait with important indirect effects on other traits (Olesen *et al*., 1995). The ovulation rate primarily influences litter size, although it is also influenced by the fertilization rate and the period of embryonic development (Getenby, 1986). The number of lambs per lambing is significantly affected by the age of the dam. Wilson *et al*. (1984) found that LS increases up to the age of five years or fourth parity and then slightly decreases beyond that age. Other studies have demonstrated that litter size increases with parity, with the highest litter size observed at the fifth parity (Berhanu and Aynalem, 2009). Peak prolificacy is generally reached between 4 and 8 years of age (Notter, 2000). Nutrition level also plays a role in litter size, as poor nutrition during the service period can lead to reduced ovulation rates, increased embryonic mortality, and consequently decreased litter size (Gautsch, 1987).

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In tropical sheep breeds, the percentage of ewes giving birth to twins typically ranges from 0 to 50%. Under traditional management conditions, this percentage tends to be below 10% (Getenby, 1986). For specific breeds, Zewdu (2008) reported a twinning rate of 39.9% or a litter size of 1.40 for Bonga sheep and 36% or a litter size of 1.36 for Horro sheep. However, lower twinning rates were observed for Menz (1.13) and Washera (1.11) sheep breeds (Mukasa-Mugerwa *et al*., 2002; Mengiste, 2008). Similar results were reported for litter size in sheep, with local Wollo sheep and Wollo x Dorper crossbreds showing litter sizes of 1.18 ± 0.02 (n=158) and 1.17 ± 0.00 (n=9), respectively, at Sirinka Research (Mesfin *et al*., 2014). It is important to note that a substantial number of observations to draw conclusions about breed effects should support these results.

The management system also contributes to variation in litter size, as highlighted by Shigdaf *et al*. (2013). Genotype, parity, season, ewe body weight at mating, and management systems are all significant sources of variation in litter size, as noted by Mukasa-Mugarwa and Lahlou-Kassi (1995). In low-input production systems where feed resources are limited in both quality and quantity, farmers generally prefer lower litter sizes (Solomon *et al*., 2018). In a study exploring the breeding objectives of smallholder Menz sheep based on farmers' trait preferences, a low percentage of farmers, 6.3% expressed a preference for higher litter size. This indicates the relative adaptation mechanism followed by farmers in low-input production systems when rearing sheep.

2.10.4. Annual reproductive rate

According to Ibrahim (1998), the annual reproductive rate (ARR) is considered the most reliable indicator of sheep and goat productivity, measuring the number of lambs/kids weaned per ewe of reproductive age per year.

In a study conducted by Mesfin *et al*. (2014), the ARR was reported as 1.37 ± 0.01 for Wollo x Dorper crossbreed and 1.49 ± 0.02 for Wollo sheep. The ARR estimates for Wollo x Dorper sheep were comparable to those of Washera sheep (1.38 ± 0.06), while the estimates for Wollo sheep and Wollo x Dorper were higher than those of Farta sheep (1.29 ± 0.08) (Shigdaf, 2011), but lower than the estimates for local sheep (1.82 ± 0.44) found in the southwestern part of the country (Berhanu and Aynalem, 2009).

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2.10.5. Productivity indices (90 days)

Assessing the reproductive efficiency of ewes and understanding flock productivity requires a comprehensive understanding of productivity indices, Wilson *et al*. (1985) developed three flock production indices based on initial lamb weaning weight and subsequent parturition interval. According to a study conducted by Martins and Peters in 1991, which focused on Karakul sheep in Botswana, the average productivity estimates were as follows: 27.7 kg of lamb per ewe per year (Index I), 0.67 kg of lambs per kg of ewe per year (Index II), and 1.71 kg of lamb per kg of ewe to the power of 0.75 per year at 5 months of age (Index III). In a separate study by Sulieman *et al*. (1990), examining Sudan Desert sheep, the reported productivity at 4 months of age was 16.8 kg (Index I), 0.42 lamb (Index II), and 1.14 kg of lamb (Index III). In their study on Djallonke sheep, Gbangboche *et al*. (2006) assessed productivity based on the body weight of a 90-day-old lamb produced per breeding female per year, which amounted to 17 kg (Index I). The productivity per kg of breeding female per year was 0.6 kg (Index II), and per kg of metabolic ewe postpartum weight breeding female per year was 1.4 kg (Index III). Another study conducted by Rastogi (2001) focused on Barbados Blackbelly sheep in Tobago, revealing that ewe productivity, measured as the total lamb weight at 56 days of age per ewe lambing, was 16 kg.

2.10.6. Survival of lambs

Although indigenous sheep breeds exhibit a reasonable level of adaptation to tropical environments, the prevailing management system for these animals is traditional and extensive, lacking specialized inputs in terms of housing, nutrition, and disease prevention or treatment. In the case of Horro sheep, perinatal lamb mortality amounts to 4% within the first three days of age, with subsequent mortality rates reported at 20% and 14% for this breed. Under the pastoral management system, mortality rates of 21% (Belete, 1985) and 46% (Coppock, 1994) have been documented for BHS. Additionally, a pre-weaning lamb mortality rate of 47.8% has been reported for the same breed at the on-farm level. Reducing lamb mortality could significantly enhance sheep productivity.

Breed differences can account for variations in pre-weaning mortality rates. Markos (2006) reported pre-weaning mortality rates of 33.1% for Horro sheep and 19.2% for Menz sheep at the

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Debre-Birhan station. Solomon and Gemeda (2000) documented an average pre-weaning mortality rate of 19.5% for Horro sheep under on-station management in the Bako area, their niche-breeding tract. Kasahun (2000) reported a 76% survival rate between birth and weaning for Horro lambs reared under intensive management in the former ILCA research site. Zewdu (2008) observed a mortality rate of 47.4% for Horro sheep under on-farm management. Shigdaf *et al*. (2013) found survival rates from birth to 30 days, three months, six months, and one year for Washera sheep to be 93%, 86%, 78%, and 67%, respectively. Yibrah (2008) reported survival rates of BHS sheep from birth to 3 days, 7 days, 30 days, 60 days, 90 days, 180 days, 270 days, and 365 days to be 90.5±0.88, 88.6±0.98, 86.2±1.13, 82.5±1.28, 79.1±1.37, 74.4±1.55, 70.8±1.65, and 65.7±1.7, respectively. On-station studies at the Debre-Birhan research station revealed pre-weaning survival rates of 83.06%, 80.69%, and 86.25% for Menz, Awassi x Menz 25-50%, and Awassi x Menz 75%, respectively (Ayele *et al*., 2016b).

According to Sulieman *et al*. (1990), Shigdaf *et al*. (2013), and Ayele *et al*. (2016b), the survival and mortality rates of lambs up to weaning are influenced by various factors, including the age of the ewe, type of birth, season of birth, and birth weight of the lamb. There is a positive association between litter size and mortality, meaning that higher litter sizes are associated with increased mortality rates. This is primarily due to twins having lower body weight compared to single-born lambs. In Horro sheep, the survival rate is significantly affected by the birth weight of lambs (Gemeda *et al*., 2005). Similarly, Markos (2006) reported higher survival rates for single-born lambs compared to twins in Horro and Menz sheep breeds in Ethiopia. The author also noted that the survival rate of lambs varies depending on birth weight, sex, parity, and season of birth. Lambs' with lighter birth weights, born to first-parity ewes and during the dry season, had a lower chance of survival compared to lambs born to higher-parity ewes and during the wet season. Ayele *et al*. (2016b) supported these findings, stating that lamb pre-weaning mortality is significantly influenced by lamb breed, lamb sex, birth season and year, lamb age, lamb birth weight category (light, medium, heavy), lamb birth parity, and ewe post-partum weight.

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Table 1. Average age at first lambing, lambing interval, litter size, annual reproductive rate and post-partum body weight of some sheep breeds.

Sheep breed	Parameters					Country	Data source
	AFL	LI	Litter size	ARR	Pre-weaning-Survival		
Menz sheep		7.6				Ethiopia	Abebe (1999)
Sheep in the pastoral	17.0					Ethiopia	Samuel, 2005
Sheep in the Argo-pastoral	20.7					Ethiopia	Adugna & Aster, 2007
Blackhead Ogaden sheep	23.6±3.6	10.5				Ethiopia	Fikirte, 2008
Adilo sheep	14.6					Ethiopia	Getahun, 2008
Menz sheep	15.7	8.5				Ethiopia	Tesfaye, 2008
Afar sheep		9				Ethiopia	Tesfaye, 2008
Bonga sheep	14.9±3.1	8.9±2.1				Ethiopia	Zewedu, 2008
Horro sheep	13.3 ± 1.7	7.8±2.4				Ethiopia	Zewedu, 2008
Dorper sheep	11.5					South A	Fourie et al., 2009
Washera sheep (On-farm)	15.23	10.1	1.05	1.4±0.04	0.9±0.01	Ethiopia	Shigdaf et al., 2013
Washera sheep (on-station)	15.7	8.8	1.03	1.5± 0.05	0.8±0.02	Ethiopia	Shigdaf et al., 2013
Local (Menz, Wollo)	15.97	8.11	1.57			Ethiopia	Tesfaye et al., 2013
Awassi cross	18.55	9.52	1.34			Ethiopia	Tesfaye et al., 2013
50% Dorper	11.1±0.5		1.88			Ethiopia	Belete et al., 2015
Wollo sheep	15.63			1.5 ± 0.02	0.7±0.02 (n=9)	Ethiopia	Mesfin et al., 2014
Dorper x Wollo	18.53			1.4 ± 0.01	0.6±0.03	Ethiopia	Mesfin et al., 2014
Dorper x Menz 50%			1.18±0.02			Ethiopia	Ayele et al., 2015
25% Dorper	12.5±0.7		1.96			Ethiopia	Belete et al., 2015
Indigenous sheep, East. Eth.	13.8±0.1	8.6±0.1				Ethiopia	Helen et al. 2015

AFL (Age at first lambing in months), LI (Lambing interval, in months), ARR (Annual Reproductive rate, in days)

2.11. Growth performance of sheep

2.11.1. Body weight of sheep (breed influence)

In their respective studies, Momoh *et al*. (2013) and Mellado *et al*. (2006) highlighted the significance of lamb's growth performance as a key indicator in meat production, as it directly influences the reproductive efficiency of the sheep. This, in turn, influences the ability of sheep to breed early and contribute to increased lifetime lamb production. Scholars such as Berhanu and Aynalem (2009) and Ayele *et al*. (2020) emphasized that achieving faster growth rates in sheep can expedite reaching marketable weights, leading to improved agricultural efficiency and early market entry. This attribute is particularly important for mutton-type breeds. Optimal growth levels play a crucial role in determining overall flock productivity and economic returns from small ruminants.

The growth performance of lambs is influenced by various factors, such as their body weight at different stages and their daily weight gain, as well as breed (genotype), nursing ability of the ewe, and environmental conditions, including the availability of sufficient and high-quality feed

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(Kassahun, 2000; Mengiste, 2008; Ayele *et al*., 2015). Studies have demonstrated variation in body weight traits among different indigenous sheep breeds (Kassahun, 2000; Markos, 2006; Sisay, 2009). For example, Horro and Bonga sheep breeds stand out as large-sized breeds that exhibit superior body weights compared to most other local sheep breeds studied in Ethiopia thus far (Solomon *et al*., 2007). In Ethiopia, the majority of studies investigating growth parameters in sheep indicate that crossbreds tend to outperform local indigenous sheep breeds (Table 2).

Table 2. Birth weight, 3, 6 and 12-month weight of lambs born from different breeds (in kg)

Breed	Weight categories in kg				Location	Management	Data source
	BWT	WWT	6-MWT	YWT			
Afar sheep	2.5				Ethiopia	On-Station	FAO, 1991
Afar sheep	2.97	13.4		25.5	Ethiopia	On-Station	Benyam, 1992
Menz sheep	2.17±0.03	9.14±0.25	11.45±0.28	19.12±0.47	Ethiopia	On-Station	Abebe, 1999
Menz sheep	2.2	8.3	12.2	16.4	Ethiopia	On-Station	Ewnetu, 1999
Dorper	4.06	30.0	36.9	64.4	S. Africa	Extensive	Synman and O., 2002
Adillo sheep	2.3	11.2			Ethiopia	Extensive	Getahun, 2008
Afar sheep	2.7	11.5	17.2	24.5	Ethiopia	On-Station	Yibrah, 2008
Blackhead Ogaden (BHS)	2.6	11.4	16.4	23.7	Ethiopia	On-Station	Yibrah, 2008
BHS x Dorper	2.90	15.51			Ethiopia		Zewdu et al, 2010
Menz sheep	2.3±0.04	9.3±0.6			Ethiopia	Extensive	Haile et al. 2014
Wollo sheep	2.36±0.05	8.57		22.38	Ethiopia	On-Station	Mesfin et al., 2014
Wollo x Dorper	3.24±0.04	14.95		31.37	Ethiopia	On-Station	Mesfin et al., 2014
Dorper sheep	3.39±0.08	16.18±0.35	24.30±0.59	34.43±0.79	Ethiopia	On-Station	Ayele et al., 2015
Dorper x Menz (F_1)	2.77±0.04	12.34±0.31	17.25±0.30	31.33±0.56	Ethiopia	On-Station	Ayele et al., 2015
Dorper x Adillo 50%	2.25±1.72	17.30±0.98			Ethiopia	Extensive	Belete et al., 2015
Menz	1.98±0.02	8.52±0.13			Ethiopia	On-Station	Ayele et al., 2016a
Wollo	1.9±0.04	10.7±0.6	15.7±0.6	21.6±1.0	Ethiopia	Extensive	Tadesse, 2018
Awassi x Wollo cross	2.4±0.04	13.8±0.5	22.7±0.6	30.4±1.0	Ethiopia	Extensive	Tadesse, 2018
Washera x Wollo cross	2.2±0.04	14.0±0.4	19.5±0.5	30.2±0.8	Ethiopia	Extensive	Tadesse, 2018

BWT= Birth Weight, WWT = Weaning Weight, 6-MWT = Six Month Weight, YWT = Yearling Weight

2.11.2. Body weight of sheep (environmental influence)

2.11.2.1. Year and season of birth

The body weight of lambs is influenced by various factors, including parity, type of birth, sex, year and season of birth, and ewe postpartum weight (Ayele *et al*., 2015; Zelalem, 2018). Understanding these factors and their impact on lamb development and growth is crucial for optimizing breeding and management practices and improving production efficiency (Bermejo *et al*., 2010). Year of birth has been shown to cause variations in the weight and performance of hair lambs due to climatic fluctuations and management practices during pregnancy (Segura *et*

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al., 1996). Studies have reported significant effects of lamb's birth year and season on birth weight, as well as weights at 3, 6, and 12 months, and pre- and post- weaning average daily weight gain (Abebe, 1999; Ayele *et al*., 2015). For Dorper sheep, significant year effects were observed for birth weight, 3-month weight, 6-month weight, and 9-month weight, but no significant effect was found at 12 months of age (Mesfin *et al*., 2014a). Similarly, a study on sheep breeds in semi-arid regions of Nigeria found that year of birth significantly influenced birth weight, weaning weight, and weight at 6 months, but not at 9 and 12 months for the same breed (Momoh *et al*., 2013).

Regarding seasonal effects, Bermejo *et al*. (2010) found no significant difference in birth weight among lambs born in different seasons, but lambs born in winter had significantly lower weights compared to those born in spring, summer, and fall. This indicates that while seasonal factors may not have influenced birth weight across all seasons, there was a specific negative impact on lamb birth weight for those born during the winter months in the study population. Some potential explanations for this result could be nutritional factors, environmental stress and differences in management practices. On the other hand, Spring-born D'man lambs were heavier at birth compared to lambs born in other seasons, which aligns with similar findings in various breeds (Al-Shorepy and Notter, 1998; Gootwine and Rozov, 2006).

Seasonal differences in birth weight may be attributed to variations in ambient temperature and maternal effects during gestation, as optimal climatic conditions in spring promote fetal growth in late pregnancy. Previous studies have also reported seasonal influences on lamb growth in other prolific breeds (London and Weniger, 1996). Therefore, the adverse effect of summer on birth weight in lambs developing during this season may hinder the advantages of out-of-season lambing in flocks with high prolificacy, particularly when lambs from large litters have relatively low birth weights. The variations in weight observed across different years and seasons can be attributed to differences in farm management, feed availability, disease prevalence, and parasite burdens (Al-Najjar *et al*., 2010; Hasan *et al*., 2014). Seasonal variations in weight may be associated with differences in rainfall, which in turn affects pasture production and feed availability (Al-Shorepy *et al*., 2002; Otuma and Onu, 2013). These changes in body weight can be influenced by the availability of pastures to pregnant dams (Hasan *et al*., 2014).

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2.11.2.2. Parity and age of dam

Lambs born to older ewes exhibited a higher growth rate, as observed in my personal experience, this can be attributed to the competition between fetal and maternal growth, particularly in first parity ewes who are still in the process of maturing (Gemeda *et al*., 2002). Mellado *et al*. (2006), in their study on intensively managed Dorper sheep in central Mexico, also noted that the effects of parity and age of the dam could be explained by the fact that young ewes who have not yet reached their adult size continue to grow. This results in a competition between muscle synthesis and milk synthesis for available nutrients, leading to a reduced milk supply for suckling lambs. It is well established that maternal ability, including milk yield, increases with parity, and older ewes tend to be larger and produce more milk. Similar responses have been documented in other sheep breeds across different environments (Rashidi *et al*., 2008; Mohammadi *et al*., 2010; Ayele *et al*., 2015; Haile *et al*., 2020). According to King (2009), an increase in average weaning weight and post-weaning weight with an increase in the age (1-3) of the dam may be attributed to differences in maternal effects, nursing behavior, and maternal care exhibited by dams of different ages.

The influence of parity on birth weight (BWT), weaning weight (WWT), 6-month weight (6MWT), and 12-month weight (12MWT) of lambs has been consistently reported in the literature. Singh *et al*. (2006) found a significant effect of parity on these growth traits. Ayele *et al*. (2015) also confirmed the significant impact of parity on BWT, 6MWT, and 12MWT, although no significant effect was observed on WWT. Similarly, in their study on sheep breeds in a semi-arid region of Nigeria, Momoh *et al*. (2013) reported a significant effect of parity on BWT, WWT, and 12MWT, but no significant effect on 6MWT and 9MWT. Marufa *et al*. (2017) observed the effects of parity on BWT and WWT, but did not find any significant effect on 6MWT. Bermejo *et al*. (2010) documented significant effects of parity on BWT and 60-day weight for Canarian hair lambs.

2.11.2.3. Sex of the lamb

The sex of the lamb has been found to have a highly significant effect on all growth traits, consistently from birth to yearling weight (Momoh *et al*., 2013). This effect is believed to be due to differences in sexual chromosomes, the position of genes related to growth, physiological

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characteristics, and the endocrine system, including hormone secretion, especially sexual hormones (Momoh *et al*., 2013). Estrogen hormone, for example, has a limited effect on the growth of long bones in females, which may contribute to their smaller body size and lighter weight compared to males (Rashidi *et al*., 2008).

Hormonal actions have also been attributed to the sex effect on growth in farm animals (Hafez, 1962). Male lambs, influenced by male hormones with anabolic effects, tend to have higher prenatal growth, resulting in higher birth weights (Hafez, 1962). As lambs continue to grow, males may begin secreting androgenic substances earlier, leading to faster growth and development compared to females (Ebangi *et al*., 1996). The higher weight of males compared to females at all ages, as well as the observed effect of litter size, is a general trend in sheep and may reflect differences in hormonal profiles favoring growth rate in males during infancy (Ebangi *et al*., 1996).

Several studies have reported significant effects of lamb sex on birth weight (BWT), weaning weight (WWT), 6-month weight (6MWT), and 12-month weight (12MWT) (Momoh *et al*., 2013; Mesfin *et al*., 2014; Alemu, 2015). Ayele *et al*. (2015), in their study on Menz, Dorper, and Dorper x Menz crossbred lambs, consistently found that male lambs had superior weights compared to females in BWT, 6MWT, and 12MWT, although similar WWT was observed for both sexes. Similarly, in another study by Ayele *et al*. (2016a) on Menz, low-grade Awassi x Menz, and high-grade Awassi x Menz sheep, male lambs had significantly higher BWT and WWT compared to their female counterparts. However, it should be noted that some studies, such as the one conducted by Al-Najjar *et al*. (2010), did not find a significant effect of lamb sex on birth weight.

2.11.2.4. Type of birth

The type of birth, whether single or multiple, has been found to have significant effects on growth parameters in lambs. This can be attributed to factors such as competition for uterine space and fetal nutrition during the last trimester of pregnancy, as well as competition for suckling after birth (Al-Shorepy *et al*., 2002).

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Single-born lambs tend to have a growth advantage in the early period compared to multiple-born lambs. This advantage may be due to lower competition for maternal nutrition supply during gestation (Zhang *et al*., 2009). Single-born lambs are generally heavier than multiple-born lambs because the maternal uterine space has a limited capacity to accommodate multiple fetuses, leading to reduced individual birth weights as litter size increases. For example, studies have shown that twins have an average birth weight that is 87% of the average singleton weight, triplets have 75%, and quads have 62% (Robinson *et al*., 1977; Gardner *et al*., 2007; Bermejo *et al*., 2010). A considerable number of authors have reported the effects of type of birth on growth parameters in lambs. Mellado *et al*. (2006), Bermejo *et al*. (2010), Ayele *et al*. (2015), and Marufa *et al*. (2017) have documented these effects at different ages of lamb growth.

2.11.3. Growth rate of lambs

According to Alfonso *et al*. (2019), the pre-weaning stage is crucial in sheep production systems focused on meat production. Admasu *et al*. (2018) emphasized that the growth performance of lambs during this stage depends on their genetic potential, as well as the adaptability and mothering ability of the ewes. Maternal ability plays a key role in lamb development and productivity at this stage. Laes-Fettback and Peters (1995) and Ayele *et al*. (2016a) supported this idea, highlighting the significant influence of birth weight on pre-weaning growth performance. Amin (2017) concluded from his studies that factors like weaning age, weaning stress, and compensatory growth can affect the growth rate of lambs in subsequent stages. For instance, post-weaning, different groups of lambs may experience weight loss due to weaning stress, influenced by both genotype and environment, particularly in the period just after weaning (Lu and Potchoiba, 1988). Tadesse (2018) mentioned that the mothering ability of the dam significantly affects the average daily weight gain and weaning weight of lambs, especially during growth stages when they rely more on milk production than forage.

Post-weaning growth rates in lambs can be influenced by both genetic and non-genetic factors. During this period, lamb's transition from a highly nutritious milk diet with some grazing to exclusive grazing, can lead to a weaning shock and lower growth rates compared to the pre-weaning period. Several researchers (Mengiste *et al*., 2009; Lakew *et al*., 2014; Ayele *et al*., 2016a) reported lower post-weaning gains in lambs compared to the pre-weaning period. Lakew *et al*. (2014), for example, found that local lambs had pre- and post- weaning growth rates of 68

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g/h/d and 38 g/h/d, respectively, while Dorper crossbred lambs had rates of 130 g/h/d and 65 g/h/d, highlighting the breed effect on post-weaning growth performance. Additionally, birth season and year have been observed to influence post-weaning growth performance in lambs by several authors (Hassen *et al*., 2002; Mekuriaw *et al*., 2011; Lakew *et al*., 2014). These variations in growth rate between seasons and years could be attributed to management differences at the breeding site and variations in climatic factors, such as rainfall, which affect the quantity and quality of forage available for the lambs, Table 3, depicts the average weight gain of lambs at different ages.

Table 3. Average weight gain of lambs at different age

Breed	Weight gain age category			Location	Management	Data source
	Pre-WNG-gain	3-6M-gain	6-12M-gain			
Menz sheep	66.01	51.45		Ethiopia	Extensive	Abebe, 1999
Wollo sheep	67.78±1.60	37.94±1.19		Ethiopia	On-station	Mesfin et al., 2014
Wollo x Dorper	129.9±2.23	64.39±1.74		Ethiopia	On-station	Mesfin et al., 2014
Dorper sheep	142.93±3.89	100.00±3.23	81.23±2.18	Ethiopia	On-Station	Ayele et al., 2016a
Dorper x Menz 50%	106.24±2.61	78.04±1.61	76.19±1.41	Ethiopia	On-Station	Ayele et al., 2016a
Menz sheep	71.4±1.32			Ethiopia	On-station	Ayele et al., 2016b
Awassi x Menz 25-50%	94.03±1.62			Ethiopia	On-station	Ayele et al., 2016b
Awassi x Menz 75%	101.18±3.59			Ethiopia	On-station	Ayele et al., 2016b
Wollo	60.1±2.1			Ethiopia	Extensive	Tadesse 2018
Awassi x Wollo	121.4±3.78	81.1±2.81		Ethiopia	Extensive	Zeleke et al., 2018
Awassi x Wollo	77.0±2.1			Ethiopia	Extensive	Tadesse 2018
Washera x Wollo	73.8±1.6			Ethiopia	Extensive	Tadesse 2018

Pre-WNG-gain (pre-weaning gain), 3-6M-gain (three to six months gain), 6-12M-gain (six to twelve months gain)

2.12. Dorper crossbreeding system in Ethiopia

2.12.1. Dorper crossbreeding strategy and program in Ethiopia

Although Ethiopia has experienced the importation of several exotic sheep breeds at different times, namely; Bleu du Maine, Merino, Rambouillet, Romney, Hampshire, Corriedale, and Awassi (Markos, 2006) aimed at improving the productivity of producers' flock, no such significant effects on sheep productivity on farmers' and pastoralists' livelihood and the national

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economy at large was evidenced (Solomon *et al*., 2013; Tesfaye *et al*., 2016; Sheriff and Kefyalew, 2018). For example, the Awassi sheep breed was imported to Ethiopia in 1980, 1984, and 1994. Previous studies on Awassi crossbred sheep have revealed significant variations in productive performance across different locations and individual producers. Between 1970 and 2000, 4,208 crossbred rams were distributed from the Debre Berhan center, while 355 were distributed from the Amed Guya center. However, a large portion of these crossbred rams were either sold or castrated for fattening purposes, rather than being used for breeding (Solomon and Tesfaye, 2009). This highlights the inconsistencies in the implementation and outcomes of the crossbreeding programs.

The major drawback in the livestock crossbreeding programs in Ethiopia has been the lack of a clear and documented breeding and distribution strategy (ESGPIP, 2011; Solomon *et al.,* 2014; Tesfaye *et al.,* 2016). Insufficient attention has been given to addressing the needs of farmers and pastoralists, their perception, and the utilization of indigenous practices. Furthermore, their involvement in the planning and execution of breeding programs has been limited or nonexistent. Further, the breeding programs lacked breeding schemes to sustain crossbreeding at the nucleus centers and the village level (Solomon *et al*., 2013; Sheriff and Kefyalew, 2018).

According to ESGPIP (2011), the lack of clear and documented national livestock breeding policies and strategies in Ethiopia has for long been a major issue of concern for the rational utilization of exotic genetic resources and conservation of indigenous livestock breeds. Nonetheless, output from on-station and on-farm pilot crossbreeding villages with Awassi sheep in the highlands of Ethiopia indicated that crossbreds outperformed the locals in their respective areas, though the performances of crossbreeds do vary by location and deepened on the management and production environment and admixture levels. In agreement with this, Tesfaye *et al*. (2016) from their study mentioned that if the interests of the farmers' are considered farmers working on crossbreeding most of the time exhibited great interest in the crossbreeding activity because of the fast growth, the large body size of crossbreds resulting in better market pay in comparison with the local ones.

A few success stories from pilot Awassi's crossbreeding work at the village level encouraged the Ethiopian government and recent livestock development projects like ESGPIP to be involved in

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the importation of Boer goats and Dorper sheep from South Africa. Indeed, ESGPIP designed a crossbreeding program of sheep and goats with Dorper and Boer breeds in some potential areas to enhance meat production (Kassahun and Gipson, 2009). On July 1, 2007, Dorper sheep were imported from the Republic of South Africa to Ethiopia primarily for crossbreeding. The breeding program encompasses four nucleus centers and ten BED sites (breeding, evaluation, and dissemination). These nucleus and BED sites, operated under the ESGPIP (Ethiopian Sheep and Goat Productivity Improvement Program), were responsible for the production, evaluation, maintenance, and distribution of purebred and crossbred Dorper sheep to farmers, pastoralists, sheep ranches, and private individuals (ESGPIP, 2011; Mekonen et al., 2014).

The ESGPIP project had implemented a three-tier breeding structure for the Dorper sheep-crossbreeding program in Ethiopia. The first tier consisted of nucleus centers focused on multiplying and maintaining purebred Dorper sheep. The second tier comprised BED centers, which were responsible for the production and supply of crossbred Dorper males. These males are then distributed to the third tier, which consists of villages or local communities.

- **First tier (nucleus centers)**

The initial tier, referred to as the nucleus centers, included the Fafen Integrated Livestock Research Centre, Werer Research Centre, and the lately added Debre Birhan and Areka Research Centers. These specific centers were assigned the responsibility of multiplying and preserving the purebred Dorper sheep. These centers are potential sources of pure Dorper sheep for BED and better-off farmers. According to personal communication, at least more than 520 male and 540 female pure Dorper lambs are born in Debre-Birrhan and Werer research centers. Areka research center has also produced 20 pure Dorper lambs.

- **The second tier (Breed Evaluation and Distribution or BED centers)**

Sirinka, Yabello, Werer, Fafen, Debre Birhan, Areka agricultural research centers. Haramaya and Hawassa Universities were designated to multiply, evaluate and maintain the F_1 Dorper crossbreed sheep. These centers are also potential sources of F_1 Dorper crossbred rams for distribution in different parts of the country. According to personal communication, a total of 279, 485, and 251 Dorper crossbred lambs were born in Werer, Debre-Birhan and Areka research centers, respectively.

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- **The third tier (villages).**

The objective was to provide F_1 males to individual smallholder farmers and pastoralists, as well as groups of farmers, for the purpose of crossbreeding with local female sheep. This crossbreeding aimed to produce and market animals with 25% Dorper sheep blood levels (ESGPIP, 2011; Mekonen *et al*., 2014).

2.12.2. Dissemination strategy

2.12.2.1. Dissemination of pure-bred stock

The primary dissemination strategy adopted by ESGPIP includes the distribution of purebred seed stocks to BED sites, private commercial farms, satellite nucleus sites, and limited supply to farmers through the provision of ram stations in nucleus centers and farmers' schools for surrounding farmers. According to ESGPIP (2011), the strategy for dissemination of Dorper crossbreds consists of promoting the production of crossbred breeding stock by commercial producers and the production and distribution of crossbred rams from its BED centers to villages.

2.12.2.2. Dissemination of crossbred Dorper sheep to villages

Dissemination of breeding stocks needs special consideration because of the uncontrolled breeding practices in villages and the low input mode of production in the majority of traditional production systems. ESGPIP disseminated half-bred Dorper rams to villages. There are alternative strategies for dissemination, such as the distribution of crossbred males with 75% exotic blood through back-crossing (e.g., Awassi cross-breeding program in Ethiopia). However, the efficiency of the two strategies of ram distribution to village flocks is similar when the number of generations required to achieve a given level of cross-breeding at the village level is considered. Secondly, the first crosses (quarter-crosses) produced in villages under the half-cross strategy could be more suitable to low input extensive production systems (ESGPIP, 2011; Solomon *et al*., 2013). A total of 89 and 321 purebred and crossbred Dorper sheep breeding stocks, respectively, have been distributed to public BED sites, satellite sites and private producers by the end of September 2011 (Table 4) for details.

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Table 4. Improved Dorper genotype delivered to ESGPIP BED sites, satellite nucleus sites, and producers by the end of September 2011

Recipients within target regions	Distributed Dorper sheep by blood level and sex				Total
	Pure		50% Dorper cross		
	Male	Female	Male	Female	
ESGPIP Nucleus and BED sites	16	-	-	20	36
Smallholder/pastoralist producers	8	-	156	12	176
Farmer groups	20	-	47	10	77
Private commercial producers	2	5	2	2	11
Satellite Nucleus sites	6	32	26	22	86
Carcass and skin quality study	-	-	24	-	24
Total	52	37	255	66	410

Adapted from ESGPIP 2011, and verified from the sites by the author

Preliminary results from the performance evaluation of Dorper crossbred sheep in the lowlands showed encouraging results. Dorper crossbreed sheep were also found to be well adapted to the conditions of mid-highland in the Southern parts of the country and the cool highlands of North Shewa. Due to the advantage of the new breed over the local breed in growth and interest for crossbreeding, farmers bought crossbred sheep from ranches and individual farmers to improve the productivity of their local sheep.

The Livestock Agency of the Amhara Regional State initiated the distribution of Dorper sheep across various areas in eastern Amhara without conducting prior research or determining specific areas for implementation. In line with this, Tesfaye *et al*. (2016) highlighted the concern that indiscriminate crossbreeding, lacking an analysis of the suitability of crossbred animals for specific production environments and without well-defined breeding objectives, poses a potential risk to indigenous breeds that are better adapted to the local conditions. Despite all this, evaluation of the Dorper sheep crossbreeding systems; ram multiplication and distribution systems adopted by ESGPIP, research centers, and ranches is of paramount importance to take corrective measures in the Dorper crossbreeding program and also understand if farmers were satisfied with the crossing system; was it effective, what were the challenges with the system were explored.

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CHAPPTER 3: METHODOLOGY

3.1. Description of the study area

3.1.1. On-farm study sites

The monitoring sites chosen for on-farm observation of Dorper sheep encompass a diverse range of locations, each providing unique insights into the breed's performance and adaptability. These sites, depicted in Figure 1, include Kewet, Efratana-Gidim, Merhabete, Basona-Worena, Raya-Kobbo, and Yabello. Additionally, the survey work extended to include additional sites such as Minjar-Shenkora, Damot-Sore, and Damot-Pulassa.

Based on factors such as altitude, rainfall, and temperature, these sites were broadly categorized into different agroecological regions. The highland areas consisted of Basona-Worena, Merhabete, Minjar-Shenkora, Damot-Pulassa, and Damot-Sore. These sites share similarities in terms of being highland regions with cool to moderate temperatures and moderate to high rainfall. The midland areas include Kewet and Efratana-Gidim, characterized by warm temperatures and moderate to high rainfall. Yabello represents the lowland area, categorized by warm temperatures and moderate rainfall. Finally, the Kobo area was classified as a midland region with hot temperatures and low rainfall. Based on the above classifications, a comprehensive understanding of Dorper sheep's behavior, health, and productivity could be obtained. This approach allows for a broader perspective on how the breed performed across various agroecological zones.

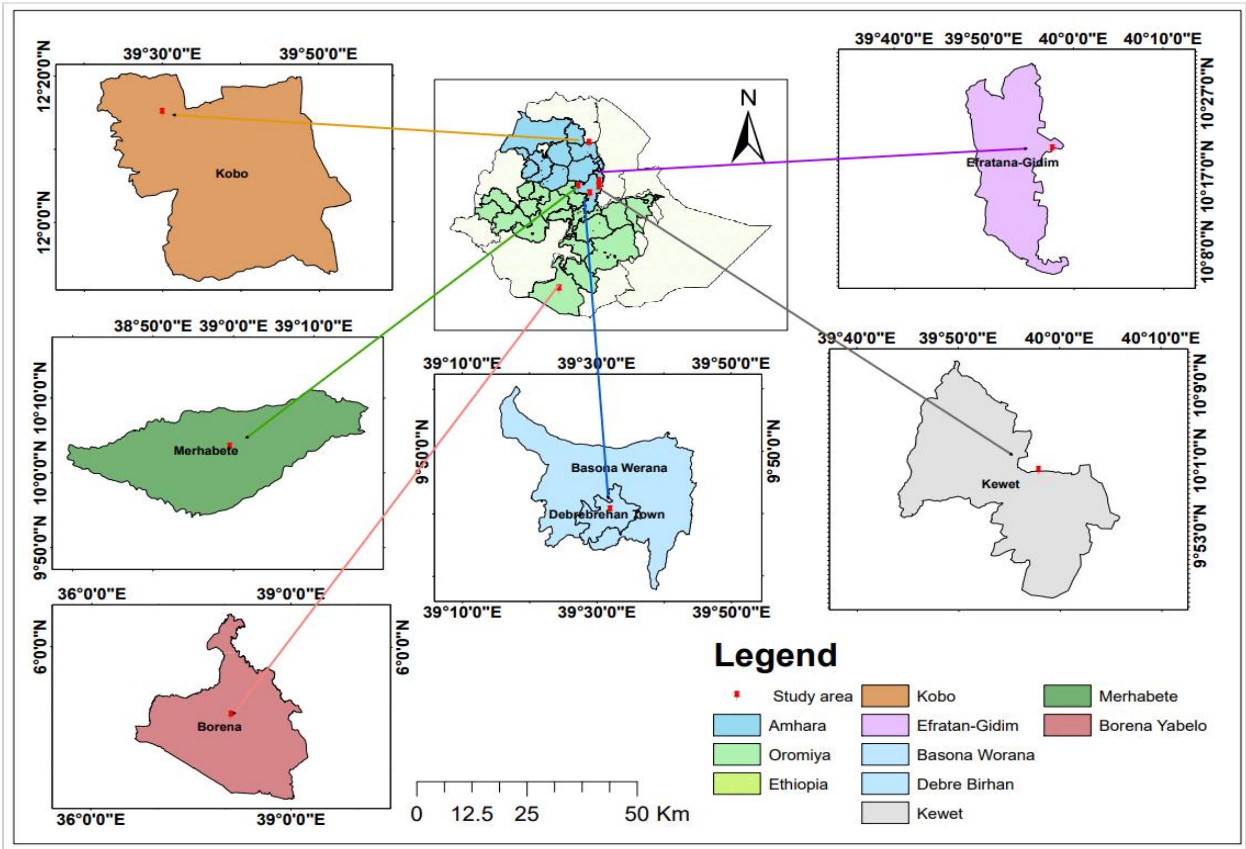

Figure 1. On-farm Dorper monitoring sites

3.1.2. On-station study sites

The on-station evaluation sites encompass a range of locations across the country, including Debre-Birhan, Areka, Werer, Fafen, Sirinka, Yabello agricultural research centers, Haramaya University, Hawassa University, and Ethiopian Meat and Dairy Technology Development Institute (EMDTI), (Table 5). Additionally, two sheep breeding and multiplication centers in the Amhara region were consolidated in 2014. As per the ESGPIP, the Nucleus sites comprise the Worer, Fafen, Debre-Birhan, and Areka research sites. On the other hand, the BED sites encompass the Yabello, Sirinka, research, Hawassa and Haromaya Universities, EMDTI, Amed-Guya, Debre-Birhan sheep breeding and multiplication centers.

These sites are further classified into low-mid-to-highland areas (Werer, Fafen, Yabello, Hawassa University, Areka, Sirinka, EMDTI, Haromaya University) and cool-sub-alpine areas

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(Debre-Birhan research, Amed-Guya, and Debre-Birhan sheep breeding and multiplication centers), based on factors such as altitude, temperature, and rainfall patterns specific to each area.

Table 5. Location and environmental descriptors of on-station performance evaluation of purebred Dorper and crossbred sheep in Ethiopia (Nucleus and BED sites).

Study Location	Altitude (m.a.s.l)	Latitude	Longitude	Temperature (ºc)			Rainfall
		(North)	(East)	Min	Max	Average	(mm)
Low-mid-to-highland	(740-1980)=1633.4			**8.9**	**40.8**	**21.5**	**790.9**
Werer research	740	9°16’	40°9’	18	40.8	29.4	571.2
Fafern research	1505	9°20'27"	42°32'50"	20	35.0	27.5	650
Yabello research	1622	$4^0$52'41"	$38^0$8'48"	13	28.9	20.9	450
Hawassa University	1714	$7^0$6'	38°51'	13	27.5	20.3	965
Areka research	1790	$7^0$4'32"	37°41'40"	13	25.0	19.0	1100
Sirinka research	1850	11°45′00″	39°36′36″	14	26.4	20.1	950
Ethiopian Meat & Dairy Technology Institute	1896	8^0 73’	$39^0$10’	8.9	28.3	19.0	851
Haromaya University	1950	9°25’	42°2'	9.7	24.0	16.0	790
Cool-sub alpine	(2800-2947)=2857			**6**	**20.0**	**12.9**	**1012**
D/Birhan SBAMC	2800	9°47’’	39°34'	7	20.0	13.5	1050
D/Birhan research	2824	9°66’’	39°49¢	6	19.7	12.9	986
Amed-Guya SBAMC	2947	$11^0$19'00"	$39^0$32'60"	6	18.6	12.3	1000

SBAMC (Sheep breeding and Multiplication Center), BED (Breeding, Evaluation and Distribution)

3.2. Study flock management practices followed

3.2.1. Farmers’ flock management practices

Commencing in 2012, volunteer farmers residing in the study areas were organized into communities with the purpose of implementing crossbreeding programs. The researchers and technical assistants from Debre-Birhan, Sirinka, and Yabello Agricultural Research Centers actively participated in delivering hands-on training sessions regarding Dorper crossbreeding techniques. Farmers who possessed 4-5 indigenous breeding ewes (in their respective sites), that shared common grazing and watering points, were grouped together into Dorper breeding groups. Regular procurement of Dorper rams was carried out from the research system.

Following the community based breeding practice (CBBP), a group of 20-25 breeding ewes was assigned to each Dorper ram for mating in order to avoid inbreeding. After a year and half, a new ram was introduced to the breeding group. This rotational approach helped maintain genetic diversity and minimize the risk of inbreeding. It is important to note that genetic material exchange occurred within each individual site, not among the other study sites. The responsibility of managing the breeding rams was assigned to individual members of the breeding group when the ram was present within their flock. The breeding program relied on natural mating, and the main source of feed for the flock was the natural grazing materials found in the respective study sites. Farmers ensured that the breeding rams received adequate nutrition by supplementing their diet with additional feed sources. They utilized the resources available to them to provide this supplementary nutrition for the rams.

The flocks of farmers received vaccinations against prevalent sheep diseases specific to their respective areas, and preventive measures were taken to protect them from external and internal parasites according to the protocols provided by the research centers. These treatments were initially administered at the project's inception and subsequently repeated every 3-6 months.

3.2.2. On-station flock management practices

Based on the research farms' protocols, the sheep flocks in different on-station sites exercised several similar management practices to ensure the health and productivity of the sheep flocks. The sheep grazed on natural pastures and received concentrate supplementation based on physiological needs. To maintain the flock's well-being, the sheep were vaccinated annually against common diseases such as sheep-pox, pasteurellosis, and anthrax. Treatment for external parasites was conducted using diazinol, while albendazole, a broad-spectrum treatment, was administered four times a year for internal parasites. Lambs were weaned at around three months of age, and separate sex groups were formed for grazing.

During the mating period, which generally lasted between 42 to 60 days, the sheep grazed on natural pastures. In addition, the flock received hay from research farms while indoors. Concentrate supplementation, on the average containing 13 MJ/kg DM and 17% CP, was provided at a rate of 200-300 grams per day during the flushing and pregnancy trimesters. Lambs born within the experiment were raised with their parents until weaning at 90 days. After weaning, the lambs were managed separately and grazed on natural pastures away from their mothers.

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Lambs were identified with numbered plastic ear tags shortly after birth. Birth weight, litter size, sex of the lamb, and dam parity were recorded within 24 hours of lambing. Regular weighing of lambs occurred at fortnightly intervals until weaning, and then monthly thereafter. Important data, including birth, reproduction and growth information of lambs, were recorded, lamb mortality within the flocks was diligently monitored and recorded, the daily records of lamb mortality were maintained for both pre-weaning and post-weaning periods.

3.3. Data source and collection

3.3.1. On-station - data source and collection

On-station data was collected from various research stations, universities, and breeding and multiplication centers. The stations included Worer, Fafen, Debe-Birhan, Areka, Yabello, Sirninka research centers, Haramaya, and Hawasa Universities, as well as Amed-Guya and Debre-Birhan sheep breeding and multiplication centers and EMDTI. The data collection period spanned from 2006 to 2022.

Specifically, mating-related data, such as conception and abortion, were collected from a total of 3,437 ewes. Among these, there were 995 Dorper purebred ewes, 274 Dorper crossbred ewes, and 2,168 local ewes. Age at first lambing data were obtained from 1,700 ewes, with 319 being Dorper purebred, 402 being Dorper crossbred, and 1,059 being local ewes. Growth-related data were collected from a total of 9,369 births. Among these births, there were 1,587 Dorper purebred lambs, 2,113 local lambs, 3,784 lambs from 50%-Dorper x local-F_1 crosses, 891 lambs from 50%-Dorper x 50%-Dorper x local *inter se* mated crosses, 155 lambs from 25%-Dorper x local crosses, and 839 lambs from 62.5% & 75%-Dorper x local crosses. Furthermore, survival data were collected from the same 9,369 lambs that were born on-station.

3.3.2. Village monitoring data source and collection

From 2012 to 2021, an extensive on-farm monitoring initiative was carried out at Basona-Werena, Merhabete, Efratana-Gidim, Raya-Kobo, Kewet and Yabello areas. The primary focus of the monitoring activities was to gather valuable reproductive, survival, growth & marketing-related data. For growth-related information, a total of 4,066 birth weight observations were utilized. Among these, 952 observations were for local sheep, 1,941 observations were for

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Dorper x local crossbred sheep with low-grade Dorper inheritance (12.5-25% Dorper inheritance), and 1,173 observations were for Dorper x local crossbred sheep with high-grade Dorper inheritance (37.5-43.75% Dorper inheritance).

Regarding litter size at birth, 3,585 records were analyzed, with 3,242 records belonging to local ewes and 343 records belonging to Dorper crossbred ewes. Survival data up to 90 days after birth were obtained from approximately 4,097 birth records. Out of these, 952 records were from local lambs, 1,941 records were from low-grade Dorper inherited lambs, and 1,173 records were from high-grade Dorper inherited lambs.

Additionally, information was collected through surveys, discussions, and on-site animal measurements and assessments at Minjar-Shenkora, Damot-Pulassa, Damot-Sore, Baso-1, Baso-2, Kobo, Merhabete, and Kewet. Farmers' perception was also taken into account. Various instruments were employed for data collection, including a salter scale balance with a 50 kg capacity and 200 g precision for weighing lambs and a weighing bridge for weighing adult mature animals. Body linear measurements were taken using appropriate measuring tools.

The survey work aimed to capture essential household information such as landholding and use patterns, livestock composition, sheep flock structure, purpose of sheep keeping, major constraints in sheep production, breeding and selection criteria, farmers' perceptions of adaptability and productivity of Dorper sheep, reproductive and productive performances, survival information, current inventory of Dorper and crossbred sheep, and challenges in the Dorper breeding program.

3.4. Data collection methods

3.4.1. Questionnaire survey, focus group discussion, and on the spot observation and measurement

A single-visit survey was conducted in areas where respective institutions facilitated the distribution of Dorper crossbred rams to gather producers' opinions on the adaptability and productivity of Dorper sheep through personal interviews using a semi-structured questionnaire, focus group discussions, measurement of morphological traits on sheep flocks, and field

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observations involving a total of 248 households from Baso-1, Damot-Pulassa, Damot-Sore, Kobo, Minjar-Shenkora, Merhabete, Kewet, and Baso-2 areas.

To assess perception, each household head was asked to rank productive traits and adaptability of local and Dorper crossbred sheep on a five-point scale (very poor, poor, moderate, good, and very good). Focus groups were also organized to validate the data obtained from individual interviews. These groups consisted of eight individuals knowledgeable about crossbreeding and crossbred sheep in their respective areas. The survey gathered data on the physical conformation and mating ability of the Dorper crossbred rams, as ranked by the farmers as poor, fair, or good. Researchers complemented this by taking the rams' body condition scores and linear body measurements, including the scrotum circumference. Additionally, the researchers took linear measurements of the local, Dorper crossbred lambs and the local, Dorper crossbred ewes they encountered during the on-site visits.

3.4.2. Growth, reproduction, and survival data collection (both on-station and on-farm)

Trained enumerators, supervised by a research and university team, collected on-farm data on various aspects of Dorper crossbreeding. These data primarily focused on the village management system. Additionally, the research team collected data on the sheep's productive, reproductive, survival, and pedigree information under on-station management conditions.

Data on the growth performance of sheep were collected to assess various weight measurements, including birth weight (BWT), weaning weight (WWT), six-month weight (6MWT), and yearling weight (12MWT). These measurements were taken both at on-station and at on-farm using calibrated scales appropriate for accurate weight measurements, following the research and university protocol.

Similar to growth performance, data on reproduction was also collected. Specifically, information was gathered immediately when a ewe gives birth, including details such as litter size, lambing ease, and any complications during the birthing process. Additionally, data on the survival of lambs and adult sheep were recorded both at on-station and at on-farm, including the causes of death if applicable. By collecting this comprehensive set of data on growth

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performance, reproduction, and survival, a holistic understanding of the overall performance and viability of the sheep population under both on-station and on-farm conditions was sought.

3.4.3. Pedigree information from both on-station and on-farm evaluation works

Each animal, including both adults and lambs, was assigned a unique identification at birth or upon joining the flock. This identification system allowed for accurate tracking and record keeping of each animal throughout their life cycle. Alongside the unique identification, information regarding the dam and sire of each animal was recorded, including their respective identification numbers. Additionally, details such as the sex, breed, and type of birth (e.g., single or twin) were also documented and associated with the corresponding lamb identification. This comprehensive identification and recording system ensured the ability to trace the lineage and genetic information of each animal within the flock.

3.4.4. Dorper crossbreeding scheme (on-farm)

The on-farm monitoring sites implemented a breeding system primarily focused on using 50% Dorper crossbred rams for mating with local ewes. In specific locations such as Efratana-Gidim, Basona-Worena, Merhabete, Yabello, and Kewet areas, various local ewe breeds were utilized, including Afar, Menz, local sheep in Merhabete, and Blackhead Somali, respectively. This crossbreeding approach resulted in the birth of both Dorper crossbred lambs and local lambs at the respective sites.

The Dorper crossbred lambs born exhibited different levels of Dorper inheritance. The lambs with 25% Dorper inheritance resulted from the mating of Dorper crossbred rams with local ewes. Subsequently, lambs with 37.5% and 43.75% Dorper inheritance were produced through upgrading. Additionally, when a quarter-bred sire mated with local ewes, downgrading occurred and lambs with 12.5% Dorper inheritance were born. Mating between local rams and ewes also led to the birth of local lambs. Trained enumerators with the follow-up of researchers collected data on productive, reproductive, survival, market, and pedigree information of the sheep under village management conditions.

To capture comprehensive data on the performance and outcomes of the Dorper crossbreeding program, extensive field visits were made and a multi-faceted data collection approach were

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employed. During the flock visits, detailed information on the Dorper crossbred lambs and ewes, including their body weight, body condition score, and linear body measurements were collected, current market prices of the Dorper crossbred animals was also estimated. Additionally, data on the proportion of Dorper crossbred lambs born compared to the local lambs within the participating farmers' flocks was collected. Through in-depth interviews with the farmers, we documented the number of Dorper crossbred lambs born within and across the study households. We also recorded the number of Dorper crossbred sires received by the farmers and assessed the farmers' perceptions on the adaptability of the Dorper crossbred rams, categorizing them as good, fair, or poor. Furthermore, information on the source of the Dorper rams (i.e., who provided them to the participating farmers) and the status of the distributed Dorper crossbred rams (whether they were currently in service, sold, died, or sold) were collected. Finally, data on the farmers' ratings of the future demand for Dorper crossbreeding, which they categorized as low, moderate, or high were collected by discussing with participating farmers. This comprehensive data collection approach allowed us to gather valuable insights into the performance and prospects of the Dorper crossbreeding program from multiple perspectives, including animal-level data, farm-level practices, and farmer perceptions.

3.4.5. Dorper crossbreeding scheme (on-station)

The on-station breeding system implemented a combination of pure and crossbreeding approaches. In the nucleus sites such as Werer, Fafen, Debre-Birhan, and Areka, a pure breeding system was employed for both Dorper and local sheep. These sites produced Dorper purebred lambs, and local and crossbred lambs utilizing specific ewe breeds like Afar sheep at Worer, Blackhead Ogaden sheep at Fafen, Menz sheep at Debre-Birhan, and Adilo sheep at Areka, and Dorper sheep in all nucleus centers. In the nucleus sites, both Dorper purebred lambs and local lambs from local ewes were produced.

In other on-station sites including Yabello, Sirinka research, Haramaya, and Hawasa Universities, Debre-Birhan, and Amed-Guya sheep breeding and multiplication centers, crossbreeding was carried out using Dorper purebred and Dorper crossbred rams with local ewe breeds. The specific local ewe breeds involved in these crossbreeding programs were Blackhead Ogaden sheep in Yabello and Haramaya, Wollo sheep in Sirinka, Menz sheep in Debre-Birhan and

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Amed-Guya, and Hararghe highland sheep in Haromaya University. Crossbreeding activities were also conducted in the nucleus sites to produce lambs with varying levels of Dorper inheritance. Under on-station management conditions, the Dorper crossbred lambs born encompassed different levels of Dorper inheritance, including Dorper x Local at 25%, 50%, 75%, and 50% x 50% (*inter se* mated). This comprehensive breeding strategy aimed to explore the potential benefits and characteristics associated with different genetic combinations and inheritance levels of Dorper sheep. Therefore, information on how many male and female Dorper purebred sheep imported, how many male and female (pure Dorper and crossbred) lambs produced, how many pure bred Dorper and Dorper crossbred sheep were distributed to the different stakeholders were captured from the nucleus and BED sites.

3.4.6. Dorper sheep multiplication and distribution (encompassing all stakeholders)

Discussions were conducted with various stakeholders separately, including Kebele extension agents, Woreda extension agents, individual farmers, key informants, focus groups, sheep researchers, and ranch experts to gain insights into the challenges facing the success of the Dorper crossbreeding program. The distribution modality of Dorper and crossbreed rams by different stakeholders was examined. Additionally, the following checklists were given due attention and pertinent data were collected.

- Identification of the entities responsible for multiplying and distributing Dorper and crossbreeds in Ethiopia (who).
- Bloodline information of Dorper sires distributed from research sites and sheep ranches.
- Recipients of Dorper sires (the research/development system, along with the year and season of distribution).
- Quantification of Dorper and crossbred rams produced and distributed from nucleus and BED sites, ranches, and private owners.
- Analysis of the distribution modality for exotic Dorper sires and crossbred rams (who, how, where)
- Evaluation of whether farmers/pastoralists were able to replace old, diseased, or non-serving Dorper sires obtained from different sources.
- Assessment of the presence of a ram exchange mechanism.

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- Examination of flock dynamics related to Dorper and crossbreeds at both on-station and producer levels.
- Identification of challenges perceived in the distribution of Dorper sires from research/development and farmers/pastoralists' perspectives.
- Ranking of the main challenges and constraints of the Dorper crossbreeding program.
- Consideration of any concerns raised regarding the program.
- These comprehensive discussions and analyses aimed to shed light on the effectiveness and potential improvements for the successful implementation of the Dorper crossbreeding program while addressing the concerns and expectations of stakeholders.

3.5. Data management and statistical analysis

3.5.1. Analysis of perception of farmers' on Dorper sheep production

- Survey data captured using a questionnaire regarding perception and data related to morphometric measurements were entered and managed into Microsoft Excel 2016.
- The data were subjected to cross-tabs of descriptive statistics to get percentage using Statistical Package for Social Sciences (SPSS, 2011 Ver. 25). Chi-square (χ^2) test was employed to test the significant differences of the variables and
- Continuous types of data were analyzed using the general linear model procedure of (SAS, 9.4 ver. 2014). An index were employed for qualitative data ranking as needed.

In general, For ranking variables, indices were constructed using the following formula: Index =Σ[3* rank 1 + 2* rank 2 + 1* rank 3] given for particular qualitative variables divided by Σ [3* rank 1 + 2* rank 2 + 1* rank 3] for all qualitative variables considered, in this particular work the same trend was followed for similar type of data.

Perception data collected using the Likert scale (scores from 1 to 5) were tested for reliability and internal consistency of the scale by Cronbach's alpha (α) test (Cronbach, 1951) using the Statistical Analysis System SAS 4 according to HOW2STATS. The formula was presented as follows: $\alpha = \frac{Kr}{(1 + k - r)r'}$

where k is number of indicators or number of items and mean inter indicator correlation. The Cronbach's alpha value (α 0.80) showed that 80% of the variance in the scores was a reliable variance. Then, the ordinal regression with the cumulative logit function was used to quantify the perception of farmers for different attributes of two genotypes because cumulative logit function is appropriate for ordinal-dependent variables with three or more levels Elkin (2012). The cumulative logit model was as follows:

$$Logit\,[P(y<j,x] = \mathrm{Log}\,[\frac{P(y\leq j)}{P(y>i)}] = \alpha j + \beta x,\ j=1,\ldots c-1,$$

Where y is an ordinal response (c categories) and x is an explanatory variable. Spearman's non-parametric correlation coefficient (r) of ranks was used to compare the ranking of traits perceived by farmers.

The cumulative probability of an event was calculated as follows:

$$\Pr(Y \leq y_j,x) = Log\,\frac{exp(\alpha j + \beta x)}{1 + exp\,(\alpha j + \beta x]},\ \ j=1,\ldots c,$$

where Pr (Y ≤ yj) is the cumulative probability of the event (Y ≤ yj); αj are the unknown intercept parameters, satisfying the condition α1 ≤ α2 ≤ ... αk; and β (β1, β2,...,βk)′is a vector of unknown regression coefficients corresponding to x.

3.5.2. Analysis of reproductive performance

The annual reproduction rate (number of lambs reared per ewe/year) and productivity indices (Index I, II and III) were calculated for each ewe having at least two consecutive lambing records. The total number of lambs reared to 90 days of lamb age per ewe per year (NLR), which reflects the annual reproduction rate, was calculated for each ewe as:

$$NLR = \frac{\text{Litter size at 90 days of lamb age}}{\text{Subsequeant parturition interval in days}} \times 365$$

Several indexes were created to evaluate the overall productivity of sheep (Gatenby, 1986). Many of these indexes measure productivity relative to the body weight of the ewes within the flock, aiming to consider the increased feed expenses associated with larger animals.

Productivity index I, which is weight (kg) of lamb production to 90 days of age per ewe per year, was calculated as:

$$\text{Index I (kg per ewe/year)} = \frac{\text{Live weight (kg)of litter at 90 days of lambg age}}{\text{Subsequeant parturition interval in days}} \times 365$$

Index II, which is weight (g) of young produced per kg dam weight per year considering the dam as the major input to the weight of young was calculated as:

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Index II (g per ewe/year) = $\frac{\text{Index I}}{\text{Postpartum ewe weight (kg)}}$

Index III, which is weight (kg) of young produced per kg metabolic weight of dam per year, was calculated as:

Index III (kg) = $\frac{\text{Index I}}{\text{Postpartum ewe weight0.73 (kg)}}$

Indices for ewes whose offspring die before 90-days of age was zero, the zeros being incorporated in the means and standard errors for the variable under consideration. Data were analyzed by the least squares technique of the GLM procedure of SAS version 9.4 (Version, 2014) using the following model:

Model I: Analysis of variance of conception, lambing rate, lambing percentage and prolifiacy for the **on-station** managed flock.

$Y_{ijklmn} = \mu + GS_i + GD_j + L_k + S_l + SL_m + Y_n + e_{ijklmn}$

Where:

$Y_{ijklmno}$= the individual animal conception, lambing and prolifically rate records from the i^{th} Sire-genotype group, j^{th} Dam-genotype group, k^{th} location, l^{th} sex of the lamb, m^{th} season of lambing, n^{th} year of lambing.

μ= Overall mean

GS_i= the i^{th} effect of Sire-genotype group (i=3; Purebred Dorper, Dorper cross, Local).

GD_j= the j^{th} effect of Dam-genotype (j=3; Purebred Dorper, Dorper cross, Local).

L_k= the k^{th} effect of Location (k=2; Low-mid-to-highland, Cool-sub-alpine).

$S_{l=}$ the l^{th} effect of sex (l=2; Male, Female)

SL_m= the m^{th} effect of Season of lambing (m=3; Main rain, Short rain, Dry season).

Y_n= the n^{th} effect of year of lambing (n=15; 2007..., 2021).

e_{ijklmn}=the random error effect

NB: similar model was employed for the Abortion, still- birth and barren ewe rate (separately)

Conception rate = (Number of ewes that conceived ÷ Number of ewes exposed to a ram) × 100= (Number of ewes lambed + aborted + still-birth ÷Number of ewes exposed)

Lambing Rate = (Number of lambs born ÷ Number of ewes exposed) × 100

Prolificacy Rate = (Number of lambs born ÷ Number of ewes that lambed)= refers to the average number of lambs born per ewe that successfully lambed.

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Model II: Analysis of variance of litter size and litter weight at birth and weaning for the on-station managed flock.

$Y_{ijklmn} = \mu + GS_i + GD_j + L_k + S_l + SL_m + Y_n + P_o + LS_p + e_{ijklmno}$

Where:

$Y_{ijklmno}$= the individual animal LS and LW records from the i^{th} Sire-genotype group, j^{th} Dam-genotype group, k^{th} location, l^{th} sex of the lamb, m^{th} season of lambing, n^{th} year of lambing, o^{th} parity of the dam, p^{th} birth litter size, p^{th} birth Litter size.

μ= Overall mean

GS_i= the i^{th} effect of Sire-genotype group (i=3; Purebred Dorper, Dorper cross, Local).

GD_j= the j^{th} effect of Dam-genotype (j=3; Purebred Dorper, Dorper cross, Local).

L_k= the k^{th} effect of location (k=2; Low-mid-to-highland, Cool-sub-alpine).

S_l= the l^{th} effect of sex of the lamb (l = 2; Male, Female).

SL_m= the m^{th} effect of season of lambing (m=3; Main rain, Short rain, Dry season).

Y_n= the n^{th} effect of year of lambing (n=17; 2006..., 2022).

P_o= the o^{th} effect of parity of the dam (o=6; 1^{st} parity…, Parity 6^{th} and above), excluding AFL.

LS_p= the p^{th} effect of birth litters size (p=3; bearing single, bearing twin, bearing triple) excluding ARR

$e_{ijklmnop}$=the random error effect

NB: similar model was employed for on-farm flock data analysis considering available traits.

Modlel III: Analysis of variance of Age at first lambing, lambing interval, and annual reproductive rate for the on-station managed flock.

$Y_{ijklmn} = \mu + GS_i + GD_j + L_k + S_l + SL_m + Y_n + P_o + LSp + e_{ijklmnop}$

Where:

$Y_{ijklmnop}$= the individual ewe AFL, LI, ARR etc records from the i^{th} Sire-genotype group, j^{th} Dam-genotype grop, k^{th} location, l^{th} sex of the lamb, m^{th} season of lambing, n^{th} year of lambing, o^{th} parity of the dam, p^{th} birth litter size.

μ= Overall mean

GS_i= the i^{th} effect of Sire-genotype group (i=3; Purebred Dorper, Dorper cross, Local).

GD_j= the j^{th} effect of Dam-genotype (j=3; Purebred Dorper, Dorper cross, Local).

L_k= the k^{th} effect of location (k=2; Low-mid-to-highland, Cool-sub-alpine).

S_l= the l^{th} effect of sex of the lamb (l = 2; Male, Female).

SL_m= the m^{th} effect of season of lambing (m=3; Main rain, Short rain, Dry season).

Y_n= the n^{th} effect of year of lambing (n=17; 2006..., 2022).

P_o= the o^{th} effect of parity of the dam (o=6; 1^{st} parity… Parity 6^{th} and above), excluding AFL

LS_p= the p^{th} effect of birth litters size (p=3; bearing single, bearing town, bearing triple)

$e_{ijklmnop}$=the random error effect

NB: similar model was employed for on-farm flock data analysis considering available traits.

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Modlel VI: Analysis of variance of annual production indices (Index-I, Index-II and Index-III) for the on-station managed flock.

$Y_{ijklmn} = \mu + GS_i + GD_j + L_k + S_l + SL_m + Y_n + P_o + LSp + e_{ijklmnop}$

Where:

$Y_{ijklmnop}$= the individual ewe annual production index (Index-I, II and III) records from the i^{th} Sire-genotype group, j^{th} Dam-genotype group, k^{th} location, l^{th} sex of the lamb, m^{th} season of lambing, n^{th} year of lambing, o^{th} parity of the dam, p^{th} birth litter size.

μ= Overall mean

GS_i= the i^{th} effect of Sire-genotype group (i=3; Purebred Dorper, Dorper cross, Local).

GD_j= the j^{th} effect of Dam-genotype (j=3; Purebred Dorper, Dorper cross, Local).

L_k= the k^{th} effect of location (k=2; Low-mid-to-highland, Cool-sub-alpine).

S_l= the l^{th} effect of sex of the lamb (l = 2; Male, Female).

SL_m= the m^{th} effect of season of lambing (m=3; Main rain, Short rain, Dry season).

Y_n= the n^{th} effect of year of lambing (n=15; 2007..., 2021).

P_o= the o^{th} effect of parity of the dam (o=6; 1^{st} parity…, Parity 6^{th} and above), excluding AFL

LS_p= the p^{th} effect of birth litter size (p=3; bearing single, bearing two, bearing triple)

$e_{ijklmnop}$=the random error effect

NB: A similar model was employed for on-farm flock data analysis considering available traits only.

3.5.3. Analysis of growth performance

All pedigree related data from on-station evaluation and on-farm monitoring works were entered and managed using Microsoft Excel 2016. The data that were used for this investigation were collected from Debre-Birhan, Werer, Areka, Fafen, Yabello, and Sirinka research stations and Haramaya and Hawassa Universities, EMDTI, and the two sheep breeding and multiplication centers. The pure and crossbreeding of Dorper with local sheep in their respective sites has been an on-going activity for the past several years.

All animals in respective research centers were identified with a unique identification number. All newborn lambs of any genotype, or sex, were also ear-tagged at birth, identified by sex, type of birth and genotype of sire and dam. Records collected at on-station and on-farm included pedigree, lambing dates, weight at birth, 90, 180, and 365 days that comprise a birth, weaning, 6 month and yearling weight. Dam post-partum weight and date, disposal dates, and reasons were also captured.

The body weight of lambs at birth, 90 days, 180 days and 365 days of age were analyzed by the least-squares analysis of variance technique using the general linear model (GLM) procedure of

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the Statistical Analysis System version 9.4 (Version 14). The fixed effects due to genotype group, location, sex, birth season, year of birth and the genotype x location were tested by the least-squares using the following linear formula.

Model V: Analysis of variance of body weight and gain traits for the on-station managed flock.

$Y_{ijklmn} = \mu + G_i + L_j + S_k + SL_l + Y_m + P_n + e_{ijklmn}$

Where:

Y_{ijklmn}= the individual body weight records from the i^{th} genotype group, j^{th} location, k^{th} sex of the lamb, l^{th} season of birth, m^{th} year of birth and n^{th} parity of the dam.

μ= Overall mean

G_i= the i^{th} effect of lamb genotype group (i=6; Purebred Dorper, 75%-Dorper cross, 50%-Dorper cross-F_1, 50%-Dorper cross (*inter se*), 25%-Dorper cross, Local sheep in their respective research sites).

L_j= the j^{th} effect of location (j=2; Low-mid-to-highland, Cool-sub-alpine).

S_k= the k^{th} effect of sex of the lamb (k = Male, 2 = Female)

SL_l= the l^{th} effect of season of birth (l=3; Main rain, Short rain, Dry season).

Y_m= the m^{th} effect of year of birth (m=17; 2006..., 2022).

P_n= the n^{th} effect of parity of the dam (2=6; 1^{st} parity…, Parity 6^{th} and above).

e_{ijklmn}=the random error effect

Model VII: Analysis of variance of body weight and gain traits for the on-farm managed flock

$Y_{ijklmn} = \mu + G_i + L_j + S_k + SL_l + Y_m + P_n + e_{ijklmn}$

Where:

Y_{ijklmn}= the individual body weight records from the i^{th} lamb genotype group, j^{th} location, k^{th} sex of the lamb, l^{th} season of birth, m^{th} year of birth and n^{th} parity of the dam.

μ= Overall mean

G_i= the i^{th} effect of lamb genotype group (i=3; local, 12.5-25%-Dorper cross (low-grade), 37.50-43.75%-Dorper cross (high-grade).

L_j= the j^{th} effect of location (j=6; Low-mid-to-highland, 2= Cool-sub-alpine).

S_k= the k^{th} effect of sex of the lamb (k=2; Male, Female).

SL_l= the l^{th} effect of season of birth (l=3; Main rain, Short rain, Dry season).

Y_m= the m^{th} effect of year of birth (m=10; 2006…, 2021).

P_n= the n^{th} effect of parity of the dam (n=5; 1^{st} parity…, 5= Parity 5^{th} and above).

e_{ijklmn}=the random error effect.

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3.5.4. Analysis of survival performance

Mortality data of lambs from birth to yearling was analyzed using multiple logistic (evaluating odds ratio and contrasts between genetic groups) regression and LIFE TEST (plotting survival probabilities) procedures of SAS version 9.4 (Version 14). The fixed effects of lamb genotype group, location, sex of the lamb, parity of the dam, month, and year of birth were fitted as an independent variable to account for the variation in survival among the lamb genotype groups using the following model:

Model 1 Logit (p) = $\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n$.

Where p is the probability of survival (p=1)

$X_1 \ldots X_n$ is the fixed effect of exploratory variables likely to influence the survival of sheep (for example, breed, location, sex of lamb, season of birth, year of birth).

β_0 = the intercept

$\beta_1 \ldots \beta_n$ = partial regression coefficients of explanatory variables

The LIFETEST procedure of SAS software will be applied to plot survival probabilities and compare survival curves for different genotype groups.

Note: the above models were also employed for village data as appropriate.

3.5.5. Analysis of some indicators for effectiveness or failure of the Dorper crossbreeding strategy

The comprehensive data collected on key indicators of the Dorper crossbreeding program's and the crossbreeding scheme effectiveness or failure - such as ram importation, production and distribution, crossbred lamb performance, market prices, farmer feedback, and future demand - was analyzed using statistical techniques like ranking, proportions, and means separation to rigorously evaluate the crossbreeding strategy and scheme.

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CHAPTER 4: RESULTS

4.1. General household characteristics of the respondent households

The study analyzed household characteristics of 248 HHs across eight different sites: Baso-1, Baso-2, Kewet, Merhabete, Minjar-Shenkora, Kobo, Damot-Pulasa, and Damot-Sore. The study examined variables such as family size, sex, age structure, and educational background. The findings presented in Table 6, show that males headed the majority of households in all areas. Overall, male-headed households accounted for 79.4% of the total, ranging from 56.1% in Baso-1 to 97% in Minjar-Shenkora. The highest proportion of female-headed households interviewed were found in Baso-1 (43.9%) and Kewet (43.8%), while the lowest was recorded in Minjar-Shenkora (3%). Additionally, the majority (65%) of households fell within the 31-50 age range, and most respondents were married (87.5%), followed by single (8.5%) and divorced (4%). The proportion of married households varied between 71% in Baso-1 and 100% in Baso-2 and Damot-Pulasa. Interestingly, Merhabete had a higher proportion (17.2%) of divorced households. Education-wise, 20.6% of households were illiterate, while 79.4% literate, that falls under read and write, completed primary and secondary to above secondary education. The average family size was 5.92 ± 0.12, with significantly higher family sizes in Damot-Pulasa and Damot-Sore ($p < 0.01$) compared to Baso-2, Kewet, Merhabete, and Minjar-Shenkora.

4.2. Land holding and use pattern

Each household in the sample owned an average of 1.38 hectares of land, which was utilized for cropland (1.08 ha), fallow land (0.04 ha), grazing land (0.21 ha), and forestland (0.09 ha). Interestingly, the study showed that the amount of land owned significantly varied ($p < 0.05$) across different sites. Specifically, Baso-1 had the highest landholding compared to other sites, while Baso-2, Kewet, Merhabete, Minjar-Shenkora, Kobo, Damot-Pulassa, and Damot-Gale had relatively similar land holdings ($p > 0.05$). Cropland holdings were similar ($p > 0.05$) between Baso-1 and Minjar-Shenkora but higher than other sites. Fallow and grazing land holdings were also greater at Baso-1 than other sites. Moreover, Baso-1 and Baso-2 had higher forestland allocations than other sites, with Merhabete and Minjar-Shenkora having the lowest forestland holdings. The land holdings and usage patterns of the surveyed farmers was illustrated in Table 7.

Table 6. General Socioeconomic and Household Characteristics of the Study Areas

Variables	Baso-1 (%)	Baso-2 (%)	Kewet (%)	Merhabete (%)	Minjar-Shenkora (%)	Kobo (%)	Damot-Pulasa (%)	Damot-Sore (%)	Over-all (%)	χ2-value	p-value
Sex structure											
Male	23 (56.1)	13 (86.7)	9 (56.3)	22 (75.9)	32 (97.0)	32 (91.4)	33 (82.5)	33 (84.6)	197 (79)	29.81	0.0001
Female	18 (43.9)	2 (13.3)	7 (43.7)	7 (24.1)	1 (3.0)	3 (8.6)	7 (17.5)	6 (15.4)	51 (21)		
Age structure											
20-30	14 (34.1)	0 (0.00)	1 (6.3)	0 (0.00)	11 (33.3)	2 (5.7)	1 (2.5)	4 (10.3)	33 (13)	99.44	<.0001
31-40	5 (12.2)	6 (40.0)	4 (25.0)	10 (34.5)	8 (24.2)	11 (31.4)	18 (45.0)	27 (69.2)	89 (36)		
41-50	8 (19.5)	4 (26.7)	9 (56.3)	10 (34.5)	5 (15.2)	11 (31.4)	17 (42.5)	7 (17.9)	71 (29)		
51-60	11 (26.8)	3 (20.0)	0 (0.00)	8 (27.6)	5 (15.2)	4 (11.4)	4 (10.0)	1 (2.6)	36 (14)		
>60	3 (7.3)	2 (13.3)	2 (12.5)	1 (3.4)	4 (12.1)	7 (20.0)	0 (0.00)	0 (0.00)	19 (8)		
Marital status											
Married	29 (70.7)	15 (100)	12 (75.0)	24 (82.8)	25 (75.5)	34 (97.1)	40 (100)	38 (97.4)	217 (88)	58.28	<.0001
Single	11 (26.8)	0 (0.00)	2 (12.5)	0 (0.00)	7 (21.2)	0 (0.00)	0 (0.00)	1 (2.6)	21 (9)		
Divorced	1 (2.4)	0 (0.00)	2 (12.5)	5 (17.2)	1 (3.0)	1 (2.9)	0 (0.00)	0 (0.00)	10 (3)		
Education status											
Illiterate	4 (9.8)	0 (0.00)	6 (37.5)	3 (10.3)	7 (21.2)	13 (37.1)	9 (22.5)	9 (23.1)	51 (20)		
Read & write	12 (29.3)	7 (46.7)	2 (12.5)	10 (34.5)	8 (24.2)	6 (17.1)	9 (22.5)	10 (25.6)	64 (26)		
Primary	12 (29.3)	5 (33.3)	5 (31.3)	11 (37.9)	11 (33.3)	13 (37.1)	11 (27.5)	13 (33.3)	81 (33)	37.35	0.1114
Secondary	11 (26.8)	3 (20.0)	1 (6.3)	5 (17.2)	5 (15.2)	2 (5.7)	11 (27.5)	5 (12.8)	43 (17)		
Above-secondary	2 (4.9)	0 (0.00)	2 (12.5)	0 (0.00)	2 (6.1)	1 (2.9)	0 (0.0)	2 (5.1)	9 (4)		
Family size (LSM±SE)	5.76 ± 0.3^{ab}	4.87 ± 0.4^{6b}	4.81 ± 0.4^{b}	5.17 ± 0.3^{b}	4.70 ± 0.3^{b}	5.97 ± 0.3^{ab}	7.55 ± 0.3^{a}	6.85 ± 0.29^{a}	5.92±0.1		<.0001

Table 7. LSM±SE for land and livestock holding/household and land use pattern in the study sites

Particulars	Baso-1 (n=41)	Baso-2 (n=15)	Kewet N=(16)	Merhabete (n=29)	Minjar-Shenkora (n=33)	Kobo (n=35)	Damot-Pulasa (n=40)	Damot-Sore (n=39)	Over-all (n=(248)	
	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	*p*-value
Total Land holding (ha)	2.56±0.14^{a}	1.45±0.23^{b}	0.62±0.22^{b}	0.91±0.17^{b}	1.40±0.15^{b}	1.25±0.15^{b}	1.27±0.14^{b}	1.00±0.14^{b}	1.38±0.06	<.0001
Cropland (ha)	1.68±0.12^{a}	1.02±0.19b^{c}	0.54±0.19^{b}	0.86±0.14^{bc}	1.36±0.13^{ab}		0.99±0.12^{bc}	0.72±0.12^{bc}	1.08±0.05	<.0001
Fallow land (ha)	0.20±0.03^{a}	0.02±0.04^{b}	0.00±0.04^{b}	0.00±0.03^{b}	0.00±0.02^{b}		0.01±0.02^{b}	0.01±0.02^{b}	0.04±0.01	0.0068
Grazing land (ha)	0.50±0.05^{a}	0.22±0.08^{b}	0.03±0.07^{b}	0.07±0.05^{b}	0.06±0.05^{b}		0.19±0.05^{b}	0.21±0.05^{b}	0.21±0.02	<.0001
Others (ha)	0.21±0.02^{a}	0.18±0.04^{a}	0.06±0.04^{b}	0.01±0.03^{c}	0.02±0.03^{c}		0.09+0.02^{b}	0.06±0.02^{b}	0.09±0.01	<.0001
Livestock Holding (n)										
Cattle (n)	6.90±0.40^{a}	4.73±0.67^{ab}	2.13±0.65^{cd}	0.93±0.48^{d}	3.76±0.45^{c}	6.20±0.44^{ab}	2.93±0.41^{c}	3.28±0.41^{c}	4.04±0.18	<.0001
Sheep (n)	16.17±0.84^{a}	14.20±1.39^{a}	8.94±1.35^{b}	7.97±1.00^{b}	7.15±0.94^{b}	11.11±0.91^{b}	2.65±0.85^{c}	3.05±0.86^{c}	8.47±0.36	<.0001
Goat (n)	0.29±0.26^{b}	0.53±0.42^{bc}	0.81±0.41^{bc}	0.30±0.23^{c}	1.21±0.29^{ab}	1.40±0.28^{ab}	0.02±0.26^{c}	0.08±0.26^{c}	0.50±0.11	0.0005
Donkey (n)	2.56±0.12^{a}	1.73±0.19^{b}	0.01±0.19^{d}	0.07±0.14^{d}	1.18±0.13^{b}	0.23±0.13^{d}	0.20±0.12^{d}	0.41±0.12^{d}	0.82±0.05	<.0001
Horse (n)	1.39±0.08^{a}	0.53±0.12^{b}	0.06±0.12^{bc}	0.00±0.09^{c}	0.03±0.08^{c}	0.00±0.08^{c}	0.00±0.08^{c}	0.00±0.08^{c}	0.27±0.03	<.0001
Mule (n)	0.00±0.02	0.00±0.03	0.00±0.03	0.00±0.02	0.03±0.02	0.09±0.02	0.00±0.03	0.00±0.03	0.02±0.01	0.0487
Camel (n)	0.00±0.11^{b}	0.00±0.17^{b}	0.00±0.17^{b}	0.00±0.03^{b}	0.36±0.12^{ab}	0.77±0.11^{a}	0.00±0.10^{b}	0.00±0.11^{b}	0.16±0.05	<.0001
Chicken (n)	4.49±0.94^{b}	7.67+1.55^{ab}	2.94±1.50^{b}	1.97±1.11^{b}	9.55±1.04^{a}	5.37±1.01^{ab}	2.43±0.95^{b}	3.79±0.96b	4.64±0.41	<.0001

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4.3. Livestock holding and species composition

According to our study, farmers in the study area keep a variety of livestock species. The average number of cattle, sheep, goats, donkeys, horses, mules, camels, and chickens per household was 4.04±0.18, 8.47±0.36, 0.50±0.11, 0.82±0.05, 0.27±0.03, 0.02±0.01, 0.16±0.05, and 4.64±0.41, respectively. Baso-1, Baso-2, and Kobo had more cattle holdings than the other study sites, while Kewet and Merhabete had lower cattle holdings ($p < 0.0001$). Baso-1 and Baso-2 had significantly ($p < 0.0001$) higher sheep holdings compared to the other sites, while Damot-Pulassa and Damot-Sore had significantly lower sheep holdings. Donkeys and horses were more abundant in Baso-1, Baso-2, and Minjar-Shenkora. Kobo and Minjar-Shenkora had a significantly higher ($p < 0.0001$) number of camels compared to other sites. Chicken rearing was more common at Minjar-Shenkora, Baso-2, and Kobo. Sheep were the most important livestock species, making up 59.3% of the overall composition, followed by cattle (28.3%), and Donkeys (5.7%), respectively (Table 7). In Damot-Pulassa and Damot-Sore, cattle were the most important species, followed by sheep.

Excluding poultry, the livestock species composition (proportion) considering mean number went in the order of 59.3%, 28.3%, 5.7%, 3.5%, 1.9%, 1.1%, and 0.1% for sheep, cattle, donkeys, goats, horses, camels, and mules, respectively, as shown in Table 8. The proportion of sheep ranged between 45.7 in Dmot-Pulassa and 88.8% in Merhabete. Compared to other livestock species in the study sites higher proportion of sheep was recorded at Merhabete (89%), Kewet (75%), Baso-2 (65%), and Baso-1 (69%), respectively. Cattle are the dominant livestock species in Damot-Pulassa (51%) followed by Damot-Sore (48%), respectively.

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Table 8. Percentage of livestock species composition in the study areas (excluding chicken)

Sites and livestock species		N	Mean herd/flock size	%	SD	Range
Baso-1						
	Cattle	41	6.90	25.27	2.42	2-12
	Sheep	41	16.17	59.21	8.15	4-35
	Goat	41	0.29	1.06	1.10	0-5
	Donkey	41	2.56	9.37	1.18	0-5
	Horse	41	1.39	5.09	1.09	0-4
	Mule	41	0.00	0.00		
	Camel	41	0.00	0.00		
Baso-2						
	Cattle	15	4.73	21.78	2.15	2-9
	Sheep	15	14.20	65.38	6.98	4-32
	Goat	15	0.53	2.44	1.13	0-4
	Donkey	15	1.73	7.97	0.96	0-3
	Horse	15	0.53	2.44	0.64	0-2
	Mule	15	0.00	0.00		
	Camel	15	0.00	0.00		
Kewet						
	Cattle	16	2.13	17.82	2.13	0-5
	Sheep	16	8.94	74.81	6.09	3-24
	Goat	16	0.81	6.78	2.56	0-10
	Donkey	16	0.01	0.08		
	Horse	16	0.06	0.50	0.25	0-1
	Mule	16	0.00	0.00		
	Camel	16	0.00	0.00		
Merhabete						
	Cattle	29	0.93	10.20	1.94	0-8
	Sheep	29	7.97	88.80	3.90	3-18
	Goat	29	0.03	0.20		
	Donkey	29	0.07	0.80	0.37	0-2
	Horse	29	0.00	0.00		
	Mule	29	0.00	0.00		
	Camel	29	0.00	0.00		
Minjar-Shenkora						
	Cattle	33	3.76	27.41	2.21	0-8
	Sheep	33	7.15	52.11	3.32	1-16
	Goat	33	1.21	8.82	2.32	0-10
	Donkey	33	1.18	8.60	1.07	0-4
	Horse	33	0.03	0.22	0.17	0-1
	Mules	33	0.03	0.22	0.17	0-1
	Camel	33	0.36	2.62	0.49	0-1
Kobo						
	Cattle	35	6.20	31.31	5.09	0-25
	Sheep	35	11.11	56.11	7.56	0-31
	Goat	35	1.40	7.07	3.00	0-15
	Donkey	35	0.23	1.16	0.55	0-2
	Horse	35	0.00	0.00		
	Mules	35	0.09	0.46	0.28	0-1
	Camel	35	0.77	3.89	1.73	0-10

Table 8. Co*ntinued*

Damot-Pulasa						
	Cattle	40	2.93	50.52	1.07	0-5
	Sheep	40	2.65	45.69	1.23	1-6
	Goat	40	0.02	0.35		
	Donkey	40	0.20	3.45	0.41	0-1
	Horse	40	0.00	0.00		
	Mules	40	0.00	0.00		
	Camel	40	0.00	0.00		
Damot-Sore						
	Cattle	39	3.28	47.10	1.23	0-6
	Sheep	39	3.05	45.80	1.64	1-8
	Goat	39	0.08	1.20	0.35	0-2
	Donkey	39	0.41	5.90	0.49	0-1
	Horse	39	0.00	0.00		
	Mules	39	0.00	0.00		
	Camel	39	0.00	0.00		
Over-all						
	Cattle	248	4.04	28.29		0-25
	Sheep	248	8.47	59.31		2-35
	Goat	248	0.50	3.50		0-15
	Donkey	248	0.82	5.74		0-5
	Horse	248	0.27	1.89		0-4
	Mules	248	0.02	0.14		0-1
	Camel	248	0.16	1.12		0-10

N = number of Households, SD = standard deviation

4.4. Sheep flock structure

In all of the study sites, the sheep flock structure showed a consistent pattern in terms of age and sex classes. Breeding ewes made up the largest class, followed by male and female lambs under 6 months of age. The overall proportion of sheep from each class in the study area was as follows: breeding ewes (45.49%), lambs (26.85%), ewe lambs (12.38%), ram lambs (7.87%), breeding rams (6.25%), and castrates (1.16%), respectively (Table 9). The study also found that the proportion of breeding ewes varied slightly across different sites, but remained relatively consistent (40.13, 41.23, 42.68, 43.73, 44.75, 46.44, 48.33 and 49.74% for Damot-Sore, Minar-Shenkora, Baso-2, Kewet, Merhabete, Baso-1, Damot-Pulassa and Kobo sites), respectively. The proportion of breeding rams and castrates was consistently lower across all study areas. Interestingly, the proportion of ewe lambs to ram lambs was similar in some sites but higher in others.

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Table 9. Flock structure per household in the study sites (%)

Class of sheep	Study sites								
	Baso-1	Baso-2	Kewrt	Merhabete	Minjar-Shenkora	Kobo	Damot -Pulasa	Damot -Sore	Over-all n=248
	%	%	%	%	%	%	%	%	%
Lambs	25.55	22.54	39.51	25.09	21.74	28.65	30.86	31.35	26.85
Ram lambs	7.42	5.63	6.99	8.53	12.76	7.03	8.55	6.58	7.87
Ewe lambs	12.39	17.39	6.99	17.06	12.76	9.58	8.55	12.23	12.38
Breeding ewe	46.44	42.68	43.73	44.75	41.23	49.74	48.33	40.13	45.49
Breeding ram	7	4.72	**2.77**	4.2	11.08	0.57	3.72	9.72	6.25
Castrates	1.2	7.04	0	0.37	0.42	0	0	0	1.16

4.5. Purpose of keeping sheep

Table 10 presents the reasons for keeping sheep at the study sites. Respondents ranked the overall purpose of keeping sheep based on weighted indexes, with income, meat consumption, saving, manure, and skin ranked in that order. The weighted index values were 0.292, 0.259, 0.210, 0.148, and 0.063, respectively. The highest ranks (1-4) for income generation, meat consumption, saving, and use for fertilizer purposes were given in Baso-1, Baso-2, Kewet, and Merhabete consistently. In the Kobo site, manure was given the 3rd rank. In Damot-Gale and Damot-Plassa, manure production was given the second most important purpose of keeping sheep next to income generation.

Table 10. Purposes of keeping sheep as was ranked by respondents (weighted index)

Purpose of keeping sheep	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damt-Sore	Overall n=248
Income	0.269	0.265	0.350	0.283	0.291	0.366	0.231	0.250	0.292
Meat	0.246	0.241	0.313	0.267	0.257	0.321	0.202	0.207	0.259
Saving	0.187	0.209	0.266	0.192	0.204	0.131	0.213	0.216	0.210
Manure	0.180	0.189	0.044	0.126	0.139	0.150	0.146	0.109	0.148
Skin	0.078	0.078	0.027	0.104	0.057	0.014	0.047	0.062	0.063
Wool	0.024	0.018	0.000	0.027	0.033	0.000	0.009	0.004	0.016
Milk	0.016	0.000	0.000	0.000	0.018	0.000	0.003	0.001	0.006
Blood	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.027	0.005
Wealth status	0.000	0.000	0.000	0.000	0.000	0.019	0.149	0.124	0.000

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4.6. Major constraints of sheep production

To improve sheep production and the livelihood of farmers, it is essential to identify the main bottlenecks in the process. Sheep keepers in our surveyed sites have identified several limiting factors, including feed shortages, high prevalence of disease and parasites, lack of improved genotype, labor shortages, lack of capital, and market issues. Based on the weighted index provided by participating farmers, the corresponding values 0.243, 0.224, 0.204, 0.128, 0.067, 0.062, and 0.028, respectively. Among the surveyed study sites, feed shortages, disease and parasites, and lack of improved genotypes were the top three constraints at Baso-1, Baso-2, Merhabete, Kobo, Damot-Pulassa, and Damot-Gale, while at Kewet and Minjar-Shenkora, lack of improved genotype was ranked as the second most important constraint for sheep production next to feed shortage (Table 11).

Table 11. Major constraints to sheep production (weighted index)

Constraints to Sheep production	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damt-Sore	Overall n=248
Feed shortage	0.250	0.261	0.266	0.279	0.234	0.266	0.219	0.216	0.243
Disease prevalence	0.243	0.241	0.206	0.242	0.159	0.264	0.235	0.205	0.224
Poor genotype	0.219	0.224	0.228	0.199	0.207	0.193	0.203	0.183	0.204
Labor shortage	0.162	0.182	0.202	0.173	0.141	0.090	0.091	0.078	0.128
Market problem	0.121	0.091	0.098	0.107	0.078	0.000	0.029	0.046	0.067
Shortage of capital	0.000	0.000	0.000	0.000	0.087	0.045	0.123	0.129	0.062
Water shortage	0.004	0.000	0.000	0.000	0.093	0.032	0.060	0.101	0.045
Drought occurrence	0.000	0.000	0.000	0.000	0.000	0.111	0.040	0.042	0.028

4.6.1. Feed resources, seasonal fluctuation and utilization

Almost all households (98.8%) reported experiencing fluctuations in feed supply in their respective areas. Feed resources availability for sheep varies and the farmers in the surveyed areas reported higher percentage, accordingly the households that reported feed resource fluctuation in Kewet was (93.8%), Damot-Pulassa (95%), and Baso-1, Baso-2, Merhabete, Minjar-Shenkora, Kobo, and

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Damot-Sore (100%), respectively (Table 12). The report indicated that the months with the highest feed shortages were December to May (79.8%), followed by all year round (17.3%), and July to August (2.8%). Most farmers (94.8%) indicated that they supplement their sheep during critical feed shortage seasons with roughage, concentrate, and common salt.

The majority of households (90.3%) supplemented their sheep with roughage, 65.5% supplemented with concentrate, and 84.3% supplemented with minerals (mainly salt). The proportion of farmers supplementing roughage to their sheep varied, and ranged from 71.4% in Kobo and 100% in Baso-2, Merhabete, and Minjar-Shenkora. In contrast, approximately 90% or more farmers supplemented their sheep with concentrate in Damot-Pulassa, Minjar-Shenkora, and Damot-Sore. Mineral supplementation varied between 54% and 100% among participating farmers in different sites. The study found that 85.9% of farmers in study sites could access natural pasture in the dry season, while farmers who can access established pasture, hay, crop residue, crop aftermath, and concentrate are 20.2%, 62.5%, 86.3%, 78.6%, and 67.5%, respectively. In the wet season, the proportion of farmers who could access feed resources was 87% (natural pasture), 31.0% (established pasture), 72.4% (hay), 48% (crop residue), 6.9% (crop aftermath), and 55.6% concentrate.

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Table 12. Fluctuation in feed supply, feed shortage months, type of supplement, dry and wet season feed source for sheep per household in the study sites (%).

Attributes	Study sites										
	Baso-1 (n=41)	Baso-2 (n=15)	Kewet N=(16)	Merhabete (n=29)	Minjar-Shenkora (n=33)	Kobo (n=35)	Damot-Pulasa (n=40)	Damot-Sore (n=39)	Over-all (n=(248)	χ^2-Value	*p*-Value
Fluctuation in feed supply											
Yes	100	100	93.8	100	100	100	95.0	100	98.8	10.56	0.2278
No	0.0	0.0	6.3	0.0	0.0	0.0	5.0	0.0	1.2		
Feed shortage months											
All-year round	0.0	0.0	93.8	62.1	30.3	0.0	0.0	0.0	17.3	160.87	<.0001
December-May	100	100	0.0	37.9	69.7	88.6	95.0	100	79.8		
July-August	0.0	0.0	6.3	0.0	0.0	11.4	5.0	0.0	2.8		
Do you supplement sheep											
Yes	100	100	93.8	100	100	82.9	90.0	94.9	94.8	18.36	0.0104
No	0.0	0.0	6.3	0.0	0.0	17.1	10.0	5.1	5.2		
Do you use Natural Pasture as dry season feed source for your sheep											
Yes	97.6	100	62.5	86.2	78.8	77.1	100	76.9	85.9	27.03	0.0003
No	2.4	0.0	37.5	17.8	21.2	22.9	0.0	23.1	14.1		
Do you use Established Pasture as dry season feed source for your sheep											
Yes	14.6	73.3	6.3	6.9	18.2	2.9	25.0	33.3	20.2	43.60	<.0001
No	85.4	26.7	93.7	93.1	81.8	97.1	75.0	66.7	79.8		
Do you use Hay as dry season feed source for your sheep											
Yes	87.8	60.0	56.2	79.3	12.1	14.3	92.5	82.1	62.5	107.18	<.0001
No	12.2	40.0	43.8	20.7	87.9	85.7	7.5	17.9	37.5		
Do you use Crop residue as dry season feed source for your sheep											
Yes	82.8	93.3	68.7	96.6	100	42.9	100	94.9	86.3	77.29	<.0001
No	17.2	6.7	31.3	3.4	0.0	57.1	0.0	5.1	13.7		

Table 12. Continued

Do you use Crop aftermath as a dry season feed source for your sheep											
Yes	89.7	100	6.2	72.4	90.9	57.1	90.0	87.2	78.6	76.80	<.0001
No	10.3	0.0	93.8	27.6	9.1	42.9	10.0	12.8	21.4		
Do you use Concentrate as dry season feed source for your sheep											
Yes	20.7	40.0	68.8	62.1	90.9	62.9	77.5	82.1	67.5	32.33	<.0001
No	79.3	60.0	31.2	37.9	9.1	37.1	22.5	17.9	32.5		
Do you use Natural Pasture as wet season feed source for your sheep											
Yes	97.6	100	62.5	75.9	60.6	88.6	100	100	87.5	51.82	<.0001
No	2.4	0.0	37.5	24.1	39.4	11.4	1.0	0.0	12.5		
Do you use Established Pasture as wet season feed source for your sheep											
Yes	12.2	53.3	6.3	6.9	3.0	2.9	62.5	87.2	31.1	123.76	<.0001
No	87.8	46.7	93.8	93.1	97.0	97.1	37.5	12.8	68.9		
Do you use Hay as wet season feed sources for your sheep											
Yes	56.1	46.7	43.8	75.9	9.1	2.9	2.5	10.3	27.4	90.51	<.0001
No	43.9	53.3	56.3	24.1	90.9	97.1	97.5	89.7	72.6		
Do you use Crop-Residue as wet season feed sources for your sheep											
Yes	56.1	86.7	68.8	93.1	90.9	5.7	17.5	15.4	48.0	117.41	<.0001
No	43.9	13.3	31.3	6.9	9.1	94.3	82.5	84.6	52.0		
Do you use Crop aftermath as wet season feed sources for your sheep											
Yes	7.3	6.7	0.0	3.4	0.0	0.0	17.5	12.8	6.9	15.99	0.0251
No	92.7	93.3	100	96.6	100	100	82.5	87.2	93.1		
Do you use Concentrate as wet season feed sources for your sheep											
Yes	29.3	26.7	68.8	55.2	78.8	22.9	80.0	74.4	55.7	55.33	<.0001
No	70.7	73.3	31.3	44.8	21.2	77.1	20.0	25.6	44.3		

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4.6.2. Prevalent health challenges impacting sheep production in the study areas

Farmers in the study areas have identified various health challenges that significantly affect the well-being of their sheep. According to Table 13, the most common sheep health challenges in these sites are pasteurellosis, parasites (internal and external), liver fluke, foot rot, and diarrhea, with weighted index values of 0.230, 0.197, 0.190, 0.238, and 0.094, respectively.

Pasteurellosis was identified as the most crucial sheep health challenge in Baso-2, Kewet, Merhabete, Damot-Pulasa, and Damot-Sore, based on farmers' suggestions. Meanwhile, liver fluke was the topmost challenge in Baso-1 and Kobo sites. In the Merhabete site, parasites (internal and external) were the most significant health challenge. Pasteurellosis was also the second most crucial sheep health challenge in Baso-1 and Kobo sites. Likewise, the prevalence of parasites (internal and external) was the second most significant sheep health challenge in Kewet, Minjar-Shenkora, Damot-Pulasa, and Damot-Sote sites. Foot rot was worth noting as the third most important challenge in Baso-1 and Damot-Sites for sheep production.

Table 13. Major health challenges that affected sheep production in the study areas

Major sheep health challenges	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damot-Sore	Overall (248)
Pasteurellosis	0.220	0.216	0.249	0.225	0.239	0.193	0.236	0.266	0.230
Parasites	0.159	0.189	0.230	0.225	0.205	0.190	0.174	0.234	0.197
Liver fluke	0.237	0.209	0.214	0.199	0.183	0.209	0.151	0.132	0.190
Foot-rot	0.163	0.149	0.089	0.158	0.111	0.120	0.122	0.169	0.138
Diarrhea	0.014	0.128	0.069	0.169	0.159	0.115	0.103	0.026	0.094
Orff	0.008	0.043	0.011	0.000	0.016	0.019	0.063	0.080	0.031
Anthrax	0.086	0.039	0.029	0.017	0.019	0.013	0.017	0.013	0.0304
Coenuruses	0.084	0.000	0.029	0.000	0.034	0.013	0.027	0.019	0.0299
Sheep-pox	0.028	0.026	0.081	0.007	0.018	0.013	0.031	0.038	0.027
Bloat	0.000	0.000	0.000	0.000	0.016	0.115	0.021	0.015	0.025
Blue-tongue	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.006	0.010

4.7. Breeding and selection criteria

4.7.1. Selection criteria for breeding ewe and ram

Selection criteria for breeding ewe:

Farmers aim to select the best ewe for breeding purposes and attribute different values to certain traits. The most important attributes for selecting female sheep for breeding (for all sites), as

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determined by weighted index values given by farmers, include body size/appearances, lambing interval, mothering ability and lamb survival, color, maternal history, age at first service, twinning rate, milk yield, and paternal history. These attributes received weighted index values of 0.177, 0.151, 0.149, 0.104, 0.104, 0.100, 0.098, 0.088, and 0.033 respectively (Table 14).

However, in some areas, farmers prioritize different attributes. For example, farmers in Kewet, Merhabete, Minjar-Shenkora, Kobo, Damot-Pulassa, and Damot-Sore prioritize body size/appearance the most, while farmers in Baso-1 prioritize lambing interval and those in Baso-2 prioritize mothering ability and lamb survival. Lambing interval is the second most important attribute for farmers in Baso-2 and Damot-Pulassa, and mothering ability and lamb survival is the second most important for farmers in Baso-1, Kewet, Merhabete, Minjar-Shenkora, and Damot-Sore. In Kewet, Merhabete, Minjar-Shenkora, Kobo, and Damot-Sore, lambing interval is the third most important attribute, while maternal history is the third most important for farmers in Baso-1 and Baso-2. Interestingly, farmers in Kobo prioritize color as the second most important attribute in selecting female sheep for breeding purposes.

Table 14. Attributes considered while selecting female sheep for breeding purposes (weighted index).

Female sheep selection criteria/attribute	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damt-Sore	Overall n=248
Body size/ appearance	0.114	0.107	0.197	0.195	0.192	0.195	0.182	0.192	0.173
Lambing interval	0.183	0.158	0.145	0.156	0.155	0.123	0.165	0.120	0.151
Mothering ability & lamb survival	0.170	0.167	0.168	0.168	0.177	0.117	0.119	0.130	0.149
Color	0.101	0.124	0.129	0.074	0.079	0.129	0.102	0.115	0.104
Maternal history	0.135	0.139	0.084	0.106	0.099	0.074	0.099	0.100	0.104
Age at first service	0.103	0.117	0.066	0.112	0.100	0.065	0.137	0.084	0.100
Twinning rate	0.092	0.096	0.071	0.083	0.094	0.109	0.091	0.130	0.098
Milk yield	0.078	0.070	0.116	0.085	0.081	0.153	0.049	0.086	0.088
Paternal history	0.024	0.022	0.024	0.022	0.024	0.035	0.057	0.042	0.033

Selection criteria for breeding ram:

The results revealed that certain traits are prioritized when selecting future sires. Specifically, body size/appearance and growth rate are the most crucial, followed by color, horn, libido, paternal and maternal history, and fertility. Weighted indices for these traits are 0.224, 0.175,

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0.156, 0.117, 0.105, 0.084, 0.082, and 0.057, respectively (Table 15). Across all sites, body size/appearance and growth rate are consistently ranked as the top two most important traits, with color being ranked second only in Kobo. Interestingly, in Kobo, growth rate is ranked third, while color is ranked third in Baso-2, Kewet, Merhabaete Damot-Pulassa, and Damot-Sore. In Baso-1, Merhanete, and Minjar-Shenkora, the presence of horns is considered the third most important trait for ram selection.

Table 15. Attributes considered while selecting ram for breeding purpose (weighted index).

Ram selection criteria/attribute	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damt-Sore	Overall n=248
Body size/ appearance	0.213	0.213	0.219	0.218	0.219	0.300	0.203	0.223	0.224
Growth rate	0.194	0.194	0.193	0.193	0.192	0.128	0.161	0.158	0.175
Color	0.152	0.160	0.162	0.154	0.132	0.234	0.131	0.152	0.156
Horn	0.154	0.150	0.143	0.154	0.168	0.092	0.049	0.066	0.117
Libido	0.108	0.095	0.111	0.106	0.084	0.043	0.145	0.121	0.105
Paternal history	0.081	0.088	0.079	0.078	0.107	0.082	0.074	0.081	0.084
Fertility	0.056	0.046	0.050	0.056	0.030	0.070	0.153	0.140	0.082
Maternal history	0.042	0.053	0.041	0.041	0.067	0.050	0.083	0.059	0.057

4.7.2. Dorper sheep breeding practice

4.7.2.1. Mating

About 67% of households reported group mating as their preferred breeding system (χ^2=98.18, p < 0.0001). The highest proportion of farmers who follow this system were in Kobo (97%), Baso-1 (95%), Kewet (94%), and Merhabete (93%), respectively. However, it was observed that significant proportions of households in Damot-Pulassa (73%) and Damot-Sore (62%) used their own flock mating system for breeding (Table 16).

Table 16. Mating followed by the household in the study sites (%)

	Study sites										
Attributes	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulasa	Damot-Sore	Over-all (n=(248)	χ^2-Value	*p*-Value
Own flock mating	4.88	20.00	6.25	6.90	60.61	2.86	72.50	61.54	33.06	98.18	<.0001
Group mating	95.12	80.00	93.75	93.10	39.39	97.14	27.50	38.46	66.94		

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4.7.2.2. Dorper ram sharing in the community

The survey indicated that more than 67% of households share rams for breeding within their communities (χ^2=72.66; p < 0.0001: Table 17). The results also showed that a higher proportion of households in Baso-1 (95%), Kewet (94%), Merhabete (93%), and Baso-2 (80%) share rams within their respective communities. However, it was noted that a considerable proportions of households in Damot-Pulassa (73%) and Minjar-Shenkora (61%) do not share rams within their community.

Table 17. Proportion of farmers that exercise ram sharing within the community (%)

Attributes	Study sites									
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulasa	Damot-Sore	Over-all n=248	χ2-Value	*p*-Value
Yes	95.1	80.0	93.8	93.1	39.4	77.1	27.5	58.9	67.3	72.66	<.0001
No	4.9	20.0	6.2	6.9	60.6	22.9	72.5	41.1	32.7		

4.7.2.3. Access to Dorper rams

According to the survey report, it was found that approximately half of the households had access to the improved ram, especially the Dorper crossbred ram (Table 18). However, there were significant variations observed among the study sites (χ^2=106.12; p < 0.0001). The results revealed that a higher percentage of farmers in Baso-1 (93%), Kobo (86%), and Baso-2 (67%) had access to the improved rams (Dorper). According to Table 18, Access to improved Dorper ranged from 8% in Damot-Pulassa to 93% in Baso-1. On the contrary, there was a lack of access to improved rams (Dorper) among some of the other sites; Damot-Pulasa (93%) and Damot-Sore (90%).

Table 18. Proportion of farmers that access improved rams (Dorper crossbred rams) (%)

	Study sites										
Attributes	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulasa	Damot-Sore	Over-all n=248	χ^2-Value	*p*-Value
Yes	92.7	66.7	50.0	62.1	39.4	85.7	7.5	10.3	50.0	106.12	<.0001
No	7.3	33.3	50.0	37.9	60.6	14.3	92.5	89.7	50.0		

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4.7.2.4. Special management to Dorper crossbred rams

Considerable attention was given to serving ram in the community. Accordingly, more than 61% the households in the surveyed sites gave supplementation for the serving ram top priority. However, there were noticeable variations among households in different locations (χ^2=19.92; p = 0.0057) (Table 19), with Baso-2 (80%), Baso-1 (78%), and Minjar-Shenkora (70%) having a higher proportions of farmers offering special management for their Dorper rams. On the other hand, a significant proportion of farmers in Damot-Pulasa (60%) and Kewet (56%) do not provide special management to their Dorper ram. The percentage of households providing special management to their Dorper rams varies between 40 and 80%. Through supplementation and by managing their rams effectively, farmers can increase their flock's productivity through improved libido and mating ability.

Table 19. Farmers experience in managing Dorper crossbred ram used for breeding (%)

	Study sites										
Ram supplementation	Baso -1	Baso -2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot -Pulasa	Damot -Sore	Over-all	χ2-Value	*p*-Value
Yes	78.1	80.0	43.8	65.5	69.7	65.7	40.0	51.3	61.3	19.92	0.0057
No	21.9	20.0	56.3	34.5	30.3	34.3	60.0	48.7	38.71		

4.7.3. Perceptions of farmers on production and adaptation of Dorper crossbred rams and lambs

4.7.3.1. Proportion of Dorper crossbred lambs over the local in the flock

Participating farmers were able to distinguish local lambs from Dorper crossbred lambs in their flock. In Merhabete, Kewet, Baso-1, and Minjar-Shenkora, 61%, 49%, 44%, and 34% respectively were identified as Dorper crosses (Figure 2). However, only a small percentage of Dorper crossbreeds were found in Damot-Sore (4%) and Damot-Pulassa (6%). In contrast to the national report from CSA claiming that the proportion of crossbred lambs in Ethiopia does not exceed 2%, the current study found that 37% of Dorper cross sheep were found in the surveyed sites (mean of all sites).

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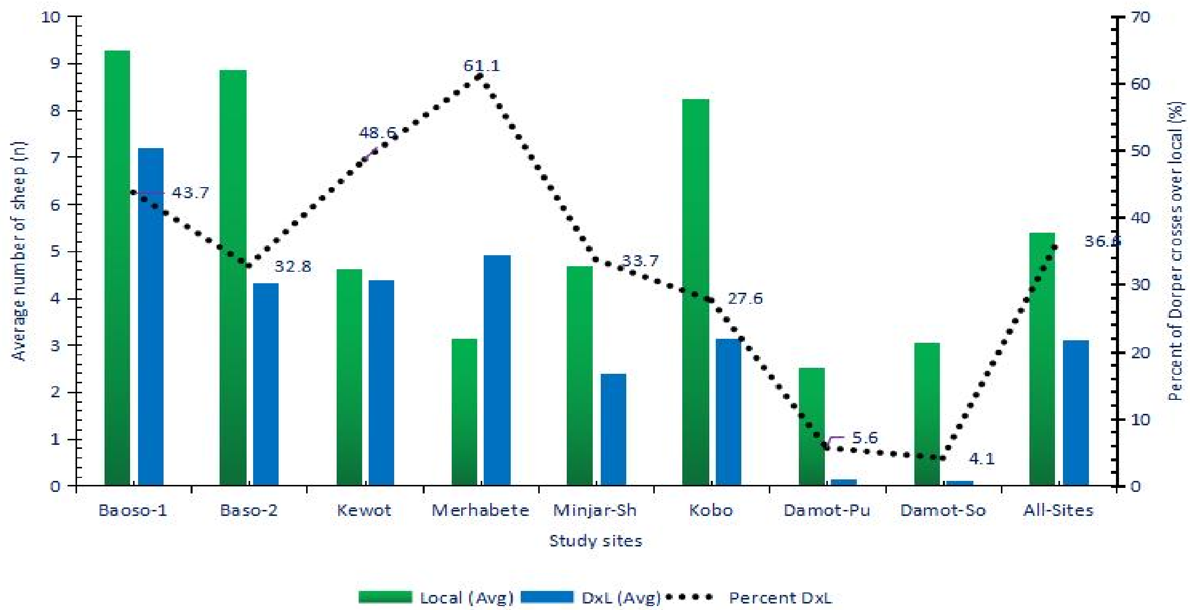

Figure 2. Proportion of Dorper crossbred lambs born over local lambs in the farmers' flock.

4.7.3.2. Physical conformation of Dorper crossbred rams

It was found that physical conformation is a highly valued trait among farmers. The study showed that 88% of farmers in the area considered the conformation of Dorper breeding rams to be good, while only 3.9% considered it poor. All farmers across all study sites agreed that Dorper rams have good body conformation (χ^2=10.91; p = 0.3650). Specifically, farmers from Kewet, Merhabete, and Minjar-Shenkora unanimously assigned the body conformation of Dorper rams as good (Table 20).

Table 20. Farmers' assessment of the conformation of distributed Dorper crossbred rams (%).

	Study sites								
Attributes	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Over-all	χ2-Value	*p*-Value
Poor	0.0	20.0	0.0	0.0	0.0	3.2	3.9		
Fair	50.0	0.0	0.0	0.0	0.0	9.7	7.7		
Good	50.0	80.0	100.0	100.0	100.0	87.1	88.4	10.91	0.3650

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4.7.3.3. Mating ability of Dorper crossbred rams

The mating ability of a breeding ram is one of the most important characteristics needed in the breeding process for it could contribute to the fertility and conception of ewes in the flock. Accordingly, farmers are keen to know the mating behavior of rams selected for breeding work. In our study, farmers were asked to rank their Dorper crossbred rams as poor, fair, and good in the mating ability. The results according to the farmers' observation and judgment was 81% of the interviewed farmers feels their rams are with good mating characteristics and only 4% of the farmers said the rams are poor in mating. Farmers who judged the mating ability of Dorper rams as good varies between 50% in Baso-1 and 100% in Kewet, Merhabete and Minjar-Shenkora areas, respectively (Table 21).

Table 21. Mating ability of distributed Dorper crossbred rams in the study sites (%).

Attributes	Study sites								
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Over-all n=248	χ^2-Value	*p*-Value
Poor	0.0	0.0	0.0	0.0	0.0	6.4	3.8		
Fair	50.0	20.0	0.0	0.0	0.0	19.4	15.4		
Good	50.0	80.0	100.0	100.0	100.0	74.2	80.8	6.5	0.7721

4.7.3.4. Testicle condition of Dorper crossbred rams (as assessed by researchers)

Rams, like other male mammals, have testicles that play a critical role in their reproductive system. The testicles produce sperm cells and secrete hormones such as testosterone. The condition of the testicles can have a significant impact on a ram's fertility and overall reproductive health. As a result, researchers assessed the testicles of rams based on their size, symmetry, shape, firmness, and overall appearance, categorizing them as poor, fair, and good. The findings showed that 83% of the rams had good testicle conditions while 15% were fair and less than 2% were poor. Additionally, the testicle conditions of rams varied at different sites, with Baso-1 having 50% good testicle conditions and Kewet, Merhabete, and Minjar-Shenkora having 100% good testicle conditions (Table 22).

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Table 22. Testicle condition of disseminated Dorper crossbred rams (%)

Attributes	Study sites								
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Over-all n=248	χ^2-Value	*P*-Value
Poor	0.0	0.0	0.0	0.0	0.0	3.2	1.9		
Fair	50.0	20.0	0.0	0.0	0.0	19.4	15.4		
Good	50.0	80.0	100.0	100.0	100.0	77.4	82.7	5.65	0.8438

4.7.3.5. Scrotum circumference, service year and body measurements of disseminated Dorper crossbred rams

The study found that the overall body condition, body weight, service year, and scrotal circumference of the distributed rams found serving in the flock of the sampled households were as follows: 3.9, 43.7 kg, 1.7 years, and 43.7 cm respectively as shown in (Table 23). The study also indicated that the body condition (BC) and service year of the Dorper crossbred rams are significantly affected by location and dentition (age), while the body weight, scrotum circumference, body condition, and service year are significantly affected by the age of rams. Location did not affect the body weight and scrotum circumference of distributed rams. Moreover, the study further elaborated that the lower values for body weight, BC, scrotal circumference, and service year of Dorper rams found serving in the flocks of sampled farmers were recorded for those rams with 1 permanent pair of incisors (PPI), compared to those with II-IV PPI.

The study also found that rams with higher body conditions were recorded at Minjar-Shenkora (4.8), Merhabete, and Kewt (4.2), respectively. Comparatively, the lower body condition of rams was recorded at Kewet (3.3), Baso-1 (3.4), and Baso-2 (3.5), respectively. The study also found that the rams found currently served for 0.4 years in Minjar-Shenkora and Kobo 2.7 years in Kobo area. The lower and higher values for scrotum circumference of the Dorper crossbred rams in the study sites were found in Merhabete (27 cm) and Kobo (33 cm), respectively. As far as body linear measurements are concerned, the study found that the location and age of rams did not significantly affect the height at the wither (HW), chest girth (CG), body length (BL), and chest width (CW) of the distributed Dorper crossbred rams. The overall HW, CG, BL, and CW of distributed Dorper crossbred rams were 64, 83, 65, and 27 cm, respectively.

Table 23. LSM±SE for body condition, body weight, dentition, testicle circumference, and body linear measurements of distributed Dorper crossbred rams in the study sites

Factors	Body weight	Body condition	Testicle circumference	Service year	Body measurements			
					HW	CG	BL	CW
Overall	43.65±1.84	3.9±0.12	30.32± 0.56	1.73±0.13	64.14±0.98	83.29±2.13	65.43±1.83	26.86±2.01
CV	17.5	11.5	7.6	31.4	3.9	6.6	7.2	19.30
R^2	0.37	0.74	0.41	0.62	0.66	0.87	0.53	0.52
Location	P =0.0993	P <0.0001	P =0.0548	P =0.0001	P =0.1272	P =0.7636	P =0.2583	P =0.4837
Baso-1	44.15±3.43 (6)	3.4±0.2^{c} (6)	28.96±1.04 (6)	1.08±0.24^{b} (6)	66.10±1.30 (4)	83.27±2.83 (4)	68.10±2.44 (4)	28.57±2.68 (4)
Baso-2	34.68±3.39 (8)	3.5±0.2^{c} (8)	27.67±1.03 (8)	1.36±0.24^{b} (8)	62.00±1.46 (3)	84.67±3.17 (3)	63.00±2.73 (3)	25.67±2.99 (3)
Kewet	39.98±4.61 (3)	4.2±0.3^{bc} (3)	29.28±140 (3)	1.97±0.34^{ab} (3)				
Kobo	50.45±3.25 (12)	3.3±0.2^{c} (12)	32.57±0.98 (12)	2.69±0.23^{a} (12)				
Merhabete	33.78±5.48 (3)	4.2±0.2^{ab} (3)	26.96±1.66 (3)	1.04±0.39^{b} (3)				
Minjar-Shenkora	39.35±3.70 (8)	4.8±0.2^{ab} (8)	29.77±1.12 (8)	0.39±0.26^{c} (8)				
Dentition	P =0.0227	P =0.0063	P =0.0256	P =0.0010	P =0.4471	P =0.3007	P =0.4596	P =0.3595
I	30.35±5.42^{b} (5)	3.8±0.3^{b} (5)	26.03±1.64^{b} (5)	0.33±0.38^{c} (5)				
II	40.67±3.50^{ab} (11)	4.4±0.2^{a} (11)	29.92±1.06^{a} (11)	1.30±0.25^{b} (11)	62.65±1.49 (3)	79.90±3.25 (3)	62.15±2.80 (3)	22.80±3.07 (3)
III	41.30±2.55^{ab} (13)	4.4±0.2^{a} (13)	29.62±0.77^{a} (13)	1.69±0.18^{b} (13)	63.50±1.79 (2)	82.50±3.88 (2)	66.50±3.45 (2)	30.50±3.67 (2)
IV	49.29±2.69^{a} (11)	3.8±0.2^{b} (11)	31.24±0.81^{a} (11)	2.38±0.19^{a} (11)	66.00±1.79 (2)	89.50±3.88 (2)	68.00±3.35 (2)	28.50±3.67 (2)

4.7.3.6. Off-take reasons and number in the past one year in the study areas

Farmers need to keep track of the off-take rate of their sheep flock to maximize their benefits. To determine the off-take rate, farmers at the study sites were asked to recall the number of sheep that were sold, slaughtered, died, gifted, shared and predated in the past one year. Based on recall basis, the average number of sheep off-take was 9.3 per year, with sales accounting for 4.2, slaughter accounting for 2.5, death accounting for 1.9, gifting accounting for 0.1, sharing and predated each accounting for 0.3, respectively.

The number of sheep sold was similar across all study sites, except for Baso-1 where the number of sheep sold was significantly higher compared to Merhabete (5.2 vs 3.1, $p = 0.0190$). The number of sheep slaughtered at Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 3.4, 3.1, 2.1, 2.3, and 1.4 respectively. The number of sheep slaughtered in Baso-1 and Baso-2 was significantly higher ($p < 0.0001$ and $p = 0.0263$) than the number slaughtered in Minjar-Shenkora. The number of sheep that died in the past one year at Baso-1, Baso-2, Kewet,

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Merhabete, and Minjar-Shenkora were 3.1, 1.6, 1.7, 1.8, and 0.9 respectively. Significantly ($p = 0.0033$) fewer sheep died in Minjar-Shenkora compared to Baso-1.

The total off-takes (number) of sheep in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 12.7, 10.5, 8.7, 7.3, and 6.3 respectively. The overall total offtake rate in Baso-1 was significantly higher ($p = 0.0015$ and $p < 0.0001$) than the off-take (number) in Merhabete and Minjar-Shenkora. The proportion of sheep sold was similar ($p = 0.0767$) across all study sites. The percentage of sheep sold (commercial off-take rate) in the past year at Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 42.2, 42.7, 61.2, 46.9 and 54.9 respectively. Similarly, the proportion of sheep slaughtered was also similar ($p = 0.1422$) across all study sites. The percentage of slaughtered sheep was 29.8, 33.7, 27.1, 30.1, and 20.1 in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora respectively. Additionally, the proportion (21.3, 15.8, 11.7, 21.6, and 12.1%) of sheep that died in Baso-1, Baso-2, Kewet, Merhabete and Minjar-Shenkora respectively was also similar ($p = 0.2104$), Table 24.

Table 24. LSM±SE for off-take reasons and estimated number of sheep out from the flock in the study sites

Attributes	Study sites						
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Over-all (n=134)	*p*-value
Number of sheep sold	5.22±0.43[a]	4.27±0.72[ab]	4.88±0.69[ab]	3.07±0.53[b]	3.53±0.49[ab]	4.21±0.26	0.0157
Number of sheep slaughtered	3.39±0.28[a]	3.07±0.46[a]	2.13±0.44[ab]	2.56±0.34[ab]	1.41±0.31[b]	2.48±0.17	0.0001
Number of sheep died	3.07±0.39[a]	1.60±0.66[ab]	1.69±0.64[ab]	1.78±0.49[ab]	0.88±0.45[b]	1.93±0.24	0.0086
Number of sheep gifted	0.15±0.06	0.27±0.09	0.00±0.08	0.00±0.06	0.00±0.06	0.08±0.03	0.0607
Number of sheep shared	0.63±0.27	0.87±0.45	0.00±0.43	0.00±0.33	0.00±0.31	0.30±0.16	0.2533
Number of sheep predated	0.27±0.10	0.40±0.17	0.00±0.16	0.19±0.13	0.47±0.12	0.28±0.06	0.1595
Total off-take	*12.43±0.88[a]*	*10.47±1.45[ab]*	*8.69±1.41[ab]*	*7.30±1.08[b]*	*6.28±0.99[b]*	*9.28±0.53*	*<0.0001*
Percentage of sold sheep	42.17±4.14	42.75±6.85	61.20±6.23	46.87±5.10	54.86±4.69	48.63±2.50	0.0767
Percentage of slaughtered sheep	29.81±3.08	33.70±5.10	27.08±4.94	30.11±3.80	20.09±3.49	27.61±1.86	0.1422
Percentage of died sheep	21.29±3.03	15.79±5.02	11.73±4.86	21.58±3.74	13.07±3.43	17.54±1.83	0.2104

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4.7.3.7. Constraints to Dorper sheep crossbreeding (weighted index rankings)

The results revealed that the overall constraints to Dorper sheep crossbreeding were lack of Dorper ram (with an index value of 0.184), feed shortage (with an index value of 0.175), and disease (with an index value of 0.156), respectively (as shown in Table 25 for the detail and Figure 3 for all sites).

Farmers from Baso-1, Kobo, and Damot-pulasa reported that disease prevalence was the most important constraint in the Dorper crossbreeding program, while farmers from Damot-Sore identified feed shortage as the most important constraint affecting the Dorper crossbreeding work in their locality. In addition, farmers from Kewet, Merhabete, and Minjar-Shenkora stated that labor was the third most important constraint that affected Dorper crossbreeding work in their area, while capital shortage was mentioned as the third most important constraint affecting Dorper crossbreeding work at Damot-Sore. Understanding the most important constraints affecting the Dorper crossbreeding program can help alleviate the challenges and create an enabling environment for the success of the crossbreeding program in Ethiopia.

Table 25. Constraints suggested to Dorper crossbreeding by farmers (index).

Constraint to Dorper sheep crossbreeding	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damot-Sore	Overall n=248
Lack of Dorper ram	0.144	0.209	0.207	0.206	0.279	0.168	0.163	0.161	0.184
Feed shortage	0.174	0.199	0.187	0.204	0.156	0.220	0.125	0.180	0.175
Disease prevalence	0.175	0.152	0.131	0.128	0.070	0.272	0.174	0.138	0.156
Market challenge	0.095	0.087	0.050	0.046	0.123	0.000	0.164	0.128	0.097
Capital shortage	0.067	0.064	0.061	0.123	0.096	0.039	0.101	0.144	0.094
Labor shortage	0.130	0.128	0.159	0.141	0.124	0.087	0.032	0.035	0.093
Poor Adaptability	0.065	0.066	0.072	0.044	0.035	0.063	0.140	0.116	0.082
Water shortage	0.108	0.051	0.051	0.045	0.092	0.035	0.035	0.063	0.062
Drought occurrence	0.043	0.044	0.081	0.062	0.026	0.117	0.065	0.035	0.056

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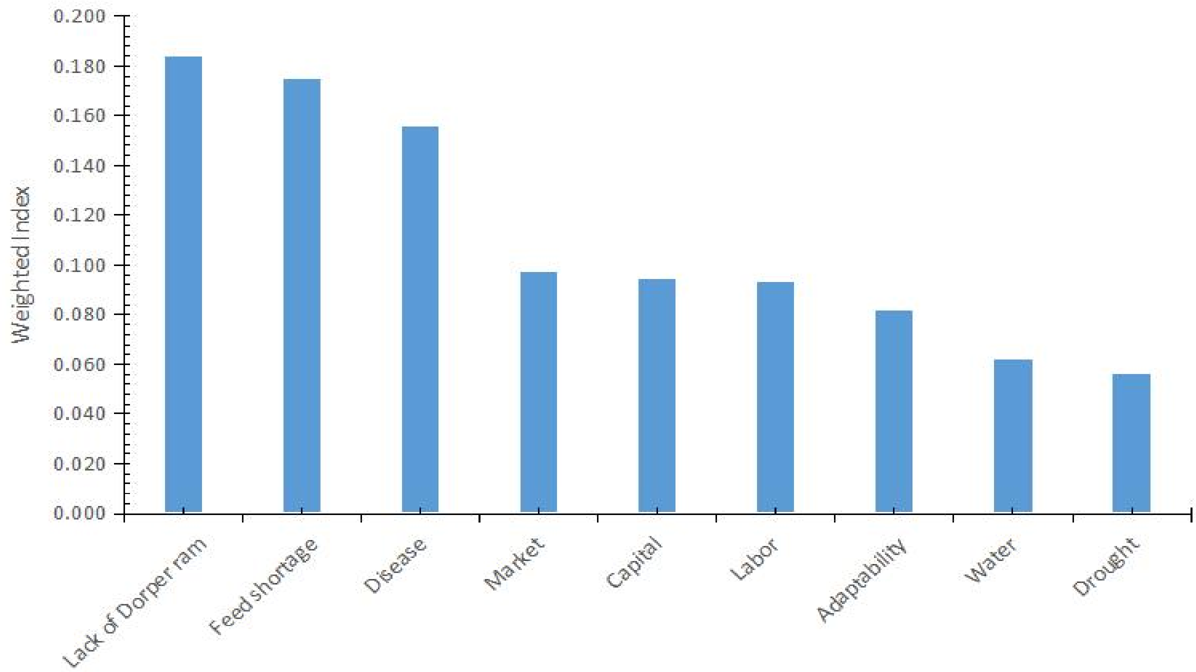

Figure 3. Constraints to Dorper sheep crossbreeding over-all weighted index ranking.

4.7.3.8. Farmers' perception on productive traits of Dorper crossbred lambs

Tables 26-32 provide data on farmers' perceptions of productivity-related traits in local and Dorper crossbred sheep. According to the pooled data from all study sites (Table 26), the results indicated that farmers preferred Dorper crossbred sheep for various productive traits compared to local sheep. The preference for Dorper crossbred sheep was significantly higher in terms of appearance/conformation (43.7 times higher, $p < 0.0001$), growth rate (75.9 times higher, $p < 0.0001$), meat yield (87.8 times higher, $p < 0.001$), milk yield of ewes (46.4 times higher, $p < 0.0001$), and wool yield (7.1 times higher, $p < 0.0001$). Farmers also believed that Dorper crossbred lambs reach market age earlier (7.9 times, $p < 0.0001$) and that Dorper crossbred ewes exhibited better mothering ability (2.2 times higher, $p < 0.0001$) compared to local ewes.

However, it is notable that in the Merhabete and Minjar sites, farmers did not observe a significant difference in wool/hair yield between Dorper crossbred sheep and local sheep. The odds ratio for the Merhabete site was 2.582 ($p = 0.0669$), and for the Minjar site, it was 2.316 ($p = 0.0665$). These findings suggest that in these specific contexts, the wool/hair production of Dorper crossbred sheep may not significantly differ from that of local sheep, according to farmers' observations.

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On the other hand, in the Damot (Sore and Pulassa) areas, farmers perceived Dorper crossbred ewes to have lower mothering ability and reproductive performance compared to local ewes. This perception was supported by an odds ratio of 0.357 (p = 0.0028). On the other hand, in the Kobo site, farmers did not observe any significant difference in mothering ability between local and Dorper crossbred ewes, with an odds ratio of 0.668 (p = 0.3500). Regarding meat quality, farmers in the Merhabete site perceived the meat quality of Dorper crossbred sheep to be similar to that of local sheep. The odds ratio was estimated to be 2.593 (p = 0.0666), which was not statistically significant. However, farmers in the Damot (Sore and Pulassa) and Baso areas preferred meat from local sheep over Dorper crossbreeds. The odds ratio for the Damot comparison was 0.476 (p = 0.0326), while for Baso, it was 0.304 (p = 0.0017), indicating a statistically significant difference in favor of local sheep.

Table 26. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for (overall).

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	1.2	2.4	53.6	33.9	8.9	1.00
	Dorper cross	-	-	2.4	17.8	79.8	43.712 (26.509 to 72.079)***
Growth-rate	Local	-	2.8	57.3	36.7	3.2	1.00
	Dorper cross	-	0.4	3.2	16.5	79.9	75.930 (42.451 to 135.812)***
Meat-yield	Local	-	2	66.1	25.8	6.1	1.00
	Dorper cross	-	-	2.8	11.3	85.9	87.781 (49.736 to 154.926)***
Milk-yield	Local	-	22.2	62.5	14.9	0.4	1.00
	Dorper cross	0.4	0.4	10.9	45.1	43.2	46.432 (27.964 to 77.095)***
Wool-yield	Local	4.4	26.2	36.7	25.4	7.3	1.00
	Dorper cross	-	3.2	21.8	39.1	35.9	7.112 (4.529 to 10.214)***
Market-age	Local	-	0.4	38.3	45.6	15.7	1.00
	Dorper cross	0.4	1.2	8.5	25.4	64.5	7.885 (5.411 to 11.489)***
Mothering-ability	Local	-	2.8	20.6	49.2	27.4	1.00
	Dorper cross	0.4	6.5	6.1	39.5	47.5	2.186 (1.560 to 3.063)***
Meat-quality	Local	-	1.2	18.2	44.8	35.8	1.00
	Dorper cross	-	1.2	12.9	42.3	43.6	1.398 (1.003 to 1.949)*

VP= Very poor, P= Poor, M= Medium, G= Good, VG= Very good, OR= Odds ratio

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Table 27. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep-for **Damot-pulasa and sore** sites

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	2.5	-	15.2	59.5	22.8	1.00
	Dorper cross	-	-	1.3	36.7	62.0	6.197 (3.151 to 12.188)***
Growth-rate	Local	-	1.3	20.3	70.9	7.6	1.00
	Dorper cross	-	1.3	3.8	36.7	58.2	11.943 (5.425 to 26.293)***
Meat-yield	Local	-	-	50.6	34.2	15.2	1.00
	Dorper cross	-	-	5.1	24.1	70.9	15.064 (7.283 to 31.156)***
Milk-yield	Local	-	12.7	57	29.1	1.3	1.00
	Dorper cross	1.3	-	5.1	55.7	38	35.059 (13.616 to 90.270)***
Wool-yield	Local	13.9	36.7	34.2	13.9	1.3	1.00
	Dorper cross	-	2.5	13.9	41.8	41.8	32.451 (14.368 to 73.296)***
Market-age	Local	-	-	16.5	64.6	19	1.00
	Dorper cross	1.3	1.3	7.6	51.9	38	2.262 (1.201 to 4.259)**
Mothering-ability	Local	-	1.3	1.3	57	40.5	1.00
	Dorper cross	1.3	1.3	6.3	70.9	20.3	0.357 (0.182 to 0.701)***
Meat-quality	Local	-	1.3	1.3	65.8	31.7	1.00
	Dorper cross	-	1.3	8.9	69.6	20.3	0.476 (0.241 to 0.940)*

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Table 28. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for **Kobo** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	2.8	5.7	82.9	8.6	-	1
	Dorper cross	-	-	8.6	25.7	65.7	138.727 (25.915 to 742.624)***
Growth-rate	Local	-	14.3	80.0	5.7	-	1
	Dorper cross	-	-	8.6	31.4	60.0	198.014 (30.962 to 999.000)***
Meat-yield	Local	-	14.3	57.1	25.7	2.9	1
	Dorper cross	-	-	2.9	20.0	77.1	100.476 (19.297 to 523.168)***
Milk-yield	Local	-	14.3	68.6	17.1	-	1
	Dorper cross	-	-	14.3	28.6	57.1	40.268 (11.049 to 146.753)***
Wool-yield	Local	-	37.1	48.6	14.3	-	1
	Dorper cross	-	-	40.0	60.0	-	13.288 (4.247 to 41.576)***
Market-age	Local	-	-	51.4	37.2	11.4	1
	Dorper cross	-	-	20.0	28.6	51.4	5.657 (2.188 to 14.621)***
Mothering-ability	Local	-	17.1	40	25.8	17.1	1
	Dorper cross	-	42.9	14.3	20	22.8	0.668 (0.287 to 1.556) ns
Meat-quality	Local	-	5.7	57.1	20	17.2	1
	Dorper cross	-	5.7	28.6	28.6	37.1	2.805 (1.148 to 6.853)*

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Table 29. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep **Minjar site**

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	-	-	69.7	27.3	3.0	1
	Dorper cross	-	-	-	12.1	87.9	309.033 (32.541 to 999.0)***
Growth-rate	Local	-	-	63.6	33.3	3.1	1
	Dorper cross	-	-	3.0	-	97.0	526.923 (45.972 to 999.0)***
Meat-yield	Local	-	-	84.9	15.1	-	1
	Dorper cross	-	-	-	3.0	97.0	179.829 (29.819 to 999.0)***
Milk-yield	Local	-	45.5	51.5	3	-	1
	Dorper cross	-	3	30.3	51.5	15.2	45. 565 (9.246 to 224.359)***
Wool-yield	Local	-	6.1	45.5	30.3	18.1	1
	Dorper cross	-	9.1	21.2	30.3	39.4	2.316 (0.944 to 5.680) ns
Market-age	Local	-	-	36.4	36.4	27.2	1
	Dorper cross	-	3	12.1	9.1	75.8	6.015 (2.165 to 16.710)***
Mothering-ability	Local	-	-	30.3	57.6	12.1	1
	Dorper cross	-	-	6.1	18.2	75.7	16.927 (5.211 to 54.980)***
Meat-quality	Local	-	-	36.4	42.4	21.2	1
	Dorper cross	-	-	6.1	27.3	66.6	7.769 (2.762 to 21.855)***

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Table 30. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for **Kewet** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	12.5	18.8	43.8	18.8	6.3	1
	Dorper cross	-	-	18.8	31.3	50.0	15.510 (3.165 to 76.001)***
Growth-rate	Local	6.3	18.8	50.0	25.0	-	1
	Dorper cross	-	-	18.8	31.3	50.0	20.540 (3.806 to 110.859)***
Meat-yield	Local	-	-	75.0	25.0	-	1
	Dorper cross	-	-	12.5	25.0	62.5	34.631 (5.338 to 224.686)***
Milk-yield	Local	6.25	31.25	56.25	6.25	-	1
	Dorper cross	-	6.25	12.5	37.5	43.75	38.693 (5.634 to 265.754)***
Wool-yield	Local	-	50.0	31.25	12.5	6.25	1
	Dorper cross	-	6.25	56.3	6.3	31.25	6.057 (1.420 to 25.834)**
Market-age	Local	-	12.5	50	37.5	-	1
	Dorper cross	-	-	18.8	25	56.25	14.690 (2.946 to 73.253)***
Mothering-ability	Local	-	-	43.75	37.5	18.75	1
	Dorper cross	-	-	-	12.5	87.5	35.010 (5.032 to 243.560)***
Meat-quality	Local	-	-	37.5	31.25	31.25	1
	Dorper cross	-	-	-	12.5	87.5	17.707 (2.861 to 10.587)***

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Table 31. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for **Merhabete** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	-	3.5	44.8	51.7	-	1
	Dorper cross	-	-	6.9	13.8	79.3	66.036 (12.111 (360.067)***
Growth-rate	Local	-	-	51.7	48.3	-	1
	Dorper cross	-	-	6.9	20.7	72.4	51.353 (9.881 to 266.890)***
Meat-yield	Local	-	-	51.7	48.3	-	1
	Dorper cross	-	-	6.9	13.8	79.3	67.827 (12.458 to 369.292)***
Milk-yield	Local	-	31.03	65.52	3.45	-	1
	Dorper cross	-	-	17.24	62.07	20.69	149.691 (16.406 to 999.999)***
Wool-yield	Local	-	10.3	20.69	51.72	17.24	1
	Dorper cross	-	6.9	13.8	34.5	44.83	2.637 (0.985 to 7.055) ns
Market-age	Local	-	3.45	24.14	62.07	10.34	1
	Dorper cross	-	-	6.9	17.24	75.86	17.839 (4.989 to 63.791)***
Mothering-ability	Local	-	-	3.45	82.86	13.70	1
	Dorper cross	-	-	-	34.48	65.52	12.163 (3.312 to 44.660)***
Meat-quality	Local	-	-	13.79	51.72	34.48	1
	Dorper cross	-	-	6.9	34.5	58.6	2.593 (0.937 to 7.177) ns

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Table 32. Odds ratio estimates of farmers' perception of productive and reproductive traits of Dorper crossbred and local sheep for **Baso** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Appearance/conformation	Local	-	-	76.8	17.9	5.4	1
	Dorper cross	-	-	3.6	3.6	92.9	171.816 (43.244 to 682.658) <0.0001
Growth-rate	Local	-	-	76.8	16.1	7.1	1
	Dorper cross	-	-	7.1	10.7	82.1	51.303 (17.985 to 146.346) <0.0001
Meat-yield	Local	-	-	78.6	16.1	5.4	1
	Dorper cross	-	-	7.1	12.5	80.4	58.166 (19.876 to 170.216) <0.0001
Milk-yield	Local	-	19.64	71.43	8.93	-	1
	Dorper cross	-	-	14.29	25	60.71	76.349 (23.249 to 250.728) <0.0001
Wool-yield	Local	-	21.4	41.07	30.36	7.14	1
	Dorper cross	-	1.79	17.9	37.5	42.86	8.044 (3.686 to 17.556) <0.0001
Market-age	Local	-	-	60.71	25	14.29	1
	Dorper cross	-	1.79	5.4	8.93	83.93	26.177 (10.101 to 67.837) <0.0001
Mothering-ability	Local	-	-	30.36	35.71	33.93	1
	Dorper cross	-	-	5.4	32.14	62.5	3.893 (1.853 to 8.178) p=0.0003
Meat-quality	Local	-	-	3.57	33.93	62.5	1
	Dorper cross	-	-	23.21	39.29	37.5	0.304 (0.145 to 0.639) p=0.0017

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4.7.3.9. Farmers' perception of adaptability traits of Dorper crossbred lambs

The current study also investigated the perception of farmers regarding the phenotype and adaptability characteristics of Dorper crossbred sheep in comparison to the local sheep population. By analyzing and consolidating data from various sites, the study yielded valuable and significant findings (Tables 33-39).

One interesting finding was that farmers showed a higher interest in maintaining the coat color of their local sheep compared to the Dorper crossbred sheep (OR=0.246, $p < 0.0001$, Table 33 for Dorper crossbreed). However, it is important to note that farmers at the Kewet site differed from the majority (Table 37). Specifically, they preferred the coat color of the Dorper crossbred sheep, particularly favoring white or light red-colored individuals (OR=19.268, $p = 0.0013$). This observation indicates that at the Kewet site, the coat color of the Dorper crossbred sheep was preferred 19 times more than that of the local sheep, however they don't have interest with the black coat color as their area is hotter.

The presence of horns is an important phenotypic characteristic in the local market. The findings of this study revealed that farmers generally favored the horns of their local sheep compared to those of Dorper crossbred sheep (OR=0.09, $p < 0.000$, for Dorper crosses). However, farmers in the Kewet site displayed a notable interest in the horns of Dorper crossbred sheep compared to the local sheep (OR=9.95, $p = 0.0040$). They encountered some of the Dorper crossbred are horned, this indicates that farmers in the Kewet area are approximately 10 times more inclined towards favoring the horns from Dorper crossbred sheep.

Grazing ability is highly valued by farmers as it allows animals to utilize local feed resources effectively. Our study found unanimous agreement among farmers in favor of the grazing capability of Dorper crossbred sheep over the local breed (OR=21.134, $p < 0.0001$). Additionally, farmers perceived that Dorper crossbred sheep initiate grazing at an early age and exhibit non-selective grazing behavior. This suggests that Dorper crossbred sheep are perceived to be 21 times more proficient in grazing compared to the local sheep. This perception was consistent among farmers from all study areas, indicating a uniform appreciation for the grazing ability of Dorper crossbred sheep across various areas of the study sites.

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Feed availability and price are major cost-intensive factors in livestock production. Farmers perceived Dorper crossbred sheep to have a higher demand for feed compared to their local counterparts (OR=56.160, $p < 0.0001$). These results indicate that Dorper crossbred sheep are perceived to have a feed requirement that is 56 times higher than that of the local sheep. On the other hand, the ability of animals to walk and access watering points is considered important in rural livestock rearing environments. In this particular study, farmers unanimously confirmed the inferior walking ability of Dorper crossbred sheep compared to the local breed (OR=0.055, $p < 0.0001$, Table 33). This finding indicates that the walking capacity of Dorper crossbred sheep is approximately 0.06 times inferior to that of the local sheep.

In animal production, it is crucial to have animals that are easily manageable. Farmers in the study areas were also asked if they could differentiate the behavior of Dorper crossbred sheep from that of their local sheep. Accordingly, they perceived Dorper crossbred sheep to have favorable behavior, making them easier to handle and more docile compared to the local sheep (OR=15.702, $p < 0.0001$). These findings indicate that the behavior and temperament of Dorper crossbred sheep are approximately 16 times more preferred by farmers compared to the behavior of their local sheep. To assess the adaptability and performance of Dorper crossbred sheep in comparison to local sheep populations, farmers were also surveyed to gather their perceptions and preferences regarding various traits. The study focused on heat tolerance, cold tolerance, drought tolerance, disease tolerance, and pre-weaning survival rates.

Heat tolerance is a crucial trait in tropical environments, and the study found that farmers perceived Dorper crossbred sheep to have lower heat tolerance compared to the local sheep (OR=0.145, $p < 0.0001$). This suggests that Dorper crossbred sheep were perceived to be approximately 0.2 times less likely to tolerate heat compared to the locally adapted indigenous sheep. However, it is noted that farmers from the Minjar site did not observe a significant difference in heat tolerance between the Dorper crossbred sheep and their local sheep (OR=1.503, $p = 0.4051$, Table 36). In terms of cold tolerance, the study examined the behavior of Dorper crossbred sheep compared to local sheep in cooler areas and seasons. The pooled data indicated that Dorper crossbred sheep are less likely to tolerate cold conditions compared to the locally adapted sheep in their specific environments (OR=0.324, $p < 0.0001$). However, interestingly, farmers from the Minjar and Kewet sites did not observe significant differences in cold tolerance between the Dorper crossbred sheep and the local sheep in their respective areas (Minjar: OR=1.408, P=0.4887; Kewet: OR=1.527, p = 0.5370).

Regarding drought tolerance, farmers perceived Dorper crossbred sheep to be less likely to withstand drought compared to the locally adapted sheep (OR=0.093, $p < 0.0001$). This suggests that Dorper crossbred sheep are approximately 0.1 times less likely to tolerate drought occurrences compared to the locally adapted sheep in their respective study areas. However, farmers from the Minjar areas did not perceive any difference in drought tolerance between the Dorper crossbred sheep and the local sheep specifically adapted to the Minjar areas (OR=0.380, p = 0.0566).

Farmers were also asked to provide their perception on disease tolerance in Dorper crossbred sheep compared to locally adapted sheep breeds. The pooled data indicated that farmers perceive Dorper crossbred sheep to have lower disease tolerance compared to the locally adapted indigenous sheep breeds (OR=0.113, $p < 0.0001$). This suggests that farmers believe Dorper crossbred sheep are approximately 0.1 times less likely to possess disease tolerance compared to the locally adapted sheep breeds in their areas. However, farmers from the Minjar site perceived the disease tolerance abilities of Dorper crossbred sheep to be on par with the local sheep in their area (OR=0.490, p = 0.1507).

In terms of pre-weaning survival rates, which are influenced by environmental factors and maternal influence, farmers perceived Dorper crossbred lambs to have better survival rates compared to the locally adapted sheep in their respective areas (OR=2.255, $p < 0.0001$). This suggests that farmers believe Dorper crossbred lambs are approximately 2.3 times more likely to survive until weaning compared to the locally adapted sheep. However, farmers from the Kobo site perceived lower pre-weaning survival rates for Dorper crossbred lambs compared to their locally adapted sheep (OR=0.119, $p < 0.0001$, Table 35), indicating a significant difference in perception between farmers in the Kobo site.

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Table 33. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep (overall, n=248)

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	0.4	14.5	33.5	51.6	1.00
	Dorper cross	-	6.1	38.7	32.2	23.0	0.246 (0.175 to 0.348)***
Horn	Local	-	1.2	12.5	30.2	56.1	1.00
	Dorper cross	-	7.3	52.0	32.6	8.1	0.091 (0.061 to 0.134)***
Grazing-ability	Local	-	-	26.2	59.3	14.5	1.00
	Dorper cross	-	0.4	3.2	15.7	80.7	21.134 (13.506 to 33.071)***
Feed-requirement	Local	-	0.8	55.7	37.9	5.6	1.00
	Dorper cross	-	0.4	3.2	15.3	81.1	56.160 (32.985 to 95.618)***
Walking-ability	Local	-	-	2.0	23.4	74.6	1.00
	Dorper cross	-	2.0	36.7	46.0	15.3	0.055 (0.036 to 0.085)***
Behavior	Local	-	4.8	41.9	46.0	7.3	1.00
	Dorper cross	0.4	0.4	8.1	25.4	65.7	15.702 (10.293 to 23.952)***
Heat-tolerance	Local	-	-	5.7	34.6	59.7	1.00
	Dorper cross	-	2.4	26.2	45.2	26.2	0.145 (0.100 to 0.211)***
Cold-tolerance	Local	0.4	0.8	8.5	39.9	50.4	1.00
	Dorper cross	-	2.4	26.2	45.2	26.2	0.324 (0.229 to 0.457)***
Drought-tolerance	Local	-	-	3.6	37.5	58.9	1.00
	Dorper cross	0.4	3.6	33.1	49.6	13.3	0.093 (0.062 to 0.140)***
Disease-tolerance	Local	-	0.4	2.8	39.5	57.3	1.00
	Dorper cross	0.4	8.1	25.4	50.8	15.3	0.113 (0.076 to 0.168)***
Lamb-survival	Local	-	0.4	19.0	54.8	25.8	1.00
	Dorper cross	-	3.6	12.5	32.6	51.3	2.255 (1.608 to 3.163)***

VP= Very poor, P= Poor, M= Medium, G= Good, VG= Very good, OR= Odds ratio

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Table 34. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for **Damot** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	-	2.5	30.4	67.1	1.00
	Dorper cross	-	12.7	59.5	22.8	5.1	0.017 (0.006 to 0.045)***
Horn	Local	-	1.3	1.3	31.7	65.8	1.00
	Dorper cross	-	8.9	73.4	15.2	2.5	0.009 (0.003 to 0.027)***
Grazing-ability	Local	-	-	6.3	84.8	8.9	1.00
	Dorper cross	-	1.3	1.3	12.7	84.8	44.168 (17.483 to 111.585)***
Feed-requirement	Local	-	-	73.4	22.8	3.8	1.00
	Dorper cross	-	1.3	1.3	24.1	73.4	80.551 (28.433 to 228.202)
Walking-ability	Local	-	-	-	21.5	78.5	1.00
	Dorper cross	-	-	30.4	64.6	5.1	0.013 (0.004 to 0.040)***
Behavior	Local	-	12.7	38	45.6	3.8	1.00
	Dorper cross	1.3	-	7.6	27.9	63.3	20.176 (9.097 to 44.748)***
Heat-tolerance	Local	-	-	7.6	46.8	45.6	1.00
	Dorper cross	-	2.5	25.3	68.4	3.8	0.099 (0.044 to 0.221)***
Cold-tolerance	Local	1.3	-	3.8	63.3	31.7	1.00
	Dorper cross	-	-	15.2	60.8	24.1	0.563 (0.297 to 1.067)ns
Drought-tolerance	Local	-	-	5.1	57	38	1.00
	Dorper cross	-	-	26.6	73.4	-	0.054 (0.018 to 0.158)***
Disease-tolerance	Local	-	1.3	5.1	63.3	30.4	1.00
	Dorper cross	-	-	16.5	76	7.6	0.241 (0.112 to 0.515)***
Lamb-survival	Local	-	1.3	8.9	77.2	12.7	1.00
	Dorper cross	-	1.3	7.6	45.6	45.6	3.739 (1.891 to 7.392)***

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Table 35. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for **Kobo** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	2.9	28.6	40.0	28.5	1.00
	Dorper cross	-	11.4	54.3	31.4	2.9	0.199 (0.077 to 0.514)***
Horn	Local	-	5.7	40.0	34.3	20.0	1.00
	Dorper cross	-	8.6	42.9	45.7	2.8	0.593 (0.246 to 1.434)ns
Grazing-ability	Local	-	-	51.4	31.4	17.2	1.00
	Dorper cross	-	-	11.4	48.6	40.0	5.138 (1.980 to 13.330)***
Feed-requirement	Local	-	5.7	68.6	20.0	5.7	1.00
	Dorper cross	-	-	14.3	28.6	57.1	18.991 (6.185 to 58.306)***
Walking-ability	Local	-	-	11.4	34.3	54.3	1.00
	Dorper cross	-	14.3	82.9	2.8	0.0	0.004 (0.001 to 0.034)***
Behavior	Local	-	5.7	57.1	31.4	5.8	1.00
	Dorper cross	-	2.9	22.9	48.6	25.6	4.817 (1.856 to 12.498)***
Heat-tolerance	Local	-	-	17.1	22.9	60.0	1.00
	Dorper cross	-	22.9	71.4	5.7	-	0.010 (0.002 to 0.056)***
Cold-tolerance	Local	-	5.7	34.3	28.6	31.4	1.00
	Dorper cross	-	17.1	65.7	14.3	2.9	0.148 (0.054 to 0.407)***
Drought-tolerance	Local	-	-	11.4	28.6	60.0	1.00
	Dorper cross	2.9	25.7	60.0	11.4	-	0.013 (0.003 to 0.056)***
Disease-tolerance	Local	-	-	2.9	28.6	68.5	1.00
	Dorper cross	2.9	57.1	37.1	2.9	-	0.001 (0.001 to 0.013)***
Lamb-survival	Local	-	-	20.00	48.57	31.43	1.00
	Dorper cross	-	22.86	45.71	22.86	8.57	0.119 (0.044 to 0.324)<0.0001

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Table 36. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for **Minjar** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	-	9.1	33.3	57.6	1.00
	Dorper cross	-	3.0	45.5	30.3	21.2	0.156 (0.058 to 0.421)***
Horn	Local	-	-	6.1	39.4	54.5	1.00
	Dorper cross	-	12.1	36.4	30.3	21.2	0.147 (0.054 to 0.400)***
Grazing-ability	Local	-	-	24.2	54.6	21.2	1.00
	Dorper cross	-	-	-	15.2	84.8	22.553 (6.386 to 79.651)***
Feed-requirement	Local	-	-	45.5	45.5	9.0	1.00
	Dorper cross	-	-	-	3.0	97.0	329.855 (32.487 to 999.0)***
Walking-ability	Local	-	-	-	45.5	54.5	1.00
	Dorper cross	-	-	12.1	48.5	39.4	0.451 (0.173 to 1.178) ns
Behavior	Local	-	-	36.4	54.6	9.0	1.00
	Dorper cross	-	-	6.1	27.3	66.6	15.350 (4.718 to 49.937)***
Heat-tolerance	Local	-	-	3.0	66.7	30.3	1.00
	Dorper cross	-	3.0	6.1	45.5	45.4	1.503 (0.576 to 3.920) ns
Cold-tolerance	Local	-	-	6.1	63.6	30.3	1.00
	Dorper cross	-	-	6.1	54.5	39.4	1.408 (0.534 to 3.711) ns
Drought-tolerance	Local	-	-	-	57.6	42.4	1.00
	Dorper cross	-	-	15.2	57.6	27.2	0.380 (0.140 to 1.028) ns
Disease-tolerance	Local	-	-	3.0	51.5	45.5	1.00
	Dorper cross	-	-	9.1	60.6	30.3	0.490 (0.185 to 1.926) ns
Lamb-survival	Local	-	-	18.2	63.6	18.2	1.00
	Dorper cross	-	-	3.0	54.6	42.4	3.879 (1.364 to 11.036)**

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Table 37. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep or **Kewet** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	-	31.3	56.3	12.5	1.00
	Dorper cross	-	-	-	31.3	68.8	19.268 (3.194 to 116.235)**
Horn	Local	-	-	56.3	31.3	12.5	1.00
	Dorper cross	-	-	6.3	50.0	43.8	9.905 (2.077 to 47.243)***
Grazing-ability	Local	-	-	31.3	56.3	12.5	1.00
	Dorper cross	-	-	6.3	6.3	87.5	33.500 (4.895 to 229.255)***
Feed-requirement	Local	-	18.8	31.3	50.0	-	1.00
	Dorper cross	-	-	12.5	25.0	62.5	20.806 (3.483 to 124.272)***
Walking-ability	Local	-	-	-	25.0	75.0	1.00
	Dorper cross	-	-	25.0	37.5	37.5	0.166 (0.037 to 0.748)**
Behavior	Local	-	-	43.8	43.8	12.5	1.00
	Dorper cross	-	-	-	12.5	87.5	55.786 (6.901 to 450.979)***
Heat-tolerance	Local	-	-	-	18.8	81.3	1.00
	Dorper cross	-	-	25.0	50.0	25.0	0.069 (0.013 to 0.369)***
Cold-tolerance	Local	-	-	18.8	31.3	50.0	1.00
	Dorper cross	-	-	6.3	37.5	56.3	1.527 (0.399 to 5.847) ns
Drought-tolerance	Local	-	-	-	25.0	75.0	1.00
	Dorper cross	-	-	25.0	43.8	31.3	0.128 (0.028 to 0.593)**
Disease-tolerance	Local	-	-	-	25.0	75.0	1.00
	Dorper cross	-	-	25.0	37.5	37.5	0.166 (0.037 to 0.748)**
Lamb-survival	Local	-	-	43.8	31.3	25.0	1.00
	Dorper cross	-	-	6.3	6.3	87.5	18.828 (3.101 to 114.316)***

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Table 38. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for **Merhabete** site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	-	6.9	20.7	72.4	1.00
	Dorper cross	-	-	17.2	58.6	24.1	0.146 (0.048 to 0.445)***
Horn	Local	-	-	10.3	31.0	58.6	1.00
	Dorper cross	-	3.5	37.9	51.7	6.9	0.089 (0.027 to 0.293)***
Grazing-ability	Local	-	-	13.8	65.5	20.7	1.00
	Dorper cross	-	-	-	13.8	86.2	24.868 (6.233 to 99.219)***
Feed-requirement	Local	-	-	24.1	65.5	10.3	1.00
	Dorper cross	-	-	-	10.3	89.7	78.470 (14.516 to 424.204)***
Walking-ability	Local	-	-	-	10.3	89.7	1.00
	Dorper cross	-	-	13.8	69.0	17.2	0.023 (0.005 to 0.109)***
Behavior	Local	-	-	27.6	65.5	6.9	1.00
	Dorper cross	-	-	-	17.2	82.8	70.631 (12.607 to 395.704)***
Heat-tolerance	Local	-	-	-	20.7	79.3	1.00
	Dorper cross	-	-	13.8	44.8	41.4	0.169 (0.053 to 0.539)**
Cold-tolerance	Local	-	-	-	6.9	93.1	1.00
	Dorper cross	-	-	10.3	55.2	34.5	0.038 (0.008 to 0.195)***
Drought-tolerance	Local	-	-	-	17.2	82.8	1.00
	Dorper cross	-	-	20.7	55.2	24.1	0.061 (0.017 to 0.220)***
Disease-tolerance	Local	-	-	-	27.6	72.4	1.00
	Dorper cross	-	-	17.2	58.6	24.1	0.108 (0.034 to 0.348)***
Lamb-survival	Local	-	-	6.9	48.3	44.8	1.00
	Dorper cross	-	-	3.5	31.0	65.5	2.317 (0.817 to 6.566) 0.1140

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Table 39. Odds ratio estimates of farmers' perception of adaptation and behavioral traits of Dorper crossbred and local sheep for Baso site

Traits	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Coat-color	Local	-	-	25.0	33.9	41.1	1.00
	Dorper cross	-	-	17.9	33.9	48.2	1.396 (0.698 to 2.794) p =0.3453
Horn	Local	-	-	3.6	19.6	76.8	1.00
	Dorper cross	-	5.4	57.1	35.7	1.8	0.011 (0.003 to 0.041) p <0.0001
Grazing-ability	Local	-	-	44.6	41.1	14.3	1.00
	Dorper cross	-	-	3.6	7.1	89.3	43.740 (14.817 to 129.127) p <0.0001
Feed-requirement	Local	-	-	51.8	42.9	5.4	1.00
	Dorper cross	-	-	3.6	7.1	89.3	98.047 (28.191 to 341.009) p <0.0001
Walking-ability	Local	-	-	1.8	12.5	85.7	1.00
	Dorper cross	-	-	46.4	35.7	17.9	0.034 (0.012 to 0.091) p <0.0001
Behavior	Local	-	-	48.2	41.1	10.7	1.00
	Dorper cross	-	-	7.1	14.3	78.6	22.762 (8.997 to 57.587) p <0.0001
Heat-tolerance	Local	-	-	1.8	17.9	80.4	1.00
	Dorper cross	-	-	37.5	37.5	25.0	0.072 (0.30 to 0.174) p <0.0001
Cold-tolerance	Local	-	-	1.8	19.6	78.6	1.00
	Dorper cross	-	-	42.9	33.9	23.2	0.069 (0.029 to 0.166) p <0.0001
Drought-tolerance	Local	-	-	1.8	17.9	80.4	1.00
	Dorper cross	-	-	44.6	33.9	21.4	0.057 (0.023 to 0.141) p <0.0001
Disease-tolerance	Local	-	-	1.8	16.1	82.1	1.00
	Dorper cross	-	-	44.6	39.3	16.1	0.038 (0.015 to 0.100) p <0.0001
Lamb-survival	Local	-	-	32.1	32.1	35.7	1.00
	Dorper cross	-	-	10.7	14.3	75.0	5.015 (2.294 to 10.966) p <0.0001

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4.8. Reproductive performance of sheep

4.8.1. Reproductive performance of sheep under village management system

4.8.1.1. Lambing distribution under village management system

The results obtained in the current study indicated that lambing is distributed in all months, with the average number of ewes lambing in a month ranging from 6 to 13% (Figure 4). This clearly indicates that ewes can come into heat at any time of the year and this is evident both for the local and for Dorper crossbred ewes. Even though lambing is possible throughout the year, the study also showed that the peak lambing (35% of the total lambing) occurred in September, October, and December.

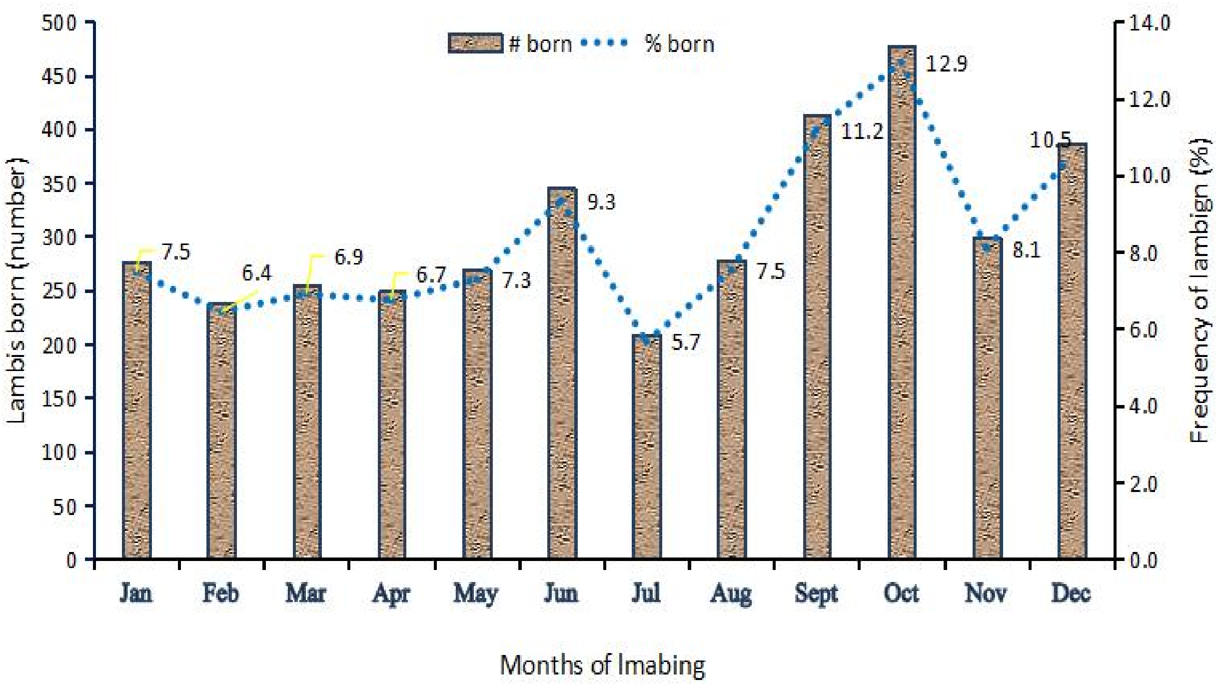

Figure 4. Lambing frequency by month for local and Dorper crossbred Lambs (on-farm).

Seasonal lambing pattern for the local and Dorper crossbreed lambs was similar except there is more lambing (39%) in the dry season followed by 33% of lambs born in the main rainy season. This indicates that more number of local and Dorper crossbred ewes came into oestrus during rainy season (Figure 5). Though Dorper is meant to be kept under an improved management system, the crossbred still maintained good performance under a smallholder marginal management system in all seasons.

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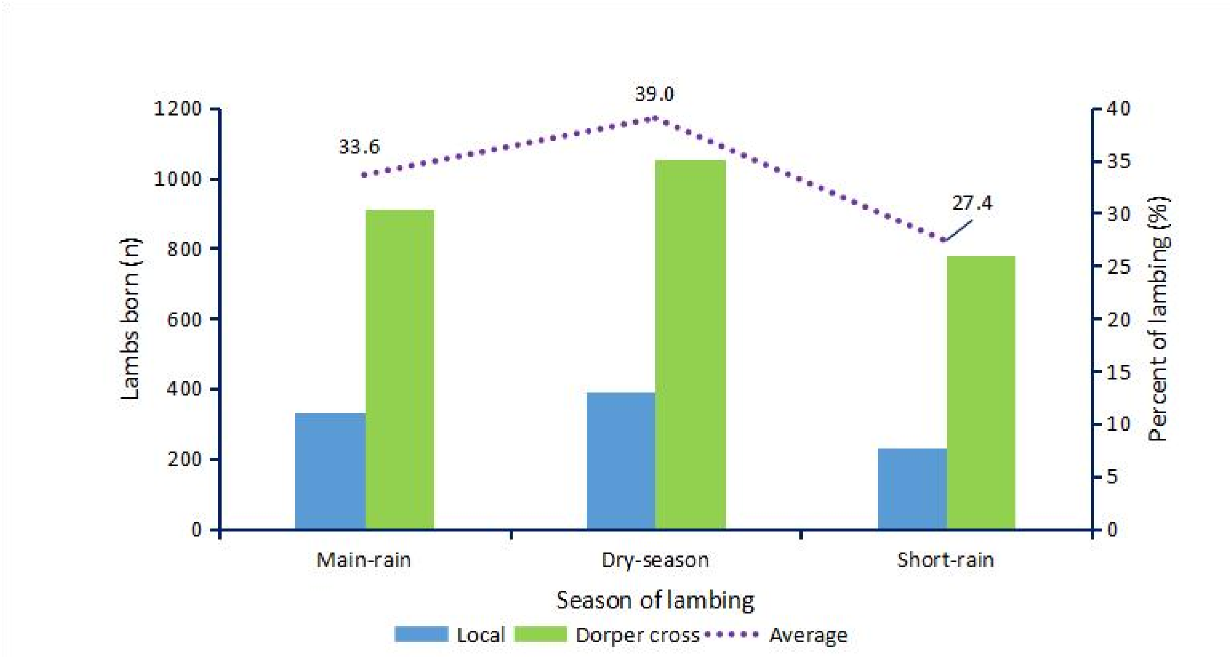

Figure 5. Seasonal distribution of lambing for local and Dorper crossbred lambs (on-farm)

4.8.1.2. Litter size at birth (LSB) under farmers' management

The overall birth litter size obtained in this study was 1.09± 0.03 (n=3585) (Table 40). Birth litter size for the local and Dorper crossbred sheep was 1.06±0.03 and 1.05±0.03, respectively. Litter size at birth (LSB) was significantly affected by the locations, the parity of ewe, lamb sex, season of lambing ($p < 0.001$), and the lambing year ($p < 0.05$). Ewe genotype had no significant effect ($p > 0.05$) on LSB.

4.8.1.3. Litter size at weaning (LSW) under farmers' management

The average litter size at weaning (LSW) obtained in this study was 0.95±0.30 (Table 40). The study also confirmed that LSW for the local and Dorper crossbred ewes were similar (0.943±0.03 and 0.944±0.04; $p > 0.05$), respectively. The study also confirmed that LSW was significantly affected by location and lambing season, ($p < 0.001$), and year of lambing ($p < 0.05$). On the other hand, other study traits such as dam genotype, parity of the dam, and lamb sex had no effect on the LSW ($p > 0.05$).

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Table 40. LSM±SE of the effects of dam genotype, location, lambing year, lambing season, lamb sex, and parity, on LSB and LSW for Local and Dorper crossbred sheep under farmers' management.

Source of variation	LSB		LSW	
	N	LSM±SE	N	LSM±SE
Overall	3585	1.09± 0.03	2904	0.95±0.30
CV (%)	3585	26.37	2904	32.03
Location		***		***
Basona-Werana	1709	1.10±0.03[a]	1459	1.00±0.04[a]
Kewet-EF	941	1.03±0.03[b]	584	0.90±0.04[b]
Kobo	460	0.99±0.03[b]	435	0.95±0.04[b]
Merhabete	475	1.09±0.04[a]	426	0.92±0.04[b]
Dam Genotype		ns		ns
Local	3242	1.06±0.03	2611	0.94±0.03
Dorper cross	343	1.05±0.03	293	0.94±0.04
Season		***		***
Dry- period	1396	1.07±0.03[a]	1149	0.92±0.03[b]
Long- rain	1235	1.03±0.03[b]	998	0.93±0.04[b]
Short- rain	964	1.06±0.03[a]	757	0.98±0.04[a]
Year		*		**
2013	69	1.05±0.04[a]	67	0.99±0.04[a]
2014	324	1.09±0.02[a]	187	0.94±.03[ab]
2015	580	1.12±0.02[a]	408	0.90±0.02[b]
2016	1068	1.11±0.01[a]	957	0.90±0.02[b]
2017	979	1.08±0.01[a]	828	0.92±0.02[b]
2018	248	1.04±0.02[b]	141	0.77±0.03[c]
2019	20	1.05±0.07[a]	19	1.05±0.07[a]
2020	220	1.10±0.02[a]	220	1.05±0.03[a]
2021	77	1.01±0.04[b]	77	0.97±0.04[a]
Parity		**		ns
1[st] Parity	2270	1.02±0.03[b]	1827	0.97±0.03
2[nd] Parity	793	1.06±0.03[a]	640	0.94±0.04
3[rd] Parity	307	1.03±0.04[b]	264	0.95±0.04
4[th] Parity	129	1.08±0.04[a]	99	0.95±0.04
5[th] & above parity	86	1.08[a]±0.04	74	0.91±0.05
Lamb Sex		***		ns
Male	1805	1.07±0.03	1430	0.94±0.03
Female	1780	1.04±0.03	1474	0.95±0.03

BLS (Birth Litter Size), WLS (Weaning Litter Size), LSM (Least Squares means), SE (Standard errors)
*Values within each sub-class are significantly different at *=p<0.05, **P<0.01, *** = p<0.0001*

4.8.1.4. Age at first lambing (AFL) of ewes under village management system

The overall Age at first lambing (AFL) was 15.51 months (Table 41). AFL for local ewes (14.69 months) was significantly lower than the Dorper crossbred ewes (16.21 months). AFL was

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significantly affected ($p < 0.001$) by location and dam genotype. However, no significant ($p > 0.05$) effect of lambing seasons on AFL was observed.

Table 41. LSM±SE of the effects of location, dam genotype, lambing year and season on average birth and weaning litter size of local and Dorper crossbred sheep.

Source of variation	AFL		LI		ARR	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	389	15.51± 0.43	298	9.36± 0.39	298	1.47±0.10
CV (%)	389	18.39	298	22.49	298	25.91
Location		***		**		***
Basona-Werana	89	16.47±0.31[a]	128	10.57±0.64[a]	128	1.43±0.05[b]
Kewet-EF	57	15.44±0.38[abc]	74	9.29±0.46[a]	74	1.41±0.05[bc]
Kobo	191	15.78±0.22[ab]	75	9.87±0.27[a]	75	1.27±0.05[c]
Merhabete	52	14.10±0.40[c]	21	7.91±0.72[b]	21	1.83±0.09[a]
Dam Genotype		***		ns		ns
Local	231	14.69±0.23	265	9.01±0.16	265	1.55±0.03
Dorper cross	155	16.21±0.23	33	9.67±0.39	33	1.42±0.07
Season		ns		ns		***
Dry- period	136	15.29±0.26	101	9.56±0.28	101	1.42±0.05[b]
Long- rain	155	15.48±0.24	108	8.98±0.28	108	1.58±0.05[a]
Short- rain	98	15.57±0.30	89	9.47±0.28	89	1.44±0.05[b]

BLS (Average Birth Litter size, number), WLS (Average Weaning Litter size, number), AFL (Age at first lambing, months), LI (Lambing interval, months), LSM (Least Squares means), SE (Standard errors), Lambing season: Dry-Period (October-January), Long-Rain (June-September), Short-Rain (February-May), ARR (Annual Reproductive rate), Index-I (annual litter weight at 90 days x number of lambing per ewe; Index-II (Index-I/Post-partum weight of dam in kg; Index-III (Index-I/metabolic post-partum weight of the dam). *Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001*

4.8.1.5. Lambing interval (LI) of ewes under village management system

Lambing interval (LI) in a ewe is a valuable indicator of reproductive efficiency in a folk. The overall LI in this particular study for the flocks managed under farmers' condition was 9.36±0.39 months. LI for local and Dorper crossbred ewes was 9.01 and 9.67 months, respectively. The study results obtained for LI in dry, main rainy, and minor rainy seasons were 9.56, 8.98, and 9.47, respectively. LI was not significantly ($p > 0.05$) influenced by ewe genotype and ewe lambing seasons, whereas it varied significantly ($p < 0.05$) by the location.

4.8.1.6. Annual reproductive rate (ARR) of ewes under village management system

The overall least-squares means for the number of lambing/ewe per year in the current study was estimated to be 1.47 lambs (Table 41). The number of lambing/ewe per year in the dry period, long- rain, and short- rain seasons was 1.42, 1.58, and 1.44, respectively. On the other hand, the number of lambing/ewe per year for Local and Dorper crossbred ewe was 1.55 and 1.42 lambs,

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respectively. Location and lambing season highly affected ($p < 0.001$) ARR. On the other hand, ewe genotype and lambing year had no effect ($p > 0.05$) on the number of lambing/ewe per year; this could partly be attributed to differences and discrepancies in environmental factors leading to climatic variation that could influence the pasture availability. However, no significant difference ($p > 0.05$) was observed in the number of lambs per ewe per year between Dorper crossbred ewes and local ewes.

4.8.1.7. Annual productive indices of ewes under village management system

Annual ewe productivity was expressed as kg of lambs reared to 90 days (Index-I), per kg ewe postpartum weight (Index II), and per kg ewe metabolic weight (Index-III). The overall productivity indices (indexes I, II and III) for the flocks managed under farmers' conditions were, 19.55, 0.76, and 1.82 kg, respectively (Table 42). Similar ($p > 0.05$) body weights of lambs were produced at weaning by the local and Dorper crossbred ewes (20.91 and 20.16 kg, respectively). Significantly ($p = 0.0024$) heavier total weight of lambs at weaning was produced per kg metabolic weight of local ewes than Dorper crossbred ewes (0.84 vs 0.72 kg) and per kg weight of local ewes than Dorper crossbred ewes ($p = 0.0055$; 2.01 vs 1.76 kg). This study also testified that the significant effect ($p < 0.05$) exerted by location and lambing season on all studied indices. However the parity of the ewe doesn't have any significant ($p > 0.05$) effect on productivity indices (II and III).

Table 42. LSM±SE of the effects of location, Dam genotype, Lambing season, Parity on subsequent productivity indices of Local and Dorper crossbred sheep.

Source of variation	Index-I		Index-II		Index-III	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	1493	19.55±0.59	1181	0.76±0.03	1181	1.82±0.07
CV %	1493	39.27	1181	40.65	1181	40.15
Location		***		***		***
Basona-Werana	699	18.99±0.50[c]	699	0.69±0.03[c]	699	1.68±0.06[c]
Kewet-EF	311	20.85±0.57[b]	311	0.79±0.03[b]	311	1.90±0.06[b]
Kobo	312	19.00±0.49[c]				
Merhabete	171	23.29[a]±0.71	171	0.86±.03[a]	171	2.10±0.08[a]
Dam genotype		ns		**		**
Local	1327	20.91±0.33	1111	0.84±0.02	1111	2.02±0.04
Dorper cross	166	20.16±0.68	70	0.72±0.04	70	1.77±0.09

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Table 30. *Continued*

Lambing season		**		***		***
Dry- period	576	19.50±0.47^b	461	0.73±0.03^b	461	1.77±0.06^b
Long- rain	529	21.16±0.50^a	411	0.79±0.03^a	411	1.93±0.07^a
Short- rain	388	20.94±0.54^a	309	0.82±0.03^a	309	1.99±0.07^a
Parity		*		ns		ns
1st	614	19.27±0.41^b	509	0.73±0.02	509	1.76±0.05
2nd	520	20.26±0.43^a	424	0.75±0.02	424	1.82±0.05
3rd	222	20.64±0.59^a	162	0.78±0.03	162	1.89±0.07
4th	81	21.04±0.91^a	54	0.78±0.05	54	1.89±0.11
5th & above parity	56	21.46±1.08^a	32	0.86±0.06	32	2.09±0.14

*Values within each sub-class are significantly different at *=P<0.05, **P<0.01, *** = P<0.0001*

4.8.2. Reproductive performance of sheep under on-station management

4.8.2.1. Mating and fertility traits of flocks managed under on-station management

The average number of ewes used per ram was 20 (Table 43). The overall conception rate was 81.56%, with ewe breed and mating year having a significant impact on the conception rate ($p < 0.0001$), while sire breed had a modest impact ($p = 0.0118$) impact. However, location and mating season did not affect the conception rate of ewes ($p = 0.4396$ and $p = 0.6065$, respectively). This study revealed that the conception rates of ewes were significantly ($p = 0.0118$) affected by the breed of the ram. Ewes sired by Dorper x Local crossbred rams exhibited a higher conception rate (91%) compared to Dorper purebred and local ewes (75% and 80%, respectively). Similarly, the conception rate was also highly ($p < 0.0001$) influenced by the breed of the ewe. Local ewes showed the highest conception rate (91%), followed by Dorper purebred ewes (80%) and Dorper x Local crossbred ewes (75%), Table 43.

The study also found that the year of mating had a significant impact on the conception rate of ewes. Higher conception rates were recorded for the years 2008, 2015, 2016 and 2018, while the lowest rate was observed in 2011. The overall lambing rate, which is calculated by dividing the number of ewes with lambs by the total number of ewes joined to the ram, was found to be 78.8%. The lambing rate was marginally influenced by the breed of the sire ($p = 0.0505$), significantly by the breed of the ewe ($p < 0.0001$), and the year of mating ($p = 0.0258$). However, no significant effect was observed due to location ($p = 0.3045$) or mating season ($p = 0.8914$). When using Dorper x Local crossbred, Dorper purebred and Local sire, the lambing rates recorded were 89%, 70% and 74%, respectively. Although the P-value was marginal (p =

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0.0505), a higher lambing rate was observed when using Dorper x Local crossbred sires for mating. The lambing rates for Dorper x Local crossbred, Dorper purebred and local ewes were 68%, 76% and 89%, respectively; indicating that higher lambing rates corresponded to local ewes. The influence of the year of mating on the lambing rate of ewes was evident ($p = 0.0258$). Accordingly, higher lambing rates were recorded in the years 2010, 2013 and 2016, while lower lambing rates were observed in the years 2017, 2018 and 2021, respectively.

The overall lambing percentage/ success rate was 96%. This was calculated by dividing the number of ewes with lambs by the number of ewes joined to the rams. The breed of the ewe had a significant effect on the lambing percentage ($p = 0.0031$). However, other factors such as location ($p = 0.3689$), sire breed ($p = 0.3277$), mating season ($p = 0.7004$), and mating year ($p = 0.1523$) did not have a significant effect on the lambing percentage. It was observed that the Dorper x Local crossbred, Dorper purebred and local ewes had lambing percentages of 91.4%, 93.8%, and 98.2%, respectively. This indicates that the local ewes had higher lambing percentages compared to the other two breeds. There was no significant difference in the lambing percentage between the Dorper x Local crossbred and Dorper purebred ewes.

The overall prolificacy rate was calculated by dividing the number of lambs born by the number of ewes lambed, resulting in a rate of 105.5%. The prolificacy rate was significantly influenced by location ($p = 0.0422$) and mating year ($p = 0.0008$). However, other fixed factors such as sire breed ($p = 0.3865$), ewe breed ($p = 0.1513$) and mating season ($p = 0.8481$) did not affect the prolificacy of sheep in this study. Though not significant, it was noted that ewes sired by Dorper x Local crossbred rams had the highest prolificacy rate of 110.2%, followed by ewes sired by Local rams at 105.6%, and Dorper purebred rams at 103.5%, respectively. Additionally, the study found that the prolificacy rate for ewes born in cool-tepid areas was 109.9%, while the prolificacy rate for ewes born in mid-to-highland areas was 102.9%. This suggests that ewes bred in cool-tepid areas relatively had a higher prolificacy rate.

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Table 43. Number proportion of local, Dorper and Dorper crossbred ewes joined, conceived and lambed in the flocks managed at on-station

Factors	# of mating groups	# of ewes joined	Average # of Ewes/ ram	Conception rate (%)	Lambing rate (%)	Prolificacy rate (%)
Overall	168	3437	20	81.56±2.02	96.06±1.42	105.53±1.75
CV (%)				11.07	6.66	7.5
R2				0.463	0.224	0.340
Location				p =0.4396	p =0.3689	p =0.0422
Cool-tepid	143	3035	21	83.58±2.18	95.74±1.54	109.90±1.89
Mid-to-highland	25	402	16	80.58±3.30	93.27±2.33	102.99±2.87
Sire breed				p =0.0118	p =0.3277	p =0.3865
Dorper purebred	123	2274	18	74.95±2.92[c]	93.63±2.06	103.50±2.54
Dorper cross	11	259	24	90.47±5.23[a]	98.51±3.71	110.23±4.57
Local	34	904	27	80.82±4.10[b]	91.36±2.90	105.60±3.57
Ewe breed				p <0.0001	p =0.0031	p =0.1513
Dorper purebred	72	995	14	80.32±2.87[b]	93.82±2.03[b]	108.54±2.50
Dorper cross	11	274	25	75.15±6.01[b]	91.44±4.24[b]	105.34±5.22
Local	85	2168	26	90.78±2.67[a]	98.24±1.88[a]	105.47±2.32
Mating season				p =0.6065	p =0.7004	p =0.8481
Dry- period	45	868	19	83.18±2.90	93.70±2.05	106.93±2.52
Long- rain	56	1017	18	82.36±2.06	94.67±1.46	106.68±1.79
Short- rain	67	1552	23	80.70±2.62	95.14±1.85	105.72±2.28
Mating year				p <0.0001	p =0.1523	p =0.0008
2007	4	37	9	79.91±5.88[a]	94.04±4.15	108.24±5.11[b]
2008	7	152	22	77.77±4.54[a]	98.72±3.21	106.24±3.94[b]
2009	6	56	9	81.99±4.54[a]	97.05±3.21	104.54±3.95[b]
2010	2	28	14	96.85±6.80[a]	86.20±4.80	111.45±5.91[b]
2011	15	189	13	89.51±3.66[a]	90.17±2.38	107.81±2.93[b]
2012	18	310	17	79.17±3.35[a]	96.10±2.37	104.44±2.92[b]
2013	12	190	16	92.66±4.19[a]	95.14±2.96	118.23±3.64[a]
2014	4	75	19	79.58±5.34[a]	93.59±3.77	103.75±4.64[b]
2015	11	257	23	84.08±3.80[a]	92.03±2.68	105.45±3.30[b]
2016	12	278	23	88.65±3.79[a]	94.81±2.68	101.65±3.30[b]
2017	2	26	13	61.36±7.23[c]	100.00±5.10	117.16±6.25[ab]
2018	9	262	29	77.23±3.84[a]	92.74±2.71	100.38±3.34[b]
2019	18	447	25	81.64±3.10[a]	96.93±2.34	103.69±2.88[b]
2020	26	584	22	82.91±2.74[a]	95.83±1.94	101.56±2.39[b]
2021	22	546	25	77.93±2.87[a]	94.03±2.03	102.11±2.49[b]

*Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001,*

The abortion rate is a crucial measure of reproductive efficiency in a flock. In our research, we calculated the overall abortion rate by dividing the number of ewes that had abortions by the total number of ewes joined to the ram. The resulting overall abortion rate was 1.59%. Our findings indicate that the breed of ewe had a significant impact on the flock's abortion rate (p = 0.0334, Table 44). However, we found that other factors, such as location (p = 0.7576), sire breed (p =

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0.2634), mating season ($p = 0.6813$), and year of mating ($p = 0.1237$), did not have a significant effect on the abortion rate of the flock studied (Table 44).

It was observed that the recorded abortion rates for the Dorper x Local crossbred, Dorper purebred, and Local ewe breeds were 5.2%, 2.1%, and 0.8%, respectively. This indicates a higher abortion rate for Dorper x Local crossbred ewes and a lower abortion rate for Local ewe.
A flock's reproductive efficiency is also influenced by the still-birth rate. As per a recent study we conducted, the overall still-birth rate of the flock was 1.46%. The breed of a ewe had a significant ($p = 0.0050$) effect on the still-birth rate, similar to the abortion rate. The study found that the still-birth rate of Dorper x Local crossbred, Dorper purebred, and Local ewes was 1.7%, 2.6%, and 0.8% respectively. This indicates that higher still-birth rates are attributed to Dorper purebred ewes, while lower still-birth rates are attributed to local ewes. One of the most significant factors that influences the reproductive efficiency of a flock is the barren-ewe rate. Our study found that the overall barren-ewe rate was 17.9% as shown in Table 44. Compared to other traits that were considered in this study, the barren-ewe rate had a much greater impact ($p < 0.0001$) on the flock's reproductive performance. Meanwhile, the abortion rate ($p = 0.0245$) and stillbirth rate ($p = 0.0137$) had a lesser impact.

The barren-ewe rate was affected by most of the fixed factors considered in this study. The sire breed had a significant impact on the barren-ewe rate ($p = 0.0090$), as did the ewe breed and mating year ($p < 0.0001$). However, the location and mating season did not have a significant effect on the barrenness of ewes ($p = 0.4293$ and $p = 0.5713$), respectively. This study also found that the barrenness rate of ewes was affected by sire breed used and was highest for ewes sired by Dorper purebred rams (24.9%), followed by ewes sired by local rams (18.8%) and ewes sired by Dorper x Local crossbred rams (9.4%). This study also discovered that the breed of ewes to significantly influence ($p < 0.0001$) the barrenness rate of ewes. The barrenness rate for Dorper x Local ewes, Dorper purebred and local ewes were 24.6%, 19.2%, and 9.24%, respectively, indicating the highest barrenness rate was recorded for Dorper x Local crossbred ewes and the lowest barrenness rate for local ewes. Moreover, the year of mating was also a significant source of variation in the barrenness rate. A higher rate of barren-ewes was recorded in the years 2017, 2018, and 2008, while relatively lower values of barrenness of ewes were

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recorded for the years 2010, 2013, and 2011, respectively. This indicates the influence of the year of mating on the rate of barren ewes.

Table 44. Number of local, Dorper purebred and Dorper crossbred ewes joined, and proportions of ewes aborted, gave to still-birth and barren-ewe in the flocks managed at on-station.

Factors	# of mating groups	# of ewes joined	Average # of Ewes/ ram	Abortion rate (%)	Still-birth rate (%)	Barren-ewe rate (%)
Overall	168	3437	20	1.59±0.67	1.46±0.62	17.96±2.02
CV (%)				190.71	190.04	50.50
R^2				0.205	0.216	0.467
Location				p =0.7576	p =0.2041	p =0.4293
Cool-tepid	143	3035	21	2.50±0.73	0.92±0.66	16.17±2.18
Mid-to-highland	25	402	16	2.90±1.10	2.43±1.01	19.25±3.31
Sire breed				p =0.2634	p =0.6280	p =0.0090
Dorper purebred	123	2274	18	3.24±0.97	1.79±0.89	24.97±2.92[a]
Dorper cross	11	259	24	0.51±1.75	0.73±1.61	9.40±5.26[c]
Local	34	904	27	4.35±1.37	2.50±1.25	18.76±4.11[b]
Dam breed				p =0.0334	p =0.0050	p <0.0001
Dorper purebred	72	995	14	2.14±0.96[b]	2.60±0.88[a]	19.24±2.87[b]
Dorper cross	11	274	25	5.20±2.00[a]	1.68±1.83[b]	24.64±6.01[a]
Local	85	2168	26	0.76±0.89[c]	0.74±0.81[c]	9.24±2.67[c]
Mating season				p =0.6813	p =0.2642	p =0.5713
Dry- period	45	868	19	2.96±0.97	2.21±0.89	16.54±2.90
Long- rain	56	1017	18	2.21±0.69	1.83±0.63	17.43±2.06
Short- rain	67	1552	23	2.93±0.88	0.98±0.80	19.16±2.63
Mating year				p =0.1237	p =0.0682	p <0.0001
2007	4	37	9	5.93±1.96	1.95±1.79	20.15±5.89[ab]
2008	7	152	22	0.79±1.52	0.34±1.39	21.99±4.54[ab]
2009	6	56	9	3.73±1.52	1.82±1.39	18.04±4.54[ab]
2010	2	28	14	6.04±2.27	6.13±2.08	2.93±6.81[c]
2011	15	189	13	4.04±1.12	3.31±1.03	8.45±3.37[b]
2012	18	310	17	1.80±1.12	1.24±1.02	20.72±3.36[ab]
2013	12	190	16	2.74±1.40	1.70±1.28	7.27±4.19[b]
2014	4	75	19	3.21±1.78	2.04±1.63	20.07±5.35[ab]
2015	11	257	23	3.49±1.27	2.69±1.16	15.91±3.80[b]
2016	12	278	23	1.91±1.27	2.29±1.16	11.28±3.80[b]
2017	2	26	13	0.71±2.41	0.44±2.21	38.77±7.23[a]
2018	9	262	29	2.47±1.28	2.96±1.17	22.71±3.84[ab]
2019	18	447	25	0.78±1.10	1.56±1.10	18.26±3.31[ab]
2020	26	584	22	1.20±0.92	2.13±0.84	17.08±2.75[ab]
2021	22	546	25	1.69±0.96	2.95±0.88	22.01±2.87[ab]

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4.8.2.2. Litter size and litter weight at birth and weaning of local, Dorper purebred and Dorper crossbred sheep under on-station management

The study found that litter size at birth of lambs was significantly influenced by various factors. The overall least squares means and standard errors for litter size at birth were determined to be 1.14±0.01. The factors that had a significant impact on litter size at birth included the breed of the sire and dam ($p < 0.0001$), as well as environmental factors such as location, ewe parity, year of lambing ($p < 0.0001$), and season of lambing ($p = 0.0004$). However, the sex of the lamb did not have a significant effect on litter size at birth ($p = 0.3474$).

In terms of specific findings, ewes from the low-mid-to-highland areas had a higher average litter size at birth compared to ewes from the cool-tepid area (1.21 vs 1.15). Ewes sired by purebred Dorper sires had a higher litter size at birth compared to both Dorper x Local and Local ewes. On the other hand, ewes sired by Dorper x Local and Local sires had similar litter sizes at birth. Additionally, Local and Dorper x Local crossbred ewes had higher litter sizes at birth compared to purebred Dorper ewes. Furthermore, ewes in their first parity produced significantly lower litter sizes at birth compared to ewes in higher parity. The season of lambing also played a role, with ewes lambing in the short-rainy season having higher litter sizes at birth compared to those lambing in the dry and long-rainy seasons.

The year of lambing was also found to influence litter size at birth, with higher litter sizes recorded in certain years such as 2014, 2010, 2007, and 2008, while lower values were observed in the years 2021, 2006, and 2022, respectively (Table 45). It was also learned that litter size at weaning was significantly influenced by various factors. The overall litter size at weaning was determined to be 0.91±0.02. The factors that had a significant impact on litter size at weaning included the breed of the sire and dam ($p < 0.0001$), environmental factors such as location ($p = 0.0001$), ewe lambing parity, year of lambing ($p < 0.0001$), and season of lambing ($p = 0.0009$). The sex of the lamb did not demonstrate a statistically significant impact on litter size at weaning ($p = 4599$).

In terms of specific findings, ewes residing in the low-mid-to-highland areas produced a higher average litter size at weaning compared to ewes in the cool-tepid areas (0.98 vs 0.92). Ewes sired with purebred Dorper sires had a significantly higher litter size at weaning compared to ewes

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sired by Dorper x Local and Local sires (0.98, 0.95, and 0.91, respectively). On the other hand, purebred Dorper ewes had significantly lower litter sizes at weaning compared to Dorper x Local and Local ewes. Interestingly, Dorper x Local crossbred ewes had similar litter sizes at weaning compared to local ewes (0.89, 0.98, and 0.98, respectively). The parity of lambing also played a role, with litter size at weaning increasing from the first parity and then starting to decline after the fourth parity. The lowest litter size at weaning was recorded in the first parity, while the highest litter size at weaning was observed in the fourth parity.

The influence of the season of lambing on litter size at weaning was significant. Ewes that gave birth during the short rainy season had higher litter sizes at weaning compared to those that gave birth during the dry and long rainy seasons. Furthermore, the year of lambing exerted an influence on litter size at weaning. Ewes that lambed in the years 2007, 2008, 2010, and 2006 had higher litter sizes at weaning, respectively. On the other hand, ewes that lambed in the years 2022, 2021, 2017, and 2018 had lower litter sizes at weaning compared to other years.

The study also investigated an important trait, namely litter weight at birth. The overall litter weight at birth was determined to be 3.25±0.03. Litter weight at birth was significantly influenced by both the genotype of the sire and dam, as well as environmental factors. The impact of the sire and dam breed on litter weight was remarkable ($p < 0.0001$). Ewes sired by purebred Dorper and Dorper x Local sires produced significantly higher litter weights at birth compared to ewes sired by local sires. This study confirmed that the use of purebred Dorper and Dorper x Local sires resulted in a 39% and 19% improvement in litter weight at birth, respectively, compared to local sires. The breed of the dam also had a significant influence on litter weight at birth. Dorper x Local, purebred Dorper, and Local ewes produced litter weights of 3.35 kg, 3.24 kg, and 3.04 kg, respectively, indicating the similar performance of Dorper x Local crossbred ewes to purebred Dorper ewes, while outperforming Local ewes.

Litter weight at birth was affected by all the environmental factors considered in the current study. Ewes residing in the cool-tepid area produced slightly higher litter birth weights than ewes in the low-mid-to-highland areas, and this difference was statistically significant ($p = 0.0272$). Lamb sex, ewe lambing parity, season, and year of lambing had a highly significant influence ($p < 0.0001$) on the litter birth weight of lambs. Ewes that gave birth to male lambs produced higher

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litter weights at birth compared to their female counterparts. Litter weight at birth increased until parity 4 and then declined. The highest litter birth weight was recorded at parity 4 (3.36 kg), while the lowest litter birth weight was observed in parity one (2.90 kg). The influence of the season of lambing on litter weight at birth was remarkable. Ewes that lambed in the dry season produced lambs with higher litter weights compared to those born in the long-rainy and short-rainy seasons (3.31 kg, 3.17 kg, and 3.15 kg, respectively). Ewes that gave birth in the long-rainy and short-rainy seasons produced similar litter weights. The year of lambing also had a noticeable impact on litter weight at birth. Ewes that gave birth in the years 2007, 2016, 2014, and 2020 produced higher litter weights at birth compared to other years, while ewes that lambed in the years 2008, 2009, 2022, 2006, and 2011 produced relatively lower litter weights compared to other years (Table 45).

Table 45. LSM±SE of litter size and weight for the local, Dorper and Dorper crossbred sheep managed under on-station management in Ethiopia.

Factors	Litter size				Litter weight			
	N	at birth	N	at weaning	N	at birth	N	at weaning
Overall mean	9370	1.14±0.01	9359	0.91±0.02	8774	3.25±0.03	5941	14.41±0.13
CV (%)	9370	30.69	9359	53.94	8774	29.36	5941	29.65
Location		p <0.0001		p =0.0001		p =0.0272		p <0.0001
Cool-tepid	6361	1.15±0.01	6352	0.92±0.01	6063	3.24±0.03	3858	14.45±0.15
Low-mid-highland	3009	1.21±0.01	3007	0.98±0.01	2711	3.18±0.03	2083	15.66±0.15
Sire-Breed		p <0.0001		p <0.0001		p <0.0001		p <0.0001
Dorper purebred	6143	1.22±0.01[a]	6132	0.98±0.01[a]	5672	3.74±0.03[a]	3761	16.75±0.14[a]
Dorper cross	1085	1.16±0.02[b]	1085	0.95±0.02[a]	1022	3.20±0.04[b]	750	15.40±0.22[b]
Local	2142	1.12±0.01[b]	2142	0.91±0.02[b]	2080	2.69±0.04[c]	1430	13.01±0.19[c]
Dam-Breed		p <0.0001		p <0.0001		p <0.00001		p <0.0001
Dorper purebred	1609	1.12±0.01[b]	1607	0.89±0.02[b]	1502	3.24±0.03[a]	1128	16.11±0.18[a]
Dorper cross	1515	1.19+0.01[a]	1515	0.98±0.02[a]	1414	3.35±0.04[a]	948	15.27±0.21[b]
Local	6246	1.17±0.01[a]	6237	0.98±0.01[a]	5858	3.04±0.03[b]	3865	13.77±0.15[c]
Lamb sex		p =0.3474		p =0.4599		p <0.001		p <0.0001
Male	4665	1.16±0.01	4696	0.95±0.01	4373	3.28±0.03	3117	15.39±0.14
Female	4705	1.17±0.01	4663	0.95±0.01	4401	3.13±0.03	2824	14.72±0.14
Ewe parity		p <0.0001		p <0.0001		p <0.0001		p <0.0001
1st parity	4747	1.09±0.01[b]	4736	0.90±0.01[c]	4487	2.90±0.02[c]	2937	14.37±0.12[c]
2nd parity	2158	1.13±0.01[b]	2158	0.95±0.01[b]	2012	3.17±0.03[b]	1407	14.95±0.14[b]
3rd parity	1219	1.15±0.01[a]	1219	0.96±0.02[b]	1130	3.24±0.03[b]	835	15.27±0.18[ab]
4th parity	678	1.20±0.02[a]	678	1.03±0.02[a]	618	3.36±0.04[a]	432	15.73±0.23[a]
5th parity	339	1.22±0.02[a]	339	0.96±0.03[b]	313	3.28±0.06[ab]	204	15.10±0.32[bc]
6th parity and above	229	1.20±0.02[a]	229	0.89±0.03[b]	214	3.29±0.07[ab]	126	14.91±0.40[bc]
Season of lambing		p =0.0004		p =0.0009		p <0.0001		p <0.0001
Dry- period	4023	1.16±0.01[b]	4020	0.93±0.01[b]	3753	3.31±0.03[a]	2666	14.37±0.14[c]
Long- rain	2859	1.15±0.01[b]	2857	0.98±0.01[a]	2735	3.17±0.03[b]	1811	15.14±0.15[b]
Short- rain	2488	1.19±0.01[a]	2482	0.94±0.02[b]	2286	3.15±0.03[b]	1464	15.65±0.18[a]

Table 45. *Continued*

Year of lambing		p <0.0001		p <0.0001		p <0.0001		p <0.0001
2006	46	1.05 ± 0.05^{c}	46	1.05 ± 0.08^{b}	45	3.06 ± 0.15^{b}	-	-
2007	38	1.23 ± 0.06^{ab}	36	1.18 ± 0.08^{a}	34	3.56 ± 0.17^{a}	32	13.381 ± 0.79^{b}
2008	65	1.22 ± 0.05^{ab}	65	1.10 ± 0.06^{a}	58	2.98 ± 0.13^{b}	55	18.39 ± 0.61^{a}
2009	374	1.11 ± 0.02^{b}	374	0.99 ± 0.03^{ab}	348	3.01 ± 0.06^{b}	263	17.22 ± 0.32^{a}
2010	488	1.25 ± 0.02^{ab}	488	1.08 ± 0.03^{a}	433	3.22 ± 0.05^{b}	405	14.93 ± 0.25^{b}
2011	428	1.14 ± 0.02^{bc}	428	0.97 ± 0.03^{ab}	392	3.07 ± 0.05^{c}	297	15.11 ± 0.28^{b}
2012	658	1.14 ± 0.02^{bc}	658	0.97 ± 0.02^{ab}	613	3.16 ± 0.04^{b}	524	16.23 ± 0.22^{a}
2013	723	1.21 ± 0.01^{ab}	723	0.92 ± 0.02^{b}	672	3.14 ± 0.04^{b}	479	15.11 ± 0.23^{b}
2014	544	1.27 ± 0.02^{a}	544	0.94 ± 0.02^{b}	486	3.37 ± 0.05^{b}	359	15.59 ± 0.26^{b}
2015	617	1.16 ± 0.02^{bc}	617	0.96 ± 0.02^{ab}	579	3.33 ± 0.44^{b}	462	16.27 ± 0.23^{a}
2016	1292	1.16 ± 0.01^{b}	1289	0.93 ± 0.02^{b}	1215	3.51 ± 0.04^{a}	803	14.45 ± 0.19^{b}
2017	772	1.13 ± 0.01^{bc}	772	0.85 ± 0.02^{b}	729	3.19 ± 0.04^{b}	399	13.97 ± 0.24^{b}
2018	848	1.15 ± 0.01^{bc}	842	0.86 ± 0.02^{b}	802	3.16 ± 0.04^{b}	511	12.94 ± 0.22^{b}
2019	636	1.17 ± 0.02^{b}	636	0.88 ± 0.02^{b}	604	3.17 ± 0.04^{b}	462	15.18 ± 0.23^{b}
2020	685	1.18 ± 0.02^{b}	685	0.92 ± 0.02^{b}	642	3.37 ± 0.04^{b}	463	15.31 ± 0.23^{b}
2021	672	1.00 ± 0.02^{c}	672	$0.79\pm0.^{02c}$	654	3.15 ± 0.04^{b}	303	13.17 ± 0.27^{b}
2022	484	1.11 ± 0.02^{c}	484	0.76 ± 0.02^{c}	469	3.01 ± 0.05^{c}	124	13.61 ± 0.41^{b}

*Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001*

4.8.2.3. Litter weight at birth and weaning of local, Dorper purebred and Dorper crossbred sheep under on-station management

The overall litter weight at weaning was determined to be 14.41±0.13 kg (Table 45). The weight of lambs at weaning was significantly influenced by all the factors considered in the study. The impact of sire and dam breed on litter weaning weight was particularly noteworthy. Ewes sired by purebred Dorper, Dorper x Local crossbred, and local sires produced weights of 16.75 kg, 15.40 kg, and 13.01 kg, respectively, indicating a 28.7% and 18.4% advantage in weight at 3 months when using purebred Dorper and Dorper x Local crossbred sires over local sires. The genotype of the dam also had a significant effect on litter weight at weaning. Purebred Dorper, Dorper x Local crossbred, and local ewes produced weights of 16 kg, 15 kg, and 13 kg, respectively, with a 17.0% and 10.9% advantage in weaning weight when using purebred Dorper and Dorper x Local crossbred ewes instead of local ewes.

The influence of location on litter weight at weaning was evident. Ewes that gave birth in the low-mid-to-highland areas had 8.4% advantage in litter weight at weaning compared to ewes that gave birth in the cool-tepid areas. Ewes that gave birth to male lambs had higher weights at weaning compared to their female counterparts. Litter weight at weaning improved as the parity of lambing advanced. The lowest litter weight at weaning and the highest weaning weight were recorded in parity one and parity four, respectively, and then started to decline. The season of

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lambing had a significant influence on litter weight at weaning. Ewes that gave birth in the dry, long-rainy, and short-rainy seasons produced weights of 14 kg, 15 kg, and 16 kg, respectively, highlighting the importance of the season of lambing on litter weight. We also observed the influence of the year of lambing on litter weight at weaning. Higher litter weaning weights were observed in the years 2008, 2009, 2012, and 2015, respectively. Conversely, lower litter weights at weaning were recorded in the years 2018, 2007, and 2017, respectively.

4.8.2.4. AFL, LI and ARR of local, Dorper purebred and Dorper crossbred ewes under on-station management.

According to Table 46, the overall least squares means and standard errors for AFL was determined to be 15.73±0.69 months. AFL in the current study was influenced by various factors, including both genetic and environmental factors. Contrary to this, AFL was not affected by litter size at birth ($p = 0.3236$) and sex of the lamb ($p = 0.5155$), respectively. Both the sire breed and dam breed had a significant impact on the age at first lambing ($p = 0.0251$ and $p < 0.0001$, respectively). Ewes sired by purebred Dorper sires exhibited a higher AFL compared to ewes sired by local sire breeds. On the other hand, ewes sired by Dorper x Local crossbred and local sires showed similar AFL. The dam breed had a substantial effect on AFL, with local ewes having a lower AFL compared to purebred Dorper and Dorper x Local ewe breeds.

Location also had a significant influence on AFL ($p < 0.0001$). Ewes residing in the low-mid-to-highland areas had relatively shorter AFL (around 1.4 months faster) compared to those in the cool-tepid areas. Lambing season also played a role in AFL ($p < 0.0001$). Ewes that gave birth in the short-rainy season had a prolonged AFL compared to those in the dry and long-rainy seasons. However, ewes that gave birth in the dry and long-rainy seasons exhibited comparable AFL. The year of lambing also had a noticeable effect on AFL. Ewes that lambed in the years 2019, 2022, 2021, and 2017 experienced significantly longer AFL, while those that gave birth in the years 2006, 2007, 2008, and 2012 had relatively shorter AFL compared to other lambing years.

The lambing interval (LI) was analyzed in the current study, and the overall least squares means and standard errors were determined to be 10.26±0.16 months. The LI, which represents the time between consecutive lambing, was found to be influenced by both genetic group and environmental factors. Notably, sire breed and dam breed had a substantial impact on LI (p =

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0.0002 and p < 0.0001, respectively). Ewes sired by purebred Dorper exhibited longer LI between lambing, while ewes sired by Dorper x Local crossbred and local sires had comparable or shorter LI. These findings confirm that local ewes generally had shorter LI compared to purebred Dorper and Dorper x Local crossbred ewes.

Environmental factors, including location, ewe lambing parity, season of lambing, and year of lambing, also exerted a significant influence on LI ($p < 0.0001$). Ewes in the cool-tepid area demonstrated shorter LI compared to those in the low-mid-to-highland areas. Ewe lambing parity had a notable effect, with ewes in their first parity experiencing extended LI compared to subsequent parities. Moreover, ewes that gave birth during the dry season displayed higher LI compared to those in the long-rainy and short-rainy seasons (10.6 vs 10.2, and 10.2 months, respectively). The year of lambing also played a role, as years such as 2017, 2022, and 2021- exhibited higher LI values, while years 2008, 2009, and 2010 had lower LI values. This indicates that certain years of lambing were associated with shorter LI compared to other years. In contrast, environmental factors such as lamb sex and birth litter size did not show a significant influence on LI ($p = 0.8163$ and $p = 0.1263$, respectively).

The overall least squares mean and standard error of ARR were ascertained to be 1.32±0.02 offspring per ewe per year. The (annual reproductive rate) ARR of ewes in the current study was significantly influenced by both genetic and environmental factors. The sire breed had a moderate impact on ARR ($p = 0.0463$), while the dam breed had a substantial impact ($p < 0.0001$). Ewes sired by purebred Dorper and Dorper x Local crossbred sires exhibited higher ARR values compared to those sired by local sires (ARR, 1.37 vs 1.32, Table 46). Surprisingly, we observed higher ARR values for local and Dorper x Local crossbred ewes compared to purebred Dorper ewes (1.39 and 1.48, respectively, compared to 1.19 for purebred Dorper ewes).

Location moderately affected the ARR of ewes ($p = 0.03712$). Ewes bred in the cool-tepid area had slightly higher ARR values (1.36 vs. 1.35). However, other environmental factors, such as dam parity, season and year of lambing, had a significant impact on ARR. ARR values increased with increasing dam parity, with significantly lower ARR values observed in the first parity compared to higher parities. Ewes that gave birth during the short rainy season had higher ARR values compared to those in the dry season and long rainy season, indicating that lambing in the

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short rainy season contributed to the production of a higher number of lambs per ewe per year. The year of lambing also made a substantial contribution to the ARR. Ewes that lambed in the years 2006, 2008, 2014, 2007, and 2009 had higher ARR values, while those that lambed in the years 2022, 2021, and 2017 had lower ARR values compared to other years. Conversely, environmental factors such as lamb sex did not significantly affect ($p = 0.6510$) the ARR of ewes.

Table 46. LSM±SE of AFL, LI, and ARR for the local, Dorper purebred and Dorper x local crossbred sheep managed under on-station management.

Source of variation	AFL		LI		ARR
	N	LSM±SE	N	LSM±SE	LSM±SE
Overall mean	1780	15.73±0.69	4105	10.26±0.16	1.32±0.02
CV (%)	1780	21.98	4105	13.26	29.23
Location		p <0.0001		p <0.0001	p =03712
Cool-tepid	530	17.45±0.70	2663	10.14±0.16	1.36±0.02
Low-mid-to-highland	1250	16.06±0.70	1442	10.54±0.16	1.35±0.02
Sire-Breed		p =0.0251		p =0.0002	p =0.0463
Dorper purebred	1122	17.13±0.69^{a}	2374	10.48±0.16^{a}	1.37±0.02^{a}
Dorper cross	336	16.72±0.72^{ab}	655	10.31±0.18^{ab}	1.37±0.03^{a}
Local	322	16.42±0.73^{b}	1076	10.22±0.17^{b}	1.32±0.03^{b}
Dam-Breed		p <0.0001		p <0.0001	p <0.0001
Dorper purebred	319	21.27±0.73^{a}	1076	11.60±0.17^{a}	1.19±0.03^{b}
Dorper cross	402	15.20±0.71^{b}	697	10.07±0.18^{b}	1.39±0.03^{a}
Local	1059	13.80±0.70^{c}	2332	9.35±0.16^{c}	1.48±0.04^{a}
Lamb sex		p =0.5155		p =0.8163	p =0.6510
Male	920	16.81±0.69	2065	10.33±0.16	1.36±0.02
Female	860	16.70±0.70	2040	10.34±0.15	1.35±0.02
Birth litter size		p =0.3236		p =0.1263	-
Single	1623	16.81±0.14	3770	10.39±0.07	-
Twin	154	17.09±2.02	324	10.54±0.10	-
Triple	3	16.37±0.32	11	10.07±0.42	-
Ewe parity	-	-		p <0.0001	p <0.0001
1st parity	-	-	1373	10.58±0.16^{a}	1.26±0.02^{b}
2nd parity	-	-	1139	10.34±0.16^{b}	1.32±0.02^{a}
3rd parity	-	-	778	10.31±0.06^{b}	1.35±0.02^{a}
4th parity	-	-	448	10.27±0.17^{b}	1.40±0.03^{a}
5th parity	-	-	226	10.25±0.18^{b}	1.38±0.03^{a}
6th parity and above	-	-	141	10.26±0.19^{b}	1.42±0.04^{a}
Season of lambing		p <0.0001		p <0.0001	p <0.0001
Dry- period	791	16.49±0.70^{b}	1969	10.55±0.16^{a}	1.32±0.02^{b}
Long- rain	486	16.33±0.70^{b}	1335	10.26±0.16^{b}	1.35±0.02^{b}
Short- rain	503	17.44±0.71^{a}	801	10.21±0.16^{b}	1.40±0.02^{a}
Year of lambing		p <0.0001		p <0.0001	p <0.0001
2006	44	12.05±0.89^{c}	2	10.29±0.99^{ab}	1.76±0.27^{a}
2007	33	12.05±0.95^{c}	32	10.38±0.30^{ab}	1.40±0.07^{a}
2008	40	12.72±0.90^{c}	56	9.56±0.25^{b}	1.48±0.06^{a}
2009	240	17.04±0.74^{b}	195	9.67±0.19^{b}	1.40±0.03^{a}
2010	130	17.58±0.75^{b}	314	10.06±0.17^{b}	1.35±0.03^{ab}

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Table 46. *Continued*

2011	90	16.87±0.79[b]	269	10.28±0.17[ab]	1.31±0.03[b]
2012	222	16.79±0.73[b]	407	10.27±0.16[ab]	1.33±0.02[b]
2013	82	16.91±0.75[b]	265	10.21±0.17[ab]	1.39±0.03[a]
2014	128	17.11±0.75[b]	329	10.09±0.16[b]	1.42±0.03[a]
2015	98	16.85±0.77[b]	297	10.51±0.17[a]	1.32±0.02[b]
2016	209	17.68±0.73[b]	350	10.55±0.16[a]	1.33±0.02[b]
2017	191	17.94±0.74[b]	209	10.81±0.17[a]	1.24±0.03[b]
2018	103	17.80±0.77[b]	384	10.58±0.16[a]	1.27±0.02[b]
2019	79	21.05±0.79[a]	358	10.57±0.16[a]	1.27±0.02[b]
2020	40	17.63±0.89[b]	327	10.45±0.17[a]	1.33±0.03[b]
2021	32	18.23±0.94[b]	246	10.71±0.17[a]	1.22±0.03[b]
2022	19	18.44±1.07[b]	65	10.75±0.23[a]	1.20±0.05[b]

*Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001*

4.8.2.5. Annual production indices for the local, purebred Dorper and Dorper crossbred ewes under on-station management.

Index I, which represents the litter weight (kg of lamb at 90 days) per ewe per year, was utilized to evaluate the reproductive performance and productivity of ewes. The findings of the current study demonstrated that the average weight of lambs produced at 90 days per ewe per year (Index I) was 17.64±0.72 kg (Table 47). The body weight of lambs at 90 days per ewe per year was significantly influenced by both genetic factors (sire breed, $p < 0.0001$; dam breed, $p = 0.0013$) and environmental factors (location, $p = 0.0017$; lamb sex; birth litter size; lambing interval; lambing season; and year, $p < 0.0001$).

The sire breed had a substantial impact on the weight of lambs produced at 90 days per ewe per year. Ewes sired by purebred Dorper and Dorper x Local crossbred sires produced 28 and 27 kg, respectively, compared to ewes sired by local sires, which produced 24 kg. This indicates that ewes sired by Dorper x Local crossbred sires can achieve similar weights to those sired by purebred Dorper sires and are superior to ewes sired by local sires (Table 47). Similarly, Dorper x Local crossbred ewes produced significantly higher weights of lambs per ewe per year at 90 days compared to local and purebred Dorper ewes, highlighting the positive heterosis effect obtained from crossbreeding efforts. Ewes from the low-mid-to-highland areas exhibited significantly higher body weights of lambs at 90 days (26.34 kg) compared to those from cool-tepid areas (25.47 kg, $p = 0.0017$).

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Ewes giving birth to male lambs produced significantly greater body weights of lambs at 90 days compared to their female counterparts. Additionally, ewes birthing triplets and twins achieved significantly higher litter body weights at 90 days compared to ewes with single lambs. Ewes in their first parity produced lambs with lower weights at weaning compared to those in higher lambing parities. The season of lambing affected the weight of lambs produced at 90 days, with ewes lambing in the dry season yielding significantly lower weights compared to those lambing in the long rain and short rain seasons. The year of lambing also influenced the weight of lambs at 90 days per ewe per year; for instance, years such as 2009, 2008, and 2012 resulted in higher weights, while ewes lambing in 2018, 2017, and 2021 produced lambs with lower weights per ewe per year compared to those giving birth in other years.

The study also examined Index II, which involves dividing Index 1 (litter weight of lambs at 90 days per ewe per year) by the postpartum weight of ewes when they are lambing. This index serves as an assessment of ewe productivity and reproductive performance, measuring the efficiency of ewes in converting their own weight into the weight of their offspring. It considers the condition and body weight of the ewe at lambing, evaluating how well she can support and nourish her lambs during the postpartum period. The overall least squares means and standard errors of Index II values were determined to be 0.50±0.05 g/kg of ewe.

The gram of lamb produced per kg of ewe (Index II) was significantly influenced by genetic group (sire breed and dam breed, $p < 0.0001$) and environmental factors such as location, birth litter size, lambing season, and year ($p < 0.0001$), as well as lamb sex ($p = 0.0008$). However, ewe parity did not affect the gram of lamb produced per kg of dam weight at lambing ($p = 0.1725$). Ewes sired by purebred Dorper and Dorper x Local crossbred sires produced significantly heavier lambs compared to ewes sired by local ewes (0.90 g/kg, 0.88 g/kg, and 0.80 g/kg, respectively). Conversely, local ewes had a higher gram of lamb per kg compared to purebred Dorper (0.71 g/kg) and Dorper x Local crossbred ewes (0.87 g/kg, Table 47).

The impact of location on the production of gram of lamb per kg of ewe was substantial. The study revealed that ewes residing in the low-mid-to-highland area produced significantly heavier lambs (0.92 g/kg and 0.80 g/kg ewe weight) compared to ewes in cool-tepid areas. Ewes giving birth to male lambs produced a higher gram/kg of lamb compared to those with female lambs.

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Ewes with triplet and twin lambs also produced significantly heavier lambs per kg ewe at 90 days compared to those with single lambs per birth.

Additionally, ewes lambing in the short rain season produced significantly heavier lambs (gram of lamb/kg ewe) compared to those in the long rain and short rain seasons, respectively. The year of lambing also influenced the production of gram of lamb per kg ewe weight at lambing. Years such as 2014, 2011, and 2015 yielded higher values, while ewes lambing in 2013, 2019, and 2018 produced lambs with relatively lower gram per kg ewe per lambing compared to other years.

Index III, calculated by dividing Index 1 (litter weight of lambs at 90 days per ewe per year) by the ewe's metabolic weight, serves as an indicator of the ewe's metabolic efficiency. In our study, the overall least squares means and standard errors of kilograms of lamb produced per metabolic weight of ewes were determined to be 1.27±0.12. This value provides an assessment of how efficiently ewes convert their metabolic energy into lamb weight and highlights the importance of genetic and environmental factors in enhancing ewe annual production indices. The kg of lamb produced per kg metabolic weight of ewes was significantly influenced by genetic group (sire breed and dam breed, $p < 0.0001$) and environmental factors such as location, birth litter size, season, and year of lambing ($p < 0.0001$), as well as lamb sex ($p = 0.0010$) and ewe parity ($p = 0.0226$). This emphasizes the significance of both genetic group and environmental factors in maximizing ewe productivity.

Ewes sired by purebred Dorper sires produced higher kg of lamb per ewe metabolic weight at lambing compared to those sired by Dorper x Local crossbred and local sires. Conversely, local ewes produced significantly higher kg of lamb per metabolic weight of ewes at lambing compared to purebred Dorper and Dorper x Local crossbred ewes. However, Dorper x Local crossbred ewes exhibited significantly better performance in terms of kg of lamb produced per metabolic weight by purebred Dorper ewes at lambing.

The location where ewes resided had a significant impact on the kg of lamb produced per metabolic weight of ewes at lambing. Ewes in the warm-mid-to-highland areas produced higher kg of lamb per kg metabolic weight compared to ewes in the cool-tepid areas. The sex of the

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lambs also influenced the index, with ewes giving birth to male lambs having higher values of Index III compared to those giving birth to female lambs. Additionally, ewes giving birth to triplet lambs produced significantly higher kg of lamb per kg of metabolic weight compared to those giving birth to twins and singletons.

The effects of birth litter size, lambing interval, birth season, and year of lambing were also found to have a significant impact on the kg of lamb produced per kg metabolic weight of ewes. These factors contribute to the variability in ewe productivity and highlight the importance of considering them in flock management and breeding strategies.

Table 47. LSM±SE of annual production indices (I-III) for the local, Dorper and Dorper x local crossbred sheep managed under on-station management in Ethiopia.

	Index-I		Index-II		Index-III
Source of variation	N	LSM±SE	N	LSM±SE	LSM±SE
Overall mean	3618	17.64±0.72	2333	0.50±0.05	1.27±0.12
CV (%)	3618	31.21	2333	27.58	26.96
Location		p =0.0017		p <0.0001	p <0.0001
Cool-tepid	2257	25.47±0.73	2257	0.80±0.05	2.17±0.16
Low-mid-to-highland	1361	26.34±0.73	76	0.92±0.05	2.45±0.13
Sire-Breed		p <0.0001		p <0.0001	p <0.0001
Dorper purebred	2137	27.56±0.73[a]	1164	0.90±0.05[a]	2.43±0.12[a]
Dorper cross	555	26.58±0.82[a]	471	0.88±0.05[b]	2.35±0.13[b]
Local	926	23.58±0.78[b]	698	0.80±0.05[c]	2.16±0.12[c]
Dam-Breed		p =0.0013		p <0.0001	p <0.0001
Purebred Dorper	959	25.05±0.77[c]	614	0.71±0.05[c]	2.01±0.12[c]
Dorper cross	591	26.81±0.81[a]	499	0.87±0.05[b]	2.37±0.13[b]
Local	2068	25.86±0.75[b]	1220	1.00±0.05[a]	2.56±0.12[a]
Lamb sex		p <0.0001		p =0.0008	p =0.0010
Male	1826	26.26±0.73	1149	0.87±0.05	2.34±0.12
Female	1792	25.55±0.73	1184	0.85±0.05	2.29±0.12
Birth litter size		p <0.0001		p <0.0001	p <0.0001
Single	3339	17.42±0.19[c]	2194	0.53±0.01[c]	1.35±0.03[c]
Twin	272	23.21±0.07[b]	138	0.62±0.02[b]	1.61±0.04[b]
Triple	7	37.09±2.03[a]	1	1.43±0.14[a]	3.98±0.03[a]
Ewe parity		p <0.0001		p =0.1725	p =0.0226
1st parity	1125	24.50±0.73[b]	663	0.86±0.05	2.29±0.12[b]
2nd parity	1041	26.01±0.73[a]	625	0.86±0.05	2.30±0.12[ab]
3rd parity	724	26.22±0.75[a]	484	0.87±0.05	2.35±0.12[a]
4th parity	405	26.95±0.76[a]	288	0.87±0.05	2.35±0.12[a]
5th parity	198	26.06±0.82[a]	156	0.85±0.05	2.30±0.12[b]
6th parity and above	125	25.70±0.86[a]	117	0.85±0.05	2.29±0.12[b]
Season of lambing		p <0.0001		p <0.0001	p <0.0001
Dry- period	1764	24.86±0.73[c]	1133	0.79±0.05[c]	2.13±0.12[c]
Long- rain	1155	25.92±0.74[b]	869	0.85±0.05[b]	2.30±0.12[b]
Short- rain	699	26.93±0.75[a]	331	0.94±0.05[a]	2.51±0.02[a]

Table 47. *Continued*

Year of lambing		p <0.0001		p <0.0001	p <0.0001
2007	31	23.96±12.8[c]	-	-	-
2008	52	30.15±1.09[a]	-	-	-
2009	186	30.25±0.86[a]	-	-	-
2010	303	26.45±0.78[b]	86	0.79±0.05[b]	2.17±0.12[b]
2011	246	26.59±0.80[b]	99	0.92±0.05[a]	2.47±0.12[a]
2012	391	27.33±0.78[ab]	134	0.88±0.05[a]	2.39±0.12[a]
2013	239	25.09±0.80[b]	99	0.78±0.05[b]	2.15±0.12[b]
2014	269	26.99±0.79[b]	183	0.95±0.05[a]	2.56±0.12[a]
2015	264	26.07±0.79[b]	199	0.90±0.04[a]	2.41±0.12[a]
2016	304	25.40±0.78[b]	250	0.89±0.05[a]	2.36±0.12[a]
2017	162	23.31±0.84[c]	135	0.83±0.05[b]	2.20±0.12[b]
2018	316	23.30±0.78[c]	293	0.81±0.05[b]	2.16±0.12[b]
2019	322	25.23±0.78[b]	322	0.89±0.05[a]	2.36±0.12[a]
2020	301	26.22±0.80[b]	301	0.89±0.05[a]	2.40±0.12[a]
2021	171	23.60±0.83[bc]	171	0.83±0.05[b]	2.22±0.12[b]
2022	61	24.54±1.05[b]	61	0.83±0.05[b]	2.23±0.13[b]

*Values within each sub-class are significantly different at *=P<0.05, **P<0.01, *** = P<0.0001*

4.9. Growth performance of sheep

4.9.1. Growth performances of lambs under village management system

4.9.1.1. Pre-weaning growth performances of lambs under farmers' management

The overall least squares means for birth weight and weaning weights were 2.82±0.04 and 12.97±0.19 kg respectively (Table 48). Pre-weaning body weights were significantly affected by lamb genotype, location of the study flock, lamb sex, birth type, parity, season, and year of lambing ($p < 0.001$ to $p < 0.05$). The birth and weaning weights of local, Dorper x Local (low grade) and Dorper x Local (high grade) were 2.21, 2.94, 3.08 and 10.57, 13.22, 13.83kg, respectively; indicating the superiority of Dorper crossbred lambs over the locals under the farmers' management system in Ethiopia. Crossbreeding using Dorper sires improved the birth and weaning weights of local lambs by 33-39% and 25-31%, respectively. Pre-weaning average daily gain (PRWADG) up to 90 days for local, Dorper x Local (low grade), and Dorper x Local (high grade) were 89.12±1.85, 112.16±1.38, and 117.98±1.71 g/h/d respectively; indicating that the Dorper crossbred lambs gained 26-32% more weight than their local contemporaries did. Sex of lamb was an important source of variation, accordingly male lambs were significantly ($p < 0.001$) heavier at birth and weaning and gained more than their female counterparts (Table 48).

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Location exerted a significant ($p < 0.001$) effect on the birth, weaning weight and PRWADG. Heavier lambs were born at Kobo and Merhabete while lighter lambs were born at Basona-Werana and Efratana-Gidim while heavier lambs were weaned at Efratana-Gidim and Merhabete and lambs with lighter weight were weaned at Yabello. Higher PRWADG was recorded at Basona-Werana while the least PRWADG was observed at Yabello (Table 48). Litter size had a significant effect on birth weight ($p < 0.01$), weaning weight, and PRWADG ($p < 0.001$). Single born lambs exhibited to have better birth and weaning weight and gained better up to 90 days.

Lambing parity of the ewe also influenced the birth weight ($p < 0.01$) and weaning weight ($p < 0.05$) of the lambs. While there was no significant ($p > 0.05$) effect on PRWADG as parity of the ewe advances. As parity increased, there was an upward trend observed in the birth weight and weaning weight of lambs. However, after reaching the 5th parity, these weights started to decline. This decline can be attributed to the diminishing potential of milk production by the ewe as it ages and reaches higher parities.

Season of lambing had a significant effect on birth weight ($p < 0.01$), weaning weight, and PRWADG ($p < 0.001$). Lambs born in the long rainy season had a bigger birth weight than those born in the short rain. Better weaning weight and PRWADG were recorded for lambs born in the long and short rainy seasons compared to the dry season. On the other hand, Year of birth also influenced the birth weight ($p < 0.01$), weaning weight, and PRWADG ($p < 0.05$) of lambs. Accordingly, the heaviest weight for birth, three months, and gain were recorded in the year 2016.

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Table 48. LSM±SE of pre-weaning growth performance of Local and Dorper crossbred lambs under on-farm management.

Factors	BWT (kg)		WWT (kg)		PRWADG (g/d)	
	n	LSM±SE	n	LSM±SE	n	LSM±SE
Overall	4066	2.82±0.08	3116	12.97±0.19	3116	112.51±2.10
CV (%)	4066	18.42	3116	16.62	3116	20.28
Lamb Genotype		***		***	***	***
Local	952	2.21±0.04^{c}	730	10.57±0.17^{c}	730	89.12±1.85^{c}
Dorper cross (low-grade)	1941	2.94±0.03^{b}	1490	13.22±0.13^{b}	1490	112.16±1.38^{b}
Dorper cross (high-grade)	1173	3.08±0.03^{a}	896	13.83±0.16^{a}	896	117.98±1.71^{a}
Location		***		***		***
Basona-Werana	1812	2.55±0.03^{d}	1454	12.77±0.13^{b}	1454	113.36±1.45^{a}
Efratana-Gidim	230	2.58±0.05^{d}	77	13.55±0.28^{a}	77	111.15±3.02^{ab}
Kewet	711	2.80±0.03^{bc}	453	12.73±0.16^{b}	453	108.54±1.79^{b}
Kobo	467	2.93±0.04^{a}	379	12.47±0.17^{b}	379	105.01±1.83^{b}
Merhabete	475	2.85±0.04^{ab}	410	13.06±0.18^{ab}	410	113.04±1.98^{a}
Yabello	371	2.73±0.04^{c}	343	10.65±0.19^{c}	343	87.42±2.02^{c}
Sex		***		**		**
Male	2027	2.78±0.03	1514	12.69±0.14	1514	107.80±1.54
Female	2039	2.71±0.03	1602	12.39±0.14	1602	105.04±1.54
Birth Type		**		**		***
Single	3711	2.79±0.02	2862	12.81±0.12	2862	108.82±1.32
Twin	355	2.70±0.04	254	12.27±0.18	254	104.02±1.96
Parity		**		*		**ns**
1st	2558	2.65±0.03^{b}	1968	12.13±0.12^{b}	1968	103.21±1.33
2nd	921	2.71±0.03^{b}	708	12.48±0.14^{a}	708	106.04±1.54
3rd	353	2.77±0.04^{a}	275	12.65±0.17^{a}	275	106.68±1.89
4th	143	2.83±0.05^{a}	100	12.72±0.24^{a}	100	106.68±2.64
5th & above	91	2.74±0.06^{ab}	65	12.72±0.29^{a}	65	109.47±3.10
Season		*		***		***
Dry- period	1621	2.74±0.03^{ab}	1249	12.25±0.14^{b}	1249	103.47±1.54^{b}
Long- rain	1330	2.77±0.03^{a}	1012	12.74±0.16^{a}	1012	108.59±1.66^{a}
Short-rain	1115	2.72±0.03^{b}	855	12.63±0.15^{a}	855	107.20±1.60^{a}
Year		**		*		*
2012	28	2.56±0.11^{c}	26	12.27±0.46^{c}	26	105.12±4.93^{bc}
2013	166	2.57±0.05^{c}	152	12.33±0.23^{c}	152	106.29±2.48^{bc}
2014	438	2.91±0.04^{a}	287	12.97±0.18^{ab}	287	109.14±1.91^{b}
2015	703	2.87±0.03^{ab}	491	13.30±0.15^{ab}	491	113.67±1.61^{ab}
2016	1077	2.90±0.03^{ab}	878	13.33±0.12^{ab}	878	114.11±1.35^{ab}
2017	979	2.80±0.03^{b}	788	12.20±0.12^{c}	788	102.62±1.33^{c}
2018	248	2.74±0.04^{bc}	109	12.49±0.23^{c}	109	106.47±2.43^{bc}
2019	41	2.82±0.09^{ab}	19	12.05±0.50^{c}	19	98.89±5.39^{c}
2020	274	2.65±0.05^{c}	254	11.99±0.20^{d}	254	100.99±2.19^{c}
2021	112	2.59±0.06^{c}	112	12.46±0.26^{c}	112	106.88±2.77^{bc}

*Values within each sub-class are significantly different at *=P<0.05, **P<0.01, *** = P<0.0001*

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4.9.1.2. Post-weaning growth performances of lambs under farmers' management

The overall adjusted 6 and 12-month weights of the lambs were 16.63±0.26 and 24.04±0.62kg, respectively. While the overall POWGAIN was 41.11±2.27 g/h/d (Table 49, Figure 6). Six-month weight of lambs was significantly affected by lamb genotype, location ($p < 0.001$), lamb sex, season, and year of birth ($p < 0.01$), parity and birth type ($p < 0.05$), respectively. Dorper x Local crossbred lambs had significantly ($p < 0.001$) higher weight at 6 months of age compared to the locals and exhibited an advantage of 30.1-33.8% more weight over their contemporary local lambs at six-month of age. Male lambs born as single in the long and short rainy seasons had higher body weight at 6 months than female lambs; Location was also a significant source of variability in 6-month weight. Year of birth was noted as one of the significant sources of variation for the differences in the six-month weight of lambs, accordingly, lambs born in 2014, 2015, 2016, and 2018 had higher six-month weights.

Figure 6. Comparative growth performances of local and Dorper x Local crossbred lambs managed by farmers

The overall yearling weight of lambs was affected by lamb genotype, location, lamb sex, birth parity ($p < 0.001$), and birth year ($p < 0.01$), respectively. On the other hand, birth type and season of birth had no significant effect ($p > 0.05$) on lamb yearling weight (Table 49). Dorper x Local crossbred lambs produced significantly ($p < 0.001$) higher weight at yearling age

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compared to the locals and exhibited an advantage of 22.8-27.5% higher weight than their contemporary local lambs at yearling. The influence of sex was significant ($p < 0.001$), male lambs weighed 5% more than their female counterparts. The birth year of the lambs played a role in the variation observed in their yearling weight. Lambs born in the years 2013-2016 exhibited higher yearling weights, while those born in the years 2017, 2020, and 2021 had comparatively lower yearling weights.

The overall average post-weaning daily gain (POWADG), recorded between weaning and yearling ages was 41.11±2.28 g/day (Table 49). POWADG had a large effect on most studied traits and it was influenced by lamb genotype, location, lamb sex ($p < 0.001$), birth type, and year of birth ($p < 0.05$), respectively.

The study also revealed that no significant ($p > 0.05$) effect has been exerted by other environmental factors such as parity and season of birth. Lamb breed was found to have a statistically significant effect on POWADG, accordingly, Dorper crossbred lambs gained 18.2-23.2% more weight compared with the local lambs under similar management conditions. Male lambs gained 7.3% more weight after weaning until yearling age and single-born lambs gained 10% more than their twin counterparts. Lambs born in Yabello gained more while the lowest gain was rerecorded for the lambs born in Merhabete area. Lambs born in 2014 gained the highest and the lowest gain was recorded in 2017.

Table 49. LSM±SE of post-weaning growth performance of Local and Dorper crossbred lambs under on-farm condition.

Factors	SMWT (kg)		YWT (kg)		POWADG (g/d)	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall mean	2625	16.63±0.26	1169	24.04±0.62	1141	41.11±2.27
CV (%)	2625	15.90	1169	15.13	1141	30.96
Genotype		***		***		***
Local	589	13.30±0.23^{c}	156	20.42±0.54^{c}	153	36.52±1.92^{b}
Dorper cross (low-grade)	1303	17.30±0.17^{b}	798	25.07±0.45^{b}	783	43.17±1.62^{a}
Dorper cross (high-grade)	732	17.79±0.21^{a}	215	26.03±0.48^{a}	205	44.98±1.77^{a}
Location		***		***		***
Basona-Werana	1241	16.16±0.18^{b}	341	24.89±0.49^{a}	313	42.30±1.79^{b}
Efratana-Gidim	63	16.52±0.38^{ab}	20	24.71±0.95^{ac}	20	42.88±3.37^{b}
Kewet	325	17.27±0.23^{a}	105	24.96±0.56^{ab}	105	42.36±2.01^{b}
Kobo	332	15.65±0.22^{b}	146	22.08±0.52^{c}	146	36.10±1.86^{c}

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Table 49. *Continued*

Merhabete	337	16.37±0.25[b]	234	22.21±0.57[c]	234	34.06±2.05[d]
Yabello	326	14.80±0.25[c]	323	24.19±0.51[ab]	323	51.64±1.83[ab]
Sex		***		***		***
Male	1257	16.41+0.19	491	24.42±0.45	479	43.02+1.65
Female	1367	15.85+0.19	678	23.26±0.45	662	40.10+1.62
Type of birth		*		ns		*
Single	2412	16.35±0.16	1088	23.87±0.57	1062	43.54±2.04
Twin	212	15.91±0.24	81	23.82±0.39	79	39.58±1.45
Parity		*		**		ns
1st	1698	15.80±0.16[c]	781	22.57±0.38[b]	757	40.02±1.37
2nd	586	16.13±0.19[bc]	268	23.54±0.43[a]	268	40.70±1.54
3rd	212	16.53±0.24[ab]	78	24.66±0.56[a]	75	43.86±2.01
4th	83	16.23±0.33[bc]	29	25.19±0.77[a]	29	43.53±2.71
5th and above	45	15.95±0.42[bc]	13	23.24±1.07[b]	12	39.69±3.92
Season		**		ns		ns
Dry- period	1041	15.79±0.19[b]	487	23.85±0.45	465	41.04±1.64
Long- rain	847	16.23±0.21[a]	294	23.88±0.48	292	41.91±1.73
Short- rain	736	16.37±0.20[a]	388	23.79±0.47	384	41.72±1.69
Year		**		**		*
2012	25	15.36±0.58[bc]	24	24.25±0.90[abc]	24	43.06±3.19[bc]
2013	137	16.19±0.31[bc]	95	24.51±0.60[ab]	95	44.21±2.13[bc]
2014	262	17.15±0.24[ab]	208	25.57±0.46[a]	208	47.12±1.65[ab]
2015	433	16.93±0.20[ab]	202	25.49±0.44[ab]	202	43.76±1.58[ab]
2016	770	16.70±0.17[ab]	253	24.57±0.42[ab]	253	40.52±1.48[c]
2017	556	15.43±0.17[c]	134	22.03±0.47[d]	134	35.38±1.67[d]
2018	43	16.29±0.42[abc]	3	23.13±2.16[bc]	3	38.46±7.58[abc]
2019	29	16.15±0.53[bc]	24	23.11±0.88[bc]	10	41.25±4.36[abc]
2020	259	15.35±0.27[c]	195	22.80±0.58[c]	181	41.32±2.07[abc]
2021	110	15.71±0.33[c]	31	22.95±0.86[bc]	31	40.49±3.04[abc]

*Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001*
SMWT= six month weight, YWT= yearling weight, POWADG= post weaning average daily gain

4.9.2. Growth performances of lambs under on-station management system

4.9.2.1. Pre-weaning growth performances of lambs under on-station management

Table 50 provides data on the birth weight (BWT), weaning weight (WWT) and pre-weaning average daily weight gain (PRWADG) of lambs. The average birth weight was 3.04±0.02 kg, while the average weaning weight was 13.71±0.12 kg. The pre-weaning average daily weight gain was 118.02±1.25 g. The birth weight was found to be significantly influenced by multiple factors, including lamb genotype, location, sex, type of birth, parity of the ewe, season, and year of birth (p < 0.0001). High-grade (75% Dorper x Local lambs) had higher birth weights than pure Dorper, local, 50%-Dorper x Local-F_1 crossbreeds, and 25%-Dorper x Local crossbreed lambs.

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Local lambs had the lowest birth weight compared to all breeds considered. Lambs born in cool-sub alpine areas were heavier than those born in low-mid-to-highland areas.

Male lambs were heavier at birth than female lambs. Single-born lambs were heavier than multiple-born lambs. The parity of the ewe at lambing had a significant effect on birth weight. Lambs born to the first parity were lighter than the following parities, while lambs born to the fourth parity were heavier. The birth weight increased as the parity of birth increased and started to decline starting from the fifth parity onwards. The birth season also had an influence on birth weight. Lambs born during the dry season exhibited the highest birth weights, whereas lambs born in the short-rainy season had the lowest birth weights. The birth year also played a significant role in determining birth weight. Lambs born in the years 2008, 2015, and 2016 had higher birth weights, while lambs born in 2008 and 2022 had lower birth weights.

Lamb genotype had a significant impact on weaning weight ($p < 0.0001$). Pure Dorper and lambs with 75% Dorper gene were heavier followed by 50%-Doper x Local-F_1 and 50%-Dorper x 50%-Dorper *inter se* mated. Local lambs were significantly lighter at 3 months of age than pure Dorper and at different levels of Dorper inheritance. Lambs born in the low-mid-to-highland areas were heavier at weaning than those born in the cool-sub alpine areas.

Male lambs were heavier than female lambs at weaning, and single-born lambs were superior to female lambs at weaning by 2.5 kg. The body weight of lambs at weaning was similar for the lambs born in the long-rainy and short-rainy seasons while lambs born in the dry season had a lighter body weight. Body weight at weaning was significantly influenced by the year of birth. Additionally, the lamb genotype had a significant impact on the pre-weaning average daily gain Accordingly, pure Dorper lambs grew at 139 g/day, while lambs with 75% Dorper inheritance grew at 131 g/day, lambs with 50% Dorper inheritance (F_1) and the 50% *inter se* mated grew at 115 and 122 g/day, respectively. The local lambs grew at 87 g/day until weaning and were inferior to pure Dorper lambs and lambs having different levels of Dorper inheritance. Lambs born in the low-mid-to-highland areas were able to grow at 121 g/day until weaning while lambs born in the cool-sub-alpine areas grew slowly and at 110 g/day. Male lambs grew faster than females until weaning age (118 vs. 112 g/day). Single-born lambs grew faster than multiple-born lambs (126 vs. 104 g/day). First parity-born lambs grew slowly compared to successive parities.

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Lambs born during the dry season exhibited a growth rate of 107 g/day, whereas lambs born in the long-rainy and short-rainy seasons had growth rates of 119 g/day and 121 g/day, respectively. Furthermore, lambs born in 2007 displayed a slower growth rate of 91 g/day, while lambs born in 2008 exhibited a faster growth rate of 148 g/day.

Table 50. LSM±SE of pre-weaning growth performance of Local, Dorper purebred and their different levels of crossbred lambs under on-station management.

Factors	BWT (kg)		WWT (kg)		PRWADG (g/d)	
	n	LSM±SE	n	LSM±SE	n	LSM±SE
Overall	9369	3.04±0.02	6227	13.71±0.12	6227	118.02±1.25
CV (%)	9369	22.41	25.06		30.95	
Lamb Genotype Group		p <0.0001		p <0.0001		p <0.0001
50%-Dorper cross-F1	3784	2.98±0.02[c]	2400	13.39±0.12[b]	2400	114.78±1.30[d]
50%-Dorper cross (*inter se*)	891	2.82±0.03[d]	639	13.86±0.17[b]	639	121.70±1.81[c]
25%-Dorper cross	155	2.76±0.06[d]	135	11.67±0.33[c]	135	99.60±3.52[e]
75%-Dorper cross	839	3.45±0.03[a]	452	15.28+0.20[a]	452	130.71±2.12[b]
Dorper purebred	1587	3.26±0.02[b]	1173	15.89±0.13[a]	1173	139.43±1.38[a]
Local	2113	2.11±0.02[e]	1428	10.04±0.15[d]	1428	86.89±1.55[f]
Location		p <0.0001		p <0.0001		p <0.0001
Cool-sub alpine	6361	3.00±0.02	3966	12.94±0.14	3966	110.40±1.50
Low-mid-to-highland	3008	2.80±0.02	2261	13.77±0.13	2261	120.64±1.32
Sex		p <0.0001		p <0.0001		p <0.0001
Male	4664	2.97±0.02	3231	13.69±0.13	3231	118.26±1.33
Female	4705	2.82+0.02	2996	13.02+0.13	2996	112.78+1.33
Birth Type		p <0.0001		p <0.0001		p <0.0001
Single	8160	3.20±0.02	5473	14.63±0.11	5473	126.31±1.16
Multiple	1209	2.59±0.03	754	12.08+0.16	754	104.73±1.68
Parity		p <0.0001		p <0.0001		p =0.0005
1st	4749	2.64±0.02[c]	2986	12.74±0.11[b]	2986	111.53±1.12[b]
2nd	2156	2.91±0.02[b]	1536	13.28±0.13[a]	1536	115.00±1.35[a]
3rd	1222	2.94±0.03[ab]	892	13.50±0.15[a]	892	117.04±1.60[a]
4th	675	2.99±0.03[a]	455	13.61±0.19[a]	455	117.81±1.99[a]
5th	338	2.95±0.04[ab]	227	13.49±0.25[a]	227	116.27±2.67[a]
6th and above	229	2.94±0.05[ab]	131	13.52±0.32[a]	131	115.48±3.41[a]
Season		p <0.0001		p <0.0001		p <0.0001
Dry- period	3965	2.99±0.02[a]	2767	12.68±0.13[b]	2767	106.56±1.34[b]
Long- rain	2806	2.88±0.02[b]	1835	13.63±0.14[a]	1835	118.58±1.48[a]
Short- rain	2598	2.81±0.02[c]	1625	13.76±0.15[a]	1625	121.43±1.54[a]
Year		p <0.0001		p <0.0001		p <0.0001
2006	47	2.91±0.11	-	-	-	-
2007	37	3.16±0.12[a]	36	11.30±0.61[c]	36	91.29±6.46[c]
2008	65	2.68±0.09[b]	60	15.99±0.48[a]	60	148.29±5.14[a]
2009	375	2.92±0.04[a]	286	15.31±0.23[a]	286	137.06±2.76[a]
2010	487	2.91±0.04[a]	441	13.14±0.21[b]	441	113.57±2.21[b]
2011	427	2.80±0.04[ab]	317	13.65±0.23[b]	317	119.09±2.39[b]
2012	658	2.90±0.03[a]	543	14.72±0.19[a]	543	130.72±1.97[a]

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Table 50. *Continued*

2013	723	2.80±0.03^{ab}	512	13.59±0.19^{b}	512	119.47±2.05^{b}
2014	544	2.93±0.03^{a}	366	13.72±0.21^{b}	366	117.81±2.21^{b}
2015	620	3.00±0.03^{a}	499	14.52±0.19^{a}	499	126.66±1.99^{a}
2016	1290	3.18±0.03^{a}	838	13.17±0.16^{b}	838	110.61±1.71^{b}
2017	771	2.88±0.03^{a}	402	12.54±0.20^{b}	402	106.42±2.10^{bc}
2018	848	2.84±0.03^{a}	532	11.33±0.18^{c}	532	93.54±1.92^{c}
2019	636	2.82±0.03^{a}	472	13.38±0.19^{b}	472	115.67±2.00^{b}
2020	687	2.97±0.03^{a}	494	13.57±0.19^{b}	494	117.08+1.99^{b}
2021	669	2.86±0.03^{a}	293	11.60±0.23^{c}	293	95.43±2.44^{c}
2022	485	2.67+0.04^{b}	146	12.15±0.30^{bc}	146	105.61+3.23^{bc}

*Values within each sub-class are significantly different at *=p <0.05, **p <0.01, *** = p <0.0001*
BWT= birth weight, WWT= weaning weight, PRWADG= pre-weaning average daily gain

4.9.2.2. Post-weaning growth performances of lambs under on-station management

Our study results, as indicated in Table 51 below, revealed that several factors, including lamb genotype, location, sex, birth type, parity, season, and year of the birth, all significantly ($p = 0.0118$ to $p < 0.0001$) influenced the six-month weight of lambs. The lambs' overall weight at six-months was 19 kg. Those lambs with 75% Dorper inheritance or purebred Dorper were heavier at six months (21 kg) than 50%-Dorper- x Local-F_1 (19 kg), This suggests that including the high level of Dorper sheep gene in locals could improve their six-month weight under on-station management conditions. Local lambs had lower body weight than the purebred Dorper or any level of crossbred Dorper x Local at six months (Figure 7).

Male lambs and single-born lambs were heavier at six months than their female counterparts or multiple-born lambs, respectively. Parity of birth also influenced the weight of lambs at six months of age. The study showed that the weight of lambs increased from parity 1 to 4 and started to decline from parity 5 onwards. Lambs born in low-mid-to-highland areas were superior to those born in cool-sub alpine areas by more than 1 kg at six months of age. Compared to lambs born in the dry season and long-rainy season, lambs born in the short-rainy season were the heaviest. .On the other hand, lambs with heavier six-month weight were born in the years 2008, 2012, 2013 and 2015, while those with lighter six-month weight were born in the years 2021 and 2022.

The overall yearling weight of lambs in the current study was 27 kg. The study also found that lamb genotype had a significant ($p < 0.0001$) effect on the yearling weight of lambs. The yearling weight of purebred Dorper, 75%-DxL, 50%-DxL-F_1, 50%-DxL-*inter se* mated, 25%-

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DxL and local lambs were 30.91, 31.18, 29.63, 26.18, 23.27 and 19.01 kg, respectively. Crossbreeding with Dorper sheep can improve the yearling weight of lambs. High-grade Dorper x Local crossbreeds had the same yearling weight as the purebred Dorper sheep. Crossbreeding also improved the yearling weight of lambs by 22% (25%-DxL), 38% (50%-DxL-*inter se* mated), 56% (50%-DxL-F_1), and 64% (75%-DxL) compared to the local lambs.

Male lambs had a weight advantage of 5.2% over their female counterparts at yearling age. Single-born lambs also had a weight advantage over multiple-born ones at yearling. Lambs born in the short-rainy season had the highest yearling weight over lambs born in the dry-season and long-rainy season. The yearling body weight of lambs born in the year 2007 was the highest (33 kg), while that of the year 2021 was the lowest (22 kg).

The study showed that both genetic and environmental factors affected the growth performances of lambs from birth to six months and from birth to yearling. The post-weaning growth performance (POWADG) of lambs with different genetic groups seemed low. The POWADG of 50%-DxL-F_1 and 75%-DxL lambs was 57 and 59 g/day, respectively. Compared to 52, 41, 39, and 31 g/day for purebred Dorper, 50%-DxL-*inter se* mated, 25%-DxL, and local lambs, respectively. This shows the slow growth performances of local lambs compared to different levels of Dorper crossbred lambs under similar management conditions. The study also revealed that 50%-DxL-F_1 and 75%-DxL crossbreeds had higher post-weaning average gain (weaning to yearling) compared to the purebred Dorper lambs. This suggests that the management practices used were not suitable for purebred Dorper lambs and failed to meet the requirements of the purebred Dorper sheep.

Table 51. LSM±SE of post-weaning growth performance of Dorper purebred, Local and Dorper x Local crossbred lambs under on-station management.

Factors	SMWT (kg)		Gain to 6m (g/d)	YWT (kg)		Gain-to-yearling	POWADG (g/d), (90-365d)	
	N	LSM±SE	LSM±SE	N	LSM±SE	LSM±SE	N	LSM±SE
Overall mean	4163	18.54±0.17	85.43±0.91	2684	26.89±0.29	65.04±0.78	2652	46.21±0.99
CV (%)	22.7		26.3		19.1	21.1	37.2	
Genotype		p <0.0001	p <0.0001		p <0.0001	p <0.0001		p <0.0001
50%-Dorper cross-F$_1$	1535	18.47±0.18^{b}	85.08±0.99^{b}	829	29.63±0.29^{a}	72.29±0.77^{a}	809	57.20±0.98^{a}
50%-Dorper (*inter se*)	431	18.17±0.26^{b}	84.40±1.37^{b}	293	26.18±0.39b	63.35±1.05^{b}	291	40.68±1.32^{c}
25%-Dorper cross	127	15.80±0.44^{c}	72.66±2.33^{c}	112	23.27±0.61^{c}	56.54±1.63^{c}	112	39.44±2.05^{c}
75%-Dorper cross	193	21.23±0.35^{a}	97.54±1.88^{a}	38	31.18±0.89^{a}	75.64±2.34^{a}	38	59.12±3.00^{a}
Dorper purebred	945	21.17±0.19^{a}	98.94±1.00^{a}	705	30.91±0.27^{a}	75.50±0.73^{a}	703	51.74±0.93^{b}
Local	932	13.67±0.22^{d}	62.91±1.19^{d}	707	19.01±0.34^{d}	45.55±0.90^{d}	669	30.87±1.14^{d}
Location		p <0.0001	p <0.0001		p =0.0051	p =0.0049		p <0.0001
Cool-sub alpine	2647	17.35±0.21	79.25±1.12	1690	27.14+0.35	65.98+0.94	1665	49.38+1.19
Low-mid-to-highland	1516	18.81±0.19	87.93±1.00	994	26.27+0.31	63.64+0.82	987	43.64+1.04
Sex		p <0.0001	p <0.0001		p <0.0001	p <0.0001		p <0.0001
Male	2127	18.85±0.18	87.30±0.98	1314	28.03±0.31	68.15±0.83	1291	50.38±1.05
Female	2036	17.32±0.18	79.88±0.98	1370	25.38±0.31	61.47±0.82	1361	42.63±1.04
Type of birth		p <0.0001	p <0.0001		p <0.0001	p =0.0155		p =0.0065
Single	3743	19.14±0.15	87.96±0.82	2422	27.38±0.27	65.92±0.71	2395	44.93±0.90
Multiple	420	17.02±0.02	79.22±1.31	262	26.03±0.40	63.71±1.06	257	48.08±1.34
Parity		p =0.0118	p =3974		p =0.6653	p =0.5967		p <0.0001
1st	1806	17.65±0.16^{b}	82.88±0.86	1100	26.56±0.26	65.36±0.70	1083	49.53±0.88^{a}
2nd	1101	17.97±0.16^{ab}	83.51±0.99	731	26.81±0.30	65.45±0.81	724	48.27±1.02^{a}
3rd	621	18.29±0.22^{a}	84.68±1.20	444	26.36±0.43	65.18±0.95	439	45.14±1.20^{b}
4th	347	18.46±0.27^{a}	85.32±1.43	232	26.36±0.43	63.80±1.15	232	44.06±1.44^{b}
5th	190	18.05±0.34a^{b}	82.77±1.83	118	26.45±0.55	63.70±1.47	117	44.17±1.85^{b}
6th and above	98	18.08±0.46^{ab}	82.38±2.44	59	27.20±0.73	65.39±1.87	57	47.88±2.50^{a}
Season		p <0.0001	p <0.0001		p =0.0238	p =0.0001		p =0.1041
Dry-period	1887	17.34±0.19^{b}	78.64±1.00^{c}	1417	26.33±0.31^{b}	63.21±0.82^{b}	1396	47.58±1.03
Long-rain	1192	17.59±0.21^{b}	81.30±1.11^{b}	717	26.70±0.35^{b}	64.95±0.94^{ab}	709	45.69±1.18
Short-rain	1084	19.31±0.22^{a}	90.83±1.16^{a}	550	27.09±0.37^{a}	66.28±0.98^{a}	547	46.25±1.24

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Table 51. *Continued*

Year		p <0.0001	p <0.0001		p <0.0001	p <0.0001		p <0.0001
2007	34	18.21±0.78[a]	83.30±4.18[b]	33	33.34±1.02[a]	82.54±2.73[a]	33	79.74±3.44[a]
2008	56	20.80±0.63[a]	99.99±3.37[a]	47	28.02±0.88[a]	69.01±2.35[b]	47	43.0±2.95[c]
2009	187	18.01±0.40[a]	82.54±2.21[b]	134	27.84±0.61[ab]	68.12±1.63[b]	134	44.34±2.05[c]
2010	299	17.97±0.32[b]	82.96±1.71[b]	176	24.30±0.51[bc]	58.28±1.36[cd]	176	37.78±1.71[cd]
2011	249	17.89±0.31[b]	82.89±1.68[b]	152	27.92±0.50[b]	68.38±1.33[b]	151	48.58±1.67[b]
2012	428	20.20±0.26[a]	95.29±1.38[a]	331	28.18±0.41[a]	68.97±1.09[b]	331	48.18±1.38[b]
2013	213	20.18±0.35[a]	94.92±1.85[a]	185	28.91±0.50[a]	70.79±1.32[b]	185	52.24±1.67[b]
2014	266	17.84±0.30[b]	81.39±1.62[b]	196	28.29±0.46[a]	68.38±1.23[b]	193	50.11±1.55[b]
2015	269	20.33±0.31[a]	95.05±1.63[a]	152	27.45±0.51[b]	66.10±1.36[b]	150	44.17±1.72[bc]
2016	549	19.33±0.24[a]	89.34±1.29[ab]	380	26.41±0.38[b]	63.65±1.01[c]	360	47.92±1.28[b]
2017	250	16.09±0.31[b]	72.19±1.68[bc]	144	23.57±0.52[c]	56.26±1.39[d]	143	39.07±1.75[d]
2018	324	15.88±0.28[b]	71.60±1.49[bc]	122	22.37±0.54[c]	53.24±1.45[d]	120	39.17±1.83[d]
2019	367	18.71±0.27[b]	87.48±1.45[ab]	268	28.19±0.41[a]	69.18±1.10[b]	267	52.82±1.39[b]
2020	398	17.54±0.27[b]	80.82±1.44[b]	273	23.98±0.41[c]	57.57±1.10[d]	271	35.23±1.39[d]
2021	213	15.51±0.33[c]	69.75±1.76[c]	91	21.82±0.60[c]	51.71±1.61[d]	91	35.17±2.02[d]
2022	61	14.85±0.58[c]	67.94±3.09[c]	-	-	-	-	-

*Values within each sub-class are significantly different at *=p<0.05, **p<0.01, *** = p<0.0001.*

SMWT= six month weight, YWT= yearling weight, POWADG= post weaning average daily gain

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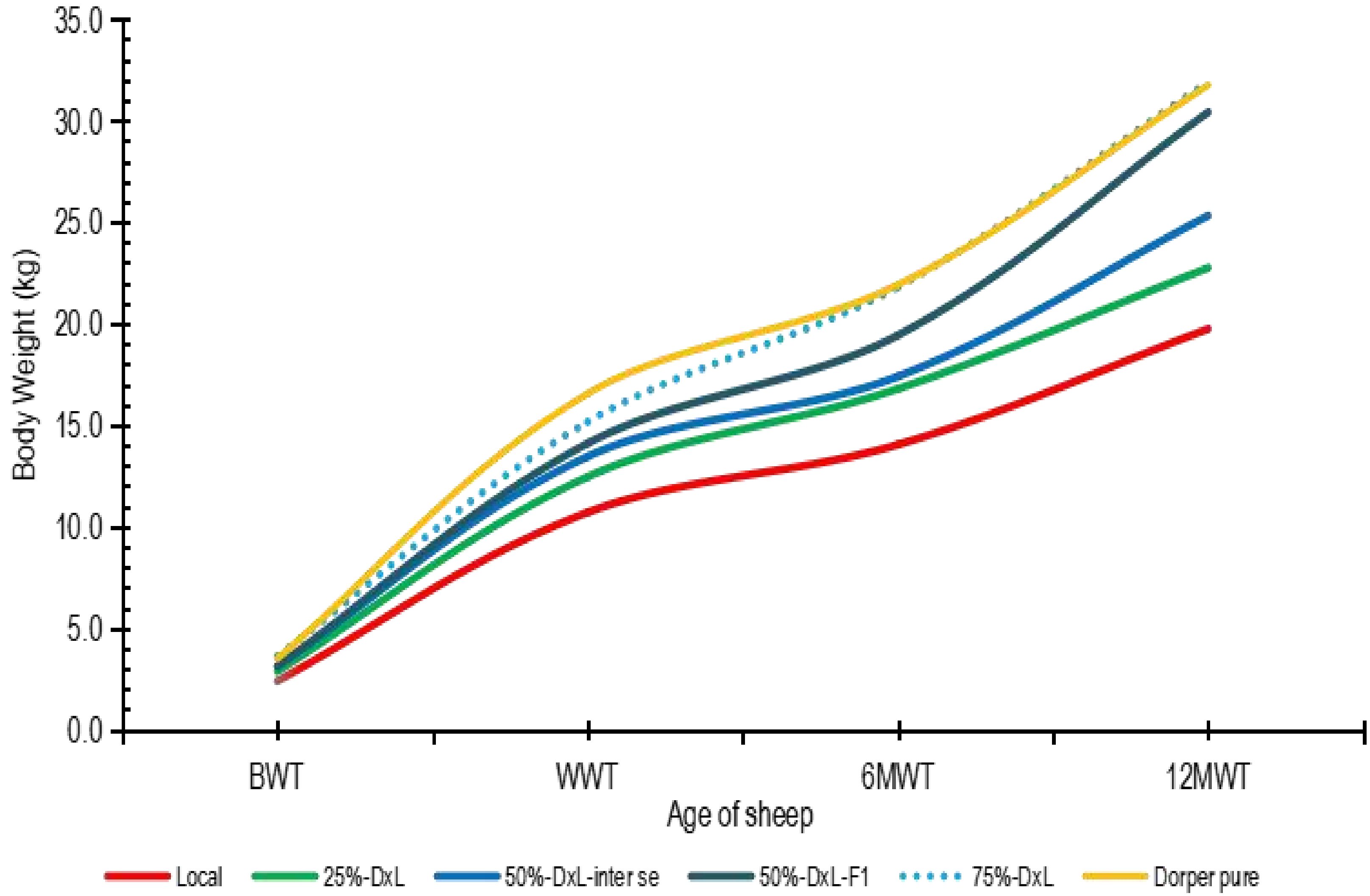

Figure 7. Growth performances of local, pure Dorper and Dorper x local crossbred lambs under on-station management

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4.10. Survival of lambs

4.10.1. Survival of lambs under farmers management condition

The overall mean survival rates of lambs up to 3, 6, and 12 months of age were 93.1%, 87.2%, and 80.1%, respectively. Specifically, the survival rates for local lambs and two grades of Dorper crossbred lambs at 3, 6, and 12 months were as follows: Local - 93.4%, 86.8%, and 76.6%; Dorper crossbred (low grade) - 93.0%, 88.0%, and 81.8%; Dorper crossbred (high grade) - 94.1%, 86.9%, and 80.0% (Table 52). These results suggest that both low and high grade Dorper crossbred lambs have comparable survival rates at 3, 6, and 12 months compared to the local lambs, when managed under similar on-farm conditions ($p > 0.05$).

Environmental factors, including location, birth season, birth year ($p < 0.001$), birth type ($p = 0.016$), and birth weight category significantly ($p = 0.017$), influenced pre-weaning survival rates of lambs. However, lamb genotype ($p = 0.439$), lamb sex ($p = 0.476$), and ewe lambing parity ($p = 0.863$) did not have a significant impact. Lambs born at Baso site had significantly higher survival rates than those born at Yabello site (OR=3.106; $p < 0.001$). Lambs born as singletons had significantly higher survival rates than those born as twins (OR=1.642; $p < 0.05$). Lambs born during long and short rainy seasons had significantly higher survival rates compared to those born during the dry period (OR=1.352 and 1.811, respectively; $p < 0.05$). Also, lambs born in the years 2014, 2015, 2017, and 2020 had significantly higher likely survival rates compared to those born in the reference year 2021 (OR=3.643, 5.860, 3.018, and 3.316, respectively; $p < 0.05$).

Lamb survival up to 6 months of age was also influenced by several environmental factors, including location, birth season, birth year ($p < 0.001$), parity, and birth weight category ($p < 0.05$). Compared to the reference year (2021), lambs born in Kewet area had a significantly lower likelihood of survival rate (OR=0.578; $p < 0.05$), while lambs born in the 1st parity had a significantly higher survival rate (OR=1.935; $p < 0.05$). The influence of the year of birth on lambs' survival to the age of 6 months was evident. Lambs born in the years 2014 and 2018 had significantly higher survival rates compared to those born in the year 2021 (OR=2.387 and 3.224, respectively; $p < 0.05$). Conversely, lambs born in the year 2018 had a significantly lower chance of survival compared to the reference year 2021 (OR=0.335; $p < 0.05$). Lambs born with

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lightweight category had a significantly lower chance of survival compared to lambs born with heavy weight category at birth (OR=0.649; $p < 0.05$).

Survival of lambs to yearling age was impacted by several environmental factors, including location ($p = 0.003$), birth season, birth year ($p < 0.0001$), and lamb body weight category ($p = 0.018$). Lambs born in Kewet area had a significantly lower likelihood of survival rate compared to lambs born in the Yabello area (OR=0.637; $p < 0.05$). Lambs born in the long rainy and short rainy seasons had significantly higher likelihood of survival rates compared to those born in the dry period (OR=1.321 and 1.521, respectively; $p < 0.05$). Lambs born in the years 2013, 2015, 2016, 2017, 2018, and 2020 had a significantly higher risk of mortality compared to those born in the year 2021 (OR=0.263, 0.295, 0.227, 0.128, 0.076, and 0.270, respectively; $p < 0.05$), indicating high risk of morality by 74, 71, 77, 87, 92, and 73% than lambs born in the year 2021. Lambs with light birth weight category (<=2kg) had significantly lower survival rates compared to those born in the heavy weight category (>3kg). (OR=0.636; $p < 0.05$). Lamb genotype, lamb sex, birth type, and parity of birth did not have a significant impact on lamb mortality at the age of yearling.

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Table 52. Lambs' survival at 3, 6 and 12 months of age, under village management system.

Effect	#	Survival to 3 months			Survival to 6 months			Survival to 12 months		
		OR	95% CI	% survival	OR	95% CI	% survival	OR	95% CI	% survival
Lamb genotype	4097	p =0.4390		93.1	p =0.2310		87.2	p =0.6770		80.1
D x L (low grade) vs Local	1941	1.145	0.749-1.751	93.0	0.912	0.651-1.277	88.0	1.015	0.768-1.341	81.8
D x L (high grade) vs Local	1173	0.903	0.588-1.387	94.1	0.772	0.565-1.054	86.9	0.917	0.710-1.184	80.0
Local	952	1.00		93.4	1.00		86.8	1.00		76.6
Location		p =0.0001			p =0.0001			p =0.0030		
Basso vs Yabello	1812	3.106***	1.603-6.016	95.7	1.325	0.748-2.345	89.1	1.017	0.638-1.623	80.4
Efrata vs Yabello	230	1.588	0.753-3.349	94.3	0.787	0.426-1.457	88.3	1.179	0.685-2.027	87.4
Kewet vs Yabello	711	1.236	0.702-2.174	91.7	0.578**	0.350-0.954	80.5	0.637**	0.423-0.958	75.4
Kobo vs Yabello	467	1.208	0.651-2.243	90.3	1.102	0.630-1.929	85.9	0.920	0.580-1.459	79.2
Merabete vs Yabello	475	1.471	0.761-2.844	90.7	1.490	0.829-2.677	88.4	0.973	0.606-1.562	77.5
Yabello	371	1.00		92.5	1.00		92.5	1.00		87.1
Lamb sex		p =0.4760			p =0.8460			p =0.100		
Female vs Male	2039	1.094	0.854-1.402	93.9	1.019	0.842-1.223	87.7	1.144	0.975-1.342	81.1
Male	2027	1.00		92.9	1.00		87.1	1.00		79.0
Birth type		p =0.0160			p =0.0960			p =0.0780		
Single vs Twin	3714	1.642**	1.095-2.461	93.6	1.317	0.952-1822	87.6	1.278	0.973-1.678	80.4
Twin	352	1.00		91.1	1.00		85.1	1.00		76.1
Ewe parity		p =0.8630			p =0.0540			p =0.2470		
Parity 1 vs Parity5+	2558	1.357	0.669-2.751	94.2	1.935*	1.160-3.229	89.7	1.440	0.891-2.327	82.2
Parity 2 vs Parity5+	921	1.250	0.610-2.560	92.8	1.597	0.949-2.689	85.5	1.283	0.787-2.090	78.4
Parity 3 vs Parity5+	353	1.128	0.529-2.404	90.8	1.415	0.813-2.463	82.1	1.122	0.669-1.882	74.2
Parity 4 vs Parity5+	143	1311	0.548-3.137	91.5	1.680	0.880-3.207	83.1	1.502	0.822-2.742	77.0
Parity 5+	91	1.00		88.8	1.00		70.3	1.00		64.8
Birth season		p <0001			p =0.2050			p <0001		
Long- rain vs Dry- period	1330	1.352*	1.1011-1.808	93.8	1.191	0.948-1.497	87.7	1.321***	1.093-1.597	81.2
Short- rain vs Dry- rain	1115	1.811***	1.303-2.516	95.7	1.199	0.943-1.525	87.9	1.521***	1.240-1.866	82.2
Dry- period	1621	1.00		91.6	1.00		86.9	1.00		77.6
Birth year		p =0.0001			p <0.0001			p <0.0001		
2012 vs 2021	28	3.615	0.651-20.071	92.9	1.521	0.285-8.126	92.9	0.253	0.058-1.092	85.7
2013 vs 2021	166	3.643*	1.320-10.053	92.8	1.574	0.622-3.979	91.6	0.263*	0.093-0.740	83.1
2014 vs 2021	438	5.860***	2.332-14.723	96.3	2.387*	1.045-5.451	94.5	0.420	0.157-1.121	89.7
2015 vs 2021	703	3.018**	1.368-6.660	93.4	1.158	0.556-2.414	89.9	0.295*	0.115-0.756	85.1
2016 vs 2021	1077	1.951	0.920-4.139	91.6	0.824	0.405-1.676	87.7	0.227**	0.090-0.576	81.7
2017 vs 2021	979	2.674*	1.245-5.744	93.6	0.509	0.252-1.029	81.2	0.128***	0.051-0.323	71.2
2018 vs 2021	248	1.229	0.546-2.767	87.1	0.335***	0.160-0.701	71.8	0.076***	0.029-0.197	59.7
2019 vs 2021	41	3.109	0.633-15.276	95.1	1.059	0.308-3.637	90.2	0.389	0.105-1.433	87.8
2020 vs 2021	274	3.316*	1.262-8.713	99.6	3.224*	0.233-8.428	97.1	0.270*	0.103-0.706	85.4
2021	112	1.00		91.1	1.00		91.1	1.00		95.5
BWT-Category		p =0.017			p =0.0580			p =0.0180		
Light vs Heavy	481	0.544*	0.342-0.864	90.8	0.649*	0.444-0.947	84.9	0.636**	0.464-0.870	73.8
Medium vs Heavy	1934	0.951	0.689-1.314	94.8	0.888	0.694-1.134	88.4	0.852	0.691-1.050	80.5
Heavy	1651	1.00		92.5	1.00		87.0	1.00		81.4

OR, odd ratio; CI, confidence interval, BWT-Category, Lamb birth weight category; <=2kg= Light, >2=3= medium, >3kg = Heavy,

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4.10.2. Survival of lambs under on-station management condition

Our study investigated the survival ability of different sheep breeds at 3 and 6 months of age under on-station management. The study evaluated the Dorper purebred and local sheep breeds along with their different levels of crossbreeds. The study found that the overall 3 and 6 months of age survival of lambs were 83% and 77%, respectively. The study revealed that the 3 and 6 months of age survival rate for Dorper purebred, local, 25%-Dorper cross, 50%-Dorper cross-F_1, 50%-Dorper-*inter se* mated and 75%-Dorper cross was 81.5% and 78.5%, 84.0% and 77.1%, 89.7% and 87.1%, 82.9% and 78.5%, 79.5% and 74.6%, 83.9% and 77.3%, respectively (Table 53).

The study showed that lamb survival at 3 and 6 months of age was greatly influenced by both genotype (Sire, Dam, Lamb) and several environmental factors. Pre-weaning lamb survival was impacted by genotype (sire, $p = 0.031$, dam, $p = 0.058$, lamb, $p = 0.001$), environmental factors such as birth year, birth season, birth litter size, lamb birth weight category ($p < 0.001$), among others. The study confirmed that lambs with less than 50% Dorper inheritance had a 3.876 times likely higher survival ability compared to the reference local lambs. Interestingly, the pre-weaning performance of Dorper purebred and other different levels of Dorper inheritances were recorded to have comparable pre-weaning survival rate when compared to the local lambs. Sire breed effect on the pre-weaning lamb survival was detected to be significant, accordingly, lambs born to Dorper crossbred sires had a 0.327 times likely lower risk of pre-weaning survival compared to the lambs born to local sires, whereas lambs born to Dorper purebred sires had similar survival ability compared to the lambs born to the local sires. The influence of dam breed on pre-weaning lamb survival was also noticed, accordingly, lambs born to Dorper crossbred and Dorper purebred dams had a 0.776 and 0.556 times likely low pre-weaning survival rate compared to lambs born to local ewes, respectively, which indicates a risk of 22% and 44% pre-weaning mortality, respectively.

Lamb pre-weaning survival was influenced by litter size and lamb birth weight category. Single-born lambs had a 2.36 times survival advantage over the lambs born as triple. Whereas lambs born as twins had similar survival rates compared to the triple born ones. On the other hand, lambs with light and medium birth weight had a 0.312 and 0.652 times less likely survival ability

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compared to lambs born with heavy weight category, signifying a survival risk of 69% and 35%, respectively, compared with the lambs born in heavy weight category. The influence of birth season of lamb's birth on pre-weaning lamb survival was confirmed, lambs born in the long rainy season had a 1.71 times likely survival ability compared to those lambs born in the dry period. The impact of year of birth on lamb pre-weaning survival was quite evidenced, and lambs born in between 2006 and 2020 had better surviving ability compared to the reference year 2022, while lambs born in 2021 had similar surviving ability with lambs born in 2022 (75.1% vs 74.2%). Notably, it was observed that lambs born in the cool-tepid and low-mid-to-highland areas had similar pre-weaning lamb survival, indicating the lesser impact of location difference on lamb pre-weaning survival under current study. It was noted that no effect of some environmental factors such as lamb sex and dam parity on lamb pre-weaning survival of lambs.

The study also assessed lamb survival at 6 months of age. Accordingly, it was learned that all factors (genetic and environmental) considered in this study influenced the lamb's survival at 6 months of age. Lamb survival at the age of 6 months was significantly ($p = 0.009$) affected by sire breed. Lambs born to Dorper crossbred sires had a 0.265 times likely less survival ability compared to the lambs born to the local sire breed group, indicating a 74% risk of survival at 6 months of age compared to those lambs born to the local sire breed. In similar fashion, those lambs born to Dorper crossbred dams had a 0.606 times less likely survival ability compared to lambs born to local dam breed, with a risk level of 35% compared to lambs born to local dam bred. Most lamb breeds had similar survival ability at 6 months of age, but lambs with less than 50% Dorper inheritance had a 5.051 times higher likely survival advantage over the local lambs breed (87% vs 77%, respectively).

The results also confirmed the influence of several environmental factors to affect the lamb's survival rate at 6 months of age. Lambs born in the cool-tepid area had a 0.828 times less likely survival ability compared to lambs born in the low-mid-to-highland areas. Lambs born in 2006, 2007 had higher survival rates compared to those lambs born in the year 2022. Similarly, lambs born in 2011, 2014, 2016, and 2020 had moderately higher survival rate records compared to the reference year 2022. However, lambs born in the years 2013, 2017, 2018, and 2021 had comparatively lower survival rates compared to the other years but were comparable to the reference year 2022 at the age of 6 months. Female lambs had moderately higher at (1.138 times)

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likely survival rate advantages over male lambs at the age of 6 months. On the other hand, single-born lambs had a (OR: 2.042) times higher advantage of survival compared to lambs born as triple at the age of 6 months. The study also observed that lambs born to parity two had a 1.301 times likely advantage in survival over parity 6 and above at the age of 6 months. The influence of birth weight on lambs survival also goes to 6 months of age, accordingly, lambs born with light and medium birth weight category had a (OR: 0.363 and 0.645 times less likely surviving ability over the lambs born to the heavy birth weight category, signifying a risk of 64% and 36%, respectively, compared to the lambs born with heavy birth weight category.

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Table 53. Lambs' survival estimation at 3and 6 months of age, under on-station management.

		Survival to 3 months			Survival to 6 months		
Effect	**#**	**OR**	**95% CI**	**%-Survival**	**OR**	**95% CI**	**%-Survival**
Location		p =0.182		82.8	p =0.013		77.3
Cool-tepid vs low-mid-to-highland	6361	0.893	0.757-1.054	81.2	0.828**	0.713-0.961	75.6
Low-mid-to-highland	3009	1.00		0.863	1.00		81.1
Birth Year		p <0.001			p <0.001		
2006 vs 2022	46	20.05 ***	2.669-150.56	97.7	21.460***	2.877-160.05	97.7
2007 vs 2022	38	7.092***	1.614-31.170	92.1	5.458***	1.591-18.722	92.1
2008 vs 2022	65	7.209***	2.697-19.267	92.3	3.748**	1.720-8.169	86.2
2009 vs 2022	374	4.252***	2.677-6.768	91.2	2.301**	1.555-3.485	84.8
2010 vs 2022	488	5.210***	3.396-7.994	92.0	3.101**	2.144-4.485	87.5
2011 vs 2022	428	2.948***	1.999-4.346	87.4	1.549*	1.108-2.165	78.3
2012 vs 2022	658	3.154***	2.230-4.459	87.8	2.233**	1.630-3.059	83.7
2013 vs 2022	723	1.893***	1.390-2.577	81.6	0.979	0.742-1.292	69.3
2014 vs 2022	544	1.895***	1.368-2.626	80.1	1.416*	1.046-1.916	74.6
2015 vs 2022	617	2.673***	1.913-3.734	872	2.195**	1.615-2.985	83.6
2016 vs 2022	1292	1.910***	1.445-2.526	84.1	1.443*	1.114-1.870	78.9
2017 vs 2022	772	1.359*	1.012-1.826	77.5	1.073	0.814-1.414	72.3
2018 vs 2022	848	1.390**	1.048-1.844	79.2	1.135	0.873-1.477	73.1
2019 vs 2022	636	1.529**	1.130-2.068	81.9	1.441*	1.086-1.911	78.0
2020 vs 2022	685	1.728***	1.270-2.353	82.9	1.621*	1.214-2.164	79.9
2021 vs 2022	672	1.012	0.762-1.343	75.1	0.999	0.764-1.306	71.6
2022	484	1.00		74.2	1.00		69.4
Birth Season		p <0.001			p =0.001		
Short- rain vs Dry- period	2488	1.146	0.993-1.321	81.0	1.133	0.994-1.291	76.1
Long- rain vs Dry- period	2859	1.710 ***	1.457-2.007	86.2	1.303***	1.134-1.497	79.2
Dry- period	4023	1.00		81.5	1.00		76.8
Lamb Genotype		p =0.001			p <0.001		
25%-Dorper cross vs Local	155	3.876**	0.845-17.781	89.7	5.051*	1.144-22.306	87.1
75%-Dorper cross vs Local	840	1.761	0.357-8.682	83.9	1.338	0.284-6.312	77.3

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Table 53 *Continued*

50%-Dorper cross-F_1 vs Local	3784	0.928	0.193-4.455	82.9	0.929	0.201-4.291	78.5
Purebred Dorper vs Local	1587	0.816	0.123-5.404	81.5	0.476	0.077-2.933	75.6
50%-Dorper cross-*inter se* vs Local	891	3.820	0.767-19.037	79.5	4.301	0.908-20.381	74.6
Local	2113	1.00		84.0	1.00		77.1
Sire Breed		p =0.031			p =0.009		
Dorper cross vs Local	1085	0.327*	0.069-1.542	79.7	0.265*	0.059-1.203	74.6
Dorper purebred vs Local	6143	0.709	0.149-3.380	82.8	0.783	0.170-3.594	77.8
Local	2142	1.00		84.2	1.00		77.4
Dam Breed		p =0.058			p =0.030		
Dorper cross vs Local	1609	0.776*	1.064-2.823	80.5	0.606*	0.398-0.924	74.7
Dorper purebred vs Local	1482	0.556*	0.341-0.907	81.3	1.281	0.448-3.661	75.5
Local	6279	1.00		83.7	1.00		78.5
Lamb Sex		p =0.073			p =0.012		
Female vs Male	4705	1.107	0.990-1.238	82.8	1.138*	1.029-1.258	77.8
Male	4665	1.00		82.7	1.00		76.9
Birth Litter Size		p <0.001			p <0.0001		
Single vs Triple	8158	2.360**	1.288-4.325	83.8	2.042**	1.138-3.664	0.785
Twin vs Triple	1158	1.689	0.914-3.121	76.3	1.492	0.825-2.699	0.701
Triple	54	1.00		66.7	1.00		0.630
Parity		p =0.063			p =0.033		
One vs 06-above	4746	1.170	0.843-1.625	82.0	1.046	0.765-1.431	76.4
Two vs 06-above	2158	1.382	0.988-1.935	84.6	1.301*	0.944-1.791	80.1
Three vs 06-above	1219	1.379	0.972-1.956	83.9	1.213	0.872-1.689	78.5
Four vs 06-above	678	1.464	1.007-2.128	84.1	1.085	0.766-1.535	76.3
Five vs 06-above	339	1.337	0.882-2.026	80.8	1.122	0.761-1.656	75.5
Parity 06-above	230	1.00		74.2	1.00		71.2
LBW Category		p <0.0001			p <0.0001		
Light vs Heavy	3043	0.312 **	0.264-0.368	75.7	0.363***	0.313-0.421	69.6
Medium vs Heavy	3088	0.652 **	0.558-0.761	84.5	0.645 ***	0.562-0.739	78.7
Heavy	3239	1.00		87.8	1.00		83.4

*Values within each sub-class are significantly different at *=p <0.05, ** p<0.01, *** = p<0.0001*

LBW-Category, Light=<=2.5kg, Medium=2.6-3.39, Heavy=>=3.4, OR= Odds ratio, #= number, CI= Confidence interval.

Low-mid-to-highland was the reference location.

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4.11. Dorper crossbreeding system in Ethiopia

4.11.1. Dorper crossbreeding strategy and program in Ethiopia

4.11.1.1. Crossbreeding scheme

The Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP), as depicted in Appendix-Figure 1 developed the Dorper crossbreeding strategy and program in Ethiopia. This study has revealed that, in contrast to previous crossbreeding programs in Ethiopia, the Dorper program has implemented a well-defined strategy encompassing importation, evaluation, multiplication, maintenance, and distribution throughout the country. As part of this strategy, the nucleus centers located at Worer and Fafen research facilities, which have recently been joined by the Areka and Debre-birhan agricultural research centers have played a pivotal role as sources of purebred Dorper sheep for breeding purposes, as well as for evaluation and distribution to the BED center and affluent farmers across Ethiopia.

The study also noted a significant level of interest arising from the regional Ministry of Agriculture (MoA) and the research unit of the Amhara region. A specific project called the 'Dorper/Boer Valley' project was implemented in the northeastern part of Amhara along the main road, spanning from North Shewa to North Wollo. The Amhara region and the Ethiopian Institute of Agricultural Research (EIAR) primarily funded this project. An important lesson learned from this project was the establishment of clear boundaries and strict regulations to control the indiscriminate distribution of exotic rams and ensure the effectiveness of crossbreeding initiatives. Under the ‘Dorper/Boer Valley project’, crossbreeding was carried out on local sheep breeds, such as the Afar sheep, in delineated areas that were not considered purebred due to their history of crossbreeding between highland and lowland sheep. The breeding tract for Afar sheep is located in the Afar areas, where the introduction of Dorper crossbreeding did not dilute the indigenous Afar sheep population in their native habitat.

The main objective of the 'Dorper/Boer Valley' project in the Amhara region was to establish nucleus flocks that would facilitate the sustainable utilization of resources. It was observed that, in addition to targeted conservation-based breeding and production strategies, community-based programs needed to be designed and implemented to address the needs of resource-poor farmers. This approach aimed to ensure the sustainable utilization of resources, alleviate food insecurity,

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and improve overall livelihoods of farmers. In contrast to the localized 'Dorper/Boer Valley' project, the ESGPIP project has a much broader scope, encompassing a vast range of areas throughout Ethiopia, including pastoral settings where the Community-Based Breeding Practice (CBBP) was not implemented. The ESGPIP project extends its reach to various regions and geographical contexts across the country, aiming to address the diverse needs and challenges of the Ethiopian livestock sector. The breeding schemes developed by the ESGPIP, followed by the 'Dorper/Boer Valley' project, involved the utilization of the Worer and Fafen research centers as nucleus sites for the ESGPIP, and the Debre-Birhana research center as the nucleus site for the 'Dorper/Boer Valley' project. Similarly, the Southern Nations, Nationalities, and Peoples (SNNP) region designated the Areka research center for the same purpose.

4.11.1.2. Importation

The importation of purebred Dorper sheep, both male and female, was carried out from the Republic of South Africa, as indicated in Appendix-Figure 1. These purebred Dorper sheep were sourced from different farms in South Africa. Prior to their importation, stringent precautions were taken, including a period of quarantine in South Africa. The first batch of purebred Dorper sheep arrived at the Sebeta quarantine facility in Ethiopia in July 2007, as depicted in Appendix-Figure 2 and 3.

A total of 341 purebred Dorper sheep, consisting of 53 males and 288 females, were imported and subsequently distributed to various research centers in Ethiopia (Table 54). These research centers, namely Worer, Fafen, Debre-Birhan, and Areka, were designated as nucleus sites for the project. The purpose of the distribution was to establish breeding populations of purebred Dorper sheep at these centers, enabling further evaluation and implementation of the crossbreeding program within the country being a source for BED and private farmers.

Yabello, Sirinka, EMDTI, Haromaya University, Hawassa University mainly served as a breed evaluation and distribution centers, however the Areka, Worer, Fafen and Debre-birhan research centers were also engaged on the production, evaluation and distribution of Dorper crossbreeds as a source of germplasm. Recently the involvement of two sheep ranches (Amed-Guya and Debre-birhan) showed the potential of multiplication and distribution of the intended blood

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levels of Dorper sheep. The third tier we noticed under the Dorper crossbreeding program was the villages or production unit where which produced crossbred lambs at farm level.

Table 54. Number of imported Dorper purebred sheep by sex and their destination in Ethiopia

Recipients of imported Dorper sheep within target regions	Imported Dorper sheep by sex		
	Male	Female	Total
Worer research	9	51	60
Fafen research	9	51	60
Debre-Birhan research	20	100	120
Areka research	15	86	101
Total	**53**	**288**	**341**

Source: ESGPIP-2011

4.11.1.3. Purebred Dorper and Dorper crossbred lamb production (on-station)

The research centers such as Worer, Fafen, Debre-Birhan, and Areka, designated as nucleus sites, played multiple roles in the production, evaluation, and distribution of purebred Dorper sheep. These sheep were then distributed to various institutions and entities, as outlined in Table 55. The recipients included the BED sites (Sirinka research, Yabello research, Mekele research, Haromaya University, Hawassa University, EMDTI), the Amed-Guya, Debre-Birhan sheep ranches as well as several private sheep producers.

The BED sites served as multiplication, evaluation, and distribution centers for half-bred Dorper sheep, which were produced through the crossbreeding program. Additionally, two sheep ranches, namely Amed-Guya and Debre-Birhan sheep ranches were utilized as multiplication and distribution sites specifically aimed to distribute to smallholder farmers in the Amhara region.

At the nucleus sites, both purebred Dorper sheep and lambs with varying levels of Dorper inheritance were produced. The production numbers for purebred Dorper sheep were as follows: Debre-Birhan (1047), Werer (296), Fafen (314), EMDTI (19), Hawassa University (6), and Haromaya University (3), respectively.

Between 2007 and 2022, the distribution of lambs born under on-station management conditions can be categorized as follows: purebred Dorper accounted for 24%, lambs with 62.5% and above Dorper blood inherited accounted for 10%, F_1 Dorper crossbred accounted for 51%, Dorper

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crossbred (*inter se* mated: 50%) accounted for 12%, and lambs with 37.5% and below Dorper blood inherited accounted for 2%. These percentages are visually represented in Table 56 and Figure 8.

4.11.1.4. Local and Dorper crossbred lamb production under farmers' condition

The study not only collected data on crossbreeding and the production of crossbred lambs, but also compared it to the local lambs in the study sites. Between 2012 and 2021, a total of 1168, 207, 580, 467, 341, and 371 Dorper crossbred lambs were born under farmers' conditions in the Basona-Werena, Efratana-Gidim, Kewet, Kobo, Merhabete, and Yabello areas, respectively. In contrast, in Basona-Werena, Efratana-Gidim, Kewet, and Merhabete areas, only 694, 23, 131, and 134 local lambs were born, respectively, as indicated in Table 56.

It is worth emphasizing that, the Basona-Werena site had a significantly higher number of Dorper crossbred lambs compared to the other sites. Furthermore, the study revealed a higher proportion of Dorper crossbred lambs born within the study in each study sites when compared to the local lambs. The findings are illustrated in Table 56.

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Table 55. Number of Dorper purebred and Dorper crossbred lambs produced by different stakeholders (under on-station) management

Factors	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Cool-tepid																	
Debere-Birhan RC																	
Pure Dorper	-	-	-	2	17	45	69	194	152	123	69	117	76	56	46	81	**1047**
DxLocal 87.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	**2**
DxLocal 75%	-	-	-	-	-	-	-	-	-	-	1	2	15	2	3	112	**135**
DxLocal 50%F_1	-	-	-	-	22	149	107	52	33	17	58	175	55	56	32	63	**819**
DxLocal 50% *inter se*	-	-	-	-	-	-	-	22	17	96	115	106	110	149	97	1	**713**
DxLocal 25%	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	**4**
Sub-total	-	-	-	*2*	*39*	*194*	*176*	*268*	*202*	*236*	*243*	*402*	*256*	*265*	*178*	*259*	*2720*
Amed Guya Ranch																	
DxLocal 50%F_1	-	-	-	-	-	-	-	-	69	332	71	57	39	78	118	29	**793**
DxLocal 75%	-	-	-	-	-	-	-	-	-	-	40	57	26	41	32	-	**196**
DxLocal 87.5%	-	-	-	-	-	-	-	-	-	-	-	2	7	11	7	1	**28**
DxLocal 93.75%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	**3**
Sub-total	-	-	-	-	-	-	-	-	*69*	*332*	*111*	*116*	*72*	*130*	*160*	*30*	*1020*
Debere-Birhan Ranch																	
DxLocal 87.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	**3**
DxLocal 75%	-	-	-	-	-	-	-	-	-	1	2	9	24	58	55	9	**158**
DxLocal 62.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	**15**
DxLocal 50%F_1	-	-	-	-	-	-	-	-	44	274	147	81	1	-	96	19	**662**
DxLocal 50% *inter se*	-	-	-	-	-	-	-	-	-	-	-	28	-	-	-	10	**38**
Sub-total	-	-	-	-	-	-	-	-	*44*	*275*	*149*	*118*	*25*	*60*	*152*	*53*	*876*
Low-mid to highland																	
Worer RC																	
Pure Dorper	19	16	44	55	71	91	-	-	-	-	-	-	-	-	-	-	**296**
DxLocal 75%	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	4
DxLocal 50%F_1	-	-	59	55	23	53	12	15	14	17	13	15	15	12	11	15	329
DxLocal 25%	-	-	-	-	7	10	7	-	-	-	53	-	-	-	-	-	**77**
Sub-total	*19*	*16*	*104*	*110*	*104*	*154*	*19*	*15*	*14*	*17*	*66*	*15*	*15*	*12*	*11*	*15*	*706*
Yabello RC																	
DxLocal 75%	-	-	-	-	7	1	5	5	-	2	-	-	-	-	-	-	**20**
DxLocal 50%F_1	-	-	-	45	41	45	4	-	-	-	-	-	-	-	-	-	**135**
DxLocal 50% *inter se*	-	-	-	-	-	-	-	-	1	22	-	-	-	-	-	-	**23**
DxLocal 25%	-	-	-	-	1	-	9	34	6	8	-	-	-	-	-	-	58
DxLocal 12.5%	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	**11**
Sub-total	-	-	-	*45*	*49*	*46*	*18*	*39*	*7*	*43*	-	-	-	-	-	-	*247*

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Table 55. *Continued*

Fafen RC																	
Pure Dorper	20	18	47	59	75	95	-	-	-	-	-	-	-	-	-	-	314
DxLocal 75%	-	-	1	4	7	-	-	-	-	-	-	-	-	-	-	-	12
DxLocal 50%-F_1	-	-	50	85	26	-	-	-	-	-	-	-	-	-		--	161
Sub-total	***20***	***18***	***98***	***148***	***108***	***95***	-	-	-	-	-	-	-	-	-	-	***487***
Sirinka RC																	
DxLocal 75%	-	-	-	-	12	20	-	9	8	18	-	-	-	-	-	-	**67**
DxLocal 50%F_1	-	-	72	66	47	30	-	23	47	54	36	2	-	-	-	-	**377**
DxLocal 50% *inter se*	-	-	-	-	-	9	-	1	-	-	16	28	-	-	-	-	**54**
DxLocal 25%	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	**2**
Sub-total	-	-	***72***	***66***	***59***	***61***	-	***33***	***55***	***72***	***52***	***30***	-	-	-	-	***500***
Haromaya University																	
Pure Dorper	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	**3**
DxLocal 75%	-	-	-	5	-	1	-	-	-	-	-	-	-	-	-	-	6
DxLocal 50%F_1	-	-	82	2	2	11	-	-	-	47	61	19	12	-	7	5	**248**
Sub-total	-	-	***82***	***7***	***2***	***12***	-	-	-	***47***	***62***	***21***	***12***	-	-	***7***	***257***
Hawasa University																	
Pure Dorper	-	-	-	-	4	2	-	-	-	-	-	-	-	-	-	-	**6**
DxLocal 75%	-	-	-	-	17	26	12	-	-	-	-	-	-	-	-	-	**55**
DxLocal 62.5%	-	-	-	17	-	-	-	6	-	-	-	-	-	-	-	-	**23**
Sub-total	-	-	-	***17***	***21***	***28***	***12***	***6***	-	-	-	-	-	-	-	-	***84***
EMIDI																	
Pure Dorper	-	-	-	-	-	-	-	-	5	6	8	-	-	-	-	-	**19**
DxLocal 50%F_1	-	-	-	-	-	-	-	-	4	5	7	6	6	5	4	3	40
Sub-total	-	-	-	-	-	-	-	-	***9***	***11***	***15***	***6***	***6***	***5***	***4***	***3***	***59***
Total (over all)	**39**	**34**	**356**	**395**	**382**	**590**	**225**	**361**	**400**	**1033**	**698**	**708**	**386**	**472**	**512**	**365**	**6956**

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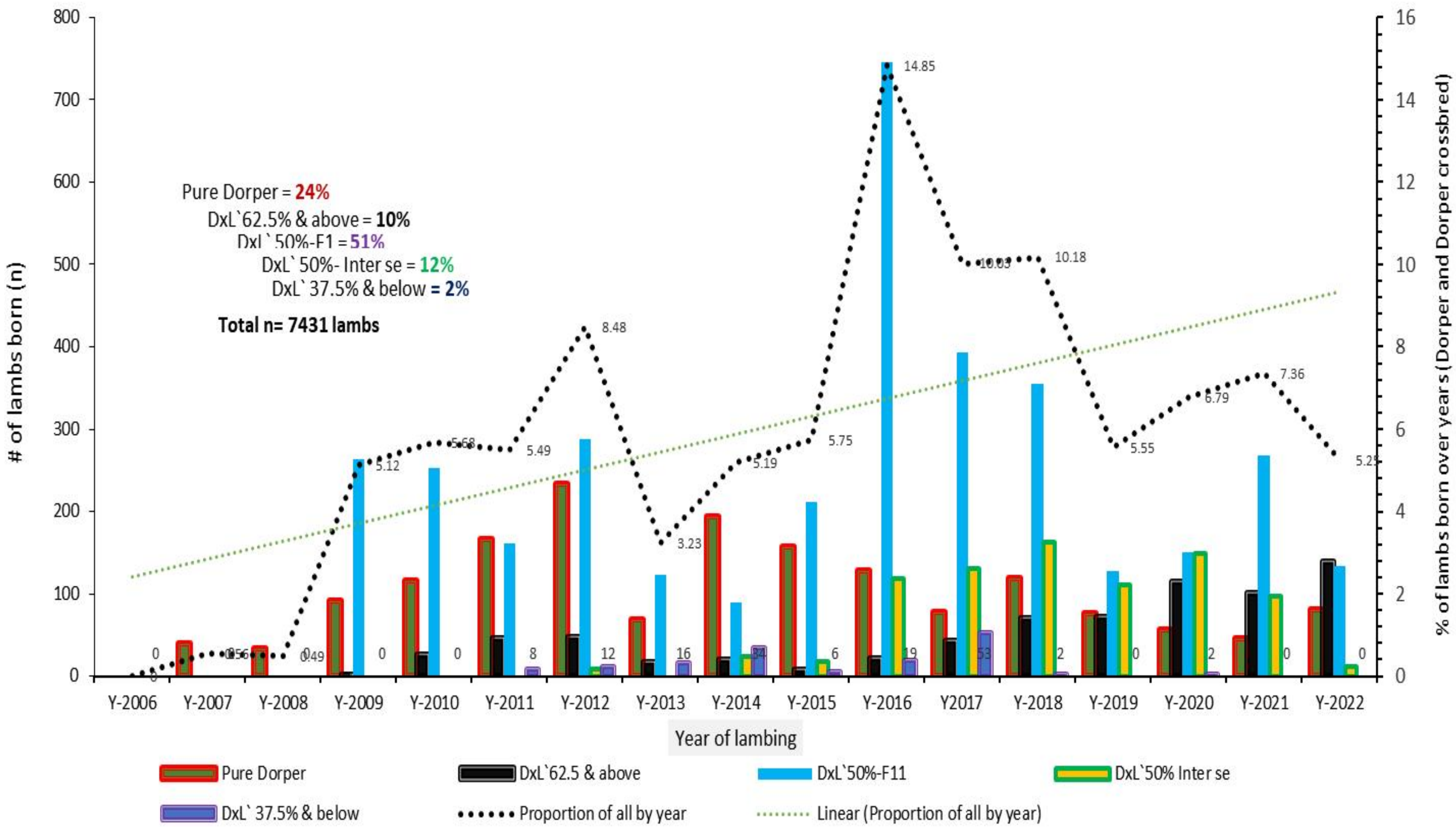

Figure 8. Number and proportion of (purebred Dorper and different levels of Dorper inherited crossbred lambs) **born** under on-station management (over all)

Table 56. Number of Dorper crossbred and their contemporary local lambs born under farmers' condition

Factors	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Basona-Werena											
DxLocal>=37.5%	0	1	55	180	262	208	78	13	71	44	912
DxLocal<=25%	0	0	1	2	5	2	2	12	166	66	256
Local	0	0	10	80	256	254	49	8	35	2	694
Sub-total	***0***	***1***	***66***	***262***	***523***	***464***	***129***	***33***	***272***	***112***	***1862***
Efratan-Gidim											
DxLocal>=37.5%	0	1	20	0	6	0	0	0	0	0	27
DxLocal<=25%	0	1	71	48	25	27	8	0	0	0	180
Local	0	2	9	11	1	0	0	0	0	0	23
Sub-total	***0***	***4***	***100***	***59***	***32***	***27***	***8***	***0***	***0***	***0***	***230***
Kewet											
DxLocal>=37.5%	0	0	0	5	18	25	5	0	0	0	53
DxLocal<=25%	0	59	88	97	132	111	40	0	0	0	527
Local	0	2	27	33	45	22	2	0	0	0	131
Sub-total	***0***	***61***	***115***	***135***	***195***	***158***	***47***	***0***	***0***	***0***	***711***
Kobo											
DxLocal>=37.5%	0	0	5	25	40	38	28	4	0	0	140
DxLocal<=25%	0	3	38	77	104	65	35	3	2	0	327
Sub-total	*0*	*3*	*43*	*102*	*144*	*103*	*63*	*7*	*2*	*0*	***467***
Merhabete											
DxLocal>=37.5%	0	0	0	1	29	28	2	1	0	0	61
DxLocal<=25%	0	0	0	21	112	136	11	0	0	0	280
Local	0	0	0	0	63	67	4	0	0	0	134
Sub-total	*0*	*0*	*0*	*22*	*204*	*231*	*17*	*1*	*0*	*0*	***475***
Yabello											
DxLocal<=25%	28	97	114	123	9	0	0	0	0	0	371
Sub-total	*28*	*97*	*114*	*123*	*9*	*0*	*0*	*0*	*0*	*0*	***371***
Total	**28**	**66**	**438**	**703**	**1107**	**983**	**264**	**41**	**274**	**112**	**4116**

4.11.2. Dissemination strategy

4.11.2.1. Production and dissemination of purebred Dorper stock

The strategy for production and distribution of purebred Dorper sheep in Ethiopia is implemented through a specific breeding scheme. This scheme involves disseminating purebred rams and ewes (ewe lambs) to BED centers and private producers. To ensure a reliable source of breeding germplasm, the Werer, Fafen, Debre-Birhan, and Areka research centers were actively involved. These research institutes have contributed a total of 440 purebred Dorper sheep (247

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males and 193 females), which have been distributed for breeding purpose to various stakeholders across Ethiopia, as outlined in Table 57. The study also indicated that 100% of Dorper breed was produced by the research system for distribution to be used for breeding.

Table 57. Source of distributed purebred Dorper and crossbreed sheep to different stakeholders in Ethiopia

Breed	Source of the breed: *Research*	*University*	*Ranch*	*Farmers (CBBP) & private*	Total
Purebred Dorper					
Male	247	0	0	0	247
Female	193	0	0	0	193
Sub-total	*440*	*0*	*0*	*0*	*440*
Crossbred Dorper 75%					
Male	9	7	76	0	92
Female	0	0	4	0	4
Sub-total	*9*	*7*	*80*	*0*	*96*
Crossbred Dorper 50%					
Male	418	8	386	84+125	1021
Female	180	1	9	0+37	227
Sub-total	*598*	*9*	*395*	*246*	*1248*
Male-total	671	15	462	209	1360
Female-total	373	1	13	37	424
Total	**1047**	**16**	**475**	**246**	**1784**

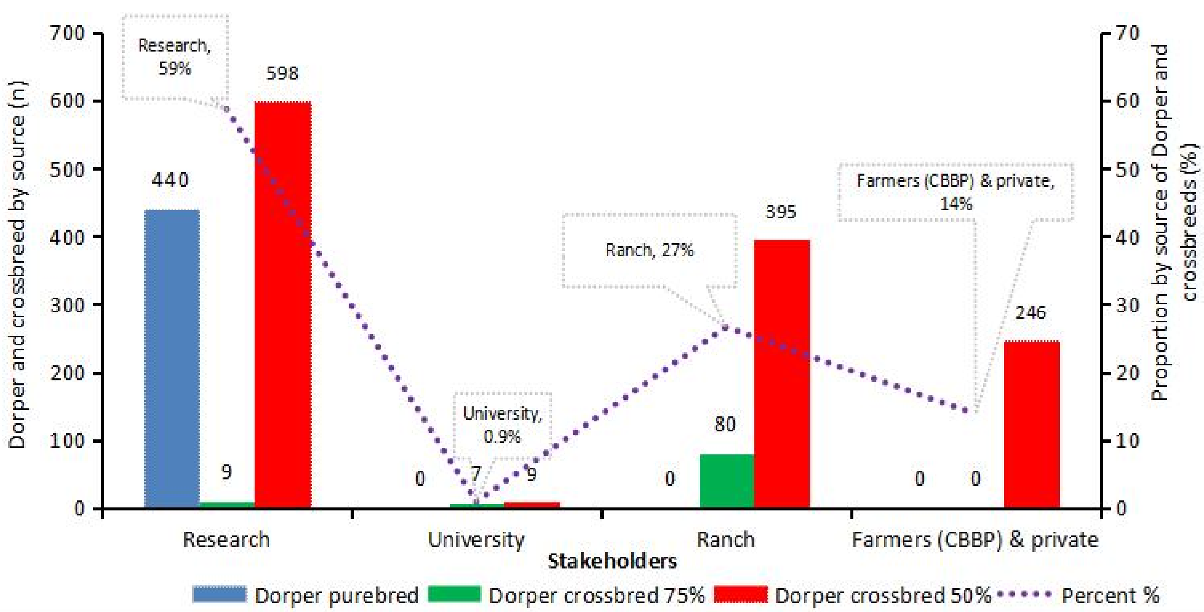

Figure 9. Proportion of Dorper and crossbred sheep produced by different stakeholders and availed for breeding in Ethiopia.

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Figure 9 above reveals the diverse sources contributing to the distribution of purebred Dorper and crossbred Dorper sheep. These sources include research, sheep ranches, farmers (CBBP and Private), and universities, with proportions of 59%, 27%, 5.2%, and 1% respectively, in descending order of contribution. These proportions shed light on the primary role played by the research system in breeding sheep, closely followed by sheep ranches. This indicates that a significant proportion of Dorper breeding sheep is produced for dissemination by these two entities. Notably, sheep ranches emerge as the primary source of high-grade Dorper crossbred rams (`75%-DxLocal) rams. Additionally, the contribution of farmers (CBBP and private) in the production of Dorper crossbred 50 for distribution is commendable and encouraging.

4.11.2.2. Production and dissemination of crossbred Dorper sheep to stakeholders

The production and distribution of Dorper crossbred sheep was guided by a meticulously designed crossbreeding scheme tailored specifically for Dorper sheep, encompassing both purebred and crossbred variations. Within this scheme, various entities, including research institutes, universities, sheep ranches, and farmers, have contributed to the production of sheep for breeding purposes, with different percentages of Dorper inheritance. Notably, the research institute has produced a total of 607 sheep, comprising 75% Dorper inheritance and 50% Dorper inheritance. Universities have contributed 16 sheep with 75% and 50% Dorper inheritance, while sheep ranches have produced 475 sheep with the same inheritance percentages and distributed them. Furthermore, farmers, both from the CBBP and from private sectors, have collectively produced 246 sheep with 50% Dorper inheritance and disseminated as indicated in Table 58.

Regarding the allocation of Dorper crossbred sheep for breeding purposes, the distribution involved multiple entities, including research institutes, universities, private sheep producers, and smallholders. Interestingly, smallholder farmers received the highest proportion of Dorper breeding sheep, accounting for 76% of the overall distribution. Universities received 10%, research institutes received 10%, private farmers received 3%, and sheep ranches received 1%. This distribution pattern contrasts with the actual number of sheep produced for this purpose, as depicted in Figure 10. Furthermore, when examining the destination of purebred Dorper sheep intended for breeding purposes, the breakdown reveals that research institutes received 163

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sheep, universities received 164, sheep ranches received 16, private farmers received 45, and smallholders received 1234 rams, as shown in Table 58 and Figure 10.

Table 58. Destination of disseminated purebred Dorper and crossbred sheep for breeding purpose to different stakeholders in Ethiopia (n, %).

Breed / Type	Recipient stakeholders					
	Research	*University*	*Ranch*	*Private-farmers*	*Small-holders/Pastoralists*	Total
Dorper purebred						
Male	113	41	13	14	67	248
Female	36	87	0	0	69	192
Sub-total	*149*	*128*	*13*	*14*	*136*	*440*
Dorper crossbred 75%						
Male	2	0	0	1	89	92
Female	0	0	0	0	4	4
Sub-total	*2*	*0*	*0*	*1*	*93*	*96*
Dorper crossbred 50%						
Male	11	7	3	26	849	896
Female	1	29	0	4	156	190
Sub-total	*12*	*36*	*3*	*30*	*1005*	*1086*
Male	126	48	16	41	1005	1238
Female	37	116	0	4	229	386
Total	163	164	16	45	1234	1624
% by recipient	10.0	10.1	1.0	2.8	76.1	100

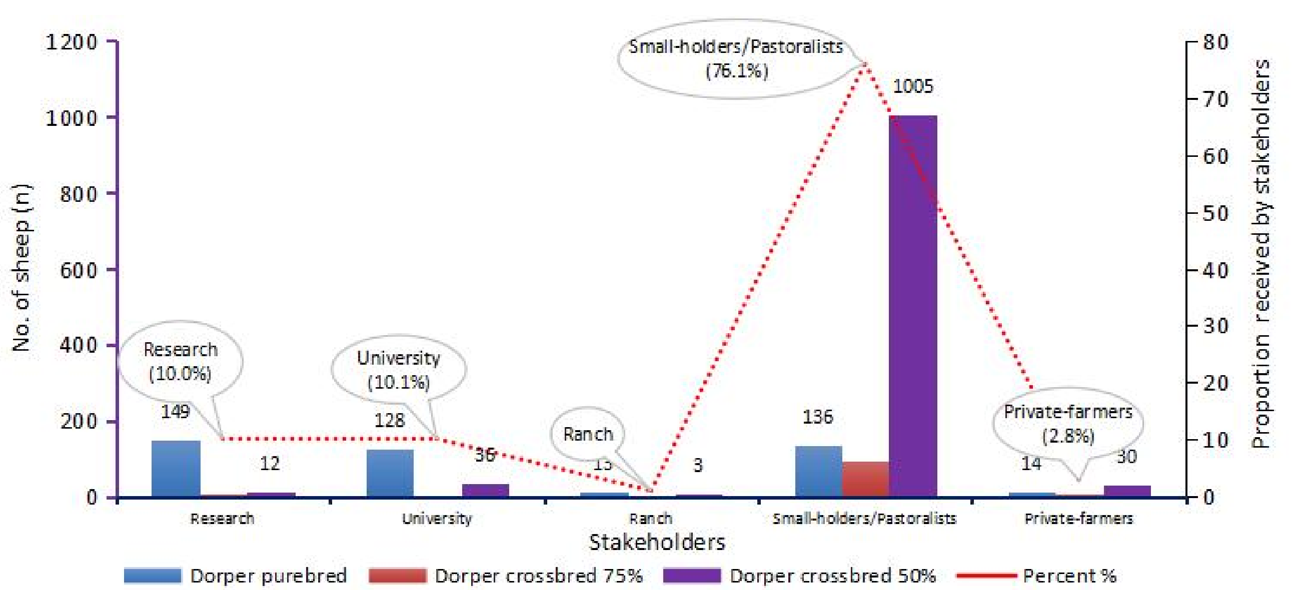

Figure 10. Proportion of Dorper and crossbred sheep received by different stakeholders for breeding purpose in Ethiopia

4.11.2.3. Status of disseminated Dorper crossbred rams to farmers

Based on the survey study conducted on several sites, it was observed that out of the total number of Dorper rams distributed to the farmers, 8% were castrated, 33% died, 36% were currently in service, 8% were slaughtered, and 15% were sold. The percentage of rams currently in service varied from 8% in Damot-Pulassa to 63% in Baso-1. In general, around 36% of households had rams currently in service (Table 59).

Table 59. Status of disseminated Dorper crossbred rams to farmers in the study sites (%).

Attributes	Study sites										
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulasa	Damot-Sore	Over-all (n=(248)	χ^2-Value	*p*-Value
Castrated	4.9	6.7	6.3	3.5	15.2	11.4	7.5	7.7	8.1		
Died	31.7	33.3	37.5	27.6	12.1	57.2	35.0	30.8	33.1		
Slaughtered	0.0	0.0	0.0	0.0	15.2	0.0	22.5	15.4	8.1		
Sold	0.0	0.0	6.3	6.9	24.2	0.0	27.5	35.9	14.5		
Serving	63.4	60.0	50.0	62.1	33.3	31.4	7.5	10.3	36.3	108.61	<.0001

4.11.2.4. Adaptation of disseminated Dorper crossbred rams to farmers

For animals to successfully reproduce, they must adapt to their environment. Farmers were asked to rank rams as not adapted, moderately adapted, or well adapted to their management systems to determine their suitability for crossbreeding purposes. Overall, 73% of the Dorper crossbred rams received crossbred rams were considered to have adapted very well. Farmers observed that rams received from research and development organizations were well adapted to their environments. Although there were significant differences among the study sites (χ^2=47.92 and p < 0.0001, Table 60), most farmers rated that Dorper rams adapted very well (Damot-Pulassa, 58%; Kewet, 75%; Baso-2, 80%; Merhabete, 83%; Minjar-Shenkora, 85%; Kobo, 86%; and Baso-1 88%). Additionally, 24% of the rams received were moderately adapted, and less than 4% did not adapt to farmers' management. These results were promising being using Dorper sheep as an improved breed for crossbreeding with due potential of improving the productivity of local sheep.

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Table 60. Adaptation of distributed Dorper crossbred rams in the study sites (%).

	Study sites										
Attributes	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulasa	Damot-Sore	Over-all (n=248)	χ^2-Value	*p*-Value
Not adapted	0.0	0.0	0.0	0.0	0.0	2.9	12.5	7.7	3.6		
Moderately adapted	12.2	20.0	25.0	17.2	15.2	11.4	30.0	53.9	23.8	47.92	<.0001
Well adapted	87.8	80.0	75.0	82.8	84.8	85.7	57.5	38.4	72.6		

4.11.2.5. Number of Dorper crossbred lambs born within the flock and in the neighbors' flock

Farmers were surveyed to determine their ability to recall the number of Dorper crossbred lambs born to their own flock and neighboring flocks. On average, farmers reported that 12 and 46 Dorper crossbred lambs were born within their own flock and neighboring flock, respectively. The average number of Dorper crossbred lambs born within their own flock ranged from 4 at Minjar-Shenkora to 20 at Baso-1. The study found significant (p = 0.0024) differences in the number of Dorper crossbred lambs among the study sites. Moreover, farmers were also asked about the number of Dorper crossbred lambs within their neighboring households (4-5 households). The farmers reported that an average of 46 lambs were born within their neighbors' flocks. There was a significant (p = 0.0107) difference in the number of Dorper crossbred lambs born among the flocks of neighbors in different sites, with lower numbers (12 Dorper crossbred lambs) observed in Minjar-Shenkora and higher numbers (83 Dorper crossbred lambs) observed in Merhabete site (Table 61).

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Table 61. LSM±SE for estimated number of Dorper crossbred lambs born within the flock and neighboring flock (farmers recall basis estimate)

Attributes	Study sites						
	Baso-1 (n=41)	Baso-2 (n=15)	Kewet N=(16)	Merhabete (n=29)	Minjar-Shenkora (n=33)	Over-all (n=134)	*p*-value
Dorper crossbred lambs born within the flock	20.17±2.84[a]	5.40±4.69[b]	12.63±4.54[a]	13.41±3.37[a]	3.61±3.16[b]	12.07±1.70	0.0024
Dorper crossbred lambs born within neighbors	70.20±15.19[ab]	13.20±25.11[ab]	20.19±24.31[ab]	83.14±18.06[ab]	11.70±16.93[b]	46.24±9.09	0.0107

4.11.2.6. Body weight, body condition and body measurements of local and Dorper crossbred lambs under farmers' condition

The overall measurements for body weight (BWT), body condition score (BC), height at wither (HW), chest girth (CG), body length (BL), and rump width (RW) were 16.9 kg, 3.0, 58.1 cm, 63.3 cm, 53.7 cm, and 19.6 cm, respectively (Table 62). We found that lambs born at Baso-2, Merhabete, and Minjar had better BWT compared to those born at Baso-1 and Kewet sites, while relatively lower BWT was recorded at Baso-1 and Kewet sites. The BC of lambs at Baso-1 was lower compared to other sites, and lambs born at Minjar had better HW compared to other sites. The study also observed that the BL and RW of lambs born at Merhabete site had lower values than other study sites. The genotype of the lambs significantly contributed to the differences in all traits considered. We noted that local lambs exhibited lower values for BWT, BC, HW, CG, BL, and RW measurements compared to the Dorper crossbred lambs of the same age. However, the sex of the lamb was not a significant source of variation for all traits considered except HW, where male lambs had higher values than their female contemporaries.

Table 62. LSM±SE for estimated body weight, body condition, and body measurements of Local and Dorper crossbred lambs in the study sites (at the age of 5 months), at the spot measurement.

			Body measurements			
Factors	BWT	BC	HW	CG	BL	CW
Overall	**16.9±0.5 (333)**	**3.0±0.1 (253)**	**58.1+0.5 (189)**	**63.3±0.6 (189)**	**53.7+0.6 (189)**	**19.6+0.2 (189)**
CV	39.7	24.6	8.9	10.9	11.7	12.5
Study sites	$p<0.0001$	$p<0.0001$	$p<0.0001$	p =0.1253	p =0.0062	$p<0.0001$
Baso-1	14.7±0.5^{b} (172)	2.7±0.1^{b} (127)	55.7±0.7^{b} (66)	63.8±0.9 (66)	53.6±0.8^{a} (66)	20.5±0.3^{a} (66)
Baso-2	22.1±1.3^{a} (29)	3.1±0.2^{a} (23)	56.5±1.2^{b} (23)	65.7±1.6 (23)	56.5±1.4^{a} (23)	20.7±0.6^{a} (23)
Kewet	16.9±0.9^{b} (50)	3.6±0.1^{a} (32)	55.5±1.0^{b} (29)	63.1±1.3 (29)	52.7±1.2^{ab} (29)	18.8±0.5b^{c} (29)
Merhabete	22.1±1.1^{a} (40)	3.4±0.1^{a} (36)	55.2±0.9^{b} (36)	62.4±1.3 (36)	51.0±1.1^{b} (36)	17.4±0.4^{c} (36)
Minjar-Shenkora	22.3±1.1^{a} (42)	3.3±0.1^{a} (35)	66.9±0.9^{a} (35)	60.9±1.3 (35)	55.6±1.2^{a} (35)	20.3±0.5^{ab} (35)
Lamb genotype	$p<0.0001$	$p<0.0001$	$p<0.0001$	p =0.0004	p =0.0003	$p<0.0001$
Dorper cross (low-grade)	19.±0.5^{b} (191)	3.5±0.7^{b} (145)	59.9±0.5^{a} (107)	64.5±0.7^{a} (107)	54.7±0.6^{a} (107)	19.9±0.2^{b} (107)
Dorper cross (high-grade)	23.6±1.1^{a} (45)	3.7±0.1^{a} (35)	59.3±1.1^{a} (32)	65.0±1.4^{a} (32)	56.1±1.3^{a} (32)	21.3±0.5^{a} (32)
Local	15.7±0.7^{c} (97)	2.6±0.1^{c} (73)	54.6±0.8^{b} (50)	59.9±1.0^{b} (50)	50.9±0.9^{b} (50)	17.4±0.4^{c} (50)
Lamb sex	p =0.5400	p =0.6590	p =0.0011	p =0.3338	p =0.2416	p =0.1112
Female	19.4±0.6 (177)	3.2±0.1 (136)	56.7±0.6 (103)	62.3±0.8 (103)	53.3±0.7 (103)	19.3±0.3 (103)
Male	19.9±0.7 (156)	3.3±0.1 (117)	59.3±0.6 (86)	63.7±0.9 (86)	54.4±0.8 (86)	19.8±0.3 (86)

DxL-12.5-25% (low-grade), DxL-37.5-43.75% (high-grade), BWT (current body weight), BC (body condition score), HW (height at wither), CG (chest girth), BL (body length), CW (chest width)

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4.11.2.7. Body weight, body condition of ewes, number of lambs born to ewe, estimated prices of local and Dorper crossbred ewes and their body linear measurements

The current study also involved conducting objective assessments on breeding ewes aged between 1-4 years, comprising both local and Dorper crossbred breeds, at various sites. The study revealed that there were significant variations among the sites in several traits such as body weight (BWT), estimated prices of ewes, height at wither (HW), chest girth (CG), body length (BL), and rump width (RW). However, there were no significant differences observed for BC ($p = 0.5324$) and the number of lambs born to each ewe ($p > 0.7497$) (Table 63).

The genotype of the ewes had a considerable influence on BWT, BC, estimated market price of ewes, and body linear measurements of ewes such as HW, CG, BL, and RW. However, the genotype of the ewes had no significant effect on the number of lambs born to either local or Dorper crossbred ewes. Local ewes showed significantly lower values for all the considered traits except for the number of lambs born to ewes. The age of ewes was also a significant source of variation for most of the traits considered, such as BWT, the number of lambs born to ewes, estimated market prices of ewes, HW, CG, and BL. However, the age of ewes didn't affect BC, estimated market prices of ewes, and RW. Ewes that had III and IV permanent incisors (~3-4 years old) had higher values for most of the considered traits compared to those having age I and II permanent incisors (~1-2 years of age).

4.11.2.8. Estimated prices for local and Dorper crossbred lambs under farmers' condition

According to the results of our study, farmers who participated in the Dorper crossbreeding work estimated the current selling prices of their local and Dorper crossbred lambs, the estimates revealed that at the age of six to eight months, nine to eleven months, and yearlings, the prices for local and Dorper crossbred lambs were 1402 vs. 1886 Birr (ETB), 1871 vs. 2459 ETB, and 2516 vs. 3186 ETB, respectively.

The study also found significant ($p < 0.0001$) differences on market prices of local and Dorper crossbred lambs among the study sites for all ages. Additionally, the market estimates showed that Dorper crossbred lambs had better market values than local lambs across all study sites and age groups (Table 64).

Table 63. LSM±SE for estimated body weight, body condition, number of lambs born, estimated price of ewes and body measurements of Local and Dorper crossbred **ewes** in the study sites, at the spot measurement.

Factors	BWT	BC	# of Lambs born	Estimated price	Body measurements			
					HW	CG	BL	RW
Overall	30.3±0.6 (241)	3.1±0.1 (241)	3.0±0.2 (241)	2757.4±81.9 (230)	61.9±0.4 (241)	74.2±0.6 (241)	59.9±0.4 (241)	21.6±0.3 (241)
CV	15.8	25.3	51.7	23.1	5.1	5.9	5.3	9.7
Study sites	p =0.0436	p =0.5324	p =0.7497	p =0.0006	p <.0001	p =0.0003	p =0.0263	p =0.0020
Baso-1	30.9±0.5^{ab} (137)	3.3±0.1 (137)	2.9±0.2 (137)	2742.2±71.2^{ab} (129)	62.0±0.4^{b} (137)	75.1±0.5^{b} (137)	61.0±0.4^{a} (137)	22.5±0.2^{a} (137)
Baso-2	30.2±1.4^{ab} (12)	3.2±0.2 (12)	2.5±0.5 (12)	2433.1±209.6^{b} (10)	59.6±0.9^{b} (12)	72.6±1.3^{b} (12)	59.6±0.9^{ab} (12)	21.6±0.6^{ab} (12)
Kewet	29.2±0.8^{b} (50)	3.1±0.1 (50)	3.1±0.3 (50)	3085.4±99.7^{a} (50)	61.5±0.5^{b} (50)	73.5±0.7^{b} (50)	58.9±0.5^{b} (50)	21.4±0.3^{a} (50)
Merhabete	32.2±0.9^{a} (37)	3.3±0.2 (37)	2.8±0.3 (37)	3067.7±125.5^{a} (36)	61.5±0.6^{b} (37)	74.6±0.7^{b} (37)	59.5±0.6^{ab} (37)	20.4±0.4^{b} (37)
Minjar-Shenkora	33.2±2.3^{a} (5)	3.2±0.4 (5)	2.8±0.8 (5)	2156.2±300.5^{b} (5)	78.5±1.5^{a} (5)	65.9±2.1^{a} (5)	60.5±1.5^{ab} (5)	20.7±0.9^{ab} (5)
Ewe genotype	p <.0001	p <.0001	p =0.3774	p <.0001	p <.0001	p <.0001	p <.0001	p <.0001
Dorper cross (high-grade)	31.9±0.9^{a} 72)	3.3±0.2^{b} (72)	2.8±0.3 (72)	3045.6±133.74^{a} (68)	64.4±0.7^{ab} (72)	73.2±0.9^{a} (72)	60.4±0.7^{a} (72)	22.8±0.4^{a} (72)
Dorper cross (low-grade)	34.7±0.8^{a} (64)	4.0±0.1^{a} (64)	2.7±0.3 (64)	2988.1±102.9^{a} (63)	66.2±0.5^{a} (64)	74.0±0.7^{a} (64)	62.3±0.5^{a} (64)	22.1±0.3^{a} (64)
Local	26.8±0.8^{b} (105)	2.4±0.1^{c} (105)	3.0±0.3 105)	2057.1±103.7^{b} (99)	63.2±0.5^{b} (105)	69.9±0.7^{b} (105)	57.0±0.5^{b} (105)	19.2±0.3^{b} (105)
Dentition	p =0.0014	p =0.0755	p <.0001	p =0.4091	p =0.0298	p =0.0075	p =0.0130	p =0.3259
I & II	30.1±0.7 (94)	3.3±0.1 (94)	1.7±0.2 (94)	2659.9±98.4 (89)	64.1±0.5 (94)	71.6±0.7 (94)	59.4±0.5 (94)	21.2±0.3 (94)
III & IV	32.2±0.7 (147)	3.1±0.1 (147)	3.9±0.2 (147)	2733.9±88.0 (141)	65.1±0.4 (147)	73.2±0.6 (147)	60.5±0.4 (147)	21.5±0.3 9(147)

DxL-12.5-25% (low-grade), DxL-37.5-43.75% (high-grade), BWT (current body weight), BC (body condition score), HW (height at wither), CG (chest girth), BL (body length), CW (chest width)

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Table 64. LSM±SE for estimated market prices by farmers for local and Dorper crossbred lambs in the study sites

Attributes	Study sites									
	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damot-Sore	Over-all	*p*-value
Six to eight months of age										
Dorper crossbred	2025.6±65.8[a] (n=39)	1700.0±109.9[a] (n=14)	2393.8±102.8[a] (n=16)	1982.7±80.6[a] (n=26)	1533.3±71.6[b] (n=33)	2223.2±79.1[a] (n=27)	1598.5±65.0[b] (n=40)	1635.7±109.9[b] (n=14)	1886.6±30.9 (n=209)	<.0001
Local	1419.6±65.8[b] (n=39)	1194.6±109.9[b] (n=14)	1459.7±102.8[b] (n=16)	1275.0±80.6[b] (n=26)	1261.9±71.6[b] (n=33)	1723.7±77.7[b] (n=28)	1455.3±65.0[b] (n=40)	1432.7±65.8[b] (n=39)	1402.8±28.8 (n=235)	
Nine to eleven months of age										
Dorper crossbred	2612.2±78.3[a] (n=39)	2162.5±130.8[a] (n=14)	3181.3±122.3[a] (n=16)	2738.5±95.5[a] (n=26)	2232.6±85.2[b] (n=33)	2723.1±95.9[a] (26)	1948.8±77.4[b] (n=40)	2075.0±130.8[b] (n=14)	2459.23±36.9 (n=208)	<.0001
Local	1828.2±78.3[b] (n=39)	1537.5±30.8[b] (n=14)	2065.6±122.3[b] (n=16)	1903.8±95.5[b] (n=26)	1837.1±85.2[b] (n=33)	2174.1±92.5[b] (n=28)	1805.8+77.4[b] (n=40)	1821.5±78.3[b] (n=39)	1871.7±34.3 (n=235)	
Yearling										
Dorper crossbred	3532.1±100.9[a] (n=39)	2950.0±168.5[b] (n=14)	3812.5±157.6[a] (n=16)	3579.8±123.6[a] (n=26)	3015.2±109.8[b] (n=33)	3310.5±144.6[a] (n=19)	2600.6±99.7[b] (n=40)	2687.5±168.5[b] (n=14)	3186.0+48.4 (n=201)	<.0001
Local	2394.9±100.9[b] (n=39)	2260.7±168.5[b] (n=14)	2778.1±157.6[b] (n=16)	2516.3±123.6[b] (n=26)	2511.4±109.8[b] (n=33)	2575.0+119.1[b] (n=28)	2557.2±99.7[b] (n=40)	2538.8±100.9[b] (n=39)	2516.5±44.2 (n=235)	

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4.11.2.9. Currently available number of Dorper and Dorper crossbred sheep at on-station and farmers' management condition

This study also investigated the availability of Dorper purebred sheep and sheep with varying levels of Dorper inheritance at different on-station centers. The findings revealed that a total of 1175 sheep were assessed, out of which 214 (18%) were classified as Dorper purebred males and females, including lambs, gimmers, and adults above 1 year of age.

The remaining 82% of the sheep consisted of Dorper crossbred individuals with inheritance levels ranging from 25% to 87.5%. Among these crossbred sheep, 66% were males and females classified as 50% Dorper crossbred, including lambs, gimmers, and adults. For a deeper insight, we suggest delving into the details provided in Table 65 and Figure 11; some of the live animals assessed both at on-station and at on-farm were indicated in Appendix-Figure 4.

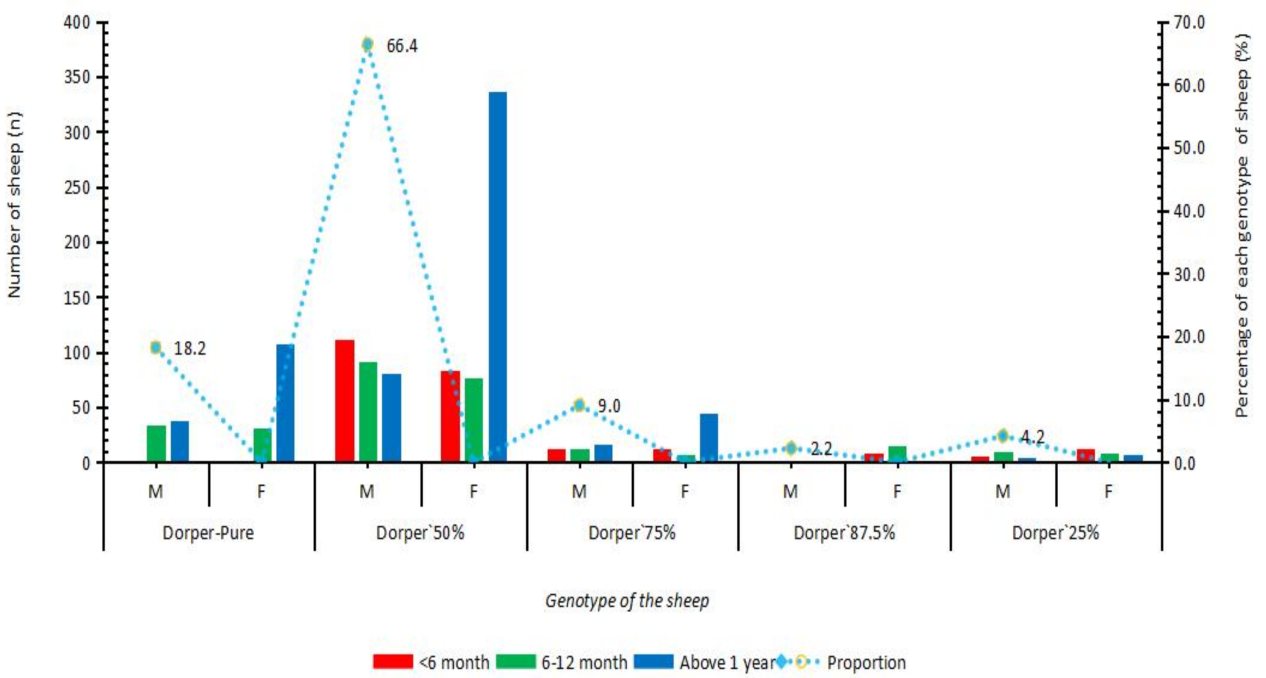

Figure 11. Number and proportion of Dorper and Dorper crossbred sheep currently found under on-station sites.

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Table 65. Number of Dorper purebred and different levels of Dorper inherited sheep currently available on-station (details).

Center	Number by age	Dorper Pure		Dorper 50%		Dorper 75%		Dorper 87.5%		Dorper 25%		Sub-total		Total
		M	F	M	F	M	F	M	F	M	F	M	F	
Debre birhan Research	Lambs less than 6 Months	1	2	51	34	0	0	0	0	0	0	52	36	176
Debre birhan Research	6 months up to yearling	34	11	14	15	0	0	0	0	0	0	48	26	74
Debre birhan Research	Above 1 year	25	108	49	157	1	1	0	0	0	0	75	266	341
Sub-total		***60***	***121***	***114***	***206***	***1***	***1***	***0***	***0***	***0***	***0***	***175***	***328***	***503***
Ranch-Amed-Guya	Lambs less than 6 Months	0	0	7	7	3	2	0	0	0	0	10	9	19
Ranch-Amed-Guya	6 months up to yearling	0	0	17	0	3	1	0	0	0	0	20	1	21
Ranch-Amed-Guya	Above 1 year	2	0	0	29	0	6	0	0	0	0	2	35	37
Sub-total		***2***	***0***	***24***	***36***	***6***	***9***	***0***	***0***	***0***	***0***	***32***	***45***	***77***
Haromay University	Lambs less than 6 Months	0	0	15	14	0	0	0	0	2	2	17	16	33
Haromay University	6 months up to yearling	0	0	10	8	0	0	0	0	1	1	11	9	20
Haromay University	Above 1 year	1	0	2	15	0	0	0	0	1	2	4	17	21
Sub-total		***1***	***0***	***27***	***37***	***0***	***0***	***0***	***0***	***4***	***5***	***32***	***42***	***74***
Worer Research	Lambs less than 6 Months	0	0	8	5	0	0	0	0	0	0	8	5	13
Worer Research	6 months up to yearling	0	0	6	7	0	0	0	0	0	0	6	7	13
Worer Research	Above 1 year	2	0	5	12	0	0	0	0	0	0	7	12	19
Sub-total		***2***	***0***	***19***	***24***	***0***	***0***	***0***	***0***	***0***	***0***	***21***	***24***	***45***
Sirinka Research	Lambs less than 6 Months	0	0	3	1	2	1	0	0	0	0	5	2	7
Sirinka Research	6 months up to yearling	0	0	4	7	10	6	0	0	0	0	14	13	27
Sirinka Research	Above 1 year	3	0	8	15	5	15	0	0	0	0	16	30	46
Sub-total		***3***	***0***	***15***	***23***	***17***	***22***	***0***	***0***	***0***	***0***	***35***	***45***	***80***
Ato Abiy-private farm	Lambs less than 6 Months	0	0	5	4	0	0	0	0	0	0	5	4	9
Ato Abiy-private farm	6 months up to yearling	0	0	15	17	0	0	0	0	0	0	15	17	32
Ato Abiy-private farm	Above 1 year	1	0	6	20	1	0	0	0	0	0	8	20	28
Sub-total		***1***	***0***	***26***	***41***	***1***	***0***	***0***	***0***	***0***	***0***	***28***	***41***	***69***
Dairy and meat institute	Lambs less than 6 Months	0	0	3	1	1	1	1	1	0	1	5	4	9
Dairy and meat institute	6 months up to yearling	0	0	1	2	0	0	2	2	1	0	4	4	8
Dairy and meat institute	Above 1 year	0	0	2	10	0	0	0	0	1	1	3	11	14
Sub-total		***0***	***0***	***6***	***13***	***1***	***1***	***3***	***3***	***2***	***2***	***12***	***19***	***31***

Table 65. *Continued*

Yabello Research	Lambs less than 6 Months	0	0	0	0	0	0	0	0	0	0	0	0	0
Yabello Research	6 months up to yearling	0	0	4	5	0	0	0	0	0	0	4	5	9
Yabello Research	Above 1 year	0	0	0	25	0	0	0	0	0	0	0	25	25
Sub-total		***0***	***0***	***4***	***30***	***0***	***0***	***0***	***0***	***0***	***0***	***4***	***30***	***34***
Ranch-Debre-Birhan	Lambs less than 6 Months	0	0	15	13	6	8	0	0	0	0	21	21	42
Ranch-Debre-Birhan	6 months up to yearling	0	0	6	8	0	0	0	0	0	0	6	8	14
Ranch-Debre-Birhan	Above 1 year	1	0	1	30	8	23	0	0	0	0	10	53	63
Sub-total		***1***	***0***	***22***	***51***	***14***	***31***	***0***	***0***	***0***	***0***	***37***	***82***	***119***
Wolayta Sodo TVET College	Lambs less than 6 Months	0	0	0	0	0	0	0	0	1	2	1	2	3
Wolayta Sodo TVET College	6 months up to yearling	0	0	5	1	0	0	0	0	1	3	6	4	10
Wolayta Sodo TVET College	Above 1 year	0	0	1	7	2	0	0	0	1	1	4	8	10
Sub-total		***0***	***0***	***6***	***8***	***0***	***0***	***0***	***0***	***3***	***6***	***11***	***14***	***23***
Areka Research	Lambs less than 6 Months	0	0	1	1	0	0	0	0	0	0	1	1	2
Areka Research	6 months up to yearling	0	0	1	2	0	0	0	0	0	0	1	2	3
Areka Research	Above 1 year	0	0	2	6	0	0	0	0	0	0	2	6	8
Sub-total		***0***	***0***	***4***	***9***	***0***	***0***	***0***	***0***	***0***	***0***	***4***	***9***	***13***
Fafen Research	Lambs less than 6 Months	0	0	4	3	0	0	0	0	0	0	4	3	7
Fafen Research	6 months up to yearling	0	0	8	5	0	0	0	0	0	0	8	5	13
Fafen Research	Above 1 year	3	0	5	10	0	0	0	0	0	0	8	10	18
Sub-total		***0***	***0***	***4***	***9***	***0***	***0***	***0***	***0***	***0***	***0***	***20***	***18***	***38***
Total-Lambs less than 6 m	Lambs less than 6 Months	1	2	112	83	12	12	1	1	3	5	129	103	232
Total-6 up to 12 m	6 months up to yearling	34	11	91	77	13	7	2	2	3	4	143	101	244
Total-Above 6 m	Above 1 year	38	108	81	336	17	45	0	0	3	4	139	493	630
Total- for all		**73**	**121**	**284**	**496**	**42**	**64**	**3**	**3**	**9**	**13**	**411**	**697**	**1775**
Total-01		**194**		**780**		**106**		**6**		**22**		**1108**		**1175**
Proportion of each blood level			**18.2**		**66.4**		**9.0**		**2.2**		**4.2**			**100.0**

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4.11.2.10. Future demand on crossbreeding using Dorper sheep

In addition to identifying the major constraints in the Dorper breeding task, farmers were also asked to share their opinions regarding the future demand for the crossbreeding work using Dorper sheep. The farmers indicated their interest in the demand for the crossbreeding work using Dorper sheep based on three scales: very high, moderate, and low. The overall index value for very-high, moderate, and low interest was 0.595, 0.242, and 0.163, respectively (Table 66 and Figure 12). However, farmers from Damot-Pulassa reported their interest in the order of low (index value of 0.362), moderate (index value of 0.333), and very high (index value of 0.305), which is contrary to the trend observed in most study sites. Meanwhile, farmers from Damot-Sore showed moderate interest (index value of 0.395), high interest (index value of 0.389), and low interest (index value of 0.216) in the future demand for crossbreeding using Dorper sheep. This information can be useful for policymakers and stakeholders to understand the potential demand for the Dorper crossbreeding program and make informed decisions regarding its implementation.

Table 66. Farmers' opinion and suggestion on the future demand on using Dorper sheep for crossbreeding.

Future demand on Dorper crossbreeding work	Baso-1	Baso-2	Kewet	Merhabete	Minjar-Shenkora	Kobo	Damot-Pulassa	Damt-Sore	Overall (248)
Low	0.000	0.000	0.048	0.000	0.000	0.179	0.362	0.216	0.163
Moderate	0.016	0.000	0.095	0.000	0.106	0.372	0.333	0.395	0.242
Very-high	0.984	1.000	0.857	1.000	0.894	0.449	0.305	0.389	0.595

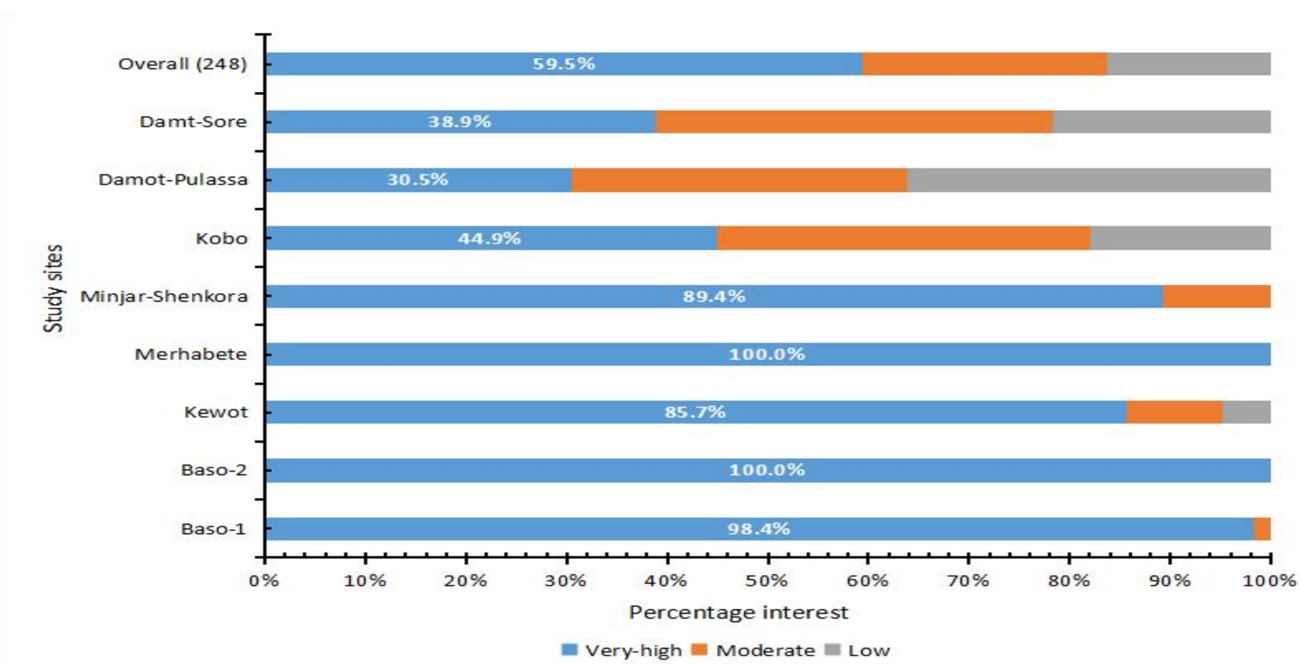

Figure 12. Future demand for crossbreeding using Dorper sheep

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CHATER 5: DISCUSSION

5.1. Socio-economic characteristics of the respondent HHs

Family size and sex of respondents: In terms of family size and sex of respondents, the study found that the overall family size of participating households in the surveyed areas was 5.92±0.12. The highest number of households was recorded in Damot-Pulassa (8) followed by Domot-Sore (6), compared to Baso-2, Kewet, and Minjar-Shenkora, where each had a family size of five. The proportion of male households participating in the survey was higher than the female counterparts (79 vs 21%). Female-headed households who participated in the study at Baso-1 and Kewet areas accounted for 44% of each site, compared to only 9% in the Minjar-Shenkora area.

The average family size observed in this study was 6 members. This suggests that there is likely a fair distribution of labor needed for both crop production and livestock rearing, particularly for the care and management of sheep. The larger family size implies that there are more hands available to assist with the various agricultural and animal husbandry tasks required, which could support the successful integration of the Dorper crossbreeding program within these households.
The overall average family size in this study (5.92) that ranged between 4.7 and 7.6 is lower than recorded at Alaba Special Woreda, which is 6.7 by Tsedeke (2007), and 7.3 and 6.2 reported by Zelalem (2018) for Bonga ram and local ram users in Southern Ethiopia, respectively. However, the overall family size discovered in the current study is slightly higher than reported by Dagne (2021) in the Habru, Minjar-Shenkora, and Raya Kobo districts of North Wollo and Shewa (5.92 vs 5.2), and the 5.6 in Shinile Zone reported by Fekerte (2008), and the national average (4.7) reported by CSA, 2021. The differences in family size may be due to differences in agro-ecology and production systems that could affect the number of households in specific areas, or such variation could be attributed to the differences in the population density in different sites.

Sex and age structure of respondents: In terms of the sex and age structure of respondents, the majority (79%) of interviewed households in the studied sites were male-headed households. Contrary to our findings, Dagne (2021) reported a higher proportion of male (85%) over female respondents in his study, and Deribe (2009) reported 88% male-headed respondents. Compared to the previous scholars' findings, we noticed that a relatively higher proportion (21%) of female-

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headed households participated in the Dorper crossbreeding activity. This finding is particularly significant, as the comparatively high proportion of female-headed households in our study can enhance the success of the Dorper crossbreeding work. It will be crucial to consider female-headed households as an integral part of the training and other program activities, ensuring their active involvement and participation. This suggests the overall engagement and support of the entire family in the Dorper crossbreeding effort, which is a positive indicator for the long-term sustainability and impact of the program.

On the other hand, the low involvement of females in the previous study could be justified due to an overburden of females with domestic work. Interestingly, we noticed a higher proportion (44%) participation in Baso-1 and Kewet areas of our study sites and quite low proportion of female in some of our study sites (3 and 13%) in Minjar-Shenkora and Baso-2 sites, respectively. According to this study result, 36% of the interviewed households fall between the age of 31 and 40, while few (8%) fall under the age above 60 years. Our study findings were in line with the reports of Zelalem (2018) who reported 41% of HHs to fall between the age of 31 and 40 and 9% of the respondents fall in the age of 60 and above.

Marital and education status of respondents: In terms of the marital and education status of respondents, larger proportions (88%) of the interviewed households were married, while smaller proportions (4%) were divorced. There were significant differences among the study sites, where 100% of households interviewed in Baso-2 and Damot-Pulasa areas were married, compared to other sites, where there were more numbers of single (unmarried) households surveyed in the Baso-1 area. Concerning the general educational background of the interviewed households, it was learned that 33% of them are in the primary education level, 26% can read and write, 20% are illiterate, 17% are at the level of secondary school, and 4% are above secondary school. Under this finding, the education status among the study sites was similar.

Our findings of the overall marital status of the respondents (88%) married were lower than the married proportions (100%) reported by Dagne (2021), but the marital status of respondents in some of our study sites (Baso-2 and Damot-Pulassa) is similar to the previous report. This could be attributed to the similar socioeconomic situations in these areas. Regarding the educational background of the study respondents, 53.6% of HHs interviewed are literate (primary school and

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above), which is quite a higher proportion compared to the 34% literates reported by Tsedeke (2007), and comparable with the same status of education reported (48%) by Zelalem (2018) and similar to the reports of Dagne (2021) which was 54.2%. Amazingly, the more than 50% literate HHs found in the current study could have significant contributions to the understanding of sheep crossbreeding and proper utilization of guidance that can come from research and development extension wings, record-keeping, selection and utilization of genetically superior crossbred animals could be applied very well.

5.2. Land holding and use pattern in the study areas

The land holdings and usage patterns of farmers surveyed are presented in Table 7. On average, each household in the study area owns 1.38 hectares of land, out of which 1.08 hectares is dedicated to cropland, 0.04 hectares to fallow land, 0.21 hectares to grazing land, and the remaining 0.09 hectares is used for other purposes like forestation. Notably, the study found that the amount of land owned varied significantly across different sites ($p < 0.05$). Specifically, Baso-1 had the highest landholding compared to other sites, while Baso-2, Kewet, Merhabete, Minjar-Shenkora, Kobo, Damot-Pulassa, and Damot-Gale had relatively similar land holdings ($p > 0.05$). Cropland holdings were similar ($p > 0.05$) between Baso-1 and Minjar-Shenkora but higher than other sites. Fallow and grazing land holdings were also greater at Baso-1 than at other sites. Moreover, Baso-1 and Baso-2 had higher forestland allocations than other sites, with Merhabete and Minjar-Shenkora having the lowest forestland holdings.

The findings in the current study were lower than those reported by Tsedeke (2007), who found 1.7, 0.38, and 0.03 hectares for cropping, grazing, and fallow land, respectively, in Southern Ethiopia. However, the land allocated for vegetation (0.10 hectares) was similar to the current study (0.09 hectares). The study also revealed that the cropland allocation in Baso-1 was comparable to that of the same report (1.68 vs. 1.70 hectares). On the other hand, the proportion of land allocated for grazing in Baso-1 was higher than the proportion allocated for grazing land in the Southern Ethiopia Alaba area (0.50 vs. 0.38 hectares), respectively, indicating the importance of livestock in the area. Similarly, Habtamu et al (2019) in the study made in the Benishagul Gumuz Region reported very high values for total land holding (4.15ha), land use for

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crop production (3.6ha), land use for grazing (0.5ha), respectively indicating the higher land holding and use pattern compared to current report.

The size of the total landholding, particularly assigned for cropland, grazing land, and fallow land, significantly contributes to the amount of feed resources available either as grazing or by-products of cropping and depicts the number of animals to herd by farmers. The larger size allocated for crop production, fallow, and grazing land in Baso-1 area indicates the capacity of the area and its suitability for animal production, particularly for sheep crossbreeding purposes. The study also revealed that farmers in the study area engage in various activities for food security.

5.3. Livestock holding and species composition in the study sites

The study found that the overall average livestock holding for cattle, sheep, goat, donkeys, horses, mules, camels, and chicken ranged from 0.9 to 6.9, with a mean of 4.04 for cattle, 2.7 to 16.2 with a mean of 8.47 for sheep, 0.20 to 1.4 with a mean of 0.5 for goats, 0.01 to 2.56 with a mean of 0.82 for donkeys, 0.00 to 1.39 with a mean of 0.27 for horses, 0.00 to 0.09 with a mean of 0.02 for mules, 0.00 to 0.77 with a mean of 0.06 for camels, and 2 to 9.6 with a mean of 4.64 for chickens. The study also found that the livestock species composition in the study areas varied, with cattle, sheep, goats, donkeys, horses, mules, camels, and chicken making up 28%, 59%, 4%, 6%, 2%, 0.1%, and 1% respectively (Table 8). The findings show that sheep are the dominant livestock species in most of the study sites, with the highest proportion in Merhabete (89%), followed by Kewet (75%), Baso-2 (65%), Baso-1 (59%), and Kobo (56%). This indicates that sheep production is a crucial component of the local agricultural systems in these areas, presenting an opportunity for the successful integration of the Dorper crossbreeding program. However, in Damot-Pulassa and Damot-Sore, cattle are the dominant species, suggesting the need for tailored interventions and the potential to integrate the Dorper crossbreeding program with the existing cattle production systems in those regions.

The study also compared its results to those of previous findings. Tsedeke (2007) found a higher number of cattle (8.5 vs 4.04), a lower number of sheep (5.0 vs 8.5), a higher number of goats (6.5 vs 0.50), a higher number of equine (1.65 vs 1.1), and a lower number of chicken (3.5 vs 4.6). Fekerte (2009) found comparable numbers of cattle (3.78 vs 4.02), a higher number of

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sheep (19.19 vs 8.47), a higher number of goats (37.39 vs 0.50), a higher number of camels (3.96 vs 0.16), and a higher number of donkeys (2.39 vs 0.82). However, the number of sheep and donkeys in Baso-1 area of the current study were relatively comparable to Fekerte's (2007) reports. Tesfaye A. (2008) also reported an average number of 3.4, 16.1, 3.2, 2.0 cattle, sheep, goat and equine, respectively in the Dessie Zuria of Sorth Wollo.

The study results we obtained show a higher proportion estimate for sheep (59%) compared to other livestock species. This finding is consistent with a previous study by Tesfaye G. (2008a) which reported a proportion of 71.7% for sheep, followed by 14.7% for cattle. Contrary to our finding, Habtamu et al (2019) in their studies at Benshangul Gumuz reported lower proportion of sheep (8.9 vs 59.3%), higher proportion of cattle (40.8 vs 28.3%), higher proportion of Goat (15.7 vs 3.5%) and lower proportion of donkeys (3.1 vs 5.7%), respectively. The differences in the species composition reports from the different areas could be attributed to the differences in the agro-ecology, production system that dictates the type and number of livestock species to be reared in the specific areas. The study concluded that households in the study areas keep different species of livestock, which helps reduce competition for feed resources, as noted in the reports of ILCA (1990). The higher proportion of sheep in most study sites could be due to dwindling grazing land and changes in agro-climatic conditions. The size of the average flock is a factor that influences various aspects of sheep's reproductive and productive performance, as well as their income and wealth value. It also influences the selection intensity and grants available for household activities.

5.4. Sheep flock structure within the study sites

The study examined the flock structure in different study areas, which includes breeding ewes (46%), lambs (27%), ewe lambs (12%), ram lambs (8%), rams (6%), and castrates (1%) (Table 9). The results showed that the proportion of breeding ewes was higher than any other category, followed by lambs, indicating the breeding objectives followed by the farmers. The findings show that the proportion of different sheep categories varies across the study areas. For instance, the proportion of breeding ewes is lower in Damot-Sore (40%) compared to Kobo (50%), and the proportion of breeding rams is lower in Kobo (1%) compared to Minjar-Shenkora (11%). This implies that there are differences in the breeding management and flock structures among the

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study locations, which should be considered when implementing targeted interventions to improve productivity. The availability and strategic deployment of breeding rams need to be tailored to the specific requirements of each study site, such as the lower proportion in Kobo, to optimize reproductive performance. The Dorper crossbreeding program should be designed with a flexible and adaptive approach to address the unique challenges and leverage the opportunities presented by the local sheep production systems in each area, considering the regional variations in flock structure and management practices, in order to provide customized recommendations and support to improve the overall productivity and efficiency of the local sheep production.

In comparison to previous studies, Taddesse (2018) reported a lower average number of breeding ewes (29%), higher number of rams (13%), and higher number of castrates (13%) for the Awassi, Washera, and Wollo flocks under farmers' management. Our study found a higher proportion of breeding ewes (46%) than Tsedeke (2007) reported for the flocks in Southern Ethiopia (39%) and Abebe et al. (2000) in Debre Birhan (42%). However, higher proportions of breeding ewes were reported by Duguma et al. (2005) (54%) in East and West Wellega and Berhanu (1998) (48%) in South Western Ethiopia.

The proportion of breeding rams in this study (6%) is similar to what Tsedeke (2007) reported (5.8%) for the flocks in Southern Ethiopia, but lower than what Taddesse (2018) reported (13%) for the flocks in Southern Wollo. In contrast, Dagne (2021) reported a comparable proportion of breeding ewes with our results (45.8% versus 46%), a higher proportion of rams (8.2% versus 6%), a higher proportion of ewe lambs (26% versus 12%), and a slightly higher proportion of ram lambs (8.2% versus 6%). The lower proportion of ram lambs recorded in our study could be attributed to the higher off-take rate of males through sales and slaughter.

5.5. Purpose of keeping sheep

The findings as indicated in Table 10 highlight the crucial role of sheep rearing in sustaining livelihoods in the rural community. Apart from income generation, sheep rearing also serves as a means to enhance family income through saving, which is the second most important purpose of keeping sheep in the Damot-Pullasa and Damot-Sore areas. Additionally, sheep production for the purpose of manure production in Kobo area comes in third, showing the importance of sheep manure in supporting vegetable production around the homestead and crop production in the

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field. However, the study noted that only a negligible proportion of farmers raised sheep for wool and milk production.

The present study's findings align with the research conducted by Tsedeke (2007) in Southern Ethiopia, where sheep production for income generation through the sale of sheep ranked first among the identified purposes. However, it is interesting to note that the same researcher reported sheep production for meat consumption to rank third, while rearing sheep for resource saving purposes stood second. These variations highlight the multifaceted nature of sheep rearing and the diverse objectives pursued by farmers in different regions. In the study made by Tesfaye G. (2008a) in the crop livestock areas the purpose of keeping sheep is income generation followed by meat production and manure production, the same author also reported the most important reason of keeping sheep in the pastoral areas of Afar areas to be milk, meat production and income generation in the order of importance.

Another study conducted by Tesfaye A. (2008) in the South Wollo Zone shed further light on the priorities associated with sheep rearing. According to this study, breeding emerged as the primary focus in sheep rearing, followed by income generation, household meat consumption, manure utilization for crop production, and saving, respectively, in order of importance. These findings underscore the context-specific nature of sheep rearing practices, as preferences and priorities can vary significantly across geographical regions and even within different sheep breeds. In contrast to the aforementioned studies, the present study revealed divergent reasons provided by farmers for keeping sheep compared to the findings reported by Abebe *et al*. (2000) regarding the Lallo Mamma Midir wereda in the north Shewa zone of the Amhara region. Each Production Area (PA) highlighted its distinct set of priorities in sheep rearing. The primary purposes identified by the farmers in this study include the sale of live sheep, wool production, household consumption, and sacrifices, with their relative importance varying in descending order. It is important to note that these findings specifically pertain to the Menz sheep breed, emphasizing the need to consider the specific breed and local context when analyzing sheep rearing preferences.

In general, the contrasting findings across these studies emphasize the complexity of factors influencing farmers' decisions and objectives in sheep rearing. Cultural, economic, and

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environmental factors, as well as breed characteristics, market dynamics, and available resources, can all contribute to the diversity of motivations observed. Understanding these variations is crucial for designing effective interventions, policy frameworks, and support systems that cater to the specific needs and aspirations of sheep farmers in different regions in Ethiopia.

5.6. Major constraints of sheep production

The findings of the current study reveal an intriguing contrast in the priorities and challenges faced by sheep keepers across the surveyed locations. In Baso-1, Baso-2, Merhabete, Kobo, Damot-Pulassa, and Damot-Gale, the top three limiting factors were identified as feed shortages (0.243), high prevalence of diseases and parasites (0.224), and lack of improved genotype (0.204). However, these farmers tend to prioritize selecting breeding ewes based on traits such as body size, good twinning rate, and shorter lambing interval. This discrepancy suggests a potential conflict between the farmers' short-term breeding goals and the long-term sustainability of the sheep production system. The emphasis on larger body size and higher prolificacy may increase the overall feed requirements of the flock, exacerbating the existing feed shortage problem. Similarly, the preference for shorter lambing intervals could put additional strain on the already limited feed resources, potentially compromising the overall flock health and productivity.

In contrast, the findings from Kewet and Minjar-Shenkora indicate that the lack of improved genotype ranked as the second most significant constraint for sheep production, following feed shortages (Table 11). This highlights the need for a more nuanced and regionally tailored approach to addressing the challenges faced by sheep keepers. To address these complexities, a more balanced and holistic approach to breeding objectives is required. This approach should consider both the genetic potential for desirable traits and the ability of the production system to support those traits sustainably. Furthermore, the integration of feed resource management, genetic improvement, and overall flock management strategies is crucial to achieve a balance between productivity and resource availability across the diverse production environments.

The findings align with reports by Zelalem (2018), which also highlighted feed shortages as a major problem in various agro-ecologies in southern Ethiopia. In his study, more than 90% of the respondents reported feed shortage as the primary issue in animal production and, specifically, in

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sheep production. This consistency in results across different studies underscores the widespread nature of feed shortages and the urgent need to address this critical constraint. However, it is interesting to note that Fekerte (2008) reported different findings in the Shinile Zone of the Somali region. According to that study, the major constraint to sheep production was disease prevalence, followed by feed shortages, water shortages, and recurrent drought. These discrepancies highlight the regional variations and the importance of considering local contexts when identifying and addressing constraints in sheep production.

In light of these findings, it is evident that feed shortages, diseases and parasites, and lack of improved genotype are significant challenges that need to be addressed to promote sustainable sheep production and improve farmers' livelihoods. Effective strategies should be developed to tackle these constraints, such as promoting better-feed management practices, implementing disease control measures, and sustainably introducing improved genotype suited to the local conditions. Furthermore, efforts should be made to provide farmers with access to capital, enhance market linkages, and address labor shortages, as these factors also contribute to the overall productivity and profitability of sheep production in Ethiopia.

5.6.1. Feed resource, seasonal fluctuation and utilization

According to the survey results, almost all households (98.8%) have experienced fluctuations in feed supply. The availability of feed resources for sheep varies among farmers in different areas. The surveyed households that reported feed resource fluctuation in Kewet was 93.8%, Damot-Pulassa 95%, and Baso-1, Baso-2, Merhabete, Minjar-Shenkora, Kobo, and Damot-Sore 100%. The report also revealed that the highest feed shortages happened between December to May (79.8%), followed by all year round (17.3%), and July to August (2.8%) (Table 12).

During critical feed shortage seasons, most farmers (94.8%) supplement their sheep with roughage, concentrate, and minerals. Roughage is supplemented by 90.3% of households, while 65.5% supplement with concentrate, and 84.3% supplement with minerals, mainly salt. The proportion of farmers supplementing roughage to their sheep varies from 71.4% in Kobo to 100% in Baso-2, Merhabete, and Minjar-Shenkora. On the other hand, approximately 90% or more farmers supplement their sheep with concentrate in Damot-Pulassa, Minjar-Shenkora, and Damot-Sore. The study also found that 85.9% of farmers could access natural pasture in the dry season, while farmers who could access established pasture, hay, crop residue, crop aftermath, and concentrate were 20.2%, 62.5%, 86.3%, 78.6%, and 67.5%, respectively. In the wet season, the proportion of farmers who could access feed resources was 87% (natural pasture), 31.0% (established pasture), 72.4% (hay), 48% (crop residue), 6.9% (crop aftermath), and 55.6% concentrate.

The study results are in line with the findings of Zelalem (2018), who reported that farmers in Southern Ethiopia understand the fluctuation in feed availability for their sheep. To address the feed shortage problem, Zelalem also reported that about 72.5% of farmers supplement their sheep with concentrate, Enset, crop residue, molasses, sweet potato, Desho grass, household leftovers, and minerals. Another study by Tsedeke (2007) reported that the sheep supplement in Alaba areas during critical periods include household food leftovers and local brewery (36.2%), grains (cooked/roasted) (34.9%), green fodder (19.7%), and mineral salt (9.2%), respectively. The differences observed in the type of supplements could be attributed to the differences in agro-ecologies that dictate the type of crops grown and the byproducts obtained for sheep feeding and supplementation.

5.6.2. Prevalent health challenges impacting sheep production in the study areas

Farmers in the study areas have identified a range of health challenges that have a significant impact on the well-being of their sheep. The findings presented in Table 13 shed light on the most prevalent sheep health challenges observed in these sites. Among them, pasteurellosis, parasites (both internal and external), liver fluke, foot rot, and diarrhea stand out as the most noteworthy issues, with respective weighted index values of 0.230, 0.197, 0.190, 0.138, and 0.094. Notably, Baso-2, Kewet, Merhabete, Damot-Pulasa, and Damot-Sore sites have identified pasteurellosis as the most critical sheep health challenge, based on recommendations provided by the farmers themselves.

Conversely, farmers at Baso-1 and Kobo sites have reported liver fluke as the foremost concern. In the Merhabete site, parasites (both internal and external) have emerged as the most significant health challenge. Furthermore, pasteurellosis has also been identified as the second most crucial sheep health challenge in Baso-1 and Kobo sites. Similarly, the prevalence of parasites (both internal and external) ranked as the second most significant sheep health challenge in the Kewet,

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Minjar-Shenkora, Damot-Pulasa, and Damot-Sote sites. Additionally, it is worth noting that foot rot has been recognized as the third most important challenge for sheep production in Baso-1 and Damot-Sites.

Similar to the results of the current study, a study conducted by Yaregal (2018) in the Jimma Zone of Oromiya underscores the significant impact of diseases and parasites on sheep production. The author specifically highlights diarrhea, sheep pox, and parasites as the most frequently reported diseases that negatively affect the productive and reproductive performance of sheep in the region. These findings align with our research, where disease and parasites were identified as the primary constraints hindering sheep production.

In another study by Ermias (2014), who evaluated Dorper sheep in the Wolaita and Siltie Zones of Southern Ethiopia, attention was given to major sheep diseases. Accordingly, this revealed that endoparasites, fasciollosis, eye diseases, ecto-parasites, and pasteurellosis were among the significant health concerns. Similarly, Deribe (2009) reported that pneumonia and parasitic diseases were the most important challenges to sheep health in the Alaba Special Woreda. Corroborating our current study results, Tesfaye G. (2008a) documented the opinions of farmers in the Menz areas, ranking the most important sheep diseases as pasteurellosis, liver fluke, coenurosis, and sheep pox in that order. These collective findings shed valuable light on the major health challenges faced by sheep farmers in the study areas. They underscore the need for targeted interventions and management strategies to improve sheep productivity. One approach that shows promise is Dorper crossbreeding, which can contribute to the overall productivity of sheep flocks, in this regard, by taking proactive measures and implementing appropriate interventions, farmers can enhance sheep production, leading to improved livelihoods and sustainable agricultural practices in the region.

5.7. Breeding and selection criteria

5.7.1. Selection of ewes and rams and criteria for breeding ram and ewe

The current study provides valuable insights into the key factors that sheep keepers consider when selecting female sheep for breeding purposes. According to the weighted index values reported by the farmers, the top attributes include body size/appearance (0.177), lambing interval

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(0.151), mothering ability and lamb survival (0.149), color (0.104), maternal history (0.104), age at first service (0.100), twinning rate (0.098), milk yield (0.088), and paternal history (0.033) (Table 14). Interestingly, the prioritization of these attributes varies across different locations. For instance, in Kewet, Merhabete, Minjar-Shenkora, Kobo, Damot-Pulassa, and Damot-Sore, body size/appearance is the primary consideration for farmers when selecting breeding ewes. In Baso-1, lambing interval took precedence, while in Baso-2, mothering ability and lamb survival were the highest-ranked attributes.

Furthermore, the study revealed that certain attributes were consistently ranked highly across multiple locations. Lambing interval was the second most important factor for farmers in Baso-2 and Damot-Pulassa, and mothering ability and lamb survival were the second most important attributes for farmers in Baso-1, Kewet, Merhabete, Minjar-Shenkora, and Damot-Sore. Additionally, farmers in Kewet, Merhabete, Minjar-Shenkora, Kobo, and Damot-Sore considered lambing interval, while maternal history held the third spot for farmers in Baso-1 and Baso-2. Interestingly, Kobo farmers prioritize color as the second most important attribute when selecting female sheep for breeding.

Farmers consider various attributes when selecting breeding rams, as these males play a crucial role in flock productivity. According to the study results, the most important traits were body size/appearance (0.224) and growth rate (0.175), followed by color (0.156), horn presence (0.117), libido (0.105), paternal history (0.084), maternal history (0.082), and fertility (0.057) (Table 6). Interestingly, body size/appearance and growth rate consistently rank as the top two most important traits across all sites. However, there were some regional differences in the prioritization of other attributes. For instance, in Kobo, color took the second place, while in Baso-2, Kewet, Merhabete, Damot-Pulassa, and Damot-Sore, color was the third most important trait. In Baso-1, Merhabete, and Minjar-Shenkora, the presence of horns was considered the third most important factor when selecting breeding rams.

These regional variations in breeding priorities for rams could be influenced by several factors. Firstly, farmers in Kobo may prioritize color as the second most important trait because they observe a higher market demand for sheep with certain coat colors, which could increase the value of their offspring. Secondly, the preference for particular coat colors in Kobo could be

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rooted in cultural or traditional significance, where certain colors hold special meaning or align with local customs. Thirdly, farmers may prioritize color for its visual appeal, aiming to create visually attractive flocks that are desirable to potential buyers. Lastly, the emphasis on specific traits, such as horn presence in Baso-1, Merhabete, and Minjar-Shenkora, may reflect the adaptation of sheep to the local environment and the practical advantages these traits provide in the production system.

The current study findings align with previous research conducted by Tadesse (2018), who reported that growth rate, body size, weaning rate, body conformation, age at first lambing, lambing rate, drought resistance, color type, disease resistance, hair type, and twin rate were ranked in order of importance as selection criteria for breeding ewes in Wollo highland sheep and their F_1 crossbred of Awassi and Washera sheep in Ethiopia. Similarly, Gizaw *et al*. (2013) found that body size was the top preferred trait for breeding objectives among owners of Menz, Bonga, Horro, and Afar sheep production areas. Furthermore, Tesfaye G. (2008a) reported that lambing interval, mothering ability, twinning rate, and color were the major selection criteria for Menz sheep in the Menz area, which is quite similar to the current findings.

Regarding the selection criteria for breeding rams, previous studies such as Tesfaye G. (2008a), Zewudu *et al*. (2012), Asresu *et al*. (2013), Yadeta (2016), and Tadesse (2018) have consistently identified body size, conformation, and growth rate as the major traits considered by farmers. These findings emphasize the significance of specific traits when selecting breeding ewes and rams. By focusing on these criteria, farmers can improve the genetic potential and overall productivity of their sheep flocks, contributing to enhanced livelihoods and sustainable sheep farming practices. The regional variations in the selection criteria for breeding ewes and rams highlight the need for a context-specific approach to genetic improvement and breeding programs. By understanding the local preferences and constraints, researchers and policymakers can develop more targeted interventions that align with the farmers' decision-making processes and the unique challenges faced in different production environments.

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5.7.2. Sheep breeding practice

5.7.2.1. Mating Followed

Based on the current survey conducted in the study areas, the majority of households (67%) prefer to utilize the group mating system for breeding (χ^2=98.18, $p < 0.0001$). The highest adoption rates of this system were observed in Kobo (97%), Baso-1 (95%), Kewet (94%), and Merhabete (93%). However, notable percentages of households in Damot-Pulassa (73%) and Damot-Sore (62%) employed their own flock mating system for breeding (Table 16). Among Dorper crossbreeding farmers, the prevalent use of the group mating system can be attributed to the delivery of breeding rams in groups, accompanied by controlled ram circulation procedures to minimize inbreeding within their flocks. The main reason why HHs from Damot-Pulassa and Damot-Sore followed their own flock mating system could be because these farmers get Dorper sire only one time and no continuous ram delivery system was followed.

In contrast, previous studies such as Tadesse (2018) indicated that farmers rearing Wollo highland sheep predominantly employed a privately controlled (own flock) mating system, followed by random mating. Similarly, Yaregal (2018) found in studies conducted in the Jimma Zone of Oromia that the dominant mating system was uncontrolled (72.2%), with partially controlled mating (27.8%) being the next most common practice. Fekerte (2008) reported a partially controlled mating system in 78% of HHs rearing Blackhead Somali sheep in the Shinile Zone, while Tesfaye A. (2008) discovered that no households followed a controlled mating system for traditionally managed Menz sheep in the Dessie Zuria district of South Wollo. Instead, communal grazing was practiced, allowing any breeding ewe in heat to mate with males from its own or other flocks. In contrast to the Dorper breeding program in the current study, the majority of farmers in other regions of the country relied on a random mating system, which resulted in challenges such as unknown parentage, limited recording, and a lack of opportunity for selecting future rams and ewes. The possible reasons for this could be the mixing of flocks in the communal grazing land, lack of awareness, and insufficient number of crossbred rams. This presented obstacles to genetic improvement efforts, including crossbreeding with productive rams and selection within the population. Overall, the study findings highlight the variation in mating systems employed by farmers in different regions, with the group mating system being favored by Dorper crossbreeding farmers in the study areas.

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5.7.2.2. Dorper crossbred ram sharing in the community

The findings of the current survey revealed that 73% of households engage in the practice of sharing rams for breeding within their communities (χ^2=72.66; $p < 0.0001$: Table 17). Moreover, it was observed that a higher percentage of households in Baso-1 (95%), Kewet (94%), Merhabete (93%), and Baso-2 (80%) actively participate in ram sharing within their respective communities. However, it is noteworthy that a significant proportion of households in Damot-Pulassa (73%) and Minjar-Shenkora (61%) areas do not partake in ram-sharing practices. These specific areas exhibited different characteristics compared to other sites in the study, with farmers in Damot-Pulassa, Minjar-Shenkora, and Damot-Sore obtaining improved Dorper rams on a limited basis. Consequently, the replacement of rams due to factors such as death, mating disability, old age, or poor serving ability was minimal. As a result, farmers in these regions tend to utilize the rams they have for extended periods, and the level of follow-up and support for ram management in these areas was reported to be insufficient by the farmers during the survey.

It would be valuable to explore how socio-cultural factors or local traditions affect farmers' willingness to engage in ram sharing in Damot-Pulassa, Minjar-Shenkora, and Damot-Sore areas. Additionally, assessing the availability of improved Dorper rams and the accessibility of extension services in these areas could provide insights into factors shaping farmers' breeding practices.

Furthermore, considering the economic factors that may influence ram-sharing practices would provide insights into the economic incentives or constraints associated with ram sharing in different regions. Finally, evaluating the level of knowledge and awareness among farmers regarding the benefits of ram-sharing, genetic improvement, and the importance of ram replacement could contribute to understanding the variations in breeding practices. It is important to note that in genetic improvement programs involving crossbreeding or selection, the delivery of rams, ram circulation, and ram replacement are essential for enhancing the breeding program and ensuring sustained and continued genetic improvement in the country.

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5.7.2.3. Access to Dorper crossbred rams

The current survey conducted among farmers revealed that approximately half of the households had access to improved ram, particularly the Dorper crossbred ram. Nevertheless, notable differences were detected among the study sites, with a significant chi-square value of 106.12 ($p < 0.0001$). The findings also indicated that a higher percentage of farmers in Baso-1 (93%), Kobo (86%), and Baso-2 (67%) had regular and continued access to the improved Dorper rams. Table 18 provides further insights, showing that access to improved Dorper rams ranged from 8% in Damot-Pulassa to 93% in Baso-1. Conversely, there was limited access to improved rams (Dorper) in other sites such as Damot-Pulasa (93%), Damot-Sore (90%), and Minjar-Shenkora (61%).

In a crossbreeding program involving improved indigenous Bonga rams in different agro-ecologies in Southern Ethiopia, as reported by Zelale (2018), farmers interested in using these improved rams faced low access rates, with only 31% of households owning and accessing the Bonga ram for their intended crossbreeding program, lower than the current study report. The author emphasizes that the remaining 69% of HHs who do not own improved Bonga rams arrange mating with rams maintained in Farmer Training Centers (FTCs) or seek ram services from model farmers who own Bonga rams. These findings highlight the importance of access to improved rams in breeding programs and genetic improvement efforts. The significant variations observed among the study sites indicate that certain areas have better access to improved rams, while others face limitations. Understanding the reasons behind these variations can provide valuable insights for improving access and promoting genetic progress.

5.7.2.4. Special management to Dorper crossbred ram

In this survey, it was observed that serving rams received significant attention within the community. Approximately 61% of HHs in the surveyed sites prioritize serving rams and provide special management for their Dorper ram. However, there were noticeable variations among HHs in different locations (χ^2=19.92; P = 0.0057), with Baso-2 (80%), Baso-1 (78%), and Minjar-Shenkora (70%) having a higher percentage of farmers offering special management for their Dorper rams. On the other hand, a significant proportion of farmers in Damot-Pulasa (60%) and Kewet (56%) do not provide special management to their Dorper ram. The percentage of

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HHs providing special management to their Dorper rams ranges between 40% and 80% (Table 19). The differences observed could be attributed to factors such as lack of awareness or insufficient supplementation feed resources in those areas.

Supplementation and delivery of special management to breeding rams is a common practice. Fekerte (2008) reported that sheep producers in the Shinile and Erer districts of Shinile Zone provide special management, such as wheat bran, to Blackhead Somali ram. However, the proportion of HHs delivering special management to Blackhead Somali rams was lower compared to the current study (45% vs. 61%). Similarly, in line with the present study, Zelalem (2018) documented the practice of supplementation for Bonga rams among farmers involved in a crossbreeding program in various agro-ecologies in Southern Ethiopia. The percentage of HHs providing supplementation to improved Bonga rams was reported to be 53.8%. The same author also found that about 62.5% of HHs using local rams supplemented their rams, which is a higher proportion compared to the results for Dorper crossbred rams and the reports by Zelalem (2018) for improved Bonga rams. The disparity in the proportions of HHs supplementing rams used for breeding purposes can be attributed to several factors. Effective ram management allows farmers to enhance their flock's productivity by improving libido and mating ability. By emphasizing these aspects, farmers can maximize the breeding potential of their rams and ultimately increase the overall productivity of their flocks.

5.7.3. Perceptions of farmers on production and adaptation of Dorper crossbred rams and lambs

5.7.3.1. Proportion of Dorper crossbred lambs born over the local in the farmers' flock

During the present survey, it was observed that households (HHs) participating in the Dorper crossbreeding program exhibited a good understanding of how to differentiate between local lambs and Dorper crossbred lambs based on various breed identification characteristics such as color, tail type, and body conformation, even at an early age. Farmers were specifically asked to identify and classify the sheep in their flocks as either local or Dorper crossbreeds. The results revealed that the proportion of sheep with Dorper inheritance was 61% in Merhabete, 49% in Kewet, 44% in Baso-1, and 34% in Minjar-Shenkora (Figure 2). However, only a small percentage of Dorper crossbreeds were identified in Damot-Sore (4%) and Damot-Pulassa (6%).

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Interestingly, our study contradicts the national report from the Central Statistical Agency (CSA 2021), which claims that the proportion of crossbred lambs in Ethiopia does not exceed 2%. Instead, our findings indicate an average of 37% of sheep were Dorper crossbred in the surveyed areas, ranging from 4% in Damot-Sore to 61% in Merhabete. Such substantial variations in the proportion of sheep with Dorper inheritance among the study sites can be attributed to various factors, including social factors, market preferences, availability of feed resources, the occurrence of diseases and parasites, adaptation to local conditions, sustained ram delivery, differences in technical knowledge and training, farmers' preferences, and other relevant factors.

In line with the current results, Yenesew *et al*. (2013) conducted a study in Burie District, North Western Ethiopia, focusing on the traditional breeding and flock structure of Washera and Horro sheep breeds. They discovered a significant proportion of Washera x Horro crosses (24.1%) within the flocks of farmers who were engaged in crossbreeding. On other hand, Feyissa et al. (2018) conducted a study in Yabello District, Southern Oromia, Ethiopia, to examine the determinants of adopting Dorper crossbreeds in pastoral areas. They identified two major factors hindering pastoralists' decision to adopt the Dorper crossbreeding program: the lack of sources for improved sheep breeds (41.5%) and limited information about the breed (17%). However, they noted that if the delivery system of Dorper rams had been maintained according to the needs of the users, the proportion of Dorper-inherited sheep within the crossbreeding farmers' flocks would have been higher. Considering these findings, it is evident that a significant adoption of the Dorper crossbreeding technology has taken place in Ethiopia. The higher proportion of Dorper-inherited sheep found within the flocks of most households in the studied areas indicates the level of adoption. This information provides valuable insights for decision-makers, as it highlights the areas where efforts should be focused to ensure the sustainability of the Dorper crossbreeding program.

5.7.3.2. Physical conformation of disseminated Dorper crossbred rams

The survey results revealed that physical conformation is a highly valued trait among farmers participating in the Dorper crossbreeding program. The majority of farmers (approximately 88%) in the surveyed areas, considered the conformation of Dorper breeding rams to be good, while only a small percentage (3.9%) considered it to be poor. This consensus was observed across all

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study sites, with all farmers agreeing that Dorper rams have good body conformation (χ^2=10.91; P = 0.3650). Notably, farmers from Kewet, Merhabete, and Minjar-Shenkora unanimously assigned a good body conformation to the Dorper rams they obtained (Table 20).

The findings regarding farmers' perception of the physical conformation of distributed Dorper rams are promising. It highlights the positive reception and recognition of the breed's desirable physical traits among the farming communities. This information should be taken into consideration by the research and extension units of the country, as it emphasizes the need for organized support to sustain the Dorper breeding communities. Establishing a national Dorper crossbreeding and dissemination unit can play a crucial role in providing continuous support and guidance to farmers, ensuring the long-term success and sustainability of the Dorper crossbreeding program.

5.7.3.3. Mating ability of disseminated Dorper crossbred rams

The mating ability of a breeding ram is a crucial characteristic that significantly affects the fertility and conception rates of ewes within a flock. Farmers recognize the importance of assessing the mating behavior of rams selected for breeding purposes. In our study, farmers were asked to assess their Dorper crossbred rams' mating ability, categorizing them as fair, good, or poor. According to the farmers' observations and judgments, a significant majority, 81% of the interviewed farmers, considered their rams to possess good mating characteristics. Only a small percentage, 4% of the farmers, rated their rams as poor in terms of mating ability. Notably, the percentage of farmers who judged the mating ability of Dorper rams as good varied across different areas, ranging from 50% in Baso-1 to 100% in, Merhabete, and Minjar-Shenkora areas (Table 21). This variation indicates that some regions may have a higher satisfaction level with the mating ability of the Dorper rams they received.

The high perception of good mating ability among farmers in the current study is promising, as mating and fertility are crucial characteristics desired by farmers in their breeding rams. Therefore, it is recommended that the extension and research units conduct breeding soundness examinations on the Dorper ram to be distributed within the sustained crossbreeding program. This examination would help ensure that the rams possess the necessary reproductive capabilities to effectively serve the ewes and contribute to successful crossbreeding outcomes.

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In support of this recommendation, Zelalem (2018) conducted studies on distributed Bonga sires and confirmed that farmers also valued the serving ability of Bonga sires. This suggests that assessing the mating ability of breeding rams is a common concern across different breeds and reinforces the need for thorough examinations to maintain and improve the breeding stock's reproductive performance. By implementing breeding soundness examinations as part of the selection and distribution process, the sustained crossbreeding program can provide farmers with rams that have proven mating abilities (which is not common currently in Ethiopia). This approach enhances the program's effectiveness and increases the chances of achieving improved fertility rates and successful crossbreeding outcomes, ultimately benefiting farmers and contributing to the overall productivity of their flocks in Ethiopia.

5.7.3.4. Testicle condition of disseminated Dorper crossbred rams

Rams, similar to other male mammals, rely on their testicles for reproductive functions. The testicles play a crucial role in producing sperm cells and secreting hormones like testosterone, which are essential for ram fertility and overall reproductive health. To assess the testicular condition of rams, researchers under current study evaluated factors such as size, symmetry, shape, firmness, and general appearance, categorizing them as poor, fair or good. The findings of the study revealed that a significant majority, 83% of the assessed rams, had good testicular conditions. Approximately 15% were categorized as fair, while less than 2% were considered to have poor testicular conditions. Notably, the testicular conditions of rams varied across different study sites. Baso-1 had 50% of rams with good testicular conditions, while Kewet, Merhabete, and Minjar-Shenkora areas had 100% of rams with good testicular conditions (Table 22).

These findings have important implications for the research and extension units responsible for distributing rams to end-users. The study highlights the need to carefully examine and assess the testicular condition of rams before distribution. This is particularly significant considering that 15% of the assessed rams were categorized as having fair testicular conditions and 2% as poor. By prioritizing the distribution of rams with good testicular conditions, the research and extension units can increase the proportion of rams with optimal reproductive health and fertility. Ensuring that a higher proportion of distributed rams have good testicular conditions can contribute to improved breeding outcomes and reproductive success. Rams with healthy testicles

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are more likely to produce adequate and viable sperm, increasing the chances of successful mating and conception within the ewe population. This, in turn, can enhance flock productivity and profitability for farmers.

To achieve this, the research and extension units should implement thorough and standardized protocols for assessing testicular conditions in rams. This may involve conducting regular breeding soundness evaluations, which include comprehensive examinations of the testicles. Additionally, educating farmers about the importance of selecting rams with good testicular conditions and providing them with the necessary knowledge and tools to make informed decisions can further support the goal of distributing rams with optimal reproductive health. By prioritizing the distribution of rams with good testicular conditions and implementing appropriate assessment and educational measures, the research and extension units can contribute to improved breeding outcomes, ensuring that farmers receive rams that have a higher likelihood of delivering successful reproductive performance and enhancing the overall efficiency and profitability of their flocks.

5.7.3.5. Body weight, body condition, scrotal circumference, service year and body linear measurements of disseminated Dorper crossbred rams

The present study confirmed that the body weight of Dorper crossbred rams found in the flocks of sampled farmers was (44 kg) ranging between 34 kg in Merhabete and 50 kg in Kobo areas (Table 23). The body weight of the rams was significantly affected by their age, with younger rams exhibiting smaller body weight and older ones exhibiting higher body weight. Our findings contradict those of Alayu *et al.* (2012), who reported a low body weight of 33 kg for distributed Washera rams in North Gondar zone of Amhara region, for the same age. However, the body weight of the rams reported by Mengiste *et al.* (2011a), who studied the performances of distributed Washera rams in South Gondar Zone, is relatively close to our findings of (44 vs 40 kg for the same age. Simirily, Zewedu (2008) in his studies on Bonga and Horo male sheep in their respective on-farm breeding tract area reported the body weight of 31 kg for the similar age. Overall, Dorper crossbred rams have good or better weight while serving in the flocks of the farmers, and were suited to the farmers' management condition, despite the numerical differences observed among our study sites.

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The average body condition of the rams ranged between 3.3 and 4.8, with an overall mean of 3.9. Rams with higher body condition scores were recorded in Minjar-Shenkora than in Kobo, Baso-1, and Baso-2 areas. This variation could arise from differences in the production system or ram management system followed by farmers in different sites. The influence of dentition (age) of the ram on the body condition of the rams was also observed, indicating that rams at a younger age (1 PPI) and older (IV PPI) ones had lower body condition scores compared to those in the middle (II and III PPI). This could be ascribed to the fact that rams with a younger age are still growing and cannot have higher body condition scores while older rams can still have lower body conditions compared to the ones in the middle due to the effects of old age and overworking (serving).

The body condition score we found in the current study is slightly higher (3.9 vs 3.5) than that reported by Alayu *et al.* (2012) for Washera rams. On the other hand, Mengiste *et al.* (2011a) for the same breed in South Gondar Zone reported a similar body condition score (3.9 vs 4.0) for distributed Washera rams. Conversely, lower (2.97) BC was reported by Zewedu (2008) for the Bonga and Horo male sheep. The optimal body condition score for a serving ram can vary depending on specific factors such as breed, age, and environmental conditions. However, a commonly used body condition scoring system for sheep is the 1–5 scale, with 1 being emaciated and 5 being obese. The ideal body condition score for a serving ram generally falls between 3 and 4, confirming the optimal management system followed by Dorper crossbreeding participant farmers in the breeding program we assessed.

The overall scrotum circumference of distributed Dorper rams was found to be 30 cm, with the lower and higher values for scrotal circumference of the Dorper crossbred rams in the sampled sites being found in Merhabete (27 cm) and Kobo (33 cm), respectively. Comparable scrotum circumferences were recorded among the study areas. However, the effect of age on scrotum circumference is evidenced in the current study, indicating that younger age rams had a relatively smaller size of scrotum compared to the size of scrotum in following ages. The scrotum circumference we obtained for distributed Dorper crossbred rams was quite higher (30 vs 24 and 30 vs 25 cm) than that reported by Alayu *et al.* (2012) and Mengiste *et al.* (2011a), for the Washera rams distributed to farmers and (30 vs 25) than reported by Zewdu (2008) for Bonga and Horro male sheep. The reason for such differences could be mainly attributed to breed

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differences and distribution areas, sample size, and age of the rams. The scrotum circumference we obtained in this work lies in the range suggested for breeding ram.

The study also disclosed that the rams currently served for 0.4 years in Minjar-Shenkora and 2.7 years in Kobo areas. This may be because farmers in Minjar-Shenkora areas recently received the rams compared to other sites. In general, the service year recorded for the rams in this work is within a 2-year limit, indicating that the ram transfer to other flocks should be maintained to reduce inbreeding.

The study in addition also aimed to determine the impact of age and location on various body linear measurements of distributed Dorper crossbred rams. The results showed that the height at the wither (HW), chest girth (CG), body length (BL), and chest width (CW) were not significantly affected by the location and age of the rams. The overall HW, CG, BL, and CW for the distributed Dorper crossbred rams were found to be 64 cm, 83 cm, 65 cm, and 27 cm, respectively. Although there were some differences in the numerical values observed among different study sites, these differences were not statistically significant. This could be attributed to the low number of observations made during the collection of body linear measurements.

The linear body measurements such as (HW, CG, and BL) for the distributed Washera rams in North and South Gondar Zones of Amhara region were 74 cm, 74 cm, 63 cm, and 71 cm, 80 cm, and 62 cm, respectively. The findings of the study showed that the HW of distributed Dorper rams was less than that of Washera rams reported by both authors. This indicates that Dorper sheep are shorter than their Washera counterparts. However, the values for CG and BL for the distributed Dorper rams in our study were higher compared to the Washera rams. This suggests that Dorper crossbred rams have good CG and BL, which could contribute to the meat-carrying capacity of the breed. It is worth mentioning that the Dorper breed was developed as a meat breed with a short and stocky appearance.

5.7.3.6. Off-take reasons, and number in the past one year in the study areas

Farmers must monitor the off-take rate of their sheep flock to maximize their benefits. To determine the off-take rate, farmers at the study sites were asked to recall the number of sheep that were sold, slaughtered, died, gifted, shared, and predated within the past one year. Based on

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recall basis, the average number of sheep off-take was found to be 9.3 per year and per HH. Sales accounted for 4.2, slaughter accounted for 2.5, death accounted for 1.9, and gifting accounted for 0.1, while sharing and predated each accounted for 0.3 sheep, respectively (Table 24). The number of sheep sold was similar across all study sites, except for Baso-1 where the number of sheep sold was significantly higher compared to Merhabete (5.2 vs 3.1, $p = 0.0190$). The number of sheep slaughtered in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 3.4, 3.1, 2.1, 2.3, and 1.4 respectively. The number of sheep slaughtered in Baso-1 and Baso-2 was significantly higher ($p < 0.0001$ and $p = 0.0263$) than the number slaughtered in Minjar-Shenkora.

The number of sheep that died in the past one year at Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 3.1, 1.6, 1.7, 1.8, and 0.9 respectively. Significantly ($p = 0.0033$) fewer sheep died in Minjar-Shenkora compared to Baso-1. The total off-takes of sheep in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 12.7, 10.5, 8.7, 7.3, and 6.3 respectively. The overall total off-take rate in Baso-1 was significantly higher ($p = 0.0015$ and $p < 0.0001$) than the off-take rate in Merhabete and Minjar-Shenkora. The proportion of sheep sold was similar ($p = 0.0767$) across all study sites. The percentage of sheep sold (representing commercial-off-take rate) in the past one year at Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora were 42.2, 42.7, 61.2, 46.9, and 54.9 respectively. Similarly, the proportion of sheep slaughtered was also similar ($p = 0.1422$) across all study sites.

The percentage of slaughtered sheep was 29.8, 33.7, 27.1, 30.1, and 20.1 in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora respectively. Additionally, the proportion (21.3, 15.8, 11.7, 21.6, and 12.1%) of sheep that died in Baso-1, Baso-2, Kewet, Merhabete, and Minjar-Shenkora respectively was also similar ($p = 0.2104$), as shown in Table 24. The differences in the number of sheep sold, slaughtered, died, and the total off-take number of sheep in the study areas could be attributed to differences in environmental factors, market access, disease prevalence that could occur in different sites, and the management differences that could be employed by the farmers in different sites.

In line with our findings, Samuel (2005) conducted a case study in the Yerer watershed of Adaa Liben District in East Shewa, Ethiopia, and reported off-take rates of 30% and 16% for sheep

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through sale and slaughter for home consumption, respectively. In comparison, our findings indicate off-take rates of 49% and 28% for sheep through sale and slaughter for home consumption. In contrast to our results, Berhanu *et al*. (2015) reported a gross commercial off-take rate of 21% for sheep in their study on factors determining HH market participation in SR production in the highlands of Ethiopia. Additionally, Negassa and Jabbar (2008) conducted studies in both highland and lowland areas of Ethiopia, and their reports indicated off-take rates of 38% through sales, 41% through death, and 21% through other reasons (2007-2008), compared to our results of 49% through sales, 18% through death, and 28% through slaughter for HH consumption.

Our study confirms that there were no significant variations in the proportion of sheep sold, slaughtered, and died in the past year among the study sites, suggesting comparable management practices and similar needs for sheep slaughter and sales among the sites. Furthermore, our study reveals a relatively higher percentage of sales and home slaughter for HH consumption in our study sites. This finding suggests potential opportunities for future expansion of Dorper crossbred production, as there is an attractive market with favorable prices, high demand, immediate returns, ease of management, a balance between benefits and risks, and suitability for house hold consumption. This finding indicates promising prospects for the future expansion of Dorper crossbred production. The presence of an appealing market, characterized by favorable prices, high demand, and immediate returns, creates a conducive environment for the growth of this production system. Additionally, Dorper crossbred sheep offer advantages in terms of ease of management, a balanced ratio of benefits and risks, and suitability for household consumption. Zeleke et al. (2018) who conducted a study evaluating the Awassi x Wollo crossbred sheep in the Atari-Mesk Watershed in North Eastern Amhara support this idea. Their findings are consistent with our results, as they also noted that farmers participating in the crossbreeding program exhibited a heightened interest in producing crossbred sheep.

The primary drivers behind this interest were the rapid growth and larger body sizes of the crossbred animals, which translated into higher market prices compared to the local breeds. In a preliminary study conducted by Ermias *et al*. (2014), the researchers examined the performance of Dorper x Adillo crossbred sheep across various production systems in Southern Ethiopia. In his preliminary investigation of Dorper crossbreeding, Dagne (2021) conducted studies in three

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distinct districts: Habru, M/Shenkora, and Raya Kobo. The objective of the research was to assess the impact of introducing Dorper sires and cross breeding systems on the body weight and marketing age of sheep flocks managed by local farmers. The findings revealed a significant transformation in these parameters compared to the previous performance levels. Dagne's (2021) investigation revealed significant changes in the body weight and marketing age of sheep flocks managed by farmers following the implementation of Dorper sires and breeding systems.

The study's outcomes (from this particular study and other investigators) underscore the advantages of incorporating Dorper genetics in sheep breeding programs, with tangible improvements observed in both growth performance and market readiness. In general, the results of their observation further validated the immense potential of Dorper sheep as a sire breed. The study demonstrated that the utilization of Dorper sheep as the paternal breed led to a multitude of benefits, including accelerated lamb growth, early attainment of market age, and impressive body weights. Moreover, Dorper sheep exhibited non-selective feeding behavior, which had a positive impact on the overall productivity of the crossbred lambs. Consequently, a significant number of Dorper crossbred lambs were consistently sent to the market (high off-take rate), highlighting the desirability and profitability of this breeding approach. In conclusion, the presence of a favorable market, coupled with the advantages associated with Dorper crossbred production, presents potential opportunities for its future expansion. Zeleke et al. (2018), who have observed similar trends in their studies, support this notion. The growth potential of Dorper crossbred production lies in its ability to offer faster growth rates, larger body sizes, and higher market prices compared to local sheep breeds.

5.7.3.7. Constraints to Dorper sheep crossbreeding (weighted index rankings)

As part of the survey work, farmers were asked to identify the major constraints they faced in the Dorper breeding task they were conducting. They were also asked to rank these constraints based on their importance. The results revealed that the overall constraints to Dorper sheep crossbreeding in the study sites were lack of Dorper ram (with an index value of 0.184), feed shortage (with an index value of 0.175), and disease (with an index value of 0.156), respectively as shown in (Table 25 and Figure 3). Interestingly, farmers from Baso-1, Kobo, and Damot-pulasa reported that disease prevalence was the most important constraint in the Dorper

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crossbreeding program, while farmers from Damot-Sore identified feed shortage as the most important constraint affecting the Dorper crossbreeding work in their locality. In addition, farmers from Kewet, Merhabete, and Minjar-Shenkora stated that labor was the third most important constraint that affected Dorper crossbreeding work in their area, while capital shortage was mentioned as the third most important constraint affecting Dorper crossbreeding work at Damot-Sore.

Current study findings partially support the reports presented by Zeleke *et al*. (2018), who identified the key challenges faced by farmers in the Atari-Mesk watershed in the North Eastern region of Ethiopia regarding the crossbreeding program involving Awassi x Wollo sheep. According to Zeleke *et al.* (2018), the primary obstacles, ranked highest by farmers, were feed shortages, limited capital, and recurring droughts. Furthermore, our findings align with those of Tesfaye G. (2008a), who conducted research in the Afar and Menz areas and identified feed shortages, droughts, and diseases as the most significant challenges in sheep production.

Similarly, preliminary studies conducted by Ermias (2014) on the on-farm performance of Dorper sheep in Silte and Wolaita Zones in Southern Ethiopia revealed the major challenges reported by farmers in relation to Dorper sheep crossbreeding. These challenges, ranked in order of importance, varied across different districts. In the Damot-Gale district, farmers cited market problems, lack of extension support, disease, and water shortages as major obstacles. In the Damot-Sore district, market problems, disease, feed shortages, and water shortages were identified as significant challenges. In the Mirab-Azernet district, water shortages, feed shortages, disease, and market problems were reported as the primary concerns. Understanding the most critical constraints that hinder the Dorper crossbreeding program is essential for mitigating these challenges and establishing a conducive environment for the program's success in Ethiopia.

5.7.3.8. Farmers' perception of productive attributes and traits of Dorper crossbred lambs

In a study comparing Dorper crossbred sheep to local sheep breeds in Ethiopia, farmer perceptions were examined to assess the advantages and preferences associated with Dorper crossbred sheep. The study explored various productive and reproductive traits, including meat yield, growth rate, wool/hair production, mothering ability, and meat quality (Tables 26-32).

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Dorper Crossbred Sheep: Preferred for Multiple Traits:

The pooled data from all study sites indicated a strong preference for Dorper crossbred sheep over local sheep breeds. The reasons for this preference were multi-faceted. Dorper crossbred sheep were found to have higher meat yield, faster growth rate, and higher milk production by the crossbred ewes. Additionally, they exhibited good and attractive appearance/conformation, early market age for lambs, relatively high wool yield, excellent mothering ability, and notable meat quality. These attributes contributed to the overall perception of Dorper crossbred sheep as superior to local sheep breeds in the study areas.

Wool/Hair Production: Context-Specific Observations:

While the overall data showed significantly higher wool/hair production in Dorper crossbred sheep compared to local sheep breeds, there were variations in perception across different sites. Farmers in the Merhabete and Minjar sites did not observe a noticeable difference in wool/hair yield between the two breeds. This suggests that local conditions and management practices in these specific areas may have influenced the perceived performance of Dorper crossbred sheep in terms of wool/hair production.

Mothering Ability and Reproductive Behavior: Site-Specific Variations:

The comparison of mothering ability and reproductive behavior between local and Dorper crossbred ewes revealed interesting insights. In general, Dorper crossbred ewes were considered to have superior characteristics. However, farmers in Damot Sore and Damot Pulassa perceived lower mothering ability and reproductive performance in Dorper crossbred ewes compared to local ewes. On the other hand, farmers in the Kobo site did not observe significant differences in these traits between the two breeds. These site-specific variations highlight the influence of local conditions and management practices on the perceived performance of Dorper crossbred ewes.

Meat Quality: Mixed Perceptions:

The subjective evaluations of farmers from the pooled data indicated a statistically significant preference for the meat of Dorper crossbred sheep in terms of visual appearance and taste. However, farmers in the Merhabete site did not perceive a significant difference in meat quality between the two breeds. Conversely, farmers in Damot Sore, Damot Pulassa, and Baso areas preferred the meat from local sheep to Dorper crossbreeds. These variations suggest that factors such as cultural preferences, local husbandry practices, and environmental conditions may

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influence the perception of meat quality. It is worth noting that sheep meat from highland sheep is quite tasty and this is known and acknowledged nationally for the small-sized Menz sheep residing in Menz areas and our study site Baso area. The findings of this study are consistent with previous research conducted by Shigdaf *et al*. (2012) and Gemeda *et al*. (2010), which also highlighted variations in farmer preferences for different sheep breeds and traits. These studies emphasized the intimate knowledge farmers possess about their local environment, conditions, problems, and priorities. Additionally, Kebede and Zekarias (2017) and Zeleke *et al*. (2023) reported high demand for Dorper crossbred sheep due to their fast growth, good meat quality, high milk yield, attractive appearance, and market preference.

The consistent perception of Dorper crossbred sheep as superior to local sheep breeds, as indicated by the pooled data, highlights the potential benefits of incorporating Dorper genetics into sheep breeding programs, while site-specific variations emphasize the importance of considering local conditions and farmer preferences in breeding and management decisions, providing valuable insights for farmers, researchers, and policymakers involved in sheep farming and breeding activities, and informing breeding programs and management strategies to maximize the benefits of Dorper crossbred sheep, with further research recommended to explore underlying factors and validate findings across a broader sample of farmers and regions.

5.7.3.9. Farmers' perception on adaptability traits of Dorper crossbred lambs

Our study aims to comprehensively examine the adaptability attributes of Dorper crossbred sheep compared to locally adapted sheep breeds under similar management conditions as experienced by farmers. The overall adaptability performance of Dorper crossbred sheep, based on pooled data obtained from various study sites, indicates that farmers highly prefer these sheep due to their excellent temperament behavior (OR=15.7, $p < 0.0001$) and their ability to graze efficiently from an early age (OR=21.1, $p < 0.0001$) (Table 33). These attributes contribute to the ease of handling and good foraging capabilities of Dorper crossbred sheep, making them desirable for farmers who value these traits.

Additionally, Dorper crossbred sheep are considered to have higher feed requirements compared to the local sheep in the respective study areas (OR= 56.2, $p < 0.001$). This higher feed requirement can be attributed to the genetic background and growth potential of Dorper sheep,

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which were originally bred for meat production. Their increased feed intake may contribute to their efficient grazing abilities and faster growth rates, which are valued by farmers who prioritize productivity and meat production.

In order to ensure the viability of animal production farms, the survival rate of lambs is an important trait to consider. With this in mind, a specific study aimed to understand farmers' perceptions regarding the pre-weaning performance of lambs, which is influenced by both environmental factors and the milk production capabilities of the dams (maternal influence). The information obtained from pooled data across all study sites indicated that farmers perceive Dorper crossbred lambs to have better pre-weaning survival compared to the locally adapted sheep in their respective areas (OR=2.255, $p < 0.0001$). This suggests that farmers believe Dorper crossbred lambs are approximately 2.3 times more likely to survive until weaning compared to the locally adapted sheep. Conversely, farmers from the Kobo site perceived lower pre-weaning survival rates for Dorper crossbred lambs compared to their locally adapted sheep (OR=0.119, $p < 0.0001$). This indicates that farmers in the Kobo site believe that the pre-weaning survival rates of Dorper crossbred lambs were slightly lower compared to their locally adapted sheep. The variation in perception between different study sites highlights the influence of local contexts and farmer preferences on the evaluation of pre-weaning performance in different sheep breeds.

To summarize, the findings of the study indicate that, overall, farmers perceive Dorper crossbred lambs to have better pre-weaning survival compared to the locally adapted sheep. This perception is supported by a statistically significant odds ratio of 2.255. However, it is important to note that farmers from the Kobo site have a different perception and believe that the pre-weaning survival rates of Dorper crossbred lambs are lower compared to their locally adapted sheep. These results emphasize the importance of considering local contexts and farmer perceptions when evaluating pre-weaning performance in different sheep breeds. The overall preference of farmers for Dorper crossbred sheep, which is based on their excellent temperament behavior, efficient grazing abilities, and better lamb pre-weaning survivability, makes them desirable for farmers who value ease of handling and good foraging capabilities. These attributes contribute to the overall adaptability and productivity of Dorper crossbred sheep in various farming systems.

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However, there are certain attributes for which Dorper crossbred sheep are less preferred by farmers. Farmers perceive these sheep to have less desirable coat color (OR=0.246, $p < 0.0001$) and are not favored for their horn characteristics (OR=0.091, $p < 0.0001$). Furthermore, Dorper crossbred sheep are perceived to have lower long-distance walking ability in search of feed and water sources like rivers (OR=0.055, $p < 0.0001$). They are also considered to have lower heat tolerance (OR=0.145, $p < 0.0001$), cold tolerance (OR=0.324, $p < 0.0014$), and drought tolerance (OR=0.093, $p < 0.0001$) compared to locally adapted sheep. Interestingly, farmers from the Kewet site showed a different preference compared to the overall perception. They exhibited a preference for the coat color of Dorper crossbred sheep, particularly favoring white or light red-colored individuals (OR=19.268, $p = 0.0013$). Additionally, in contrast to the overall findings, farmers in the Kewet site displayed a notable interest in the horns of Dorper crossbred sheep compared to local sheep (OR=9.905, $p < 0.0001$), indicating a strong inclination towards favoring horns in the Kewet area.

Regarding environmental adaptability, the perception of farmers varied across different sites. In terms of heat tolerance, farmers from the Minjar site did not observe a significant difference between Dorper crossbred sheep and local sheep (OR=1.503, $p = 0.45051$). Similarly, in Minjar and Kewet, farmers did not perceive significant differences in cold tolerance between the two breeds (OR=1.408, $p = 0.4887$ for Minjar) and (OR=1.527, $p = 0.5370$) respectively.

Farmers were also asked to provide their perception of disease tolerance in Dorper crossbred sheep compared to locally adapted sheep breeds. The pooled data from all study sites indicated that farmers perceive Dorper crossbred sheep to have lower disease tolerance (OR=0.113, $p < 0.0001$). However, farmers from the Minjar site perceived the disease tolerance abilities of Dorper crossbred sheep to be on par with the local sheep in their area (OR=0.490, $p = 0.1507$).
In terms of lamb survival, the overall perception of farmers across all study sites suggests that Dorper crossbred lambs have better pre-weaning survival rates compared to locally adapted sheep (OR=2.255, $p < 0.0001$). However, farmers from the Kobo site perceived lower pre-weaning survival rates for Dorper crossbred lambs compared to their locally adapted sheep (OR=0.119, $p < 0.0001$). These disparities in preference can be attributed to personal preferences and cultural factors specific to each region or site. The coat color and horn characteristics of

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Dorper crossbred sheep may not align with the aesthetic preferences or traditional values of some farmers, leading to a lower preference for these attributes.

The walking ability of Dorper crossbred sheep can be attributed to their genetic background, as Dorper sheep were originally bred for meat production rather than extensive grazing. Their reduced tendency for long-distance travel may affect their ability to access distant grazing areas or water sources, which could be a disadvantage in certain farming systems or environments. On the other hand, the less tolerance to heat and cold situations perceived by frames on the Dorper crossbred sheep compared to the locals could be attributed to and the perceptions may stem from the genetic differences between the two breeds.

Dorper crossbred sheep, being a result of crossbreeding with Dorper sheep, which originated from arid regions, may have inherited lower tolerance to extreme temperatures and drought conditions compared to locally adapted sheep breeds that have evolved and adapted to the specific environmental challenges of their regions. In addition, the perception of farmers regarding disease tolerance in Dorper crossbred sheep is relatively lower compared to locally adapted sheep. This perception could be due to genetic factors or differences in immune response between the two breeds. It is possible that locally adapted sheep have developed a higher level of disease tolerance through natural selection and adaptation to the prevalent diseases in their respective regions, whereas the crossbred Dorper sheep may not possess the same level of resistance, as they are the new entry to the sites.

An interesting observation was made in the Damot-Sore region of Southern Ethiopia, where farmers expressed their interest in crossbreeding their local sheep with Dorper rams. While enhancing productivity is important, it is crucial to find a balance between production and adaptation abilities, especially in tropical conditions. Introducing crossbreeds to smallholder farmers requires intervention measures such as providing adequate veterinary services and developing suitable forage options. The current study findings align with previous reports by Kebede and Zekarias (2017), Kebede *et al*. (2023), and Zeleke *et al*. (2023), which indicate that farmers prioritize traits like coat color, horn type, and the relative susceptibility of crossbreeds to disease and drought. Conversely, Shigdaf *et al*. (2012) found that Washera x Farta crossbred sheep were preferred by farmers due to their overall adaptability and productivity. These reports

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collectively highlight the need for improved and integrated management systems to enhance the adaptation of crossbreeds to disease and drought occurrences.

By combining the previous discussion with the current results, we have provided a more comprehensive overview of the perceptions and preferences of farmers regarding the adaptability attribute of Dorper crossbred sheep compared to locally adapted sheep breeds. The discussion highlights both the similarities and disparities in farmers' preferences across different attributes and sites, shedding light on the factors that influence their choices. Overall, the disparities in perception for attributes such as coat color, horn characteristics, long-distance walking ability, heat tolerance, cold tolerance, and disease tolerance can be influenced by various factors including personal preferences, cultural values, genetic background, and environmental adaptation. Understanding these factors is important when considering the preferences and needs of farmers in different regions and when implementing breeding and management strategies for crossbred sheep.

5.8. Reproductive performance

5.8.1. Lambing distribution under village management system

Despite sheep being seasonal breeders in temperate regions, the presence of rams in tropical flocks leads to year-round lambing without a specific lambing season (Shigdaf *et al*., 2013; Deribe *et al*., 2014). The findings of the current study support this, as it was observed that lambing occurred in all months, with an average of 6 to 13% of ewes lambing each month (Figure 4). This suggests that both local and Dorper crossbred ewes have the ability to experience estrus (heat) throughout the year, without being restricted to specific seasons. While lambing can occur throughout the year, the study also revealed that the peak lambing period, which accounted for 35% of the total lambing, took place in September, October, and December. This aligns with a previous study conducted by Kumaravelu and Serma (2012) on flocks in Tamilnadu, which reported that the peak lambing season was in November, followed by October and December, although lambing was observed throughout the year. In contrast, Martins and Peters (1991) found that the peak lambing months for Karakul, Afrikander, and Blackhead Persian sheep and their crosses were April, May, and August, with lambing percentages of 16%, 17%, and 19%, respectively. In contrast to our findings, Shigdaf *et al*. (2013) reported that

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Washera and Farta sheep breeds had a higher proportion of lambs born in January and February. Gbangboche *et al*. (2006) studied Djallonke sheep and found that there were significant numbers of births each month, with peaks in January, February, May, and June.

The seasonal lambing pattern for local and Dorper crossbred lambs was similar, with 39% of lambs born in the dry season and 33% in the main rainy season (Figure 5). This suggests that a greater number of local and Dorper crossbred ewes went into estrus during the rainy season. This finding is consistent with Niar *et al*. (2001), who reported similar patterns for Algerian sheep. Gani and Niar (2019) also concluded that local ewe breeds raised in the challenging climatic conditions of southwestern Algeria exhibit relative non-seasonality, with only a slight decrease in productive activity. This characteristic is supported by the study of Rosa and Bryant (2003), which stated that in tropical and sub-tropical environments, ewes are either completely aseasonal or intermittently polyoestrus, with breeding activity influenced by the quality and availability of feed. Additionally, the study by Molokwu and Umunna (1980) indicated that seasonal variation in feed supply triggers the lack of seasonality in estrus behavior in tropical sheep breeds (Mittal and Ghosh, 1980). Despite the Dorper breed being intended for improved management systems, the crossbred sheep still exhibited good lambing performance under smallholder marginal management systems in all seasons (Figure 5).

5.8.2. Mating and fertility traits of flocks managed under on-station management

The pregnancy rate (%) of ewes was examined under on-station management conditions, taking into account various factors. The results showed that the sire breed used ($p = 0.0118$), dam breed, and mating year ($p < 0.0001$) significantly influenced the conception rate. However, the location and season of mating did not have a significant effect on the conception rate of ewes. These findings highlight the importance of both genetics and environmental factors in determining the conception rate of ewes in this study. In terms of sire breed, ewes sired by Dorper x Local crossbred rams exhibited the highest pregnancy rate (90.5%), surpassing the rates observed in ewes sired by Dorper purebred rams (74.9%) and local rams (80.8%).

Similarly, the breed of the ewe also had a significant impact on the conception rate ($p = 0.0118$). Local ewes had the highest pregnancy rate (90.8%), followed by Dorper purebred ewes (80.3%) and Dorper x Local crossbred ewes (75.2%). These results suggest that local ewes had a greater

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propensity for pregnancy compared to the other breeds in this study ($p < 0.0001$). Interestingly, the location and mating season did not affect the pregnancy rate of ewes. This could be attributed to the comparable management system (on-station management) implemented across the different sites. It is worth noting that in a study conducted by Boujenane (2002) on the development of synthetic breeds in Morocco, a higher pregnancy rate of 82.8% was reported. This finding exceeded the rates obtained for Dorper crossbred ewes (75.1%) and was similar to those observed in Dorper purebred ewes (80.3%) and lower than local ewes (90.8%).

In contrast, the conception rate reported by Boujenane was higher than that of ewes sired by Dorper purebred rams in this study (74.9%), comparable to ewes sired by local rams (80.8%), and lower than ewes sired by Dorper crossbred rams (90.5%). Muhammad (2007) in his studies on Kajli sheep in Pakistan reported 88% fertility rate and he also described that year of lambing and age of ewe to significantly affect the ewe fertility. Yibra (2008) in his studies on Afar and Blackhead Somali sheep breeds also reported lower pregnancy rate (whether a ewe is mated or not) compared to our findings (71.1%). Another study by El-Hag *et al*. (1998) investigated ewe productivity under range conditions in Kordofan, Sudan. The researchers reported a pregnancy rate of 95.8% with supplementation and 66.7% under range conditions alone. These findings indicate the positive impact of ewe supplementation prior to mating and during late pregnancy on the pregnancy rate. Overall, the results of this study emphasize the complex interplay between genetic factors, environmental conditions, and management practices in determining the conception rate of ewes.

The lambing rate, calculated by dividing the number of ewes with lambs by the total number of ewes joined to the ram, was found to be influenced by the genotype of the dams ($p = 0.0031$). However, the current study did not observe significant effects of sire breed, location, mating season, and mating year on the lambing rate ($p = 0.3277$, 0.3689, 0.7004, and 0.1523, respectively). This could be attributed to the comparable management system employed at the respective on-station sites regarding ewe management.

The lambing rates for Dorper x Local crossbred, Dorper purebred, and local ewes were 91.4%, 93.8%, and 98.2%, respectively, indicating that higher lambing rates were associated with local ewes. This finding aligns with the study conducted by Idris *et al*. (2010) on the reproductive

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performances of Sudanese Desert sheep, where they reported a lambing rate of 53% for ewes managed under range conditions without supplementation and 75-91% for ewes provided with supplementation through flushing and steaming-up. Similarly, Thieme *et al*. (1999) studied the performances of village flocks in Central Anatolia, focusing on the fertility and productivity traits of ewes. They found that the dam genotype influenced the lambing rate, with Merino ewes having the highest lambing rate (97.8%), followed by crossbred (92.2%) and Akkaraman (91.7%) ewes.

The study conducted by Gavojdian *et al*. (2015) on reproductive efficiency in White Dorper, Dorper, and Tsigai sheep under temperate European conditions reported similar observations to our findings regarding the lambing rates of the different ewe breeds. According to their findings, the lambing rate for Tsigai ewes was 82.8%, for Dorper ewes, it was 81.04%, and for White Dorper ewes, it was 86.7%. These results indicate significant differences in lambing rates among the three ewe breeds studied. These findings are consistent with the results of the current study, as local ewes exhibited the highest lambing rate. However, no significant difference in the lambing percentage was observed between Dorper x Local crossbred and Dorper purebred ewes.

The overall prolificacy rate, calculated by dividing the number of lambs born by the number of ewes lambed, was determined to be 105.5% in this study. The analysis revealed that the prolificacy rate was significantly influenced by the location of the sheep ($p = 0.0422$) and the mating year ($p = 0.0008$). However, other factors such as the sire breed ($p = 0.3865$), ewe breed ($p = 0.1513$), and mating season ($p = 0.8481$) did not have a significant effect on sheep prolificacy.

Although not statistically significant, the study indicated that ewes sired by Dorper x Local crossbred rams had the highest prolificacy rate at 110.2%, followed by ewes sired by Local rams at 105.6%, and Dorper purebred rams at 103.5%. While there were some variations in the prolificacy rates among the different ewe breeds, with Dorper purebred ewes at 108.54%, local ewes at 105.47%, and Dorper crossbred ewes at 105.34%, these differences were not statistically significant. Therefore, under the on-station management conditions implemented in Ethiopia, Dorper purebred, Dorper crossbred, and local ewes exhibited comparable levels of prolificacy.

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Additionally, the study found that ewes in the cool-tepid area had slightly a higher prolificacy rate compared to those in the mid-to-highland areas (109.9% vs. 102.9%, $p = 0.0422$). This indicates the influence of location on ewe prolificacy rate. In comparison, Idris *et al*. (2010) reported a prolificacy rate of 103% for ewes managed under range conditions, while those provided with supplementation through flushing and steaming-up had rates ranging from 108% to 116%. On the other hand, Snyman and Olivieier (2002) conducted a study on the productive performances of wool and hair-type Dorper sheep under extensive conditions and reported prolificacy rates of 128.7% and 124.0%, respectively. However, no significant difference was found between the two groups. Taken together, these findings highlight the significant influence of location and mating year on sheep prolificacy, while the effects of sire breed, ewe breed, and mating season were not statistically significant in this study.

The findings of the current study suggest that the environmental factors or the sire breed did not significantly influence the abortion rate in ewes. The overall abortion rate observed was 1.59%, which falls within the accepted range for healthy sheep, as Menzies (2011) states that the normal proportion of aborting ewes is between 2% and 5%. However, the study revealed that ewe breed had an impact on the abortion rate. Local ewes had an abortion rate of 0.76%, Dorper purebred ewes had a rate of 2.14%, and Dorper crossbred ewes had the highest rate of 5.2%. Notably, all three ewe breeds tested had abortion rates within the accepted range for sheep. While not statistically significant, there were numerical differences observed in the abortion rates among ewes served by the different sire breeds. The abortion rate was 0.51% for ewes sired by Dorper crossbred sires, 3.24% for ewes sired by Dorper purebred sires, and 4.35% for ewes sired by local sires.

The study found no significant effect from the environmental factors, which may be attributed to the similar management systems employed by the different sites in managing breeding ewes under on-station management conditions. The abortion rate is an important indicator of flock reproductive efficiency and a crucial measure of reproductive performance. The low abortion rate observed in local ewes is encouraging, while the slightly higher rate in Dorper crossbred ewes is a cause for concern and should be addressed to improve flock reproductive efficiency.

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The likely causes of the differences in abortion rates among the different ewe breeds and sire breeds could be attributed to the genetic makeup and inherent reproductive characteristics of the different breeds, where the local ewes may have better-adapted reproductive systems, leading to lower abortion rates, while Dorper breeds may be more susceptible to certain reproductive issues. The higher abortion rate in Dorper crossbred ewes could be related to potential genetic incompatibilities or the loss of hybrid vigor in the crossbred offspring, leading to reproductive challenges. The sire breed may also play a role in the abortion rate, as the genetic contribution and compatibility from the paternal side can influence the reproductive success of the offspring. The local ewes may be better adapted to the environmental conditions and management practices, resulting in lower abortion rates compared to the introduced Dorper breeds, which may not be as well-suited to the local environment.

The abortion rate serves as an important indicator of flock reproductive efficiency and is a crucial measure of reproductive performance. The low abortion rate observed in local ewes is encouraging, while the slightly higher rate in Dorper crossbred ewes is a cause for concern and should be addressed in order to improve flock reproductive efficiency. These findings are consistent with the results reported by Idris *et al*. (2010) in their studies on Sudanese Desert sheep, where abortion rates ranging from 2.1% to 5.43% were observed in ewes managed with different levels of supplementation, and a 15% abortion rate was reported for ewes maintained on natural grasslands. Similarly, Zebari (2021) reported abortion rates of 4% and 5% in sheep when comparing reproductive performances between synchronized and spontaneous estrus, respectively. Furthermore, Mahboub *et al*. (2013) reported abortion rates ranging from 1% to 25% for three Egyptian sheep breeds maintained under farm conditions. Subtle differences in management practices or nutritional inputs at the different sites, even under similar on-station conditions, could potentially contribute to the observed variations in abortion rates. Understanding the underlying causes of these differences can help inform targeted interventions and breeding strategies to optimize the reproductive performance of the flock, particularly for the Dorper crossbred ewes, which exhibited the highest abortion rate.

Similar to the findings on abortion rate, the still-birth rate in the current study was influenced by the breed of the dam but not by the sire breed or the environmental factors considered (location, mating season, and mating year). The overall still-birth rate observed in the study was 1.46%,

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which is within an acceptable range. The still-birth rates for local ewes, Dorper crossbred ewes, and Dorper purebred ewes were 0.74%, 1.68%, and 2.60% respectively, with a statistically significant difference (p-value = 0.0050).

Furthermore, the study noted that, similar to abortion and still-birth rates, ewe barrenness was affected by the genotype of the ewe. However, the study also found significant impacts of sire breed ($p = 0.0090$) and mating year ($p < 0.0001$) on ewe barrenness. Environmental factors such as lactation ($p = 0.4293$) and mating season ($p = 0.5713$) did not have a significant effect on barrenness, which aligns with the findings on abortion rate and still-birth rate. The study also revealed that the barrenness rate of ewes varied depending on the sire breed used. Ewes sired by Dorper purebred rams had the highest barrenness rate (24.9%), followed by ewes sired by local rams (18.8%), and ewes sired by Dorper crossbred rams (9.4%). This indicates that Dorper purebred ewes had the highest barrenness rate, while the lowest barrenness rate was observed in Dorper x Local crossbred ewes. Similarly, the breed of the ewes significantly influenced ($p < 0.0001$) the barrenness rate. The barrenness rates for Dorper x Local ewes, Dorper purebred ewes, and local ewes were 24.6%, 19.2%, and 9.24% respectively, further emphasizing the higher barrenness rate in Dorper crossbred ewes and the lower barrenness rate in local ewes.

The year of mating also had a significant impact on the barrenness rate, with higher rates observed in 2017, 2018, and 2008, and relatively lower rates in 2010, 2013, and 2011. Comparing these findings with other studies, Idris *et al*. (2010) reported barrenness rates ranging from 6.19% to 17.58%, which are in agreement with the overall barrenness rate (17.96%) observed in the current study. However, Idris *et al.* also reported a high proportion (25%) of barrenness rate in ewes managed under range conditions for Sudanese Desert sheep. Additionally, Zebari (2021) reported barrenness rates of 18% and 10% for Karadi sheep breed ewes ovulated spontaneously and synchronized, respectively, and 15% and 6% for Awassi sheep, respectively, in his studies on these breeds.

Based on the results above, there are several actions that can improve flock efficiency. One approach is genetic selection, where breeders can choose ewes and rams with a history of low still-birth and barrenness rates to improve the genetic potential of the flock. Additionally, implementing improved management practices such as optimizing nutrition, vaccination, and disease prevention protocols, as well as providing suitable housing and environmental conditions, can help minimize the occurrence of still-birth and barrenness. Regular reproductive health monitoring, including nutrition, vaccination, and housing assessment, is also crucial for identifying and addressing issues promptly. Proper nutritional and disease management should be implemented to support reproductive health. Lastly, it is important to assess and optimize the environmental conditions in which the flock is managed, taking into consideration factors such as temperature, ventilation, and stocking density, to reduce reproductive problems. By implementing these measures, flock efficiency can be enhanced, leading to a reduction in still-birth and barrenness rates.

5.8.3. Litter size at birth (LSB) under farmers' and on-station management

The current study examined the effects of genotype and environmental factors on litter size (LSB) under both farmers' and on-station management conditions. The results indicated that location significantly influenced LSB under farmers' conditions. Ewes giving birth in Bason-Werana and Merhabete had higher LSB values compared to those reared in Kewet-EF and Kobo areas, this suggests that the geographical location of the farming environment can influence litter size, possibly due to variations in climate, forage availability, or other environmental factors. However, there was no significant effect observed for local and Dorper crossbred ewes managed under farmers' conditions, this suggests that the impact of management practices employed by farmers may override the genetic influence on litter size in these specific breeds.

It is possible that the management practices, such as feeding, flock health management, and overall care provided by the farmers, play a more dominant role in determining litter size than the genetic background of the ewes. Additionally, ewes giving birth in the long- rain season had lower LSB values compared to those giving birth in the dry and short- rain seasons under farmers' management; this could be attributed to differences in forage availability and quality during different seasons. Ewes lambing during the long- rain season may have had limited access to high-quality forage, resulting in reduced litter size compared to ewes lambing during seasons with better forage availability.

The study also revealed significant differences in LSB among different birth parities and the year of lambing under farmers' management, this finding aligns with previous research that suggests

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older and more experienced ewes tend to have larger litter sizes compared to younger ewes. The increased litter size in higher parities could be attributed to improved reproductive efficiency and better maternal care provided by more experienced ewes. Furthermore, ewes giving birth to male lambs had higher LSB values compared to those giving birth to female lambs under farmers' management, the scientific explanation for the finding that ewes giving birth to male lambs had higher litter size values compared to those giving birth to female lambs could be attributed to differences in reproductive physiology between male and female fetuses.

Under on-station management conditions, the effects of genotype (sire and dam) and environmental factors on LSB were evident. Ewes sired by Dorper purebred sires had higher LSB values compared to those sired by Dorper crossbred and local sires, while Dorper crossbred and local ewes had similar LSB values, which were better than those of Dorper purebred ewes, these results suggest that the genetic background of both the sire and dam can contribute to variations in litter size. The parity of birth also had a significant effect, with higher LSB values observed in ewes at birth parities 3-6 and above compared to earlier parities. The lambing season showed significant effects, with ewes giving birth in the short-rain season having higher LSB values compared to the long-rain and dry periods. The lambing year also had a significant impact on LSB under on-station management; this finding indicates that the timing of lambing within the year can affect litter size, possibly due to variations in forage availability and nutritional status of the ewes during different seasons.

The findings of this study align with previous research conducted in the field. For instance, Wilson and Durkin (1988) reported litter size values ranging from 1.05 to 1.15 for tropical breeds. Similarly, Shigdaf *et al*. (2013) found litter size values of 1.03 and 1.05 for local Washera sheep in both station and on-farm management settings. In another study, Sisay *et al*. (2014) reported litter size values of 1.03 for local ewes and 1.04 for Awasi crossbred ewes. However, the average litter size observed in this study for local and Dorper crossbred sheep was lower than the 1.28 reported for Dorper sheep by Schoeman (2000), but higher than the 1.02 reported by Baker *et al*. (1998) for Dorper sheep under extremely unfavorable conditions.

The study also emphasized the influence of environmental factors such as location, ewe lambing parity, ewe lambing season, and year on litter size. Improving these environmental factors,

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including feed quantity and quality, as well as maintenance management, can support ewe productivity. In conclusion, the study revealed that both genotype and environmental factors play significant roles in determining litter size in sheep. The results from farmers' and on-station management conditions provide valuable insights into the complex interplay between genetic and environmental influences on LSB. The findings highlight the importance of considering both genetic selection and appropriate management practices to optimize litter size and enhance flock productivity.

5.8.4. Litter size at weaning (LSW) under farmers' and on-station management

The present study aimed to investigate the effects of genotype and environmental factors on litter size at weaning (LSW) in ewes managed under farmers' and on-station management systems. The overall LSW values were found to be 0.95±0.30 and 0.91±0.02 under farmers' and on-station management conditions, respectively.

The study revealed that environmental factors such as location, lambing season, and lambing year significantly influence LSW under farmers' management conditions; this suggests that these factors played a major role in determining the weight of lambs born under the care of farmers. Contrary to this, the dam's genotype and other environmental factors such as lambing parity and lamb sex did not have a significant effect on LSW in this management system. These findings indicate that the management practices employed by farmers may have a dominant influence on LSW rather than the specific genetic background or environmental factors considered in the study under farmers' management condition. Hence, further improvements in environmental factors that do have a significant effect on LSW under farmers' management conditions could lead to an increase in LSW.

In contrast, LSW was found to be highly influenced by genotype and environmental factors in flocks managed under on-station conditions. Genotype, including sire and dam genotype, had a significant effect on LSW ($p < 0.0001$), as did several environmental factors such as location ($p = 0.0001$), dam parity ($p < 0.0001$), lambing season ($p = 0.0004$), and lambing year ($p < 0.0001$). Similar to farmers' management conditions, lamb sex did not have a significant effect on LSW in the on-station management system. Ewes sired by Dorper purebred rams and Dorper crossbred rams had higher LSW values compared to those sired by local rams. Furthermore, Dorper

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crossbred ewes and local ewes had comparable and higher LSW values than Dorper purebred ewes, with values of 0.98, 0.98, and 0.89, respectively, this indicates that the genetic background of the sire and dam can influence the LSW. Ewes reared in low-mid-to-highland areas had higher LSW values compared to those reared in cool-tepid areas, this suggests that the geographical location, which may be associated with differences in climate, forage availability, and other environmental factors, can affect litter size at weaning.

Parity also influenced LSW, with ewes at the first parity having lower LSW values, while ewes at the fourth parity had the highest values, and ewes in the other parities fell in between, this could be attributed to the increased maternal experience and improved reproductive efficiency of ewes with higher parities. Similar to flocks managed under farmers' conditions, lambing season and lambing year had an impact on LSW. Ewes giving birth in the long-rain season had higher LSW values under on-station management, while those in the short-rain season had higher LSW values under farmers' management conditions, suggesting that variations in environmental factors across different seasons and years can LSW.

Comparing the results to previous studies, the LSW values obtained in this study were slightly lower than those reported by Marufa *et al*. (2017) for Abera sheep under the CBBP in Ethiopia (0.978). However, the litter size at weaning (LSW) values for both local and Dorper crossbred ewes in this study were higher compared to the values reported by Rodriguez *et al*. (1998) for hair sheep in annual and accelerated lambing programs. The reported values by Rodriguez *et al*. (1998) ranged from 0.56 to 0.72 for the annual system and 0.46 to 0.94 for the accelerated system, calculated on a per-lambed-ewe basis. Comparing the results between the two management systems, it is evident that the on-station management system showed a stronger influence of genotype and environmental factors on LSW compared to farmers' management conditions. This may be due to the controlled and standardized conditions in on-station management, which allow for a clearer assessment of genetic and environmental effects on LSW. In contrast, the farmers' management system involves a broader range of management practices and environmental variations, which may overshadow the genetic and environmental factors considered in the study.

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Overall, the study emphasized the importance of considering both genotype and environmental factors in sheep management to optimize LSW and improve flock productivity. While the farmers' management system showed a greater influence of management practices, the on-station management system demonstrated the significant role of genotype and specific environmental factors on LSW. The findings provide valuable insights for farmers and researchers to make informed decisions regarding breeding strategies, management practices, and environmental interventions aimed at improving LSW in different management systems.

5.8.5. Litter weight at birth and at weaning under on-station management

The study also investigated a crucial characteristic, specifically the weight of litters at birth. The average litter weight at birth was determined to be 3.25±0.03. Both the sire and dam's genotype, as well as environmental factors significantly influenced the weight of litters at birth. The impact of the sire and dam breed on litter weight was remarkable ($p < 0.0001$). Ewes sired by purebred Dorper and crossbred Dorper sires produced significantly higher litter weights at birth compared to those sired by local sires. This study confirmed that using purebred Dorper and crossbred Dorper sires resulted in a 39% and 19% improvement in litter weight at birth, respectively, compared to the use of local sires. This demonstrates the significant influence of sire breed on litter weight at birth. The breed of the dam also had a significant impact on litter weight at birth. crossbred Dorper, purebred Dorper, and local ewes produced litter weights of 3.35 kg, 3.24 kg, and 3.04 kg, respectively, indicating that crossbred Dorper ewes performed similarly to purebred Dorper ewes while outperforming local ewes, However, the reported values for Doyogena sheep by Kebede *et al*. (2022a), with a litter weight at birth (LWB) of 5.24 kg, exceed the LWB values we obtained for all the ewe breeds considered in our study.

Litter weight at birth was affected by all the environmental factors considered in the current study. Ewes residing in cool-tepid areas produced slightly higher litter birth weights than those in low-mid-to-highland areas, and this difference was statistically significant ($p = 0.0272$). This suggests that the geographical location, which may be associated with variations in climate and available resources, can affect litter weight at birth.

Lamb sex, ewe lambing parity, season, and year of lambing had a highly significant influence ($p < 0.0001$) on the litter birth weight of lambs. Ewes that gave birth to male lambs produced higher

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litter weights at birth compared to those that gave birth to female lambs. Litter weight at birth increased until parity 4 and then declined. The highest litter birth weight was recorded at parity 4 (3.36 kg), while the lowest litter birth weight was observed in parity one (2.90 kg).

The influence of the season of lambing on litter weight at birth was remarkable. Ewes that lambed in the dry season produced lambs with higher litter weights compared to those born in the long-rainy and short-rainy seasons (3.31 kg, 3.17 kg, and 3.15 kg, respectively). Ewes that gave birth in the long-rainy and short-rainy seasons produced similar litter weights. The year of lambing also had a noticeable impact on litter weight at birth (Table 45).

Litter weaning weight is considered one of the most important traits for assessing the reproductive performance of ewes in the current study. Accordingly, the overall litter weight at weaning was determined to be 14.41±0.13 kg. The weight of lambs at weaning was significantly influenced by all the factors considered in the study.

The impact of sire and dam breed on litter weaning weight was particularly noteworthy. Ewes sired by purebred Dorper, crossbred Dorper, and local sires produced weights of 16.75 kg, 15.40 kg, and 13.01 kg, respectively, indicating a 28.9% and 18.4% advantage in weight at 3 months when using purebred Dorper and crossbred Dorper sires over local sires. The genotype of the dam also had a significant effect on litter weight at weaning. Purebred Dorper, crossbred Dorper, and local ewes produced weights of 16 kg, 15 kg, and 13 kg, respectively, with a 23.08% and 15.58% advantage in weaning weight when using purebred Dorper and crossbred Dorper ewes instead of local ewes, In comparison to the reported litter weight at weaning (LWW) of 24.14 kg by Kebede *et al*. (2022a), our findings for all the ewe breeds considered were lower. This difference can be attributed to the unique characteristics of the Doyogena breed. The Doyogena breed is known for its high prolificacy, with a higher percentage of ewes giving birth to multiple lambs.

The influence of location on litter weight at weaning was evident. Ewes that gave birth in the low-mid-to-highland areas had an 8.4% advantage in litter weight at weaning compared to ewes that gave birth in the cool-tepid areas. Ewes that gave birth to male lambs had higher weights at weaning compared to their female counterparts. Litter weight at weaning improved as the parity

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of lambing advanced. The lowest litter weight at weaning and the highest weaning weight were recorded in parity one and parity four, respectively, and then started to decline. The season of lambing had a significant influence on litter weight at weaning as well. Ewes that lambed in the dry season produced lambs with higher weights at weaning compared to those born in the long-rainy and short-rainy seasons. Ewes that lambed in the long-rainy and short-rainy seasons had similar litter weights at weaning. The year of lambing also had a noticeable impact on litter weight at weaning. Ewes that lambed in certain years produced higher weights at weaning compared to other years.

The importance of considering litter weight at birth and weaning has been highlighted by several previous authors. Boujenane (2002), in his studies on ewe reproduction and the development of synthetic breeds in Morocco, reported a litter birth weight of 4.14 kg and a litter weaning weight (at 90 days) of 19.91 kg. These values are higher compared to the findings in our study for both litter weight at birth and weaning. Boujenane also reported the effects of the age of ewes and lambing year on both traits, which is consistent with current findings that highlight the influence of ewe parity of lambing and year of lambing. In another study by Abd-Allah *et al*. (2011) on Rahmani and Chiose sheep in Upper Egypt conditions, the authors evaluated the reproductive performance of these breeds and reported a litter weight of 4.25 kg and a litter weaning weight of 19.75 kg. Similar to our findings, these authors detected the effects of dam breed and dam lambing parity on litter weight at birth, and they also appreciated the influence of dam breed on litter weight at weaning. However, unlike our findings, these authors did not find a significant effect of mating season (winter, autumn, and summer) or mating year on litter weight at birth and weaning, and they also did not find an influence of the age of ewes on litter weight at weaning.

In their studies on Doyogena sheep, Kebede *et al*. (2022a) investigated the effects of various factors on litter weight at birth (LWB) and litter weight at weaning (LWW). They found that lamb birth type, location, lambing year, and season had significant effects on LWB, while the influence of ewe parity on LWB was not detected. Similarly, they reported that ewe birth parity, lamb birth type, location, and birth year influenced LWW, but lambing season did not have a significant effect on LWW. These findings are consistent with a study conducted by Morsy (2002), which also found that parity (dam age) influenced litter weight at birth and weaning. Our study aligns with these previous findings and further demonstrates that as the age of the ewe advances, litter weight at birth and weaning increases. Other authors such as Hohenboken et al. (1976), Iniguez et al. (1986), and Boujenane (2002) support this observation. Overall, the results from our study, as well as previous research, emphasize the significant influences of genotype and environmental factors on litter weight at birth and weaning. Factors such as the genotype of the sire and dam, environmental conditions, ewe lambing parity, and year of lambing all play important roles in determining the weights of litters at birth and weaning in sheep. Understanding these influences can assist in making informed decisions to improve the reproductive performance and productivity of their flocks under on-station management systems.

5.8.6. Age at first lambing under farmers' and on-station management

The present study aimed to investigate the Age at First Lambing (AFL) under both farmers' and on-station management systems. The results revealed that AFL was influenced by genotype and environmental conditions in both scenarios. Under farmers' management conditions, local ewes exhibited shorter lambing intervals compared to Dorper crossbred ewes. Additionally, the study found that AFL values varied depending on the location. Ewes reared in Merhabete had lower AFL values, while those in Basona-Werana had higher AFL values. Ewes reared in Kewet-EF and Kobo areas fell in between. This indicates the importance of location on AFL for ewes managed under farmers' conditions. However, the study did not find any significant differences in AFL among ewes that gave birth in different seasons under farmers' management.

Under on-station management conditions, both the genotype (sire and dam) and environmental factors were observed to influence AFL. Ewes sired by local rams had relatively lower AFL values compared to those sired by Dorper purebred rams. No significant AFL differences were observed between ewes sired by Dorper purebred rams and those sired by Dorper crossbred rams. Similarly, ewes sired by Dorper crossbred rams had comparable AFL values to those sired by local rams. The breed of the ewe also influenced AFL, with local ewes having lower AFL values, followed by Dorper crossbred ewes, and Dorper purebred ewes having higher AFL values.

Similar to farmers' management, the study also observed the influence of location on AFL under on-station management. Ewes bred in the low-mid-to-highland areas had lower AFL values compared to those reared in cool-tepid areas. The influence of location on AFL was evident in both management systems. However, contrary to farmers' management conditions, AFL was

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significantly affected by the season of lambing under on-station conditions. Ewes giving birth in the dry period and long-rain period had lower AFL values compared to those giving birth in the short-rain season. Ewes giving birth in the short-rain season were mated in the dry period when grazing pasture is poor and scarce, leading to longer AFL values. The study also observed the influence of the year of lambing on AFL under on-station management. Notably, the study did not find significant influences of birth litter size and lamb sex on AFL in ewes managed under on-station conditions.

The AFL values observed in current study for local, Dorper crossbred and Dorper purebred ewes (15-17 months) are consistent with previous reports from tropical regions by various authors (Armbruster *et al*., 1991; Galina *et al*., 1996). Furthermore, our findings align with the results reported by Shigdaf *et al*. (2013) for Washera sheep under both on-station and on-farm management systems (15.7 and 15.2 months, respectively). Our AFL values are also comparable with those reported by Asrat *et al*. (2021) for the Bonga sheep breed within the CBBP, which was recorded as 15.1 months. For the indigenous local sheep, the AFL values obtained in our study under farmers' and on-station management conditions (14.69 and 13.80 months), respectively are slightly higher than the reported values for local sheep breeds in different regions of Ethiopia. For example, Solomon A (2007) reported AFL values of 13.67 months for Gumuz sheep, Getahun (2008) reported 13.52 months for Afar sheep, and Edea (2008) reported 13.3 months for Horro sheep.

However, the AFL value for Dorper crossbred ewes under farmers' and on-station management conditions (16.21 and 15.20 months), respectively are higher than the reported values from the same authors. It is worth noting that Destaw and Kefyalew (2017) reported slightly higher AFL values (15.67 months) for indigenous Menz sheep. In contrast, Ermials *et al*. (2014) observed lower AFL values for Dorper crossbred ewes under farmers' management in the southern parts of Ethiopia, specifically Dorper x Local 50%, which were recorded as 12.5 months in their preliminary observations. Additionally, Senderos *et al*. (1995) reported AFL values ranging from 14.9 to 16.5 months for Menz, Corriedale crossbred, and Awassi crossbred ewes in Ethiopia.

Improving AFL is crucial for enhancing the lifetime productivity of ewes. Initiatives such as selecting and breeding ewes at an earlier age (7-9 months) rather than later in life (18 months)

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can lead to greater overall productivity (Dickerson and Glimp, 1975). These insights highlight the importance of considering AFL values specific to different sheep breeds and regions when implementing breeding and management strategies for improved productivity. Farmers can enhance the reproductive efficiency and long-term performance of their sheep flocks by prioritizing early breeding. In summary, our study provides valuable insights into the age at first lambing among local and Dorper crossbred sheep. The significant impact of location on AFL highlights the importance of considering geographical factors and management practices. Continued investigation and interventions targeted at maximizing the AFL have the potential to enhance productivity and sustainability within sheep production systems.

5.8.7. Lambing interval under farmers' and on-station management

The evaluation of lambing interval (LI) for ewes managed under farmers' and on-station management systems in our study demonstrates that LI is influenced by both genotype and environmental factors under on-station management while dam genotype didn't affect LI on lambs reared under farmers' condition. This implies that the genetic makeup of the ewes, as well as the conditions they were raised in (on-station management), played a role in determining the time between successive lambing. Similar to the on-station management condition, LI under farmers' management was affected by location. However, LI under farmers' management was not influenced by environmental factors such as lamb sex and birth litter size, which was consistent with the findings under on-station management. This implies that these specific factors did not have a significant impact on the time interval between lambing.

In contrast to the farmers' management condition, under on-station management LI was highly affected by genotype (sire and dam) and environmental factors such as ewe lambing parity, season of lambing, and year of lambing ($p < 0.0001$). Lower LI values were recorded at Merhabete compared to the Kewet-EF, Kobo, and Basona-Werana sites under farmers' condition. Similarly, lower LI values were observed for ewes in the cool-tepid areas compared to ewes reared in the low-mid-to-highland areas under the on-station management condition, this suggests that geographical variations, such as climate or resource availability, may have influenced the reproductive performance of the ewes.

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The effect of sire breed on LI for ewes managed under on-station conditions was evident. Ewes sired by Dorper crossbred and local sires had comparable LI values. Similarly, ewes sired by Dorper purebred and Dorper crossbred sires showed comparable LI values. However, ewes sired by local sires had lower LI values compared to ewes sired by Dorper purebred sires. This indicates that the genetic background of the sire influenced the reproductive efficiency of the ewes. In contrast to the results obtained under farmers' management, ewe breed influenced the LI of ewes under on-station management. Local ewes had shorter LI compared to Dorper crossbred and Dorper purebred ewes. This suggests that similar breeds may have different reproductive characteristics, which affected the lambing interval under different management systems.

Additionally, LI values for Dorper crossbred ewes under on-station conditions were shorter than those for Dorper purebred ewes, indicating contrasting LI values among the local, Dorper crossbred, and Dorper purebred ewes, highlighting the genotype effect on LI. The study also observed longer LI for first parity ewes under on-farm management conditions, this suggests that younger ewes may require more time between lambing to recover and achieve optimal reproductive performance. Contrary to the results for ewes managed under farmers' management conditions, we found significant effects of lambing season on LI under on-station management conditions. Ewes giving birth in the dry period had longer LI values compared to those giving birth in the long-rain and short-rain seasons. This indicates that the environmental conditions during the dry season may have negatively affected the reproductive performance of the ewes. However, ewes that gave birth in the long-rain and short-rain seasons demonstrated comparable LI values under on-station management conditions. The study also noted significant effects of lambing year on LI for ewes.

According to Ampong *et al*. (2019), lambing interval (LI) in a ewe is a valuable indicator of reproductive efficiency. Our results on LI for local ewes under farmers' and on-station management conditions (9.01 and 9.35 months, respectively) were similar to the reported values for local ewes (9 months) and better than the values reported for Awassi crossbred ewes by Sisay *et al*. (2014). However, the current LI values for Dorper crossbred ewes (9.67 and 10.07 months, respectively) under farmers' and on-station management conditions, and 11.6 months for Dorper purebred ewes under on-station management, fall within the range of LI estimates (7.7-14.6 months) reported elsewhere in Africa (Wilson, 1989). The LI results obtained for the dry season, long-rain season, and short-rain season under farmers' and on-station management conditions (dry period: 9.56 and 10.55 months, long-rain: 8.98 and 10.26 months, short-rain: 9.47 and 10.21 months, respectively) are comparable to the LI reported for Menz sheep in the dry season (9.37 months) by Mukasa-Mugerwa and Lahlou-Kassi (1995), and 9.6 months for Abera sheep reported by Marufa *et al*. (2017). In general, the LI values obtained in this study for local and Dorper crossbred ewes were similar to or better than reported values for similar breeds in previous studies. The LI values for Dorper purebred ewes fell within the range of LI estimates reported for African sheep breeds. The LI values observed in different seasons were comparable to those reported for other sheep breeds in similar conditions. Overall, the results indicate that factors such as genotype, location, season and year of lambing, type of management, and ewe parity play significant roles in determining the lambing interval of ewes. These findings contribute to our understanding of reproductive efficiency in sheep and can inform breeding and management strategies to improve productivity.

5.8.8. Annual reproductive rates under farmers' and on-station management

The study aimed to assess the annual reproductive rates (ARR) of ewes and determine their reproductive efficiency under farmers' and on-station management conditions. The results obtained from the farmers' management condition revealed that ARR in ewes was significantly influenced by environmental factors such as location and season of lambing ($p < 0.0001$). However, the dam genotype group did not have a significant effect on ARR in the farmers' management condition, possibly due to the limited number of observations on Dorper crossbred ewes. In contrast, under on-station management conditions, ARR was highly influenced by dam breed and moderately influenced by sire breed. Additionally, similar to the farmers' management condition, ARR was significantly affected by the season of lambing. However, location did not have a significant impact on ARR under on-station management conditions, which is different from its effect under farmers' management conditions.

Under farmers' management conditions, higher ARR values were recorded at the Merhabete site, while lower ARR values were observed at the Kobo site, with Kewet-EF and Basona-Werana falling in between. Similarly, higher ARR values were associated with ewes giving birth during the long-rain season compared to the dry period and short-rain season. Ewes that gave birth

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during the dry period and short-rain seasons showed similar ARR values under farmers' management conditions. These effects of the season of lambing on ARR were also evident under the on-station management scenario. Accordingly, higher ARR values were recorded for ewes giving birth during the short-rain season compared to the dry period and long-rain season. Ewes giving birth during the dry period and long-rain season had comparable ARR values under on-station management conditions.

When comparing our findings from the flocks managed by farmers with previous studies, the annual reproductive rate (ARR) values observed for local and Dorper crossbred sheep in this study (1.55 and 1.42, respectively) were lower than the reported number of lambings per ewe per year for Abera sheep (1.9) by Marufa *et al*. (2017). However, the ARR values for Dorper crossbred ewes in our study closely resembled the results reported for Karakul sheep in Botswana (1.42 vs. 1.45) by Martins and Peters (1991).

Furthermore, the ARR values for local and Dorper crossbred ewes in our study differed and is better than the results reported by Shigdaf *et al*. (2013) for Washera and Farta sheep (1.38 and 1.29, respectively) under on-farm management. These variations could be attributed to differences in ewe genotype and location. Additionally, our ARR values were slightly higher than the results obtained by Sisay *et al*. (2014) for local and Awassi crossbred ewes, which were 1.4 and 1.2 lambs per ewe per year, respectively.

As was suggested by Rodriguez *et al*., 1998, the findings suggest that the efficiency of meat production from sheep could be improved by increasing the number of lambs marketed per ewe per year. The ARR values obtained in this study for local and Dorper crossbred ewes indicate slightly higher reproductive rates compared to some previous studies, but comparable rates to others. These variations could be attributed to differences in ewe genotype and location. In summary, the study revealed that ARR in ewes was influenced by environmental factors, including location and season of lambing, and type of management as well as dam and sire breed. The ARR values obtained were comparable to or slightly higher than those reported in previous studies for specific ewe breeds, highlighting the importance of considering these factors in breeding and management strategies to improve reproductive efficiency and meat production in sheep.

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5.8.9. Annual productive indices of ewes under farmer' and on-station management

The current study assessed the reproductive efficiency (reproductive component of the productivity indices) of ewes under different management conditions. The focus was on evaluating the factors influencing the litter weight (measured in kilograms of lamb at 90 days) produced by the ewes, referred to as Index-I. The study found that under on-station management conditions, both genotype and environmental factors influenced the litter weight. However, under farmers' management conditions, the litter weight was not affected by the dam's genotype. Specifically, the study recorded similar Index-I values for local ewes and Dorper crossbred ewes, indicating comparable productivity between the two groups.

Location also played a role in Index-I values in both management conditions. Ewes giving birth in Merhabete had the highest Index-I value of 23.29, while those in Basona-Werana and Kobo areas had values of 18.99 and 19.00 and Kewet in between. This suggests that the geographic location has an impact on the reproductive performance of ewes. The study also compared low-mid-to-highland areas to cool-tepid areas under on-station management conditions. Ewes lambed in the low-mid-to-highland areas produced more kilograms of lamb per ewe per year (Index-I) compared to ewes lambed in the cool-tepid areas. Additionally, ewes giving birth to male lambs had higher Index-I values compared to those giving birth to female lambs under on-station management conditions.

The influence of lambing season on index-I was evident in this study, with ewes giving birth in the long-rain and short-rain seasons having higher values compared to those giving birth in the dry period under farmers' management. Similarly, ewes giving birth in the dry period had lower values of index-I under on-station management conditions. The lambing season, therefore, has a significant effect on reproductive component of productivity index-I in both management scenarios. The study also observed a pattern of influence by lambing parity on index-I. Ewes giving birth for the first time (1st parity) had the lowest Index-I values compared to later parities under both management settings. This suggests that the parity of the ewe (number of times she has given birth) affects her reproductive productivity.

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On the other hand, under the on-station management situation, the study found that the sire breed also influenced index-I. Ewes sired by local sires had lower values compared to those sired by Dorper purebred and Dorper crossbred sires. The study observed similar patterns but higher values for ewes sired by Dorper purebred and Dorper crossbred sires compared to ewes sired by local sires under on-station management conditions. This indicates that the choice of sire breed can influence the reproductive performance of ewes. Crossbreeding efforts resulted in a positive heterosis effect, as evidenced by the significantly higher weights of lambs per ewe per year at 90 days in Dorper x Local crossbred ewes compared to local and purebred Dorper ewes, indicating the crossbreeding efforts that can result in crossbred ewes producing a higher weight of lambs per ewe per year compared to purebred ewes.

This study further analyzed index-I values based on the type of birth. Ewes giving birth to triplets (stipples) had the highest values, followed by twin-bearing ewes and then single-bearing ewes. This suggests that the number of offspring born to the ewe influences her reproductive productivity. The year of lambing also had an important influence on index-I values under on-station management conditions. The values ranged between 23.3 and 30.2 kilograms per ewe per year, indicating that different years can have varying impacts on reproductive component of productivity index. In addition to assessing the litter weight, the study also evaluated the per kilogram ewe postpartum weight, referred to as index-II, under both farmers' and on-station management conditions. Factors such as location, dam genotype, and ewe lambing season influenced the index-II values in both management scenarios. However, ewe lambing parity did not have a significant influence on index-II values in either management condition.

Under farmers' management conditions, ewes giving birth at the Merhabete site had higher index-II values compared to ewes reared at Kewet-EF and Basona-Werana. Additionally, ewes lambed in low-mid-to-highland areas had higher index-II values compared to those in cool-tepid areas under on-station management conditions. These findings indicate the importance of location, as factors such as temperature and rainfall can affect feed availability and quality, ultimately influencing the postpartum weight of the ewes and thereby the index-II.

Local ewes reared under farmers' conditions had higher index-II values than Dorper crossbred ewes. Similarly, local ewes managed under on-station management conditions had higher index-

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II values compared to the Dorper crossbred and Dorper purebred ewes, respectively with values of 1.00, 0.87, and 0.71 kg, respectively. The study results suggest that local ewes have higher and better index-II values compared to Dorper crossbred and Dorper purebred ewes, respectively. This could be attributed to the advantage of low ewe postpartum body weight exhibited by local ewe breed. Contrary to this, ewes sired by local sires had significantly ($p < 0.0001$) lower index-II values compared to the ewes sired by Dorper crossbred and Dorper purebred sires, respectively. One possible reason could be the influence of genetic superiority in the Dorper crossbred and purebred sires, which may contribute to improved traits and overall performance in their offspring, another factor could be the presence of heterosis in the crossbred sires, resulting in hybrid vigor and enhanced performance in their progeny.

The study also found that ewes giving birth in the short and long rain periods had higher Index-II values compared to those birthing during the dry period under farmers' management conditions. Similarly, ewes lambing during the dry period had lower Index-II values under on-station management conditions. However, under this management scenario, the study discovered higher Index-II values in the short-rain period compared to the long-rain period, which is opposite to the results obtained under farmers' management conditions, additionally, management practices, nutrition, and environmental factors may also contributed to the observed differences in index-II values among the different sire groups.

The study confirmed that ewes giving birth to male lambs had higher index-II values under on-station management conditions. Similarly, under this management condition, ewes giving birth to triplets had higher index-II values compared to those giving birth to twins and singles. These findings highlight the influence of lamb sex and birth litter size on the postpartum weight of ewes. The effect of the year of lambing on index-II values was also detected under on-station management conditions. The values ranged between 780 (2013) and 950 grams per kilogram (2014), indicating variations in ewe productivity and reproductive performance across different years. index-II is an important parameter for assessing ewe productivity and reproductive performance. It measures the efficiency of ewes in converting their own weight into the weight of their offspring. The index takes into account the condition and body weight of the ewe at lambing, providing insights into how well she can support and nourish her lambs during the postpartum period.

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The results of the study indicate that the kilograms of lamb produced per metabolic weight of ewes (index-III) is influenced by various factors under both farmers' and on-station management conditions. These factors include location, dam breed, season of lambing, sire breed, lamb sex, parity of birth, and year of lambing. Ewes at the Merhabete site had higher index-III values compared to those at Kewet-EF and Basona-Werana, suggesting that location can affect ewe productivity. Similarly, in on-station management, ewes in low-mid-to-highland areas had higher index-III values compared to those in cool-tepid areas, indicating the influence of environmental conditions on ewe productivity. Local ewe breeds generally had higher index-III values compared to Dorper crossbred and Dorper purebred ewes in both management scenarios. This could be due to the advantage of lower postpartum metabolic weight exhibited by local ewes. Conversely, under on-station management conditions, ewes sired by local sires had lower index-III values compared to those ewes sired by Dorper crossbred and Dorper purebred sires, respectively, suggesting the influence of sire breed on ewe productivity.

The study also found that ewes giving birth to male lambs had higher index-III values compared to those giving birth to female lambs. Additionally, ewes with triplets had higher index-III values compared to those with twins and singles, indicating the impact of lamb sex and birth litter size on ewe productivity. The year of lambing and season of lambing were also found to affect index-III values. Under on-station management conditions, the values varied across different years, suggesting variations in ewe productivity and reproductive performance. Additionally, the season of lambing influenced index-III values, with different patterns observed under farmers' and on-station management conditions.

The kilogram of lambs weaned per ewe/year (index-I) obtained for the local, Dorper crossbred, and Dorper purebred ewes in this study was higher than the results reported by Rodriguez *et al*. (1998) for hair sheep, which ranged between 9.8 and 18.6 kg in the annual breeding system and 11.2-20.0 kg for the accelerated system, respectively. In another study conducted by Martins and Peters (1991) on Karakul sheep in Botswana, they obtained 27.7 kg of lamb per ewe per year, which is slightly higher than the results in this study for local, Dorper crossbred, and Dorper purebred ewes. The results of this study also indicated that the values of the indices increased with the advancing parity of the dam, which aligns with the patterns observed for Djallonke

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sheep reported by Gbangboche *et al*. (2006). Thieme *et al*. (2019), in their studies on the performance of ewe flocks in central Anatolia, reported index values of 16.0 kg for index-I, 360 g for index-II, and 1.01 kg for index-III, respectively.

Although the above authors did not discover the effects of location, ewe breed (Merino vs. crossbred), and season of lambing on all three indices, they found that ewe age and the sex of the litter had significant effects on the indices, which is consistent with the findings of this study.

Sisay *et al*. (2012) conducted studies on Menz, Washera x Menz, and Bonga x Menz sheep in Ethiopia and reported index values for ewes. For Menz ewes, the reported values were index-I = 11.51 kg, index-II = 515 g, and index-III = 1.19 kg, respectively. The corresponding values for Washera x Menz crossbred ewes were 10.69 kg, 456 g, and 1.07 kg, and for Bonga x Menz crossbred ewes were 12.63 kg, 479 g, and 1.16 kg, respectively, under on-station management conditions. In another study conducted under farmers' management conditions, Sisay *et al*. (2014) again reported index values for local and Awassi x local crossbred sheep. For local ewes, the values were 15.6 kg for index-I, 647 g for index-II, and 1.52 kg for index-III, respectively. The corresponding values for Awassi x local crossbred ewes were 17.1 kg, 686 g, and 1.63 kg, respectively.

The distinction in annual productivity indices between local and Dorper crossbred ewes became more noticeable when taking into account the postpartum ewe weight. This is because Dorper crossbred and purebred Dorper ewes tend to have higher postpartum body weights. Additionally, the decreased productivity observed in Dorper crossbred ewes became more evident when productivity was expressed based on the weight of the ewe, due to a slight variation in lambing interval. Furthermore, the study highlighted higher index-I to index-III values for ewes managed under on-station conditions, compared to those managed by farmers. It also emphasized the productivity disparities between ewes sired by local, Dorper crossbred, and Dorper purebred sires, with the latter two exhibiting higher indices. Local ewe breeds demonstrated superiority across all indices, except for index-I, where local and Dorper crossbred ewes had comparable values. Under on-station management conditions, the Dorper crossbred ewes fell between the two pure breeds for index-II and index-III but surpassed them in index-I. Overall, the study investigated multiple factors impacting ewe reproductive component of productivity, including

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genotype, environmental conditions, lambing season, sire breed, location, birth type, year of lambing, and management type. The findings provide valuable insights into the complex interactions between these factors and their influence on ewe productivity.

5.9. Growth performance of sheep

5.9.1. Growth performances of lambs under village and on-station management systems

5.9.1.1. Pre-weaning growth performances of lambs

The overall least squares means and standard errors for birth weight and weaning weights of lambs born under farmers' management and under on-station management systems were 2.82±0.04 vs 3.04±0.02 kg, and 12.97±0.19 kg vs 13.71±0.12 kg, respectively (Tables 48 and 50). Whereas the overall pre-weaning body weight gains of lambs in the corresponding sites were 112.51±2.10 vs 118.02±1.25 g/d. The birth weights of Dorper x Local (low grade), Dorper x Local (high grade), and local lambs reared under farmers' management were 2.94, 3.08, and 2.21 kg, respectively. The corresponding birth weight values for the lambs born under on-station management for (50%-Dorper cross-F_1, 50%-Dorper cross (*inter se*), 25%-Dorper cross, 75%-Dorper cross, Dorper purebred and local) was 2.98, 2.82, 2.76, 3.45, 3.26, and 2.11 kg, respectively. The weaning weights of lambs (Dorper x Local (low grade), Dorper x Local (high grade), and local) reared under farmers' management were 13.22, 13.83, and 10.57 kg, respectively. Similarly, the weaning weights of lambs (50%-Dorper cross-F_1, 50%-Dorper cross (*inter se*), 25%-Dorper cross, 75%-Dorper cross, Dorper purebred and local) was 13.39, 13.86, 11.67, 15.28, 15.89, and 10.04 kg, respectively.

The pre-weaning (90 days) weight gain for the lambs born under farmers' management (Dorper x Local (low grade), Dorper x Local (high grade), and local lambs) reared under farmers' management were 112.16, 117.98, and 89.12 gram per day, respectively. The corresponding pre-weaning gain values for the lambs reared under on-station management for (50%-Dorper cross-F_1, 50%-Dorper cross (*inter se*), 25%-Dorper cross, 75%-Dorper cross, Dorper purebred and local) lambs were 114.78, 121.70, 99.60, 130.71, 139.43, 86.89 gram per day, respectively. The performance of Dorper crossbred lambs at birth, weaning and PWADG managed both under farmers' and on-station management were better than the local counterparts, indicating the superiority of Dorper crossbred lambs under the farmers' and on-station management system in

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Ethiopia. Crossbreeding using Dorper sires improved the birth weight of local lambs under farmers' management by 33-39% (using low-grade/12.5-25% and high-grade/37.5-43.75% Dorper crosses, respectively). The corresponding improvement in birth weight for local lambs under on-station management was 31-64% (using 25-75% Dorper x local crosses, respectively). The pre-weaning average daily gain advantage of Dorper crossbred lambs over local lambs was 25-31% under farmers' management and 16-52% under on-station management. The pre-weaning daily gain advantage of Dorper crossbred lambs was 26-32% under farmers' management and 15-50% under on-station management. On the other hand, Dorper purebred lambs were superior to local lambs in terms of birth weight, weaning weight, and pre-weaning growth (gain) by 55%, 28%, and 60% respectively under an on-station management system.

The current study results that were based on the evaluation of Dorper crossbred lambs with different levels of inheritance both in the farmers' and on-station management declare that the Dorper crossbred lambs outperformed the local counterparts, signifying the possible adaptation and better performances from the Dorper crossbred sheep under Ethiopian condition. The mean birth weight (2.94, 3.08 kg) for low-grade and high grade Dorper crossbred lambs managed under farmers' management and (2.67, 2.98, 2.82, 3.45 kg) for 25%-Dorper cross, 50%-Dorper cross-F_1, 50%-Dorper cross (*inter se*), and 75%-Dorper cross managed under on-station management condition is higher than the mean birth weight 2.08 recorded by Zeleke *et al.* (2018) for Awassi x Wollo sheep studied in North Western Ethiopia, comparable with 3.1 kg reported by Mekonnen *et al.* (2016) for Awassi x Tikur sheep, higher than 2.20 and 2.31 kg reported for 50% Dorper cross and 25% Dorper cross by Ermias (2014) for Dorper x Adillo crossbred lambs studied in Wolaita and Silte Zones in the Southern Ethiopia, lower than reported 3.68 and 3.61 kg for Dorper x Menz 50% and Dorper x Menz 75% by Dagne (2021), higher than 2.4, 2.2 kg reported by Tadesse (2018) for Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses, respectively, comparable to 3.25 kg recorded by Hassen *et al.* (2002) for Awassi crossbred lambs under village condition in the cool highlands of central Ethiopia.

The average weaning weight of Dorper crossbred lambs, categorized as low-grade and high-grade, managed by farmers (13.22 kg and 13.83 kg respectively), and the weaning weights of lambs from different crossbred categories (25%-Dorper cross, 50%-Dorper cross-F_1, 50%-Dorper cross *inter se*, and 75%-Dorper cross) under on-station management conditions (11.67 kg,

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13.39 kg, 13.86 kg, and 15.28 kg respectively) were higher compared to the mean weaning weight of 12.99 kg reported by Zeleke *et al*. (2018) for Awassi x Wollo sheep in North Western Ethiopia. They were also comparable to the weaning weight of 13.04 kg reported by Mekonnen *et al*. (2016) for Awassi x Tikur sheep.

However, these weaning weights were lower than the weights of 19.00 kg and 15.05 kg reported for 50% crosses and 25% crosses respectively by Ermias (2014) for Dorper x Adillo crossbred lambs studied in Wolaita and Silte Zones in Southern Ethiopia. Additionally, they were lower than the reported weights of 15.64 kg and 16.16 kg for Dorper x Menz 50% and Dorper x Menz 75% respectively by Dagne (2021). On the other hand, they were higher than the weights of 13.8 kg and 14.0 kg reported by Tadesse (2018) for Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses respectively. The weaning weights were also higher than the results obtained by Ayele *et al*. (2016b) for Awassi x Menz crossbred lambs with different Awassi inheritance (9.54 kg), and higher than the weight of 8.85 kg recorded by Hassen *et al*. (2002) for Awassi crossbred lambs under village conditions in the cool highlands of central Ethiopia.

The growth rate of lambs; average pre-weaning daily gain (112.16, 117.98 g/d) for low-grade and high grade Dorper crossbred lambs managed under farmers' management is lower than 121.40 g/d reported by Zeleke *et al* (2018) for Awassi x Wollo sheep studied at Atari-Mesk watershed, North Western Ethiopia. The 99.60, and 114.78 g/d pre-weaning average daily weight gain recorded for under on-station management for 25%-Dorper cross, 50%-Dorper cross-F_1 was also lower than reported by Zeleke *et al* (2018). The pre-weaning daily gain for 50%-Dorper cross (*inter se*), and 75%-Dorper crosses managed under on-station management condition (121.70 and 130.71 g/h/d) is higher than reported by by Zeleke *et al* (2018). The PRWADG observed in the current study for low-grade (112.16 g/d) and high grade Dorper crossbred lambs (117.98 g/d) managed under farmers' management is lower than 127.39 g/d reported by Mekonnen *et al.* (2016) for Awassi x Tikur sheep, but higher than Awassi x Menz crossbred (94.07 g/d); Awassi x Menz 75% (101.8 g/d), higher than 77.00 and 73.80 g/d reported by Tadesse (2018) for Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses, respectively.

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Various factors were found to significantly affect birth weight, weaning weight, and pre-weaning body weight traits. These factors included lamb genotype, environmental factors (such as location, season, and year of lambing), lamb sex, birth type, and parity ($p < 0.001$ to $p < 0.05$). The effects of these factors were observed in both management systems, indicating their importance in determining the weight and growth of lambs. Overall, Dorper crossbred lambs exhibited a significant advantage over local lambs in terms of birth weight, weaning weight, and pre-weaning growth under both farmers' management and on-station management systems in Ethiopia. The percentage advantage of Dorper crossbreeds varied depending on the specific cross and the trait being considered. For birth weight, the advantage ranged from approximately 31 to 64% for Dorper crossbreeds compared to local lambs. Similarly, for weaning weight, the advantage ranged from approximately 16% to 52%. The pre-weaning growth rates of Dorper crossbreeds were also higher, with percentage advantages ranging from approximately 15% to 50%. These findings highlight the adaptability and growth potential of Dorper crossbred lambs in the Ethiopian context. Crossbreeding with Dorper sires resulted in substantial improvements in birth weight, weaning weight, and pre-weaning weight gain compared to the local lambs. Notably, Dorper purebred lambs performed exceptionally well in all growth parameters under on-station management.

The study examined the impact of different management systems on the birth weight, weaning weight, and average daily gain (PRWADG) of lambs in various study sites. The findings revealed significant variations ($p < 0.001$) across the different locations. Under farmers' management, Kobo and Merhabete showed higher birth weights, whereas Basona-Werana and Efratana-Gidim had lower birth weights. Similarly, Efratana-Gidim and Merhabete had heavier weaned lambs, while Yabello had lighter ones. Basona-Werana recorded higher PRWADG, while Yabello had the lowest (Table 48).

Furthermore, under on-station management, lambs born in the cool-sub alpine areas were heavier at birth compared to those born in low-mid-to-highland areas. However, lambs born in low-mid-to-highland areas had higher body weights at weaning and achieved greater weight gain compared to their counterparts in the cool-sub alpine areas. This suggests that although lambs in the cool-sub alpine areas were born with higher weights, they exhibited slower growth and lower body weights at weaning. This could be attributed to differences in grazing availability and feed

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quality, variations in management practices, and temperature differences that can influence lamb growth. Our findings are consistent with previous studies. Mengiste (2008) observed the effect of study sites on birth weight and weaning weight in his research on Washera sheep in Yilmanadensa and Quarity districts. Zelalem (2018) reported the impact of agro-ecology on birth weight, weaning weight, and PRWADG in Bonga crossbred lambs in different regions of Southern Ethiopia. Mekonnen *et al*. (2016) found that study location influenced birth weight, weaning weight, and PRWADG in Awassi x Tikur crossbred and Tikur sheep in the highlands of Eastern Amhara. However, Deribe (2009) did not observe any effects of study sites on birth weight, weight at 90 days, and gain to 90 days in his study on indigenous sheep and goats. Similarly, Ermias (2014) did not identify any effects of study sites on birth weight and weaning weight in Dorper crossbred lambs in Wolita and Siltie, Southern Ethiopia.

The variations in body weights (birth, weaning) and PRWADG across locations can be attributed to differences in agro-ecological conditions, including variations in the quantity and quality of forage available for the sheep, as well as variations in individual farmers' management practices. These results highlight the importance of considering location when designing breeding programs and focusing on areas with potential for optimal sheep performance. The effect of lamb sex on birth weight, weaning weight at 90 days, and average daily gain (PRWADG) at 90 days was examined, revealing significant differences influenced by different management systems. Males consistently displayed higher weights at birth and 90 days and achieved greater weight gain compared to females, whether under farmers' or on-station management (Tables 48 and 50). These findings align with previous studies conducted by Zelalem (2018) on Bonga crossbred lambs in Southern Ethiopia and Samuel (2010) on Menz and Awassi x Menz crossbred sheep, both reporting the superiority of male lambs in terms of birth weight, weaning weight, and PRWADG. However, contrasting results were observed by Mekonnen *et al*. (2016) in their study on Awassi x Tikur crossbred and Tikur sheep in the highlands of Eastern Amhara, as well as Zeleke *et al*. (2018) on Awassi x Wollo sheep in Northwestern Ethiopia, where no significant influence of lamb sex on these traits was found.

The observed superiority of males over females in terms of birth weight, weaning weight, and PRWADG can be attributed to various factors. Genetic differences, hormonal influences, nutritional efficiency, sexual dimorphism, and maternal effects all contribute to these disparities.

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However, the divergent findings among scholars can be attributed to several factors, including differences in study design, breed and population variations, environmental factors, data analysis approaches, sample size and representativeness, and sex-specific differences. Considering these factors, it is important to interpret and reconcile the varying results of these studies. Future research should aim for standardized methodologies, larger and more representative sample sizes, and comprehensive analyses to gain a clearer understanding of the potential differences or similarities in birth weight, weaning weight, and growth between male and female lambs.

The current study provided evidence of the impact of birth litter size on the birth weight, weaning weight, and growth up to weaning (PRWADG) of lambs ($p < 0.001$). Specifically, the study found that lambs born as singles had significantly higher birth weights and exhibited faster growth (PRWADG) compared to lambs born as twins or multiples. These findings were consistent across both on-farm and on-station management settings. In support of these results, Deribe (2009) who conducted a study on indigenous sheep and goats in Alaba, Southern Ethiopia, similarly reported the superiority of single-born lambs in terms of birth weight, weaning weight, and gain up to 90 days (PRWADG) when compared to multiple-born lambs. Similarly, Mekonnen *et al*. (2014), in their studies on Awassi x Tikur crossbred and Tikur sheep in the highlands of Eastern Amhara, observed that single-born lambs had higher birth weights than twin-born lambs. Interestingly, they did not find differences in growth up to three months (PRWADG). In comparison to the current study, Tadesse (2018) who conducted research on Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses did not observe differences in birth weight between lambs born as singletons or twins. However, the same author reported that singletons were heavier at three months (weaning) and had higher growth rates compared to twins at the age of three months (PRWADG). Similarly, Ermias (2014) who conducted studies on Dorper crossbred lambs in Wolita and Siltie, Southern Ethiopia, found no difference in birth weight among single, twin, and multiple-born lambs. However, Ermias observed significant differences in weight at three months of age, with single-born lambs being heavier and exhibiting higher growth rates compared to twins and multiples.

These contrasting findings can be attributed to various factors, including environmental conditions, management practices, and breed-specific characteristics. Additionally, birth type, maternal effects, and the timing of measurements can also influence the observed differences in

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birth weight, weaning weight, and growth up to weaning (90 days). It is crucial to consider these factors when interpreting the results reported by different scholars. Overall, the heterogeneity of findings underscores the complexity of the relationship between birth litter size and lamb growth traits. Further research considering larger sample sizes, standardized methodologies, and comprehensive analysis that accounts for genetic, environmental, and maternal factors would contribute to a more comprehensive understanding of the differences or similarities in birth weight, weaning weight, and growth between single-born and multiple-born lambs.

The present study also yielded significant findings regarding the influence of birth parity on lamb birth weight and growth up to 3 months. The analysis revealed that parity of birth had a significant effect on both birth weight ($p < 0.05$) and weight at 3 months ($p < 0.01$). However, no significant differences were observed among birth parities in terms of pre-weaning gain under farmers' management conditions. Specifically, lambs born in the first parity exhibited lower values for birth weight and weaning weight. Conversely, under the on-station management system, birth parity had a significant impact on birth weight, weaning weight, and growth up to 90 days (PRWADG), with lambs born in the first parity displaying lower values for these traits. These findings align with a study conducted by Zelalem (2018) on Bonga crossbred lambs in Southern Ethiopia. Zelalem (2018) reported the effect of birth parity on birth weight and weaning weight, although the author noted that lambs born in the first parity had a higher birth weight compared to those born in the second parity, but similar birth weights to lambs born in the third and fourth parities. Additionally, the same author found that lambs born in the first parity had higher weaning weights than lambs born in the second and third parities, but no significant effect of parity on pre-weaning growth (PRWADG) was detected.

Contrary to our results, Tadesse (2018) did not observe the influence of birth parity on lamb birth weight, weaning weight, or PRWADG in his study on Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses. Similarly, Samuel (2010) found no significant influence of birth parity (considering parities 1, 2, and 3 and above) on the birth weight of Menz and Awassi x Menz crossbred sheep. However, Samuel did recognize the effect of birth parity on weaning weight, noting that lambs from the first parity had lower weights and slower growth compared to subsequent parities. These divergent results may be attributed to various factors, including differences in genetic backgrounds, management practices, environmental conditions, and

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sample sizes. It is important to consider these factors when interpreting the impact of birth parity on lamb growth traits. Further research with larger and more diverse populations, along with standardized methodologies, would enhance our understanding of the relationship between birth parity and lamb performance. In conclusion, the current study demonstrated the influence of birth parity on lamb birth weight and growth up to 3 months. While some studies corroborated these findings, others reported contrasting results. The disparities observed could be attributed to various factors, highlighting the complex interplay between birth parity and lamb traits. Further investigations are warranted to elucidate the underlying mechanisms and provide more comprehensive insights into the influence of birth parity on lamb performance.

The study also examined the impact of birth season and birth year on lamb birth weight, lamb weaning weight, and lamb growth (PRWADG). Under farmers' management conditions, the season of lambing significantly affected lamb birth weight ($p < 0.05$), lamb weaning weight, and pre-weaning gain ($p < 0.0001$). Specifically, lambs born in the dry period and long-rain seasons exhibited similar birth weights, while lambs born in the dry period and short-rain seasons also had similar birth weights. However, lambs born in the long-rain season had higher birth weights compared to lambs born in the short-rain season. Additionally, lambs born during the dry period had lower weaning weights and lower pre-weaning gains at 90 days compared to lambs born in the long-rain and short-rain seasons, respectively. The effect of the year of birth was also evident in lambs' birth weight ($p < 0.001$), weaning weight, and pre-weaning gain ($p < 0.01$) under farmers' management conditions. Similar effects of birth season and year of lambing were observed under on-station management. Birth weight, weaning weight, and pre-weaning gain were significantly influenced ($p < 0.0001$). Lambs that were born during the short-rain season exhibited lower body weights in comparison to lambs born during the long-rain and dry periods. Conversely, lambs born during the short-rain season displayed superior weaning weights and greater pre-weaning gains when compared to lambs born during the dry period and long-rain season.

These findings coincide with a study conducted by Mekonnen *et al*. (2016) involving Awassi x Tikur crossbred and Tikur sheep in the highlands of Eastern Amhara. The study highlighted the influence of the season and year of birth on lamb birth weight, revealing that lambs born during the dry period had higher birth weights in contrast to lambs born during the wet season. However,

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no significant disparities were observed in the weight at 3 months (weaning weight) and pre-weaning gain between lambs born during the dry period and wet season. Similarly, Zeleke *et al*. (2018) who conducted a study on Awassi x Wollo sheep in Northwestern Ethiopia observed the effect of birth season on lamb birth weight. They found that lambs born in the wet season significantly outweighed lambs born in the dry period at birth, but no differences were observed in weaning weight and pre-weaning gain between lambs born in the dry period and wet season.

In the current study, seasons were classified as follows: June, July, August, and September as the long-rain season, October, November, December, and January as the dry period, and February, March, April, and May as the short-rain season. It is important to note that ewes pregnant during the long-rain season give birth during the dry period, which may contribute to higher birth weights due to ample feed intake during the preceding long-rain season. Conversely, ewes pregnant during the dry period (a period of feed scarcity) give birth during the short-rain season, which may result in lower birth weights for the lambs.

In conclusion, the study demonstrated the significant influence of birth season and birth year on lamb birth weight, weaning weight, and pre-weaning gain. These findings were consistent with previous research, highlighting the impact of environmental factors on lamb growth. The classification of seasons and consideration of ewes' pregnancy periods provided valuable insights into the variations observed in birth weights. Further research is needed to explore the underlying mechanisms and develop strategies for optimizing lamb performance under different seasonal and management conditions.

5.9.1.2. Post-weaning growth performances of lambs

The lambs' overall adjusted weights at 6 and 12 months were 16.63±0.26 kg and 24.04±0.62 kg, respectively. Additionally, the overall POWGAIN was recorded as 41.11±2.27 g/h/d under farmers' management conditions. For lambs managed under on-station condition, the corresponding values were 18.54±0.17 kg, 26.89±0.29 kg, and 46.21±0.99 g/d for 6-month weight, 12-month weight, and POWGAIN, respectively (Tables 49 and 51, Figure 6). Both genotype and environmental factors significantly affected the weight of lambs at 6 months, yearling age, and post-weaning grain, under both farmers' management and on-station management conditions.

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Under farmers' management, the influence of lamb genotype was evident, as the local lambs consistently showed inferior performance compared to the crosses in terms of weight at 6 and 12 months, as well as POWGAIN. Notably, the Dorper cross (high-grade) lambs were heavier at 6 months and yearling age compared to the Dorper cross (low-grade) lambs. However, no significant difference was observed between the two groups in terms of POWGAIN. Similarly, the effects of lamb genotype on weight at 6 and 12 months, as well as POWGAIN, were observed among the different lamb breeds and genotype groups managed under the on-station management system. Under this management system as well, the local lambs demonstrated lower values in terms of weight at 6 and 12 months, as well as POWGAIN, compared to the Dorper crossbred lambs with varying levels of Dorper inheritance and Dorper purebred lambs.

Surprisingly, it was observed that lambs with 75% Dorper inheritance performed similarly at 6 and 12 months of age but exhibited higher POWGAIN compared to the Dorper purebred lambs. When comparing the 50%-Dorper-F_1 crossbreed lambs to the 50%-Dorper (*inter se* mated) lambs, it was discovered that they performed similarly at 6 months, but the F_1 crosses outperformed the *inter se* mated lambs and displayed better POWGAIN, this could be the effect of heterosis. In contrast, lambs with 25% Dorper inheritance performed less favorably when compared to Dorper crossbred lambs with higher levels of Dorper inheritance under the on-station management system signifying the effect of blood level on growth performance (Table 51). Under farmers' management, Dorper crossbred lambs showed a 30-34% superiority in 6-month weight compared to the local lambs. Moreover, advantages of 16%, 33%, 35%, and 55% were noticed under on-station management system in 6-month weight over local lambs when the genetic inheritance of Dorper was 25% (Dorper cross), 50% (Dorper *inter se* mated), 50% (Dorper-F_1), and 75% (Dorper crosses), respectively. Dorper x Local crossbred lambs exhibited significantly higher weight at the yearling age compared to the local lambs under farmers' management, with an advantage of 23-27% over their contemporary local lambs. The values recorded for advantage in yearling weight under on-station management for Dorper crosses with 25% Dorper inheritance, 50% Dorper (*inter se* mated), 50% Dorper-F_1, and 75% Dorper inheritance were 22%, 38%, 56%, and 64% higher than the local lambs, respectively.

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Under both farmers' management and on-station management scenario, it was consistently observed that the local lambs showed inferior performance compared to the Dorper crossbred lambs. This indicates that introducing Dorper genetics into the local lamb population can significantly improve their growth and market weight. The advantages of Dorper crosses over the local lambs ranged from 16% to 55% in terms of 6-month weight, depending on the level of Dorper inheritance. In line with the current study, Tadesse (2018) conducted research on Awassi x Wollo highland-F_1 cross and Washera x Wollo-F_1 crosses. The findings indicated that Washera cross and Awassi crossbred lambs managed under farmers' management conditions had a significant advantage over the local lambs. At 6 months of age, the advantage reported by the author was 24% and 45%, respectively. Furthermore, at 12 months of age, the advantage was reported as 40% and 41%, respectively.

Similarly, in a study conducted by Mekonnen *et al*. (2016) on Awassi x Tikur crossbred sheep in the Eastern Amhara region, it was observed that lambs with 28-48.75% Awassi inheritance exhibited higher weights at 6 months. The authors also noted that lambs with 48.75% Awassi inheritance were heavier at 12 months of age compared to lambs with 23.44-32.5% Awassi inheritance. Additionally, Zelalem (2018) investigated the effect of crossbreeding using the Bonga breed in Southern Ethiopia under farmers' management conditions. The study reported a significant advantage of 34% and 36% in 6-month weight and post-weaning weight, respectively, of crossbred lambs compared to the local lambs. In summary, these studies consistently demonstrate the positive impact of crossbreeding programs involving Awassi, Washera, and Bonga breeds on lamb weight and growth performance. The crossbred lambs exhibited considerable advantages over the local lambs, highlighting the potential of crossbreeding strategies to improve the productivity and profitability of sheep farming.

Cognizant of this, the results from our study revealed that lambs with more than 50% Dorper inheritance performed similarly to Dorper purebred lambs in terms of weight, but exhibited higher average daily weight gain (POWGAIN) under on-station management system. This suggests that the Dorper genetics contribute not only to overall weight but also to the rate of weight gain, making them highly desirable for commercial lamb production. Dorper sheep are renowned for their adaptability to various environmental conditions, including hot and arid regions. The results of the present study concurrently highlight the merits of using Dorper sheep

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to improve the growth performance and market weight of local lambs. The promising POWGAIN further supports the potential of Dorper sheep in enhancing the overall productivity of lambs.

Location of the study sites, both under farmers' management and on-station management systems, had a significant impact on the weight of lambs at 6 months and 12 months, as well as their average daily weight gain (POWADG) ($p < 0.001$). Under farmers' management, lambs born in Kewet and Efratana-Gidim demonstrated higher weights at 6 months, while lambs born in Yabello had inferior weights at 6 months (17.27 kg, 16.52 kg vs. 14.8 kg). Similarly, lambs born in Kewet had higher weights at 12 months, and lambs born in Basona-Werana, Efratana-Gidim, and Yabello sites showed good weights at 12 months. Conversely, lambs born in Kobo and Merhabete areas exhibited lower weights at 12 months, with Merhabete having the lowest. The findings of the current study further validate the impact of location on the performance of lambs at 6 months and 12 months, as well as their average daily weight gain (POWADG).

The study highlights that lambs born in low-mid-to-highland areas exhibited superiority in terms of weight at 6 months compared to their counterparts born in cool-tepid regions. However, lambs born in the cool-tepid areas displayed higher weights at 12 months and had a higher average daily weight gain (POWADG). The reason for such discrepancies could be attributed to the differences in nutritional factors and management strategies, environmental conditions, developmental factors. It is important to consider these factors collectively to understand the complex interactions influencing lamb growth in different sites. In line with our findings under farmers' management, Zelalem (2018) observed the effect of location on weight gain at 6 months of age but did not find differences in 6-month weight. In contrast to our findings, Mengiste (2008) found no differences in lambs' weights at 6 months of age and gain from 90 to 180 days (POWADG) in his studies on Washera sheep in Yilmanadensa and Quarit districts in the Amhara region. Similar to the current study, Mekonnen *et al*. (2016) observed variability in body weight at 6 months and 12 months, as well as POWADG of lambs in the highlands of the Eastern Amhara region.

The study examined the impact of lamb sex on weight at 6 and 12 months, as well as average daily weight gain (POWADG), under both farmers' and on-station management systems. The

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results revealed that male lambs exhibited higher weights at 6 and 12 months of age and had superior POWADG ($p < 0.0001$). This finding aligns with similar observations made by several other researchers, including Abebe (1999), Hassen *et al*. (2002), Mesfin *et al*. (2014), and Zelalem (2018), in their respective studies. However, contrary to these findings, other scholars such as Mengiste (2008) and Tadesse (2018) did not observe any significant effects of lamb sex on body weight at 6 and 12 months of age or POWADG. It is very important to note that the influence of lamb sex on weight and growth can be influenced by various factors, including genetic attributes, nutrition, and management practices. Further research might be necessary to explore the underlying reasons for the observed differences and to gain a more comprehensive understanding of the relationship between lamb sex and growth traits.

In our study, we also examined the influence of lamb birth type on post-weaning body weight performance at 6 and 12 months of age, as well as post-weaning gain (POWADG). Our findings revealed that lambs born as singles exhibited higher weights at 6 months of age under both farmers' and station management, along with better POWADG. Interestingly, we also observed that lambs born as singles and managed under farmers' conditions showed similar weights at 12 months of age but lambs born as single and manged at on-station condition had better 12 months weight compared to single born ones. Supporting our findings, several authors have reported significant effects of lamb birth type on post-weaning weight and POWADG. For instance, Tadesse (2018) observed significant effects in Awassi x Wollo highland-F_1 crosses and Washera x Wollo-F_1 crosses, with single born lambs being heavier at 6 months and displaying better gain (POWADG). However, Tadesse did not observe any effects of birth type on 12-month weight. Similarly, Zelalem (2018) found that single-born lambs outperformed twins and triplets at 6 months and had higher weight gain within that period. Mekonnen *et al*. (2016), studying Dorper x Local lambs in Eastern Amhara, also reported higher weights at 6 months for single-born lambs compared to twins, but no differences in 12-month weight or POWADG.

In contrast, Mengiste (2008) observed the superiority of single-born lambs in terms of body weight at 6 months, but did not find the same effect for gain between 3 and 6 months. Additionally, Mesfin *et al*. (2014) did not detect any differences in weight or POWADG between single and multiple-born lambs at 6 and 12 months in their on-station studies. These collective findings emphasize the importance of lamb birth type in post-weaning growth, while also

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highlighting the potential variability in outcomes depending on specific genetic and management factors. Further research is needed to better understand the underlying mechanisms driving these effects and to develop targeted management strategies that optimize lamb growth and performance based on birth type. This study also investigated the impact of birth parity on body weight at 6 and 12 months of age and POWADG under both farmers' and on-station management conditions. Our findings revealed interesting trends. Specifically, we observed lower values for 6-month weight in parity one, while lower values at 12 months were recorded in parity one and parity five and above under farmers' management. However, we did not observe any differences in POWADG among the different lambing parities under farmers' management. Under on-station management conditions, we noticed lower values of body weight at 6 months in parity one and higher values in later parities. Additionally, the study noted variations among parities for POWADG, but no differences were observed among parities for yearling weight under on-farm management conditions.

These findings align with previous research conducted by other scholars. For example, Sisay *et al*. (2021) observed differences among birth parities in 12-month weight but did not detect such differences for 6-month weight in their studies on Washera and Gumuz sheep under farmers' management in the North-Western part of Ethiopia. Similarly, Abebe (1999) and Zelalem (2018) did not observe any effects of birth parity on 6-month weight and gain up to 6 months in their respective studies. Other researchers such as Mengiste (2008), Tadesse (2018), and Aschalew *et al*. (2020) also did not find any differences in 6-month weight, 12-month weight, and POWADG among the different birth parities in their studies. These collective findings highlight the complex relationship between birth parity and post-weaning lamb performance. It is evident that the influence of birth parity on weight and growth can vary depending on management conditions and specific genetic factors. Further investigation is warranted to better understand the underlying mechanisms contributing to these variations and to develop practical strategies for optimizing lamb growth and performance based on birth parity.

The current study also assessed the effects of birth season on post-weaning growth performance in lambs, specifically focusing on body weight at 6 and 12 months and POWADG under both farmers' and on-station management conditions. The results revealed significant effects of birth season on lambs' post-weaning weight under farmers' management. Lambs born during the long-

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rain and short-rain seasons exhibited higher body weights at 6 months compared to those born during the dry period. However, no differences were observed in 12-month body weight and POWADG. The results from current study also confirmed that year of birth had significant effect on the body weight of lambs at 6 and 12 months and POWADG.

Similarly, under on-station management conditions, our study found significant differences among lambs born in different seasons. However, lambs born in the short-rain season had higher body weights at 6 and 12 months compared to those born during the dry period and long- rain season. These findings align with previous research. Hassen *et al*. (2002) reported lower body weights at 5 months for lambs born in the dry season compared to the lighter and heavy rain seasons in their study on indigenous and crossbred sheep under farmers' conditions. Mengiste (2008) also observed that lambs born in the wet season had higher body weights at 6 months and better weight gain compared to those born in the dry season, although no differences were found in 12-month body weight and gain from birth to 12-month. Mesfin *et al*. (2014) reported higher values for lambs born in the dry period in terms of 6 and 12-month body weight and gain to 6 months in their study on Dorper x Local and local lambs. However, they did not observe differences in gain from birth to 12 months. Aschalew *et al*. (2020) found that lambs born in the dry season had lower values at 6 and 12 months compared to those born during the long rain and short rain seasons in their study on Menz sheep in a community-based breeding program. Sisay *et al*. (2021) also reported significantly lower values for lambs born in the dry season in terms of 6 and 12-month body weight in their study on Gumuz and Washea sheep.

Contrary to the above findings, Zelalem (2018) did not observe differences in 6-month weight and gain to 6 months due to birth season (autumn and winter) in their study on Bonga crossbred and local lambs in different agro-ecologies under farmers' management. In conclusion, the influence of birth season on post-weaning growth performance in lambs is evident, with variations observed in body weight at different ages. However, the specific effects can vary depending on the management conditions and breed studied. Further research is necessary to better understand the underlying mechanisms and develop strategies to optimize lamb growth based on birth season.

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In general, the findings of the current study also highlight the importance of considering both genotype and environmental factors in lamb management. Genotype, referring to the genetic makeup of the lambs, plays a crucial role in determining their growth performance and weight. The study specifically focuses on the comparison between local lambs and Dorper crossbred lambs with varying levels of Dorper inheritance, as well as Dorper purebred lambs. Dorper sheep are known for their superior growth and meat production characteristics, which makes them a valuable breed for crossbreeding programs. In summary, the study emphasizes the benefits of incorporating Dorper genetics into local lamb populations to enhance growth performance and market weight. Dorper sheep possess desirable traits for meat production and exhibit superior performance compared to local lambs. By selectively breeding and managing lambs with appropriate levels of Dorper inheritance, farmers can improve the productivity and profitability of their sheep farming operations.

5.10. Survival of lambs

5.10.1. Survival of lambs under farmers' management condition

The current study assessed the survival rates of lambs of different ages under farmers' management conditions; the study revealed that environmental factors, rather than lamb genotype, significantly influenced the survival rate of lambs. Specifically, Dorper cross (low-grade), Dorper cross (high-grade), and local lambs exhibited similar survival abilities under farmers' conditions, both during the pre-weaning stage and up to 6 and 12 months of age. These findings align with a study by Shigdaf *et al*. (2013), who reported no significant differences in survival ability among Washera, Farta, and crossbred lambs at 90, 180, and 360 days of age under on-farm conditions. However, our results indicated a lower survival rate at 3 months for Dorper x local (low-grade) lambs (93.0%), Dorper x local cross (high-grade) lambs (94.1%), and local lambs (93.4%) compared to the survival rates reported by Shigdaf *et al*. (2013) for Farta x Washera cross (98%), Farta (98%), and Washera (98%), respectively.

Nevertheless, the survival rates recorded in our study at 6 and 12 months of age were comparable to the reports of Shigdaf *et al*. (2013) under on-farm management conditions, Belay *et al*. (2021b) conducted a study that also examined the impact of blood level on the survival rate of 25% Dorper x local and 37.5% Dorper x local crossbred lambs at 3, 6, and 12 months of age under on-

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farm conditions. Their findings indicated that blood level had no significant effect on the survival rate of these lambs. Interestingly, our results align closely with the survival rates reported by Belay *et al*. (2021b). These findings provide further support to the notion that blood level does not have a substantial impact on the survival rate of these crossbred lambs managed under farmers' management conditions. In contrast, Zelalem *et al*. (2018) reported a difference in survival rates between different lamb breeds in the Southern part of Ethiopia under farmers' management conditions. They found a 95.2% pre-weaning survival rate for Bonga crossbred lambs compared to 92.9% for their local counterparts.

Contrary to the current findings, Ferreira *et al.* (2015), in their studies on the effect of breed of lamb on lamb survivability reported higher survival rates of 94.1, 86.6, and 84.2% for East Friesian, maternal breeds, and meat breeds respectively notifying higher survival rates for the East Friesian compared to other breeds studied, this could be attributed to East Friesian's, exceptional milk production, coupled with their attentive and nurturing behavior, ensures the well-being and success of their lambs.

Location of the study sites, where the flocks were managed under farmers' engagement, had a significant influence on lamb survivability at 3, 6, and 12 months of age. Lambs born at Baso had a 3.106 times higher chance of survival compared to those born at Yabello at 3 months of age, this suggests that the environmental conditions or management practices at Baso were more favorable for lamb survival during this period. On the other hand, lambs at Kewet had 0.578 and 0.637 times lower chances of survival compared to those born at the Yabello site at 6 and 12 months, respectively. The effect of location on lamb survival under on-farm conditions has been reported in previous studies, including Shigdaf *et al*. (2013) at 90, 180, and 365 days of age, as well as Kebede *et al*. (2022a) in their study on Doyogena sheep in the Southern part of Ethiopia, which examined the effect of location on pre-weaning survival. Overall, these findings demonstrate that location of the study sites plays a significant role in lamb survivability, and this effect has been observed in previous studies as well. It suggests that factors such as climate, forage availability, disease prevalence, and management practices vary between locations and can influence the survival rates of lambs at different ages.

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The current study did not find any significant effects of the sex of the lamb on survival rates at 3, 6, and 12 months of age ($p > 0.05$). These findings are consistent with previous research. For instance, Shigdaf *et al*. (2013), in their study on Washera sheep under on-farm conditions, also failed to detect any impact of lamb sex on the survivability of lambs at 90, 180, and 365 days of age. Regarding the survival ability of 25% and 37.5% Dorper crossbred lambs, the results reported by Belay *et al*. (2021b) in their study on on-farm management conditions align with our findings at 3, 6, and 12 months of age. On the topic of lamb sex and survival ability, Zeleke *et al*. (2020) reported no significant effects of lamb sex on survival at 3 months of age. However, their study did find that male lambs had a better survival rate than female lambs at 6 and 12 months of age. Similarly, Kebede *et al*. (2022a) reported a higher survival rate for male lambs compared to females at 90 days for the Doyogena sheep breed managed under farmers' conditions in Southern Ethiopia. They suggested that the preferential management of male lambs, including feed supplementation and medication, might contribute to the higher survival rate of males for the interest of selection among male lambs for breeding purposes. It's important to note that the sample size differed in these studies, with larger numbers of males than females. In our study, both male and female lambs were represented by similar numbers of observations, providing fair results.

There are variations in the findings from different reports, and the reasons for these disparities require further investigation. Turkson and Sualisu (2005) reported higher mortality in female lambs compared to males, while Gowane *et al*. (2020) found that male animals had a greater risk of death compared to females, in their studies Gaur *et al.* (2022), on lamb survival up to waning in Harnali sheep disclosed that the hazard of death for male lambs up to weaning was higher compared to the female contemporaries. These conflicting results highlight the complexity of factors influencing lamb survivability and the need for additional research to understand the underlying mechanisms. In summary, results from the current study, along with previous research, did not find a significant effect of lamb sex on lamb survival rates. However, there are discrepancies among studies, indicating the need for further investigation into the factors that contribute to the survival ability of male and female lambs.

The current study also investigated the impact of birth litter size on lamb survival at different ages under farmers' management conditions. We found that lambs born as singles had a 1.642

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times higher survival ability compared to those born as twins at 3 months of age. However, as the lambs grew older (at 6 and 12 months of age), our study did not detect similar effects. In line with our findings, Zeleke *et al*. (2020) reported a lower survival ability of twin-born lambs compared to single-born lambs, with a 0.0351 and 0.0310 times lower survival rate at a young age (3 months and 6 months). However, the same authors did not find any significant effect of birth litter size on survival at 12 months of age.

Consistent with our findings, Kebede *et al*. (2022a) found that single-born lambs had a 6.53 times higher survival ability compared to triplets under village management conditions. They also observed a 6.84 times higher survival ability for twin-born lambs compared to triplets at 3 months of age. The lower survival rate in higher litter sizes could be attributed to lamb competition with littermates for colostrum and milk, as suggested by Hatcher *et al*. (2010). In contrast, Shigdaf *et al*. (2013) did not find any significant effects of birth litter size on lamb survivability until yearling age. However, their results were consistent with ours, which testified no significant effects of litter size at 180 and 365 days of age that we discovered. In summary, our study, along with previous research, found that single-born lambs had a higher survival ability compared to those born as twins or triplets at a young age. The competition for resources within larger litters may contribute to the lower survival rates observed. However, the effects of birth litter size on lamb survival may vary at different ages and among different studies. Further research is needed to fully understand the underlying mechanisms and to determine the most effective management strategies to improve the survival rates of lambs born in larger litters.

This study found no significant influence of ewe lambing parity on lamb survival at 3 and 12 months of age. However, we did observe a slight influence of birth parity on lamb survival at 6 months of age. Specifically, we noticed an odds ratio (OR) of 1.935 ($p = 0.0540$, 95% confidence interval = 1.160-3.229), indicating a 1.935 times higher survival ability for lambs born to parity one compared to those born in parity 5 and above (with survival rates of 89.7% and 70.3%, respectively). This finding suggests that there may be factors related to birth parity that contribute to differences in lamb survival. In agreement with our findings, Kebede *et al*. (2022a) also did not detect any effect of lambing parity on lamb survival at 3 months of age. However, Belay *et al*. (2021b), in their study on Dorper crossbred lambs reared on-farm, reported an influence of birth parity on lamb survival at 3, 6, and 12 months. They observed differences

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between parity one and parity 5 and above at 6 months, which aligns with our findings. Interestingly, Belay *et al*. (2021b) identified differences between parity two and parity 5 (OR = 0.24, $p < 0.05$). These similarities and differences in the results among previous studies and our study may be attributed to various factors that require further investigation.

In summary, our study found no significant impact of ewe lambing parity on lamb survival at 3 and 12 months of age. However, we observed a potential influence of birth parity on lamb survival at 6 months of age, with lambs born to parity one showing a higher survival ability. The differences in findings among studies may be attributed to a range of factors that warrant further exploration.

In the current study, we also assessed the implication of birth season on lamb survival at different ages. The results from farmers' flocks showed a significant influence of birth season on lamb survival at 3 and 12 months of age. However, we did not find the same influence at the age of 6 months ($p = 0.2050$). Specifically, lambs born during the long-rain and short-rain seasons had higher odds of survival (OR = 1.532 and 1.811) at 3 months of age, and (OR = 1.321 and 1.521) at 12 months of age, respectively. This indicates that lambs born during the long-rain and short-rain seasons had a 1.5 and 1.8 times higher chance of survival compared to those born in the dry season. Similarly, we observed a 1.3 and 1.5 times higher chance of survival at 12 months of age. Our findings are consistent with a study by Shigdaf *et al*. in 2013, which also observed a significant influence of birth season on lamb survival at 90 and 365 days. However, when examining lambs at the age of 6 months in our study, we did not observe similar effects. In contrast, other researchers, such as Kebede *et al*. (2022a) and Belay *et al*. (2021b), did not report any impacts of the lambing season on pre-weaning survival rate or lamb survival at 3, 6, and 12 months of age in their investigations of flocks managed by farmers in Ethiopia. The divergence between our findings and those of other studies may be attributed to various factors. Further research is necessary to explore and comprehend the underlying mechanisms and potential confounding variables that may contribute to these divergences.

The current study also examined the impact of lambing year on lamb survival across different ages, and the results demonstrated a significant effect ($p < 0.001$). Specifically, we observed odds ratios (OR) indicating higher survival abilities for lambs born in certain years compared to the reference year of 2021. At 3 months of age, lambs born in 2013, 2014, 2015, 2017, and 2020 had ORs of 3.643, 5.860, 3.018, 2.674, and 3.316, respectively, indicating a greater likelihood of survival compared to lambs born in 2021. Similarly, lambs born in 2014 and 2020 had ORs of 2.387 and 3.224, respectively, indicating higher survival abilities compared to lambs born in 2021. Conversely, lambs born in 2018 had a lower survival ability (OR = 0.335) compared to the reference year at 6 months of age. Furthermore, the influence of the year of lambing on lamb survival persisted until the lambs reached the yearling age. We observed a higher percentage of survivors among lambs born in the reference year of 2021 (96%). Additionally, lambs born in 2013, 2015, 2016, 2017, 2018, and 2020 had ORs of 0.263, 0.295, 0.227, 0.128, 0.076, and 0.270, respectively, indicating lower survival abilities compared to the reference year of 2021.

Several other scholars, including (Mukasa-Mugerwa *et al.,* 2000; Vatankhah and Talebi, 2009; Getachew *et al.*, 2015; Zeleke *et al.*, 2020; Belay *et al.*, 2021b, and Kebede *et al.*, 2022a), have also addressed the influence of the year of lambing on lamb survival in their evaluations of farmers' flocks, and their findings align with our study. However, Mengiste (2008), in his studies on flocks of Washera sheep managed by farmers, did not detect an effect of the year of lambing on the survival of lambs at 90 and 180 days. Interestingly, Mengiste did report a significant effect of lambing year on lamb survival at 365 days, which is consistent with our findings. Similar to Mengiste (2008), Gowane *et al*. (2020) on their study on lamb survival in sheep in dry arid tropics of India reported no effect of lambing year on lamb neonatal survivability of sheep. The variations in lambing year can have significant effects on lamb survival at different ages, and these effects can be attributed to several factors. One key factor is the variation in climate conditions across different years. Climate variations can affect forage availability, disease prevalence, and environmental stress levels, all of which can influence lamb survival. Years with favorable weather conditions may have abundant forage, leading to better nutrition for lambs and higher survival rates. Additionally, variations in disease prevalence between years can affect lamb health and survival.

Furthermore, differences in the management practices employed by farmers in different years can also contribute to variations in lamb survival. Farmers may implement different strategies in terms of nutrition, disease prevention, and predator control, which can directly affect lamb survival rates. When considering the disparities observed in the effects of lambing year on lamb

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survival at different ages, several factors come into play. Firstly, variations in study design can contribute to differences in the reported results. Factors such as sample sizes, methodologies, and statistical analyses employed in different studies can influence the outcomes.

Geographic differences are another potential source of disparities. Studies conducted in different regions may encounter varying environmental conditions, farming practices, and breed characteristics, which can lead to divergent results. The time frame in which a study was conducted can also influence the outcomes. Environmental conditions, management practices, and disease prevalence can change over time, leading to disparities in the observed effects of lambing year on lamb survival.

To better understand these disparities and similarities among studies, it is crucial to consider specific details such as study design, geographic location, time frame, and management practices employed. Considering these factors will contribute to a more comprehensive understanding of the relationship between lambing year and lamb survival at different ages.

The current study also assessed the effects of lamb birth weight categories on lamb survivability at different ages within farmers' flocks. The results revealed that lamb survival was significantly influenced by all ages considered. Specifically, lambs born with a birth weight of 2 kg and below (light weight category) had an odds ratio (OR) of 0.544 ($p = 0.017$) compared to lambs born with a birth weight greater than 3 kg (heavy weight category) at 3 months of age. The corresponding results for 6 and 12 months of age were an OR of 0.649 ($p = 0.05$) and an OR of 0.636 ($p = 0.0180$), respectively. This indicates that lambs born with a light weight have a 0.5, 0.7, and 0.6 times lower survival rate than those born with a heavy weight, highlighting the importance of higher birth weight for lamb survival at 3, 6, and 12 months of age. However, no significant differences were observed between lambs born with a birth weight greater than 2 kg but equal to 3 kg (medium birth weight category) and lambs born with a birth weight greater than 3 kg (heavy weight category).

In comparison to the outcomes of other studies conducted under similar circumstances, Kebede *et al*. (2022a) discovered that in their study on Doyogena sheep breed managed under a (CBBP), lambs with a birth weight of 2 kg and below were at a greater risk of mortality during the pre-

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weaning period of 90 days, in contrast to lambs born with a birth weight of 4 kg and above. Similarly, Mengiste (2008) found that lambs born with a birth weight below 2 kg (light weight) had lower survival rates compared to lambs born with a birth weight of 2-3 kg (medium weight) and above 3 kg (heavy weight) at 90 days of age in his study on farmers' flocks in the Yilmanadensa and Quarit districts of the Amhara region. Mengiste also reported a higher survival rate for lambs born with a heavy birth weight compared to those born with a medium or light birth weight. At 90 days of age, lambs with a medium birth weight exhibited better survival rates than those born with a light birth weight. Furthermore, Shigdaf *et al*. (2013) conducted a study on Farta and Washera sheep, as well as crossbred sheep, managed under farmers' conditions. Their research demonstrated that lambs born with a birth weight below 2 kg (light weight) had lower survival rates compared to lambs born with a birth weight of 2-3 kg (medium weight) and above 3 kg (heavy weight) at 180 and 365 days of age. However, no significant differences were observed between lambs born with a medium or heavy birth weight at 90 days of age.

Despite some minor variations in the findings regarding the influence of lamb birth weight categories on survival at different ages, our results, along with the studies by Kebede *et al*., Mengiste, and Shigdaf *et al*., consistently highlight the importance of improving the birth weight of lambs to achieve higher survival rates. This has significant implications for stock replacement and increasing the availability of lambs for sale. Berhanu and Aynalem (2011) emphasize that understanding the factors influencing lamb livability under farmers' conditions can contribute to the development of economically efficient management schemes and effective breeding strategies. In conclusion, our study, along with previous research, underscores the significance of birth weight categories in determining lamb survival at various ages within farmers' flocks. Improving lamb birth weight is crucial for enhancing survival rates and optimizing flock productivity.

5.10.2. Survival of lambs under on-station management condition

The study assessed the survival of lambs under different management conditions and examined the impact of genotype and environmental factors on their survivability under farmers' and on-station management conditions. The overall survivability of lambs under on-station management

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at 3 months of age was reported to be 82.8%, and at 6 months of age, it was 77.3%. These rates were lower compared to the survivability rates obtained under farmers' conditions, which were 93.1% at 3 months and 87.2% at 6 months.

The study also compared the survival rates of lambs based on different genotype under on-station management conditions. The survival rates at 3 and 6 months of age for lambs with different genotype combinations were as follows: 25%-Dorper crossbred: 89.7% (3 months) and 87.1% (6 months), 50%-Dorper-F_1 crossbred: 83.9% (3 months) and 77.3% (6 months), 50%-Dorper crossbred (*inter se* mated): 82.9% (3 months) and 78.5% (6 months), Dorper purebred: 81.5% (3 months) and 75.6% (6 months), and, Local: 79.5% (3 months) and 74.6% (6 months). Comparatively, the survival rates for lambs with Dorper cross (low grade), Dorper cross (high grade), and local genotype were higher at both 3 and 6 months of age. For example, the survival rates at 3 months were reported as follows: under farmers' management condition. Dorper cross (low grade) - 93.0%, Dorper cross (high grade) - 94.1%, and Local - 93.4%. Similarly, at 6 months of age, the survival rates were: Dorper cross (low grade) - 88.0%, Dorper cross (high grade) - 86.9%, and Local - 86.8% under farmers' conditions. The survivability of Dorper crossbred lambs ranged between 80-90% while the pure breeds, Dorper purebred 82% and local 84% under on-station management conditions at 3 months of age and the corresponding values at 6 months were 75-87% for Dorper crossbred and 76 and 77% for the Dorper purebred and local lambs.

The survivability rates obtained in this study were higher than the reported rates by Ayele *et al.* (2016b), which were 83.1%, 80.7%, and 86.3% at 3 months for local, Awassi x Menz 25-50%, and Awassi x Menz 75%, respectively, Similarly Fadili *et al.* (2011) in their studies reported 84% survival rate at 90 days for INRA 180 synthetic sheep breed. Lamb survivability is influenced by various factors, including lamb genotype, sire genotype, and dam genotype. However, our study did not find a significant influence of lamb genotype on the survivability of lambs at 3 and 6 months of age on the flocks managed under farmers' conditions.

Under on-station management conditions, it was observed that 25%-Dorper crossbred lambs had significantly higher survivability compared to local lambs, with an odds ratio (OR) of 3.876 (CI: 0.845-17.751, $p = 0.001$) at 3 months and an OR of 5.051 (CI: 1.144-22.306, $p < 0.001$) at 6

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months. This indicates that 25%-Dorper crossbred lambs had 3.876 and 5.051 times more than the surviving ability of their local counterparts at 3 and 6 months, respectively. The influence of sire genotype on lamb survival was also observed in the current study. Lambs sired by Dorper crossbred sires had 0.327 and 0.265 times less survivability compared to lambs sired by local sires at 3 and 6 months of age, respectively. Similarly, the ewe genotype also had an impact on lamb survival. Lambs born to Dorper crossbred and Dorper purebred ewes had 0.776 and 0.556 times less survivability at 3 months of age, while lambs born to Dorper crossbred ewes had 0.606 times less surviving ability at 6 months compared to lambs born to local ewes. However, no significant difference in survivability was observed between lambs born to Dorper purebred ewes and lambs born to local ewes at 6 months.

Previous studies have also reported differences in lamb survivability based on breed. For instance, Maan (2020) found lower survivability in local Awassi lambs compared to Turkish Awassi lambs at various ages. Ayele *et al*. (2016b) observed higher survivability in Awassi x Menz75% crossbreed lambs compared to Menz and Awassi x Menz25-50% lambs under a semi-intensive management system. Mekonnen *et al*. (2016) reported higher survivability in 50%-Dorper cross lambs compared to 75%-Dorper crossbred lambs at 3 and 6 months of age. Similarly, Chaudhari *et al.* (2017) observed survivability differences between Nilagiri and Nilagiri Synthetic sheep breeds at different age intervals under semi-intensive management. It is important that the differences in pre-weaning mortality between the Magra and Marwari sheep breed under semi-intensive management were not significant, indicating that both breeds exhibited excellent survival with better management conditions, as reported by Gowane *et al*. (2020). This finding is consistent with our results obtained under farmers' management conditions. Our study's findings under farmers' management conditions indicated that lambs born under these conditions have comparable survival rates at 3 and 6 months of age. This can be attributed to the management practices provided by farmers, which appear to be more suitable for the genetic potential of the lambs. It is interesting to note that our results (both from farmers' and on-station management conditions) align with the global range of pre-weaning survival rates, of lambs falling between 10% and 30%, as reported by Southey *et al*. (2004) and Swawalha *et al*. (2007).

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The effects of environmental factors on lamb survival under on-station management conditions were recorded. It was found that the survival of lambs up to 3 months of age was not significantly influenced by location. However, at 6 months of age, the influence of location on lamb survival was observed. Specifically, lambs born in cool-tepid areas showed 0.828 times less survival ability compared to those born in low-mid-highland areas (OR=0.828, 95% CI 0.713-0.961, p = 0.013). Furthermore, significant effects of location on lamb survival at 3, 6, and 12 months of age were observed in farmers' flocks. Our observations in this study, which considered all age groups, indicated that flocks managed under farmers' management conditions were influenced by location in terms of lamb survival at 3, 6, and 12 months of age. In a study conducted by Shigdaf *et al*. (2013), significant differences in the survivability of lambs at 90, 180, and 365 days were observed between lambs of Washera sheep managed under on-station and on-farm conditions were noted. Overall, our findings suggest that environmental factors, particularly location, play a significant role in lamb survival under both on-station and farmers' management conditions. These results highlight the importance of considering environmental factors when managing lambs for optimal survival rates.

The lower survival rates observed in lambs born in the cool-tepid areas compared to lambs born in the low-mid-to-highland areas may be attributed to several potential factors related to the environmental conditions in these respective locations. Some possible reasons could include Temperature and Climate; cool-tepid areas may have lower temperatures or experience temperature fluctuations that can negatively affect lamb survival. Cold temperatures can make it more challenging for lambs to maintain their body temperature, leading to increased stress and vulnerability to health issues. Forage Availability, the availability and quality of forage, which is a critical feed source for lambs, can vary across different locations. Low-mid-to-highland areas might have more abundant and nutritious forage options, providing better nutrition and supporting healthier growth and development in lambs. Disease and parasite pressure, management practices, the management practices employed in different locations can also contribute to the differences in lamb survival rates. For example, farmers in low-mid-to-highland areas might have better access to resources, veterinary care, and knowledge of optimal lamb-rearing practices, resulting in improved lamb survival rates.

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The study found no significant difference between male and female lambs at 3 months of age. However, at 6 months of age, the sex of the lambs had a considerable influence on survival. Female lambs exhibited a 1.138 times higher survival ability compared to male lambs under on-station management conditions. Interestingly, when the lambs were managed under farmers' conditions, we did not observe any influence of lamb sex on survival at 3, 6, and 12 months of age. This finding diverges from several previous reports. Studies conducted by Fadili (2011), Shigidaf *et al*. (2013), Mellado *et al*. (2016), Deribe *et al*. (2017), Gowane *et al*. (2020), and Belay *et al*. (2021b) all disclosed that male and female lambs had no difference in survivability at 3 months of age. On the other hand, Ayele *et al*. (2016b) and Chaudhari *et al*. (2017) reported significant effects of lamb sex on survival, noting higher survivability of females compared to their male counterparts. Conversely, Zeleke *et al*. (2020) disclosed that female lambs had lower survival ability at 6 months of age. These discrepancies in previous research findings suggest that the influence of lamb sex on survival can vary depending on various factors such as management conditions, breed, and environmental factors. Further investigation is necessary to better understand the underlying mechanisms behind these observations and to elucidate the specific factors contributing to the varying effects of lamb sex on survival in different contexts.

Under on-station management conditions, the current research revealed significant effects of lamb birth litter size on lamb survival at 3 and 6 months of age. Specifically, lambs born as singles exhibited better odds of survival, with 2.360 and 2.042 times higher survival ability at 3 and 6 months of age respectively, compared to lambs born as triplets. However, no significant differences were observed between twin and triplet born lambs. Similarly, under farmers' conditions, we also observed a higher survival ability of lambs born as singles compared to those born as twins at 3 months of age. However, we did not notice the same influence at 6 and 12 months of age under this condition. These findings align with previous studies conducted by Ayele *et al*. (2016b), Solomon *et al*. (2000), Zeleke *et al*. (2020), and Belay *et al*. (2021b), who reported higher survival rates of single-born lambs compared to twin-born lambs. On the other hand, Shigdaf *et al*. (2013) and Chaudhari *et al*. (2017) found no influence of birth type on lamb survival at 3, 6, and 12 months of age. These differences in previous research highlight the complexity of the relationship between birth litter size and lamb survival. Other factors such as maternal care, nutritional availability, and environmental conditions may also contribute to the

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observed differences. Further investigation is needed to gain a comprehensive understanding of the underlying mechanisms and to account for potential confounding factors that may influence the relationship between birth litter size and lamb survival.

The survival of lambs is influenced by the parity of the dam, but its impact is only partially observed in both farmer-managed and on-station flocks. Specifically, the survival of lambs is not affected by the birth parity of the dam up to three months of age. However, significant effects of dam parity are evident at six months of age in both management systems. At the age of six months, lambs born from the second parity show a higher survival ability compared to lambs born from the sixth parity and above, with an odds ratio of 1.301 (95% CI 0.944-1.791; p = 0.033). This suggests that lambs born in the second parity have a 1.301 times higher chance of survival compared to lambs born in the sixth and higher parities under on-station conditions. The influence of dam parity on lamb survival is also observed in flocks managed under farmers' conditions at six months of age, but not at 12 months of age.

A study conducted by Ayele *et al*. (2016b) in the highlands of Ethiopia, focusing on flocks of different genotypes (Menz, Awassi x Menz25-50%, and Awassi x Menz75%) under semi-intensive management conditions, found that lamb mortality up to three months of age was influenced by dam parity. Similarly, Shigdaf *et al*. (2013) reported significant effects of dam parity on lamb survival at 90, 180, and 365 days in their studies on Washera sheep, both in on-station and on-farm conditions. Belay *et al*. (2021b) observed the influence of birth parity on lamb survival up to three, six, and 12 months of age in their studies on Dorper crossbred lambs managed under farmers' conditions. However, Boujenane (2002) did not find the age of ewes to affect lamb survival from birth to 90 days in their studies on DS synthetic sheep breed.

In contrast, Mukasa *et al*. (2000) observed the influence of dam parity on lamb survival up to three, six, and 12 months of age in their studies on Menz and Horro sheep under on-station management. Macedo and Hummel (2006) did not find the effect of ewe parity on lamb survival up to weaning age in their studies on lamb performance in Mexican dry tropics using Pelibuey sheep managed under intensive conditions. Bulent *et al*. (2007) also did not observe the effects of parity on Kivircik ewes at pre-weaning age. However, Sodiq *et al*. (2011) observed

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significantly different lamb survivability among parities, with survival increasing with advancing parities in their studies on Batur Sheep in upland areas of Indonesia.

The inconsistencies regarding the influence of dam parity on lamb survival across different reports, as well as the partial effects observed in our findings, highlight the complexity of this relationship. It is important to note that various factors can contribute to these inconsistencies, including differences in sheep breeds, management systems, environmental conditions, and study methodologies. The contradictory results may also arise from the fact that lamb survival is influenced by multiple interacting factors, such as maternal care, nutrition, disease prevalence, and overall flock management practices. These factors can differ significantly between studies and contribute to the variations observed in the impact of dam parity on lamb survival. Furthermore, the specific age at which the influence of dam parity becomes significant may vary. Some studies only observed significant effects at six months of age, while others found effects at different time points, such as 90, 180, or 365 days. This suggests that the impact of dam parity on lamb survival may change as lambs grow and develop.

This study also conducted an evaluation of the influence of lamb body weight category (light, medium, and heavy) during lambing on the survival of lambs at 3 and 6 months of age under on-station conditions. The research findings consistently revealed that lambs born with light and medium weight categories exhibited lower survival rates compared to those born with heavy weight. Additionally, the study observed that lambs had lower survival ability compared to heavy weight lambs, but no significant differences were noticed between lambs born with medium body weight and heavy body weight under farmers' management at 3, 6, and 12 months of age. The on-station results further indicated that lambs born with light weight had lower odds ratios (OR) compared to medium and heavy weight lambs at both 3 and 6 months of age, indicating a reduced survival ability. Specifically, the OR values were 0.312 and 0.652 at 3 months, and 0.363 and 0.645 at 6 months for light weight lambs compared to medium and heavy weight lambs, respectively. These findings suggest that lightweight lambs have 0.312 and 0.652 times less survival ability at 3 months, and 0.363 and 0.645 times less survival ability at 6 months when compared to medium and heavy weight lambs.

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Several reports from previous studies support the idea that lamb birth weight category influences lamb survival at different ages, with lower birth weights being associated with higher mortality rates. Studies conducted by Mukasa *et al*. (2000), Mellado *et al*. (2006), Shigndaf *et al*. (2013), Ayele *et al*. (2016b), Deribe *et al*. (2017), Zeleke *et al*. (2020) and Kebede *et al*. (2022a) have all reported similar findings. In some of these reports, the mortality rate of lambs under 2 kg (light weight) reached as high as 33%, 48%, and 55% at 3, 6, and 12 months of age, respectively, indicating a significant loss of lambs.

However, there are a few contrasting findings in the literature. Chaudhari *et al*. (2017) did not observe significant differences in survivability among different body weight categories of lambs between 6-9 and 9-12 months of age. Similarly, Mekonnen *et al*. (2016) conducted a study on Dorper crossbred lambs where good management practices for ewes and lambs, such as providing a concentrate level of 400 g/d/animal and improved forage on top of grazing for 7 hours per day, were implemented. In this study, no influence of lamb birth weight category on survival was observed at 3 and 6 months of age. These findings suggest that proper management practices can potentially mitigate the influence of lamb birth weight on survival.

In conclusion, the study provides evidence that lamb birth weight category has a significant impact on lamb survival, with lower birth weights being associated with decreased survival rates. This finding is consistent with previous reports in the literature. However, some conflicting findings suggest the influence of lamb birth weight on survival may be mitigated by good management practices. Further research is needed to explore the underlying mechanisms and identify effective management strategies to improve the survival of lambs with lower birth weights.

The study also investigated the impact of the birth season of lambs on their survival at 3 and 6 months of age, considering both on-station and farmers' management conditions. The results revealed that the birth season significantly affected lamb survivability under on-station management. Lambs born during the long-rain season exhibited higher odds of survival compared to those born during the dry period, with a 1.1710 and 1.303 times higher likelihood of survival at 3 and 6 months, respectively. Similarly, under farmers' management, lambs born in the rainy seasons showed higher odds of survival at 3 months (OR=1.352 and 1.811 for the long-

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rain and short-rain, respectively). However, no significant differences in lamb mortality were observed at 6 months of age for different birth seasons under farmers' management.

These findings are consistent with previous studies. Deribe *et al*. (2017) reported higher survival rates of lambs born in the dry season (98%) compared to the light-rain season (92%). Ayele *et al*. (2016b) studied local and Awassi crossbred lambs and found higher survivability in the short-rain and cold-dry seasons compared to the dry and big-rain seasons, respectively. Shigdaf *et al*. (2013) observed higher lamb survivability during the dry season compared to the wet season at 90, 180, and 365 days. Mukasa *et al*. (2000) reported higher mortality rates for lambs born in the wet season compared to the dry season up to 3, 6, and 12 months of age in their study on Horro and Menz sheep.

However, Belay *et al*. (2021b) did not find significant differences in lamb survival among different birth seasons (dry, main, and short rain seasons) at 3, 6, and 12 months of age. Gowane *et al*. (2020) observed the influence of the birth season on neonatal mortality in Marwari lambs but not in Magra lambs under station management. Kebede *et al*. (2022a) also did not find an influence of the birth season (rainy, small-rainy, and dry seasons) on lambs managed under farmers' conditions. In summary, the study provides evidence that the birth season of lambs can affect their survivability, with higher survival rates observed during certain seasons. Nevertheless, contradictory results could be found in the existing literature, suggesting that the impact of birth season on lamb survival may differ based on the specific management conditions and sheep breeds under investigation. To gain a more comprehensive understanding, additional research is required to delve into the underlying mechanisms and establish suitable management strategies that can enhance lamb survival across various birth seasons.

Under farmers' condition, the study examined the influence of the lambing year on the survivability of lambs at 3 and 6 months of age. The results revealed that certain years, such as 2006-2016 and 2020, showed higher odds ratios (OR) for survivability at 3 months compared to the base year of 2022. Similarly, in specific years, including 2006-2010, 2012, and 2015, higher OR for survivability at 6 months was observed compared to the base year of 2022. Additionally, the study found that lambs reared under farmers' management had higher OR for survivability at 3 months in the years 2014 and 2015 compared to the base year of 2021. Conversely, lower OR

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for lambs born in the year 2018 compared to the base year of 2021 were observed under farmers' management. Furthermore, under farmers' management, the study indicated lower OR in the years 2016-2018 compared to the base year of 2021, suggesting the impact of the lambing year on survivability extending up to the yearling age for flocks managed under farmers' conditions too. These findings align with previous studies conducted by Mukasa *et al*., 2000; Fadili, 2011; Shigdaf *et al*., 2013; Ayele *et al*., 2016b; Mekonnen et al., 2016; Zeleke *et al*., 2020; Belay *et al*., 2021b; and Kebede *et al*., 2022a, which support the influence of the lambing year on lamb survivability at different ages.

The overall alignment of our findings with previous reports underscores the importance of management conditions, genotype combinations, and lamb age in determining survivability. Farmers' management practices seem to create a more favorable environment for lamb survival compared to on-station management conditions. Certain genotype combinations, particularly those involving Dorper crossbreeds, demonstrate higher survivability rates. However, it is crucial to consider that our study's results are specific to the evaluated conditions and genotypes. Factors such as sample size, geographical location, and other environmental variables can influence the generalization of these findings. The survivability of lambs is influenced by various factors, including their inherent survival capability, sire genetics and vigor, maternal abilities of the ewe, and management practices during lambing and the rearing period.

5.11. Dorper crossbreeding system in Ethiopia

5.11.1. Dorper crossbreeding strategy and program in Ethiopia

5.11.1.1. Crossbreeding scheme

The effectiveness of the Dorper crossbreeding program in Ethiopia can be attributed to the well-defined strategy developed by the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) and the Dorper/Boer Valley project. Unlike previous crossbreeding initiatives, the Dorper program encompasses various stages such as importation, evaluation, multiplication, maintenance, and distribution throughout the country. Nucleus centers, including the Worer and Fafen research facilities, as well as the Areka and Debre-Birhan agricultural research centers, have played a crucial role as sources of purebred Dorper sheep for breeding purposes. These centers have also been involved in evaluating and distributing Dorper sheep to the BED center

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and affluent farmers across Ethiopia. The Dorper crossbreeding scheme has been implemented at the village level, taking into consideration the preferences of farmers and the consent of researchers.

The study found that crossbred rams, comprising 50% exotic and 50% local breeds, were distributed to farmers in various areas such as Merhabete, Baso-2, Efratana Gidim, Kobo, Yabello, Damot-Pulassa, Damot-Sore, and Shewa Robit. In Milky (Baso-1), farmers received pure Dorper rams and successfully produced 50% Dorper crossbred lambs. The choice of breeding scheme at the Milky site was made through consensus among farmers after they were educated about the principles and advantages of different breeding schemes. The study observed that farmers in Milky were able to achieve 75% Dorper sheep through a grading-up system. These farmers are now selling crossbred rams for breeding purposes, which is in agreement with the findings of Tesfaye *et al*. (2016) for the Awassi crossbreeding program, while farmers from other sites are producing 25% and 37.5% Dorper lambs and primarily selling the male lambs for meat. Most farmers have shown a preference for retaining the female crossbred sheep and re-breeding them to increase the Dorper blood level in their flocks. The study did not find any farmers from the study sites practicing terminal crossing, which is a breeding system aimed at providing quick income for resource-poor farmers who cannot maintain crossbred flocks. Instead, all farmers were retaining the female crossbred ewes and predominantly selling the male crossbred lambs.

The current study also highlighted the lack of linkage between upgrading and terminal crossing farms at any of the sites. The challenge with terminal crossing lies in the disposal of female crossbreds produced on the farm. While these sheep can be fattened and sold, this option may not be economically viable. Alternatively, crossbred females could be sold at a premium price as breeding animals to upgrading flocks (Solomon *et al*., 2012). Establishing links between terminal crossing farmers and upgrading farmers can facilitate this process and accelerate the build-up of crossbred flocks while minimizing inbreeding. The study suggests that the Debre-Birhan Agricultural Research Center (DBARC) should take the initiative to establish links between upgrading and terminal crossing farms, considering the presence of an upgrading flock near the research site and the recent scaling out of Dorper crossbreeding in villages in North Shewa initiated by DBARC with minimal involvement by ICARDA. This collaboration would facilitate

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the exchange of knowledge and resources, further enhancing the success of the Dorper crossbreeding program in Ethiopia. Similar findings were reported in a study by Solomon *et al*. 2012 on a village-based Awassi crossbreeding scheme, where they suggested designing and testing a community-based crossbreeding scheme in model villages for future adoption and scaling up.

The successful implementation of the crossbreeding scheme necessitates the establishment of flocks and facilities. The ESGPIP and Dorper/Boer Valley project have designated several sites in the Amhara region, including Sirinka research, Yabello research, Haromaya University, Hawasa University, and two recently joined sheep multiplication centers in Amhara region. The Dorper nucleus sites, including Werer, Fafen, Debre-Birhan, and Areka research centers, are responsible for the production and dissemination of purebred Dorper sheep in Ethiopia. However, it is unfortunate that most of the nucleus and BED sites that were actively engaged in the crossbreeding task during the ESGPIP project (2007-2011) period have ceased their operations due to budgeting and coordination challenges that arose when the project ended in September 2011, untimely and without a proper handover.

Despite the challenges faced by the Dorper crossbreeding program in Ethiopia, a few centers, notably the Debre-Birhan Agricultural Research Center (DBARC), have remained dedicated to the program for over a decade. Currently, they are the sole source of 100% pure Dorper rams and ewes in the country. However, it is very important that the level of support from the Ministry of Agriculture for the Dorper program is comparatively lower than the support provided to indigenous (CBBP). This highlights the need for increased recognition and support for the Dorper crossbreeding program to fully realize its potential in improving sheep productivity and benefiting both the commercial and smallholder farmers in Ethiopia.

Sheep ranches in the Amhara region have emerged as functional sources of Dorper crossbred rams; however, they faced challenges due to the insufficient availability of pure Dorper rams. Despite this, these ranches have managed to produce a significant number of Dorper crossbred rams and distributed them to various zones and districts. The distribution of rams from these ranches did not follow a CBBP approach, as individual farmers pay the extension wing from the Woreda to purchase the rams from the ranches. Lack of awareness has led some farmers, such as

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those in Minjar-Shenkora, to slaughter the Dorper rams intended for crossbreeding after realizing male crossbred lambs were being born in their flock. This lack of training on effective Dorper ram usage is a significant challenge that needs to be addressed. Similar issues were observed at the Areka research site, where NGOs distributed Dorper crossbred rams to farmers without proper guidance, and at the Yabello site. The recommended approach is to follow the established crossbreeding scheme and adopt a Community-Based Breeding Program (CBBP) for smallholder farmers. Alternatively, private commercial farmers could be offered single-use Dorper rams after creating awareness on their proper utilization.

A study conducted by Feyissa *et al*. (2023) in the pastoral areas of Yabello district, Southern Oromia, Ethiopia, examined the performance of Dorper crossbred sheep. The findings revealed that pastoralists expressed a willingness to continue with Dorper crossbreeding. However, they encountered difficulties due to the unavailability and inconsistent access to improved Dorper sires. The study also revealed that farmers in the Yabello area preferred the thin-tailed, highly demanded by the market, color and appearance, high-quality red meat from the 25% of Dorper crossbred sheep farmers perceived that the Dorper crossbred sheep in the Yabello district outperformed other breeds in terms of marketability, body weight, meat yield, drought resistance, and disease resistance. These findings highlight the potential benefits of the Dorper crossbreeding program and the importance of addressing access issues and providing continued support to farmers to fully capitalize on these advantages. In their study on farmers' perception towards Awassi Menz crossbred sheep and management practices in North Shoa, Demeke *et al*. (2015) discovered that all of the respondents expressed a preference for the distributed crossbred rams over local rams in both districts. The respondents favored crossbred rams as the desired sires for the next generation. This preference was driven by several factors including the high market value, rapid growth, as well as the color and appearance of the crossbred lambs.

As part of the Dorper crossbreeding scheme, this study also evaluated the production of *inter se* mating to produce a self-replacing 50% Dorper crossbred sheep breed. The Debre-Birhan Research Center made commendable efforts in crossbreeding and evaluating the animals. They have reached the F_4 levels and the growth, reproduction, and survival of the self-replacing 50% Dorper crossbred animals have shown promising results. This aligns with the findings of Solomon *et al*. 2012, who reported successful outcomes for the *inter se* mated 50% Awassi x

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Menz crosses. Researchers involved in the Dorper crossbreeding program have observed an interesting feature regarding the color of the lambs from *inter se* mating. They have noted a higher number of lambs with full white and light-red colors being born, which are preferred by farmers in most locations, especially in lowland areas like Shewarobit. This preference is due to the fact that farmers in hotter regions do not favor black sheep. This observation highlights the importance of considering local preferences and environmental factors when implementing breeding programs, ensuring that the resulting offspring are well-suited to the specific needs and preferences of the farmers in a particular region. The research center should be encouraged to conduct further *inter se* mating (F_9) to achieve genetic fixation and produce an Ethiopian Dorper synthetic breed. This endeavor requires strong support from the government and other bilateral bodies to ensure adequate budgeting and infrastructure for fruitful outcomes. Strengthening the sheep ranches with infrastructure and the delivery of pure Dorper rams can further enhance such work.

The Dorper breeding scheme implemented at the nucleus sites has shown overall good performance. The designated sites successfully multiplied purebred Dorper sheep and distributed them to various stakeholders. However, after the project evacuation, sites like Fafen, Areka, and Worer faced difficulties in maintaining their pure breeding tasks and providing sheep to users. Currently, the Debre-Birhan research site remains the sole source of Dorper purebred sheep in the country. The discontinuation of breeding activities in other sites can be attributed to budget constraints and a lack of coordination and support from responsible authorities.

Breeding in the multiplication sites was successful, especially with the support of ESGPIP, which provided both technical and financial assistance. However, access to purebred Dorper rams was limited in most of these sites now. Since 2012, the Debre-Birhan research site has become the exclusive source of purebred Dorper rams. Additionally, there has been an encouraging initiative to produce half-bred Dorper progeny, which should be further promoted. It has been observed that significant efforts have been made at Debre-Birhan to generate a self-replacing 50% Dorper crossbred sheep. This successful approach can be expanded to other breeding and multiplication centers (ranches) in order to produce Ethiopian self-replacing Dorper crossbred sheep.

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Breeding in the village has shown promising results, with successful upgrading of farmers' flocks. The Dorper inheritance in the farmers' flock has reached 43.75%, indicating progress. However, there are still lambs with only 12.5% Dorper inheritance, revealing a gap in the implementation of the breeding scheme. The scheme emphasizes the use of terminal crossing in the village flock, but this study did not observe any related efforts being made. It is important to note that there have been recent initiatives in the Debre-Birhan research mandate area, which should be further supported and strengthened.

The Dorper crossbreeding program in Ethiopia has been implemented through research centers, universities and projects, with the aim of improving sheep productivity and economic opportunities for farmers. The Dorper crossbreeding program has shown some positive indicators of success in crossbreeding and distributing the rams, farmers readily accept the breed but challenges remain in fully implementing the crossbreeding scheme, low budget, poor national coordination, lack of farmer awareness and training (in some areas), and a lack of strong commitment among stakeholders. It is important to establish links between upgrading and terminal crossing farms, enhance CBBP approaches, and provide ongoing support to research centers and ranches involved in the program (Solomon *et al*, 2014). Additionally, the program has shown promising results in *inter se* mating; with the production of a self-replacing 50% Dorper crossbred sheep breed (Ayele *et al*., 2024, unpublished). Further efforts and supports are needed to achieve genetic fixation and develop an Ethiopian Dorper synthetic breed. According to a report by Tesfaye *et al.* (2016), it has been indicated that crossbreeding programs necessitate robust research and development support from public service and non-governmental institutions. This support is crucial for the sustainable design, optimization, and implementation of crossbreeding programs within well-defined production environments. Therefore, The successful realization of the Dorper crossbreeding program's benefits depends on the efficient application of the suggested crossbreeding scheme and the proper utilization of the distributed rams. However, the study found a lower demand for Dorper rams in the Damot-Pulassa and Damot-Sore areas compared to other sites like Merhabete, Baso-1, Baso-2, Minjar-Shnkora, and Kewet. This decreased demand in Damot-Pulassa and Damot-Sore can be attributed to inconsistent delivery of the rams and inadequate follow-up from research and extension services after the rams were provided. Addressing these issues of inconsistent supply and lack of post-distribution support

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can help better meet the varying demand for Dorper rams across the different sites, ultimately enhancing the overall effectiveness of the crossbreeding initiative.

5.11.1.2. Importation

A total of 341 purebred Dorper sheep, comprising 53 males and 288 females, were successfully imported from the Republic of South Africa. These sheep were placed in a designated nucleus for multiplication, maintenance, and distribution to BED sites and to private commercial farmers. The selection of male and female Dorper sheep for importation was based on ten farms in South Africa, and stringent precautions, including a quarantine period in both the country of origin and the receiving country, were followed. In July 2007, the first batch of purebred Dorper sheep arrived at the Sebeta quarantine facility in Ethiopia. After completing the quarantine period in Sebeta, the animals were transferred to Worer, Fafen, DBARC, and Areka research centers. This demonstrated a well-coordinated effort and successful importation of improved genetic stock (live sheep) that should be encouraged.

This success aligns with the findings of Tesfaye *et al*. (2016), which reported successful animal importation in Ethiopia. After 17 years since the importation of 341 Dorper sheep, it is evident that there is a potential risk of inbreeding, as there are currently only 73 male and 121 female Ethiopian-born purebred Dorper sheep remaining for both pure breeding and crossbreeding purposes. This limited number raises concerns about genetic diversity and the potential negative impact of inbreeding on the breed's overall health and productivity. To address this issue, it is necessary to introduce additional purebred Dorper sheep from external sources to expand the genetic pool and prevent the accumulation of detrimental genetic traits. Close monitoring and management of the crossbred offspring is essential to maintain and improve desirable traits through selective breeding. By prioritizing genetic diversity and effectively managing the purebred and crossbred populations, the Dorper crossbreeding program can continue to yield positive outcomes in terms of marketability, body weight, meat quality, drought resistance, and disease resistance. To ensure the long-term success of the Dorper crossbreeding program, it is crucial to take proactive steps, such as introducing new purebred Dorper sheep to enhance the genetic base. The existing crossbreeding scheme lacks a clear strategy for injecting pure Dorper genetics into the program in Ethiopia.

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5.11.1.3. Purebred Dorper, and crossbred Dorper lamb production

The analysis of purebred Dorper lambs born under the on-station management system in Ethiopia reveals fascinating and remarkable findings. The Debre-Birhan Agricultural Research Center (DBARC) emerges as the primary contributor, accounting for 62% of the total purebred Dorper lambs produced. Worer and Fafen research centers collectively contribute 36%, while the remaining 2% comes from Hawasa University, Haromaya University, and EMDTI. This substantial contribution from DBARC can be attributed to the dedicated efforts of researchers and officials from the Amhara Agricultural Research and Ethiopian Agricultural Research institutes, who provided both technical and financial support. It is very crucial, however, that the study observed a reduction or complete halt in the production of purebred Dorper lambs at nucleus sites such as Worer, Fafen, and Areka research centers after the ceasing of the ESGPIP project that may recall re-initiation with due enhancement.

The allocation of purebred Dorper sheep to various recipients is also noteworthy. The recipients include the BED sites (Sirinka research, Yabello research, Mekele research, Haromaya University, Hawassa University, EMDTI), Amed-Guya, Debre-Birhan sheep ranches, and several private sheep producers. The BED sites played a crucial role in multiplying, evaluating, and distributing half-bred Dorper sheep produced through the crossbreeding program. Additionally, the Amed-Guya and Debre-Birhan sheep ranches were specifically utilized as multiplication and distribution sites, targeting smallholder farmers in the Amhara region. At the nucleus sites, both purebred Dorper sheep and lambs with varying levels of Dorper inheritance were produced.

The role of research centers and sheep ranches in the production, evaluation, and distribution of Dorper crossbred sheep is commendable and should be continued, as it positively influences the production of Dorper crossbred lambs among farmers, pastoralists, and commercial private farmers in Ethiopia. Between 2009 and 2022, under on-station management conditions, the data recorded the number of lambs born with different levels of Dorper inheritance. Notably, 32% of the Dorper crossbred lambs with different Dorper inheritance were produced at DBARC.

Furthermore, among farmers in the Basona-Werena, Efratana-Gidim, Kewet, Kobo, Merhabete, and Yabello areas, a significant number of Dorper crossbred lambs were born between 2012 and

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2021, totaling 1168, 207, 580, 467, 341, and 371, respectively. In contrast, the numbers of local lambs born in these areas were considerably lower, with 694, 23, 131, and 134 recorded in Basona-Werena, Efratana-Gidim, Kewet, and Merhabete areas, respectively. These figures clearly indicate a higher proportion of Dorper crossbred lambs born within the farmers' clock compared to local lambs in these areas, highlighting the success and popularity of the Dorper crossbreeding program, this in line with the reports by Tesfaye *et al.* (2016) for the Awassi sheep in Ethiopia.

The support of research institutes, the establishment of nucleus sites, and the distribution to different recipients have played pivotal roles in achieving these outcomes. Continued efforts in these areas will likely yield positive results and further drive the success of the Dorper crossbreeding program in the country. In conclusion, it is highly suggested to promote and support private commercial farmers in Ethiopia, while simultaneously transforming the existing sheep breeding and multiplication centers into advanced sheep production, multiplication, maintenance, and distribution enterprises. Such a transition will greatly contribute to the sustainable availability of enhanced genetic materials for various stakeholders involved in the sheep industry.

By encouraging private commercial farmers, the Ethiopian government can foster entrepreneurship and innovation in the agricultural sector. Private farmers often bring unique perspectives, expertise, and resources to farming practices, leading to increased productivity and efficiency. Additionally, supporting private farmers can stimulate economic growth, create employment opportunities, and enhance food security in the country.

5.11.2. Dissemination strategy

5.11.2.1. Dissemination of purebred Dorper stock

The strategy for production and distribution of purebred Dorper sheep in Ethiopia was implemented through a specific breeding scheme designed for this purpose. This scheme involves disseminating purebred rams and ewes (ewe lambs) to BED centers and private producers. To ensure a reliable source of breeding germplasm, the Werer, Fafen, Debre-Birhan, and Areka research centers are actively involved. These research institutes have contributed a

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total of 433 purebred Dorper sheep (240 males and 193 females), which have been distributed for breeding purpose to various stakeholders across Ethiopia. The study also indicated that almost the entire Dorper breed was produced by the research system. Similarly, the Amed Guya and Debre-Birhan sheep ranches (DSABMC, 2007) solely produced purebred Awassi sheep.

The distribution of purebred sheep was done to research centers (149), small-holders and pastoralists (136), universities (128), private-farmers (14), and sheep ranches (6), signifying that the highest proportion of purebred Dorper male and female sheep was received by the research system and the universities (64%), followed by the small-holder farmers/pastoralists and private-sheep producers (35%). However, a very small proportion of purebred Dorper male sheep was delivered to the sheep ranches (1%). Dissemination of the purebred Dorper sheep seems skewed positively to the research system and universities and negatively to the sheep ranch and private-farmers.

It is suggested that distribution to the private commercial farmers and sheep ranches should be revised for sustainable production of purebred Dorper as well as Dorper crossbred sheep for further distribution and sale for mutton. The overemphasis on distributing purebred Dorper sheep to the research system and universities raises questions about the overall sustainability of the breeding program. While research centers and universities play a crucial role in breed preservation and research, it is imperative to ensure a broader distribution pattern that includes private commercial farmers and sheep ranches. Private commercial farmers and sheep ranches can have a significant stake in the livestock industry and contribute to the commercialization and expansion of sheep production.

By revising the distribution strategy (through optimization), the production of purebred Dorper sheep can be made more sustainable, ensuring wider access to quality breeding stock. This, in turn, will facilitate the production of Dorper crossbred sheep for mutton, meeting the growing demand for meat in Ethiopia. Exercising modern biotechnology tools in research, universities, and private commercial farmers and sheep ranches can help a lot in the production and distribution of purebred Dorper sheep in the country and widen the genetic bases.

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In conclusion, the distribution strategy for purebred Dorper sheep in Ethiopia has shown positive outcomes through the involvement of research centers and universities. However, the current distribution pattern neglects private commercial farmers and sheep ranches, hindering the sustainable production of purebred Dorper. By revising the distribution strategy, fostering collaborations, and providing necessary support, Ethiopia can enhance the production and distribution of purebred Dorper sheep, ensuring a thriving sheep industry and meeting the demand for mutton, there by encourage the research system in the development of Ethiopian version purebred Dorper sheep.

5.11.2.2. Dissemination of crossbred Dorper sheep to villages

The production and distribution of Dorper crossbred sheep in Ethiopia are carried out through a specific crossbreeding scheme designed for this purpose (ESGPIP-2011; Solomon *et al.,* 2014). This scheme involves collaborative efforts from research institutes, universities, sheep ranches, and farmers, contributing to the production of sheep with varying percentages of Dorper inheritance. The distribution of Dorper crossbred sheep among these entities can be analyzed to understand their respective contributions and the distribution patterns. Based on the available data, the research institute has played a significant role, accounting for 45% of the production of Dorper crossbred sheep. Sheep ranches have contributed 35%, while farmers, including smallholders and private commercial farmers, have produced 18%. Universities have accounted for 1% of the production.

Similar to our findings it is also stated in Tesfaye *et al*. (2016) and Dagne (2021) that sheep ranches serve as sources for the distribution of Awassi crossbred rams in Ethiopia. Additionally, it is mentioned that farmers in the Chiro area of South Wollo, who are organized as an Awassi breeder group, have also contributed to the production of 50% Awassi x Local rams for distribution. The involvement of sheep ranches as sources for distributing Awassi crossbred rams highlights their role in the Ethiopian sheep crossbreeding processes. Furthermore, the participation of farmers in the Chiro area of South Wollo, organized as an Awassi breeder group, demonstrates the collaborative efforts of local farmers in contributing to the production of 50% Awassi x Local rams. The recent effort by the farmers in Milky area as a source of 50% DxL rams should be encouraged. This collective approach allows for the involvement of farmers in

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the breeding and distribution of Awassi crossbred rams, promoting local engagement and knowledge sharing. The findings from Tesfaye *et al*. (2016) emphasize the significance of both sheep ranches and organized farmer groups in Ethiopia's efforts to enhance the distribution of Awassi crossbred rams. These collaborative initiatives contribute to the overall improvement of the sheep industry, support local farmers, and promote the sustainable production of high-performing Awassi crossbred rams for various purposes.

5.11.2.3. Status of disseminated Dorper crossbred rams to farmers

Based on the current survey conducted across multiple sites, it was observed that, within the past 5 years, out of the total number of Dorper rams distributed to farmers, 8% were castrated, 33% died, 36% were currently in service, 8% were slaughtered, and 15% were sold. The percentage of rams currently in service varied, ranging from 8% in Damot-Pulassa to 63% in Baso-1. Overall, approximately 36% of HHs had rams currently in service (Table 59). The results of this survey also revealed significant differences in the availability of serving Dorper rams within the flocks (χ^2= 108.61; $p < 0.0001$). In discussions with individual HHs and focus groups in the Minjar-Shenkora, Damot-Pulassa and Damot-Sore areas, it was learned that Dorper ram delivery was not conducted on a regular basis, particularly with no replacements for dead, non-serving, or old-age rams. The variations in the proportion of currently available serving rams within the flocks can be attributed to factors such as the number of distributed Dorper rams that died, were sold, castrated, or slaughtered, leading to a lower number of Dorper rams available for mating being replaced.

Despite the farmers' need for Dorper rams to improve their flocks, the proportion of currently serving rams accounted for only 36% compared to the total number of rams distributed. To ensure the continuity of the crossbreeding program, there should be a continuous and sustainable ram delivery system that includes replacements for non-serving rams due to various reasons, such as rams sold because of old age or defects. Additionally, castration should be considered for rams reaching old age or to prevent inbreeding by using the same ram for more than 1-2 years in the same flock. Similar to our finding, Tesfaye G. *et al.* (2008b) in their studies on distributed Washea rams for crossbreeding purposes in South Wollo Zone learned that the proportion of Washera rams found serving was 16.1%. A similar challenge was reported by Zelalem (2018)

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regarding the distribution of improved indigenous Bonga rams in different agro-ecologies in Southern Ethiopia. Evidence supporting the need for continuous ram delivery and replacements can be found in Zelalem's study on improved indigenous Bonga rams. The challenges identified in that study align with the current findings, highlighting the importance of addressing the issue to ensure the sustainability of crossbreeding programs in Ethiopia's various agro-ecologies.

5.11.2.4. Adaptation of disseminated Dorper crossbred rams to farmers

For animals to successfully reproduce, they must adapt to their environment. Farmers were asked to rank rams as not adapted, moderately adapted, or well adapted to their management systems to determine their suitability for crossbreeding purposes. Overall, 73% of the Dorper crossbred rams received for crossbreeding were considered to have adapted very well. Farmers observed that rams received from research and development organizations were well adapted to their environments. Although there were significant differences among the study sites (χ^2=47.92 and $p < 0.0001$, Table 60), most farmers rated that Dorper rams were adapted very well (Damot-Pulassa, 58%; Kewet, 75%; Baso-2, 80%; Merhabete, 83%; Minjar-Shenkora, 85%; Kobo, 86%; and Baso-1 88%). Additionally, 24% of the rams received were moderately adapted, and less than 4% did not adapt to farmers' management. These results are promising for the use of Dorper sheep as an improver breed for crossbreeding, and to improve the productivity of local sheep.

The study results from this work on Dorper rams is in line with the reports of Tesfaye G. *et al*. (2008b) which reported that the Wahsera rams distributed for crossbreeding purpose in to the Wogidi (lower altitude) and Dessie Zuria and Wadla (high altitude) performed well and adapted to those areas along with the lambs born as Wahsera crossbred. Reports by Mengiste *et al.* (2011a) for Washera sheep ram in the distributed areas of South Gondar Zone of Amhara Region indicated that about 74% of HHs surveyed indicated that they wanted to use Washera rams for the crossbreeding purpose because of several positive attributes of the breed including adaptation of the rams and crossbred lambs, this was also supported by Alayu *et al*. (2012) in the studies for the same breed (Washera) in North Gondar Zone of Amhara region. Similarly, according to a study conducted by Shigdaf *et al*. (2012) on the distributed Washera rams in the South Gondar Zone of the Amhara region, it was discovered that farmers in the study area embraced the Washera sheep breed due to its notable characteristics.

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These characteristics included large body size, smooth hair, fast growth, a big fat tail, and appealing coloration. however, the relative susceptibility to disease and drought in addition to the lack of horn was considered as a drawback to the breed, the crossbred lambs obtained from this crossbreeding were reported to be supper for they have the merits of productivity and adaptation, the relative susceptibility of rams could also happen to any one breed distributed to the new environment especially in the first week of distribution as was noted from the Dorper keeping farmers. In areas where distributed rams are well-suited to the local management system and where crossbred sheep are present, the likelihood of adopting this new technology is expected to increase. This finding aligns with the conclusions drawn by Solomon *et al*. (2015) and Dehinenet *et al*. (2014) in their respective studies, where they observed a positive and significant correlation between total farm income and the adoption of Awasi crossbreed sheep and dairy technology, respectively.

5.11.2.5. Number of Dorper crossbred lambs born within the flock & in the neighbors' flock

A survey was conducted among farmers to assess their ability to recall the number of Dorper crossbred lambs born in their own flock as well as in neighboring flocks. On average, the farmers reported that their own flock had produced 12 Dorper crossbred lambs, while neighboring flocks had an average of 46. However, there were variations in the average number of lambs born within their own flock across different study sites, ranging from 4 in Minjar-Shenkora to 20 in Baso-1. The study revealed statistically significant differences ($p = 0.0024$) in the number of Dorper crossbred lambs among the various study sites. Furthermore, the farmers were also questioned about the number of Dorper crossbred lambs in neighboring households consisting of 4-5 households. According to the farmers' responses, an average of 46 lambs were born in their neighbors' flocks. There was a notable difference ($p = 0.0107$) in the number of Dorper crossbred lambs born among the flocks of neighbors in different sites, with lower numbers (on average 12 lambs) observed in Minjar-Shenkora and higher numbers (on average 83 lambs) observed in the Merhabete site (Table 61).

These discrepancies in the number of lambs born within farmers' own flock and within neighboring flocks could be attributed to various factors such as flock size, individual interest and commitment to adopting the Dorper crossbreeding task, accessibility to markets, number of

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years they engaged on Dorper crossbreeding and the demand for Dorper crossbred lambs. In support of our study, Tesfaye G. *et al*. (2008a) reported on the average number of Washera crossbred lambs in different areas of South Wollo and Wadla and Meket districts in North Wollo. They found an average of 13 crossbred lambs, which is comparable to our study results. However, the corresponding values for Washera crossbred lambs born outside the flock were lower, with an average of 24, compared to current study's 46 Dorper crossbred lambs. These findings suggest an indication that the adoption of Dorper technology has led to a higher number of crossbred lambs within the community.

Moreover, our results align with previous reports by Feyissa *et al*. (2018) on Dorper x Blackhead Somali sheep in pastoral communities within the Yabello district. These reports highlighted the market demand for Dorper crossbred lambs and their high-quality meat, particularly the higher proportion of red meat compared to fat content. The successful adoption of Dorper technology can be attributed to these market factors. To further enhance the income and livelihoods of households engaged in Dorper crossbreeding, it is crucial to ensure a regular supply of Dorper rams and improve market demand in areas where awareness of the breed is lacking. These measures would contribute to increased sales of Dorper crossbred lambs, benefiting households and securing their livelihoods. By addressing these factors, decision-makers can focus on strategies that promote the sustained success of the Dorper crossbreeding program.

5.11.2.6. Body weight, body condition, and body measurements of local and Dorper crossbred lambs

During our visit to farmers' flock, we conducted an objective evaluation of 5-month-old lambs by measuring their body weight (BWT), body condition score (BC), and various body measurements including height at wither (HW), chest girth (CG), body length (BL), and chest width (CW). We assessed both local lambs and Dorper crossbred lambs, and observed significant differences in all measurements among the study sites, except for BL. The overall measurements for BWT, BC, HW, CG, BL, and CW were 16.9 kg, 3.0, 58.1 cm, 63.3 cm, 53.7 cm, and 19.6 cm, respectively (Table 62). We found that lambs born at Baso-2, Merhabete, and Minjar had higher BWT compared to those born at Baso-1 and Kewet sites, while relatively lower BWT was recorded at Baso-1 and Kewet sites. The BC of lambs at Baso-1 was lower compared to other sites, and lambs born at Minjar had better HW compared to other sites. Additionally, the study observed that the BL and CW of lambs born at the Merhabete site had lower values than the other study sites.

The genotype of the lambs significantly contributed to the observed differences in all traits considered. Local lambs exhibited lower values for BWT, BC, HW, CG, BL, and CW compared to the Dorper crossbred lambs of the same age. However, the sex of the lamb did not significantly affect the traits, except for HW, where male lambs had higher values than their female counterparts. The differences in morphometric measurements among the study sites could be attributed to the variations in lamb breeds (local vs. Dorper crossbred) and the blood levels of the lambs (Dorper cross low-grade: 12.5-25% Dorper inheritance, vs. Dorper cross high-grade: 37.5-43.75% Dorper inheritance).

In comparison to previous findings, Alayu *et al*. (2012) reported morphometric values of 18.1 kg (BWT), 3.25 (BC), 58.6 cm (HW), 60.0 cm (CG), and 49.1 cm (BL) for 5-6 months old Washera x Siemien crossbred lambs in North Gondar of Amhara region. Compared to our results for 5-month-old Dorper crossbred lambs, which had measurements of 23.1 kg (BWT), 3.6 (BC), 59.6 cm (HW), 64.8 cm (CG), and 55.4 cm (BL), it indicates that Dorper crossbred ram lambs in the current study exhibited higher morphometric measurements for BWT, BC, CG, and BL. However, the values reported for Washera x Simien crossbred lambs of the same age had higher measurement values compared to the current study results for local lambs, with 15.7 kg (BWT), 2.6 (BC), 54.6 (HW), but comparable values for 50.9 (BL) and 59.9 cm (CG), respectively. On the other hand, Mengiste *et al*. (2011b) reported 15.1 kg (BWT), 3.00 (BC), 57.7 cm (HW), 58.0 cm (CG), and 48.8 cm (BL) for Washeara x local progenies under traditional management in South Gondar of Amhara region at the age of 4-5 months. Conducting a morphometric assessment of Dorper crossbred and local lamb populations on farms can provide several benefits and insights for farmers including genetic evaluation, growth assessment, Here are some potential advantages of taking such an assessment, breeding program improvement, bench-marking and selection among the crossbred lambs and marketability and value.

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5.11.2.7. Body weight, body condition of ewes, number of lambs born to ewe, estimated prices of local and Dorper crossbred ewes and their morphometric measurements

During the study, objective evaluations were conducted on both local and Dorper crossbred breeding ewes ranging in age from 1 to 4 years at various locations. The study revealed that there were significant variations among the sites in several traits such as body weight (BWT), estimated prices of ewes, height at wither (HW), chest girth (CG), body length (BL), and rump width (RW). However, there were no significant differences observed for BC ($p = 0.5324$) and the number of lambs born to each ewe ($p > 0.7497$) (Table 63). The genotype of the ewes had a considerable influence on BWT, BC, the estimated market price of ewes, and body morphometric measurements of ewes such as HW, CG, BL, and RW. However, the genotype of the ewes had no significant effect on the number of lambs born to either local or Dorper crossbred ewes. Local ewes showed significantly lower values for all the considered traits except for the number of lambs born to ewes. The age of ewes was also a significant source of variation for most of the traits considered, such as BWT, the number of lambs born to ewes, and estimated market prices of ewes, HW, CG, and BL. However, the age of ewes didn't affect BC, estimated market prices of ewes, and RW. Ewes that had III and IV permanent incisors (~3-4 years old) had higher values for most of the considered traits compared to those having age I and II permanent incisors (~1-2 years of age).

The differences in body weight (BWT), estimated prices of ewes, and morphometric measurements of ewes reared in different sites may be due to differences in feed resources and market accessibility among the sites. The observed variations among the ewe breeds for BWT, estimated price, and morphometric measurements in the current study depend on their conformation and phenotype status. The crossbred ewes had higher values for most traits considered, which may indicate optimal management and care of the crossbred ewes and their adaptation to the farmers' management practices Tesfaye *et al.* (2016). The most significant finding from this study is that the number of lambs born to the crossbred ewes is comparable to that of the local ewes. This suggests that the crossbred ewes have similar reproductive performance to the local ewes under similar management conditions on the farmers' farm, but it is normal for the morphometric measurements of ewes to vary with age.

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5.11.2.8. Estimated prices for local and Dorper crossbred lambs produced by farmers

Based on our study, farmers who participated in the Dorper crossbreeding project provided estimates of the current selling prices for both local and Dorper crossbred lambs at different ages. The overall estimated market prices, according to the farmers across various sites, showed that at six to eight months of age, the prices for local sheep ranged between 1194 and 1723 ETB, while the prices for Dorper crossbreeds at the same age ranged between 1533 and 2393 ETB. Similarly, at nine to eleven months of age, the prices for local lambs were estimated to be between 1537 and 2174 ETB, whereas the prices for Dorper crossbred lambs ranged from 1948 to 3181 ETB. For yearlings, the estimated prices for local lambs were between 2260 and 2778 ETB, whereas the prices for Dorper crossbred lambs ranged from 2600 to 3812 ETB.

The study results also revealed variations in the prices of local and Dorper crossbred lambs among the different study areas. The survey indicated significant differences ($p < 0.0001$) in market prices between local and Dorper crossbred lambs at all ages across the study sites. Furthermore, the market estimates demonstrated that Dorper crossbred lambs commanded higher market values compared to local lambs across all age groups and study sites (Table 64). Feyissa *et al*. (2018) on Dorper also detected such differences x Blackhead Somali sheep in pastoral communities within the Yabello district, Negassa and Jabbar's findings (2008) highlight the multifaceted benefits of enhancing production, marketing, and processing in the agricultural sector. By implementing improvements in these areas, significant value gains can be achieved, resulting in various positive outcomes. This is supported by the better price and demand created for Dorper crossbred lambs in the local market which indicates the adaptability and market appeal of these crossbreeds in different areas. To further capitalize on this market potential, the sales value of sheep can be improved by implementing enhanced management systems that cater to the demand for Dorper crossbred lambs.

5.11.2.9. Future demand on crossbreeding using Dorper sheep

The present study aimed to identify the key constraints in Dorper breeding and sought farmers' opinions on the future demand for crossbreeding using Dorper sheep. The farmers' interest in crossbreeding work with Dorper sheep was assessed using three categories: very high, moderate, and low. The overall index values for very high, moderate, and low interest were found to be

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0.595, 0.242, and 0.163, respectively (Table 66 and Figure 12). Interestingly, farmers from Damot-Pulassa reported their interest in the order of low (index value of 0.362), moderate (index value of 0.333), and very high (index value of 0.305), which contrasts with the overall trend observed in most study sites. On the other hand, farmers from Damot-Sore expressed moderate interest (index value of 0.395), high interest (index value of 0.389), and low interest (index value of 0.216), respectively, in the future demand for crossbreeding using Dorper sheep. Among the study sites, Baso-2 and Merhabete had a unanimous opinion of very high (100%) future demand for using Dorper sheep for crossbreeding, while Baso-1, Minjar-Shenkora, and Kewet sites also indicated a very high to moderate interest compared to the remaining sites. These findings suggest the importance of understanding the specific characteristics of different sites and tailoring interventions accordingly, with a focus on areas where adoption seems to be high.

The results of this study are supported by previous research. Tadesse (2018), in his evaluation of distributed Awassi and Washera sheep in South Wollo, reported a high demand for introduced rams among farmers due to their fast growth, early market readiness, high fertility rate, and low mortality, making them suitable for genetic improvement practices. Ermias (2014), in his evaluation of Dorper breed in Wolaita and Siltie Zone, found that Dorper crossbred sheep exhibited good performance and high adaptability, generating interest among farmers. According to the findings of Demeke *et al*. (2015), farmers in the Angolela-tera and Basona-werena districts of North Shewa demonstrated a strong interest in Awassi x Menz crossbred rams. The researchers discovered that all of the interviewed farmers were enthusiastic about using these crossbred rams as the sires of their lambs.

The farmers' preference for crossbred lambs stemmed from their awareness of the numerous benefits associated with them, such as their high market value, rapid growth, appealing color, and impressive appearance. These findings align with our own research results. Similarly, Zeleke *et al*. (2018) conducted studies on the performance of Awassi x Wollo crossbred sheep and farmers' interests, revealing that approximately 88% of respondents desired a new breed, while the remaining 12% preferred to retain their local breed. The authors further indicated that 47% of the respondents required introduced Awassi rams, 43% preferred introduced Washera rams in their locality, and 10% expressed interest in keeping both Awassi and Washera crosses. This preference might stem from farmers' positive experiences with three-way crosses (Awassi x

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Washera x local), which demonstrated enhanced hybrid vigor. Corresponding to our current findings, Dagne (2021) conducted a study on Dorper x Menz crossbred sheep in the Amhara region and reported that 86% of farmers in Habru, 83.3% in Minjar/Shenkora, and 92.9% in Raya Kobo districts stated that they benefited from the Dorper crossbreeding work, while only 13.56% did not observe the immediate importance of crossbreeding with Dorper sheep.

Overall, the majority of the results pertaining to the crossbreeding work using Dorper sires were perceived as beneficial. However, it is crucial to consider the specific environmental factors affecting the viability, productivity, and market aspects of Dorper crossbreeds. Therefore, the information generated from this study can be valuable for policymakers and stakeholders in comprehending the potential demand for the Dorper crossbreeding program and making well-informed decisions regarding its implementation.

5.11.3. Dorper crossbreeding coordination

Livestock production plays a significant role in Ethiopia, providing food, income, employment, and various other contributions (MoA, 2021). Recognizing the importance of the sector, the Government of Ethiopia has formulated policies and strategies to address livestock productivity challenges, particularly the low production of local breeds. These plans involve increasing agricultural inputs, strengthening the marketing system, and enhancing research and development activities to sustainably increase agricultural productivity.

The objectives of these initiatives encompass fulfilling the increasing need for food, industrial raw materials, import substitution, and generating foreign currency earnings. To align with these objectives, the establishment and execution of a Dorper crossbreeding program can play a vital role in addressing the shortfall in domestic meat production. However, such programs need to be participatory and inclusive of the relevant stakeholders. To achieve this, the program must be developed alongside effective coordination mechanisms. Such a project plays a vital role in achieving the targets set for sheep meat production in Ethiopia, as outlined in the EASM (2015). The road map aims to increase sheep meat production from 115 thousand tons in 2015 to 171 thousand tons in 2020 and 237 thousand tons in 2025. Similarly, the projected consumption of sheep meat is expected to rise from 76 thousand tons in 2015 to 105 thousand tons in 2020 and 169 thousand tons in 2025.

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The Dorper crossbreeding program to contribute much in this regard has to be well coordinated. Effective coordination and collaboration among various stakeholders are crucial for the success of Dorper crossbreeding programs in Ethiopia. These stakeholders include the Ministry of Agriculture, animal health institutes, quarantine centers, research institutes, universities, sheep ranches, science and technology institutions (meat industry sector), abattoirs, exporters, marketing institutions, agricultural banks, cooperatives, loan offering sectors, crossbreeding groups (breeder societies), international research institutes, NGOs, and farmers (commercial, smallholders, pastoralists). A coordinated approach facilitates the exchange of knowledge, resource sharing, and implementation of standardized breeding practices, leading to improved outcomes and increased efficiency and thereby sustainability.

However, the coordination of Dorper crossbreeding programs in Ethiopia appears to be fragmented. During the ESGPIP project period (2007-2011), the project served as a coordination unit, and the emerging Dorper/Boer Valley project was responsible for the eastern Amhara region. Unfortunately, the ESGPIP project was prematurely withdrawn without fully completing agreed-upon tasks, such as establishing national database systems and appropriately handing over the project, including infrastructure and animals, to the relevant institutions (EIAR 2014). Although a written document was prepared in August 2011 outlining the coordination and responsibilities, the formation of a consortium with all the mentioned responsibilities was not executed. It can be concluded that the project was not adequately transferred to the responsible body with the necessary leverage power and budget. Therefore, it is timely and essential to revisit the situation and devise a proper course of action. In conclusion, the development of a robust Dorper crossbreeding program and effective coordination among stakeholders are essential for sustainable livestock production in Ethiopia. By addressing the existing challenges and establishing a coordinated approach, Ethiopia can enhance its sheep meat production, meet market demands, and contribute to the overall development of the livestock sector.

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CHAPTER 6: CONCLUSIONS AND RECOMMENDATION

Comprehensive evaluation of Dorper sheep performance based on on-farm flock monitoring, on-station evaluation, survey and at the spot measurement studies as demonstrated in this thesis revealed tremendous potential to improve the productivity of indigenous sheep through incorporation of Dorper sheep genetics.

Livestock holdings were dominated by sheep, which accounted for 59% of the total, followed by cattle, goats, and donkeys. Breeding ewes accounted 46% in the flocks of the farmers and sheep were kept primarily for income generation, meat consumption, and savings, with feed shortages, diseases, and lack of improved genotype identified as the top production constraints.

The investigation into the village management system unveiled that lambing took place year-round, demonstrating the ability of both local and Dorper crossbred ewes to breed and give birth at any given time. However, a significant surge in lambing activity was observed during September, October, and December, constituting approximately 35% of the total lambing occurrences.

Under on-station management condition, the study also examined mating and fertility traits, revealing that the pregnancy rate of ewes was influenced by sire and dam breed, as well as the mating year. Ewes sired by Dorper x Local crossbred rams had better conception and lambing rates, while local ewes had higher conception and lambing rates.

Factors such as location, dam parity, lambing season, and lambing year influenced litter size at birth (LSB), with Dorper purebred rams siring lambs of higher LSB. Litter weight at birth and weaning, age at first lambing (AFL), and lambing interval (LI) were also affected by genotype, environment, and location. Dorper sires (pure and crossbred) produced higher litter weights under semi-intensive management, while local ewes had shorter AFL under both farmers' and semi-intensive management systems. Both local and Dorper crossbred ewes had comparable lambing intervals under farmers' management, but local ewes showed shorter LI under semi-intensive conditions. The annual reproductive rate (ARR) was similar for local and Dorper crossbred ewes across both management systems, however, management system was a source of variability in kg of lamb produced at 3 months by local and Dorper crossbred ewes under semi-intensive conditions, but not under farmers' management.

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Sire breed and dam breed were the limiting factors for conception rate in flocks managed under semi-intensive conditions. Ewes sired by Dorper crossbred rams, and local ewes had the higher conception rates. Interestingly, abortion rates were not influenced by the sire breed, but rather by the dam breed for flocks under semi-intensive management. These findings suggest that the genetic makeup of both the sire and dam play important roles in determining reproductive performance, particularly in more intensive management systems. The local ewes appear to have the optimal combination of traits for maximizing conception rates under semi-intensive conditions. In contrast, the dam breed seemed to be the primary driver of abortion rates, irrespective of sire genetics. This indicates that the innate adaptability and physiological characteristics of the local ewes may confer advantages in terms of maintaining pregnancies, even in the more demanding semi-intensive environment.

Sire and dam breeds were significant sources of variability for litter weight at birth (LWB) and weaning (LWW) under semi-intensive management. Ewes sired by Dorper crossbred rams, and Dorper crossbred dams produced heavier litter weight at weaning. Compared to Dorper crossbreeds, local lambs had lower birth, weaning, 6-month, and yearling weights, as well as slower growth rates, regardless of management system. Under semi-intensive conditions, 50% Dorper x 50% local (DxLocal-50%) *inter se* lambs exhibited comparable weaning and 6-month weights to the DxLocal-50%-F_1 lambs. However, the DxLocal-50%-F_1 lambs had higher yearling weights than the DxLocal-50% *inter se* lambs. These results highlight the productivity advantages conferred by Dorper crossbred genetics, particularly in more intensive management environments. The performance differences between the DxLocal-50% *inter se* and DxLocal-50%-F_1 lambs also suggest that strategic crossbreeding approaches can further optimize growth and weight traits in these transitional production systems.

Group mating was the preferred method for ewes, with a significant proportion of households engaging in the practice of sharing rams for breeding within their communities. Accessibility to improved rams, particularly the Dorper crossbred ram, varied among different study sites, with approximately half of the households having access to Dorper crossbred rams. The breeding and selection criteria emphasized the importance of physical traits, reproductive performance, and

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maternal/paternal history for both ewes and rams. While group mating was a common practice, access to improved Dorper crossbred rams varied across the different sites.

The study also examined on-station mating and fertility traits, revealing the superiority of Dorper crossbred rams in terms of conception and lambing rates, litter size, and litter weights. Lamb survivability was influenced more by environmental factors than genotype under farmers' management.

The majority of distributed Dorper rams (59%) were produced by the research system, while 27% came from sheep breeding and multiplication centers. However, most (76%) of the distributed Dorper crossbred rams were received by smallholder farmers. Currently, the proportion of farmers with serving rams ranged from 8-63% across the study sites of Merhabete, Baso-1, and Baso-2. Though 76% of farmers perceived the Dorper rams had adapted to their management system, and 81% judged the mating ability of the rams as good, the actual Dorper genetic proportion in farmers' flocks varied, ranging from 4% in Damot-Sore to 61% at Merhabete. Nonetheless, 82% of farmers wanted to continue with Dorper crossbreeding, indicating the program's potential for success with proper implementation.

The survivability of lambs was primarily influenced by environmental factors such as, location, birth season, birth year, and birth weight category but not by lamb genotype under farmers' management. Under semi-intensive management DxLocal-25% lambs had higher survival rates at the age of 3 and 6 months of age.

Farmers' perceptions of desirable sheep traits revealed a nuanced preference for Dorper crossbreds and local breeds. For productive traits, farmers tended to favor Dorper crosses for their superior appearance, growth rate, meat yield, meat quality (red meat), shorter market age/market readiness, favorable and high prices. Regarding adaptability traits, farmers expressed a preference for their local sheep breeds, appreciating characteristics like coat color, horn presence, heat and cold tolerance, and drought resilience. However, farmers were also satisfied with the non-selective grazing behavior, early start of grazing, docile temperament, and good mothering ability exhibited by the Dorper crossbreds. This highlights the farmers' recognition of the complementary strengths of the local and Dorper breeds. They appear to value the enhanced productivity traits of the crossbreds while still maintaining a preference for the adaptive traits of

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the local sheep. This suggests that a strategic cross-breeding approach, which harnesses the benefits of both genetic pools, may be a desirable direction for sheep improvement programs in the Ethiopia. The farmers' nuanced preferences underscore the importance of incorporating local knowledge and preferences into the design and implementation of livestock development initiatives. By understanding the specific traits that farmers' value, interventions can be tailored to better meet the needs and expectations of the end-users, ultimately enhancing the adoption and sustainable impact of such programs.

The dissemination of purebred Dorper and Dorper crossbred stocks was carried out through a breeding scheme involving research centers, universities, sheep ranches, and farmers. The study emphasized the need for effective coordination and collaboration among stakeholders to ensure the success and sustainability of Dorper crossbreeding programs in Ethiopia. The study identified several indicators of the acceptance of Dorper crossbreeds, including the ram distribution and monitoring strategy, the proportion of lambs with Dorper gene inheritance, and the current interest of farmers to continue breeding with Dorper sheep. However, it also noted that aspects of the breeding scheme, such as the organization of upgrading units and linking with crossbreeding farmers, were still in their early stages.

Based on the findings of the current study, the following recommendations are forwarded:

- **Incorporate Dorper sheep genetics to improve productivity of indigenous sheep**: The study demonstrated the tremendous potential to enhance the productivity of local sheep through the integration of Dorper sheep genetics. For Farmers with Traditional Management Practices; we suggest incorporating up to 25% Dorper genetics into existing indigenous sheep herd. This level of Dorper influence has been shown to significantly improve key productivity metrics, such as growth rates, meat yields, market age without drastically altering the core phenotypic characteristics of local sheep breed. For Semi-Intensive Production Systems; more substantial productivity gains can be achieved by integrating 50-75% Dorper genetics into sheep breeding program. This higher level of Dorper influence can unlock even greater improvements in growth, meat yield, and overall output under semi-intensive management conditions involving supplementary feeding, improved housing, and enhanced healthcare.

- **Address constraints and enhance access to improved Dorper crossbred rams**: Address the major constraints identified by farmers, including feed shortages, diseases and parasites, and lack of improved genotype. Develop strategies to improve feed availability and quality, implement disease prevention and control measures, and provide access to high-quality breeding stock on time and sustainably, the study noted that accessibility to Dorper crossbred rams varied across different study sites, indicating the need to improve access and availability of these superior genetic resources to smallholder farmers.

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- **Site-specific interventions**: Tailor interventions and strategies to the specific characteristics and needs of each study area. Consider factors such as landholding patterns, local market dynamics, and farmer preferences to design targeted interventions that maximize the potential impact of Dorper crossbreeding programs in Ethiopia.

- **Promote group mating and communal ram sharing**: The study highlighted the widespread practice of group mating and sharing of rams within farming communities, suggesting the importance of leveraging these existing social structures to facilitate the dissemination of improved genetics.

- **Incorporate farmers' preferences in livestock development initiatives**: The study's findings on farmers' nuanced preferences for both Dorper crossbreeds and local breeds underscore the need to integrate local knowledge and preferences into the design and implementation of livestock improvement programs.

- **Genetic selection**: Emphasize the importance of genetic selection in breeding programs (within the crossbred population). Effective genetic selection is crucial for the success of crossbreeding programs. Farmers should be encouraged to prioritize desirable traits such as body size, growth rate, fertility, survival and mothering ability when selecting breeding ewes and rams. To ensure the quality of distributed rams, it is recommended to conduct breeding soundness examinations and assess their breeding values before dispersal. Promoting the use of genetically superior Dorper crossbred rams with high breeding values can significantly improve overall flock productivity for participating farmers. Therefore, highlighting the importance of genetic selection and comprehensive ram evaluation, the crossbreeding program can better realize its intended benefits for smallholder farmers.

- **Optimize crossbreeding strategies:** The performance differences observed between the DxLocal-50% inter *se* and DxLocal-50%-F_1 lambs (yearling weight) suggest that strategic crossbreeding approaches can further optimize growth and weight traits. In the mean time the on-going DxLocal inter *se* mated population development should be encouraged

- **Strengthen coordination and collaboration among stakeholders**: The study emphasized the importance of effective coordination and collaboration among research centers, universities, sheep ranches, and farmers to ensure the success and sustainability of Dorper crossbreeding programs in Ethiopia. Formation of consortium and nationally responsible coordinating body with all leverage powers and responsibilities should be sought. The breeding, multiplication and distribution should be strictly based on the crossbreeding schemes developed and the approach for small holders' should be CBBP style.

- **Monitor and evaluate the ongoing breeding scheme**: The study identified several indicators of the acceptance of Dorper crossbreeds, such as the ram distribution and monitoring strategy, the proportion of lambs with Dorper gene inheritance, and farmers' interest in continuing Dorper crossbreeding. Ongoing monitoring and evaluation of these aspects can help to refine and improve the breeding scheme.

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APPENDICES

Appendix I: Questionnaire used to capture information from different stakeholders.

Title: Assessment of the Effect of Crossbreeding Using Dorper Breed on Sheep Production in Ethiopia.

ANNEX 1: Basic steps to be followed in conducting the proposed study:

STEP 1: Identify organizations/institutions (research, development, NGOs, private sector etc… involved in Dorper crossbreeding program in Ethiopia.

STEP 2: Communicating and actual visiting of organizations/institutions identified in step 1.

STEP 3: Consult available sources of secondary information and conduct informal discussion with group of experts and key informants.

STEP 4: Based on the information obtained from organizations/institutions identified above, the next step is to visit offices at Woreda level (Woreda agricultural development, NGOs) to obtain names of villages (*kebels*) individual farmers provided with Dorper crossbred sires.

STEP 5: Stratify the villages into groups depending the existing condition

STEP 6: Conduct cross-sectional rapid appraisal in accessible villages within each strata. The rapid survey will be conducted **in at least 2 villages** within each stratum and at least 15-**20 farmers per** village will be interviewed individually. Inclusion of women farmers should be considered.

ANNEX 2: Checklist of information to be collected from organizations/institutions involved in Dorper sheep crossbreeding program in Ethiopia.

Tools:

- Informal discussion with technical staff and managers of the farm
- Field visit and observation of the farm
- Consulting secondary information (office documents/strategies/fliers/posters etc...), accessing data on performance of Dorper and crosses.

1. Date of visit: ____
2. Name of organization: ______________________________________
3. Geographical location and ecology:
   Administrative location: _________________________
   Altitude: _______________________________________.
   Average annual RF and seasons: __________________/ ________________________.
   Temperature: _________________________.
   Agro-climate: _________________________
   GPS data: ___________________________.
4. Major duty of the organization: ______________________________.
5. Organizational landscape (organizational structure) and collaborators:
6. Description of the crossbreeding program:
   6.1. **Historical** background of sheep/goat crossbreeding: ____________________
   ____
   6.2. Terms of references of the program (**purposes**): ____________________
   ____
   6.3. General breeding **objective** (s): ____________________
   ____
   6.4. Current status of the program (On-going/ suspended/discontinued): ____________________
   ____
   ____
   6.5. Reasons and date if the program is **suspended** or **discontinued**: ____________________
   ____

`

7. If the crossbreeding program is currently on-going:

7.1. General description of the crossbreeding program:

____

____

7.2. Local and exotic breeds involved:

Species	Local breed (s)		Exotic breed (s)		Remark
	Name	Initial source(s)	Name	Initial source(s)	

7.3. Inventory of current flock size and composition by species, genotype, blood level (Local, 50% Dorper, 75% Dorper, ...100% Dorper, Local), by sex, age

Genotype (blood level)	Age group	Sex		Total No. of animals	Remark (F_1, F_2, …
		Female	Male		
Local (L)	*0-6 months*				
	6-12 months				
	1-2 years				
	≥ 2 years				
	Total				
L x D 75%	*0-6 months*				
	6-12 months				
	1-2 years				
	≥ 2 years				
	Total				
L x D 50%	*0-6 months*				
	6-12 months				
	1-2 years				
	≥ 2 years				
	Total				
L x D 50 x L x D 50%	*0-6 months*				
	6-12 months				
	1-2 years				
	≥ 2 years				
	Total				
Pure Dorper	*0-6 months*				
	6-12 months				
	1-2 years				
	≥ 2 years				
	Total				
Total					

`

7.4. Description of flock management strategy being practiced by the farm:

- Feeding management ____
- Health management: ____
- Breeding management: ____
- Reproduction management: ____
- Housing management: ____
- Routine husbandry practices (ID, weaning, castration, shearing, milking, etc... ____
- Preferential management for local and crossbred animals: ____

7.5. Record keeping system, measurements and volume of data recorded: ____

7.6. Data analysis and information (published & unpublished): ____

8. Expert level assessment of Dorper and Dorper crossbred animals
   - 8.1. On-station performance levels of Dorper crossbred animals:
   - 8.2. Merits and demerits of Dorper crossbreds versus local breeds under on-station management:

Merits	Demerits
✓	✓
✓	✓

9. Scoring of pure local and their crosses with Dorper breeds for the most important trait categories (maximum score value = 10 for ***excellent*** performance)

Breeding ewes

Trait category	Local breeds	Crossbreds	Exotic breeds
Body size & growth			
Body conformation (*Qumena*)			
Age at 1st lambing/kidding			
Lambing/kidding interval			
Mothering ability			
Milk yield			
Drought tolerance			
Disease resistance			
Feed requirement			
Feeding behavior (Selective)			
Morphological appearance			
Ease of management			
Market acceptance			
Meat yield			
Meat taste			
Skin quality			
Fleece yield & quality			

`

Breeding sires

Trait category	Local breeds	Crossbreds	Exotic breeds
Body size & growth			
Body conformation (*Qumena*)			
Age at 1st breeding			
Mating ability (libido)			
Drought tolerance			
Disease resistance			
Feed requirement			
Feeding behavior (Selective)			
Morphological appearance			
Ease of management			
Market acceptance			
Meat yield			
Meat taste			
Skin quality			
Fleece yield & quality			

10. History of ***dissemination*** of Dorper crossbred animals out of the farm:

10.1. If yes, describe the purpose of dissemination (exit) of crossbred animals ______________________________
____
____.

10.2. Number of Dorper crossbred animals disseminated in the past 10-15 years by sex, age genotype group, blood level and year of distribution, clients (Woreda MoA office/ research/NGO/smallholder farmers/private farms)

Year	Genotype & blood level	Sex	No. disseminated	Client		Remark
				Name	*Full address*	

10.3. The modality of dissemination of crossbred animals (if there is any dissemination scheme adopted): ________
____
____

10.4. Monitoring and evaluation system: ____
____

10.5. Feedback information from end-users: ____
____

10.6. Level of current demand by end-users for crossbred animals: ________________________________
____

10.7. Level of satisfaction of the farm in meeting the demand. ____
____

11. Effects (impacts) of dissemination at end-user, regional and national level:

12. If effect (impact) is not realized, then what do you think the most important reasons would be? ____________
____
____
____

13. Suggestion for introduction of other exotic breeds ____
____
____

`

Farm capacity

11.1. **Infrastructure**

Indicators	Availability (rating)				Trend 5 years (Increasing/decreasing)	Remark
	0	1	2	3		
A. Physical facility						
Land						
Offices						
Water source						
Farm buildings						
Farm machineries						
Feed development						
Husbandry equipment						
B. Supplies						
Office						
Farm						
Husbandry						
C. Manpower						
Technical staff						
Support staff						
Staff training						
D. Communication						
Vehicles						
Information services						
Technical support						
Collaborative support						
E. Finance						
Budget						
Donor						

11.2. Annual **budget** amount directly related to sheep crossbreeding (past 5 years):

Year/ EC	Amount	Source	Remark
2008			
2009			

12. Strengths and weaknesses of the **Dorper crossbreeding** program:

Strength	Weakness	Remark

13. Factors contributing to the efficiency and effectiveness of the farm:

External factors	Internal factors	Remark

14. Major technical and administrative problems of the farm:

1	
2	

15. Final comment:

16. Body measurement of pure exotic, crossbreeds and locals

ID	BREED	AGE	SEX	*BW*	*HW*	*CG*	*BL*	*CW*	*RW*	*BC*	*SC*	

BW: Body weight, HW: Height at Wither, CG: Chest Girth, BL: Body Length, CW: Chest width, RW: Ramp Width. BC: Body Condition (1-5), SC: Scrotal C.

`

ANNEX 3: Checklist of information to be collected at Wereda level from offices involved in supplying Dorper crossbred animals to end-users

Tools:

- Informal discussion with staff at wereda offices
- Consulting secondary data
- Note-taking

1. Date of visit: ______________________________
2. Name of Wereda and zone: ______________________________
3. Name and major duties of the office: ______________________________
4. Geographical location and ecology:______________________________
5. Agro-climate (*wurch*/*dega*/*weynadega*/*kola*/*berha*): ______________________________
   GPS data: *Latitude*__________________________, *Longitude*______________________________
6. Human and livestock population & distribution by *kebele*: * in **Dorper sire** distributed *Kebeles*

Kebele	Human population	Cattle	Sheep	Goat	Equine	Poultry

7. Date (s), **numbers** and **sources** of **Dorper** sires distributed:

Genotype	Source	Date of dissemination	No. of sires	Name of *Kebeles*	No. of farmers	Remarks

8. Purpose (objective) of Dorper crossbreeding: ______________________________
   ____
9. **Modality** for dissemination (*community based*/*individual farmer*/*private investment*/*associations*...) __________
   ____
   ____
   ___.
10. Monitoring & evaluation system of the activity: ______________________________
    ____
11. Feedback information from end users: ______________________________
    ____
12. Technical support and training to end-users: ______________________________
    ____
13. Assessment of effects (***impacts***) of Dorper crossbreeding by Wereda level experts: ________________________
    ____
14. Estimated number of total crossbred progeny born in the wereda ______________________________
15. General assessment on merits and demerits of crossbreed sires:

Merits	Demerits

16. Assessing the **level of satisfaction** of experts on the breeding service provided ___________________________
    ____
17. Level of current **demand** and future-plan: ______________________________
18. **Final comments** by wereda level experts:

____
____
____
____

`

ANNEX 4: Checklist of information to be collected at *kebeles* where Dorper crossbred sires have been disseminated.

Tools:

- Group discussion with key informants such as *kebele* administration body + extension agents.
- Consulting secondary data (posters).

1. General

1.1. Date: ______________________________

1.2. Name of wereda and *kebele*:____________________/____________

1.3. Access to veterinary service: ______________________________

1.4. Access to market (distance): ______________________________

1.5. Human population of the *kebele* (no. of households): ____________________

2. Physiographic description:

2.1. Agro-ecology (*wurch*/*dega*/*weynadega*/*kola/berha*): ____________________

2.2. Topography of the area: ______________________________

2.3. Altitude: ______________________________

2.4. Seasons & amount of RF/season:______________________________

GPS data: *Latitude*__________, *Longitude*______________________________

2.5. History of **drought** occurrence in the area (frequency and severity and its effect on livestock production): ___

____

____

3. Agricultural resources and major activities

3.1. Total land area of the *kebele* (ha):______________________________

3.2. Land use pattern of the *kebele* :

Land use	Area (ha)	%	Remark
Arable land			
Rain-fed			
Irrigation			
Grazing land			
Forest land			
Waste land			

3.3. Major agricultural activities (crop/livestock/mixed): ____________________

3.4. Major crops of the *kebele* in order of importance:

Crop type	Area (ha)	Yield/ha
1.		
2.		

`

3.6. Livestock population of the *kebele* by species:

Species	Genotype		Total population	Remarks
	Local	*Cross*		
Cattle				
Sheep				
Goat				
Chicken				
Donkey				
Horse				
Mule				
Camel				

4. Major constraints in order of importance

Importance	Crop production	Livestock production	Crosscutting	Remark
1				
2				

5. Description of general sheep management

- Feeding management____
- Health management ____
- Breeding & reproduction management (sire selection and mating system/castration/weaning) ____________
  ____
- Housing management____
- Herding management (grazing system) __________________________________
- Other husbandry practices (castration/fattening/identification...) __________________
- Marketing ____``________

6. Feed resources

6.1. List major feed sources for sheep

Feed source	Rank	Remark
Grazing		
Crop residues		
Browsing		
Concentrate		
Cultivated fodder		
Household by-products		
Others, specify		

`

6.2. Type of grazing land in the *kebele*

Resources	Rank	Trend			Reason
		Increasing	*decreasing*	*Remain same*	
Open grassland					
Fallow land					
Tree covered grassland					
Bush/shrub grassland					
Stone covered grassland					
Swampy grassland					
Other, specify					

7. Major health problems

7.1. Common **sheep** health problems

Health problem	Symptoms	Rank	Seasons/months	Remark

8. Sheep crossbreeding

8.1. History of sheep crossbreeding in the *kebele*?:

8.2. Objective of introducing **Dorper crossbred** genotypes:

8.3. Number and genotype of Dorper crossbred **sires introduced** so far:

Ear Tag	Year	Genotype	Source	No. of sires	No. of farmers provided

8.4. Extension service and **training** support related to **sheep** production:

8.5. Current status of Dorper crossbred sires (still serving as breeding sire/not): _______________

Status	No. of sires	Reason
Died		
Sold out		
Castrated		
Slaughtered		
Abandoned		

`

8.5. Assessment of the adaptability of Dorper crossbred sires to the local environment (Well adapted/Moderately adapted/Not adapted

Specify:

8.6. Estimated number of total crossbred progeny born in the *kebele* ____________________

8.7. Assessing merits and demerits of **Dorper crossbred** sheep

Merits	Demerits

9. Farmers' impression and demand for Dorper crossbred sires: According to DA's observation

10. Final comments:

1.

ANNEX 5: Rapid appraisal of individual smallholder sheep owners and their flocks: *Effect of Crossbreeding Using Dorper Breed on Sheep Production in Ethiopia.*

Tools:

- Semi-structured informal interviewing.
- Field observation.
- Record linear body measurements (HW, BL, CG, CW), body weight, body condition score, coat color, dentition (age) of crossbred and local progeny born in the flock.

1. Interview Details:

Serial No:	
Name of the interviewer:	
Date of interview:	
Name of Wereda:	
Name of *Kebele*:	
Position in the household:	***HH-head, Spouse of head, Relative, Son, Daughter, Other (specify)_______________.***
Remark:	

2. General Information

Name of the respondent:		
Sex (M/F):		
Age:		
Marital Status: (*tick as appropriate*)	1. Single	
	2. Married	
	3. Divorced	
	4. Widow	
Education:	1. Illiterate	
	2. Read & write	
	3. Primary Education: 1-6	
	4. Secondary Education: 7-10	
	5.	
Religion		

`

3. Household Characteristics

3.1. ***Family size by age group***

Age group	Sex		Total
	Male	*Female*	
≤14 years			
≥15 - ≤60 years			
≥61 years			

3.2. ***Education level of household members***

Level of education	Sex		Total
	Male	*Female*	
Illiterate			
Read & write			
Primary education (1-6)			
Secondary education (7-10)			

4. Major sources of family food and income (Rank)

Source	Food	Income	Remark
Crop production			
Livestock			
Other			

5. Land holding and use structure

5.1. ***Total land holding*** (ha): __________________________

5.2. ***Land use*** **(ha)**

#	Land use	**Own** (ha)	**Rent** (ha)
1	Crop		
2	Fallow		
3	Private grazing /pasture land		
4	Irrigation		
5	Others, Specify		

5.3. ***Major crops grown (last season)***

Crop type	Area (ha)	Yield (ha)	Remark
1.			
2.			
3.			

6. Livestock holding

6.1. *Type and no. of livestock*

Type	Local	Crossbred	Total	Remarks
Cattle				
Oxen				
Cows				
Heifers				
Calves				
Sheep				
Goat				
Chicken				
Donkey				
Horse				
Mule				
Camel				

6.2. *Sheep flock composition*

Age group	Genotype				Total (M/F)		Remarks
	Local (**M/F**)		*Cross* (**M/F**)				
Lambs < 6 months							
6 month-1 year							
> 1 year							
Ram (intact over one year)							
Castrated							

6.3. *Purpose of keeping sheep (***rank***)*

Purpose	**Local**	**Cross**	**Remark**
Income (sale)			
Meat Consumption			
Saving			
Milk			
Manure			
Fleece			
Skin			
Other, specify			

`

6.4. *No. & reason for exit of sheep from the flock (*in the last year*)*

Reason	Genotype		Total No.
	Local	*Cross*	
Sale			
Slaughter			
Death			
Gift			
Shared			
Predated			

7. Sheep management

7.1. *Sheep feed resource/ availability* (Rank): 1=High, 2= Medium, 3= Low

Type	Sept-Nov	Dec-Feb	Mar-May	Jun-Aug
Communal grazing				
Private grazing				
Crop residues				
Hay				
Cultivated forage				
Grain				
Concentrate				
Household by-products				

8. Major sheep production constraints (Rank)

Constraints	Rank	Coping mechanism
Feed shortage		
Genotype		
Health		
Market		
Labor		

9. Major health problems

9.1. *Common sheep health problems* (rank)

Health problem (Disease/parasite)	Most affected class of sheep		Seasons/months
	Local	*Dorper crossbred*	

10. **Breed identification**

- *Breeds of your current stock* ____
- *Other local breeds* ____
- *Characteristics used for breed definition* ____
  ____

Why do you have the breed you currently have?

____

`

11. Sheep crossbreeding

11.1. ***History of Dorper crossbreeding in the flock?***

11.2. ***Objective of introducing Dorper crossbred sheep***:

11.3. ***Number and genotype of* Dorper *crossbred sires provided so far***:

Year	Genotype	Source	No. of sires	Remarks

11.4. ***Current status of crossbred sires*** (still serving as breeding sire/not): _______________

Status	No. of sires	Reason
Died		
Sold out		
Castrated		
Slaughtered		
Abandoned		

11.5. ***Assessment of the adaptability of Dorper crossbred sires to the local environment:*** (tick as appropriate)

- Well adapted _____________________________.
- Moderately adapted ________________________
- Not adapted ______________________________.

Reason:

____

11.6. ***Type of mating used: 1.*** Own flock ☐ ***2.*** Communal ☐

11.7. ***How many Dorper crossbred rams do you get up to now?***

Year obtained	Source	Blood level	Price	Disposal year	Disposal reason

11.8. ***Do you practice ram exchange? 1. Yes*** ☐ ***No*** ☐

11.9. ***Is there any special management for breeding crossbred Dorper ram? 1. Yes*** ☐ ***2. No*** ☐

If yes, specify the type of management for the Dorper crossbred ram____

____

11.10. ***History and number of Dorper crossbred progeny born from Dorper crossbred ram.***

Own flock (n)	**Neighbors'** and/ or **other flock** (n)

11.11. ***No. of* Dorper *crossbred lambs born in the flock*** (including those disposed off)

Male	Female	Total

`

12. Estimated price for local and Dorper crossbred sheep of different ages

Age category	Sex	Estimated price (ETB)	
		Local sheep	*Dorper crossbred sheep*
6-9 months	*Male*		
	Female		
9-12 months	*Male*		
	Female		
>12 months	*Male*		
	Female		

13. Assessment of merits and demerits of Dorper crossbreed *sires* and *progeny*:

Merits	Demerits
✓	✓

14. Market acceptance of Dorper crossbred sheep

____

____.

15. Farmer's demand for Dorper crossbred sires:

____

16. Effects (advantages) of Dorper crossbreeding on *performance traits*:

16.1. ____

16.2. ____

17. Crossbred sire performance assessment

17.1. ***Individual* Dorper *ram examination***

Blood Level	Dentition	Service Period (year)	Coat color	Body weight	BC*	Mating ability**	Testicle Circumference	Testicle condition	Physical conformation

Note: *BC = *Body condition score* (1 to 5); **Mating ability = farmers assessment (*poor/fair/good*) & no. of lambs born from the ram including neighboring flocks.

17.2. **Dorper *crossbred progeny performance assessment*** (Dorper crossbred Vs local sheep)

TAG #	Genotype	Sex	Coat color	Date of birth (EC)	Dentition	Body weight	BC*	HW	CG	BL	PW	RH

17.3. ***Farmer's assessment and preferences on* Dorper *crossbred lambs:***

- What traits have been changed (either positively or negatively) in Dorper x local crossbred progeny compared to purebred local ones?____
  ____
- Preference by farmers among known sheep breeds & specific reason for the preferred type:____________________
- Market (buyer's) preference and market value: ____
  ____

17.4. ***Overall flock management***

- Breeding management (ram control, ram exchange): ____
  ____
- Crossbred sire management and use pattern among neighboring flocks or single flock use:____________________
  ____
- Presence of intact rams of local breeds in the flock: Yes/No (how many)?______________________________
- Ability of farmer to recall info (*eg. date of birth of lambs, sire & dam identification*):________________________
  ____

`

18. **Ewe performance**

Blood level	Dent/ Birth date	Coat color	BW	BC	HW	CG	BL	PW	RH	Parity	No. of lambs born	Estimated price

19. **Assessing the merits of Dorper crossbreds compared to the local sheep** (For each traits tick one box in a raw): 1= Very poor, 2= Poor, 3= Medium, 4= Good, 5= Very good).

Component traits	Local					Dorper Crossbred				
	1	*2*	*3*	*4*	*5*	1	2	3	4	5
Body **size**										
Growth **rate**										
Body **conformation** (*Qumena*)										
Meat **yield**										
Meat **quality**/taste										
Reproduction (*age at 1st Lambing ,Interval), Motherin*										
Heat tolerance										
Cold tolerance										
Ability to walk long **distances**										
Drought tolerance										
Disease resistance										
Lamb **survival**										
Feed requirement										
Grazing ability										
Market age & Preferment										
Behavior										
Color										
Horn										
Fleece yield										
Skin quality										

20. **What are the main constraints for Dorper crossbreeding program? (rank** with significance**)**

Constraints	Rank	Remarks
Lack of Dorper **ram**		
Disease susceptibility		
Poor **adaptability**		
Market **preference**		
Feed shortage		
Water shortage		
Lack of **capital**		
Labor shortage		
Drought		
Other (specify)		

21. **Future demand for Dorper crossbred sires**

i Very high ☐
ii Moderate ☐
iii Low ☐

22. **Final comment by the farmer about genetic improvement of local sheep using Dorper sheep breed**

Thank you for your precious time, willingness and response.

`

Appendix II: Statistical analysis results

Dependent Variable: **Age at first lambing** (AFL),semi-intensively managed flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	402.259395	36.569036	4.58	<.0001
Error	374	2985.037899	7.981385		
Corrected Total	385	3387.297294			

R-Square	Coeff Var	Root MSE	AAFL Mean
0.118755	18.20902	2.825134	15.51503

Dependent Variable: **Annual reproductive rate** (ARR),farmers flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	7.24673258	1.20778876	8.12	<.0001
Error	291	43.28615978	0.14874969		
Corrected Total	297	50.53289236			

R-Square	Coeff Var	Root MSE	ARR Mean
0.143406	26.24321	0.385681	1.469640

Dependent variable: **Lamb birth weight** (LBWT),semi-intensively managed flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	687.124946	28.630206	106.20	<.0001
Error	4041	1089.408860	0.269589		
Corrected Total	4065	1776.533806			

R-Square	Coeff Var	Root MSE	LBWT Mean
0.386778	18.42420	0.519220	2.818138

Dependent Variable:**Body condition score** (BC),farmers flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	15.04937500	3.00987500	10.52	<.0001
Error	27	7.72395833	0.28607253		
Corrected Total	32	22.77333333			

R-Square	Coeff Var	Root MSE	BC Mean
0.660833	13.42738	0.534857	3.983333

`

Dependent Variable: **Litter size at birth** (LSB), semi-intensively manged flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	31	1199.230259	38.684847	120897	<.0001
Error	9338	2.987990	0.000320		
Corrected Total	9369	1202.218250			

R-Square	Coeff Var	Root MSE	LSB Mean
0.997515	1.576031	0.017888	1.135005

Dependent Variable: **Adj12MWT** (Adjusted 12 months weight), semi-intensively managed flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	29	80550.8235	2777.6146	105.81	<.0001
Error	2654	69671.0031	26.2513		
Corrected Total	2683	150221.8266			
R-Square	Coeff Var	Root MSE	Adj12MWT Mean		
0.536213	19.05092	5.123604	26.89426		

The GLM Procedure

Dependent Variable: **Number of breeding_Ewes in the flock,** farmers flock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1358.372215	194.053174	24.48	<.0001
Error	240	1902.321333	7.926339		
Corrected Total	247	3260.693548			

R-Square	Coeff Var	Root MSE	Breeding_Ewe Mean
0.416590	71.68512	2.815375	3.927419

The GLM Procedure

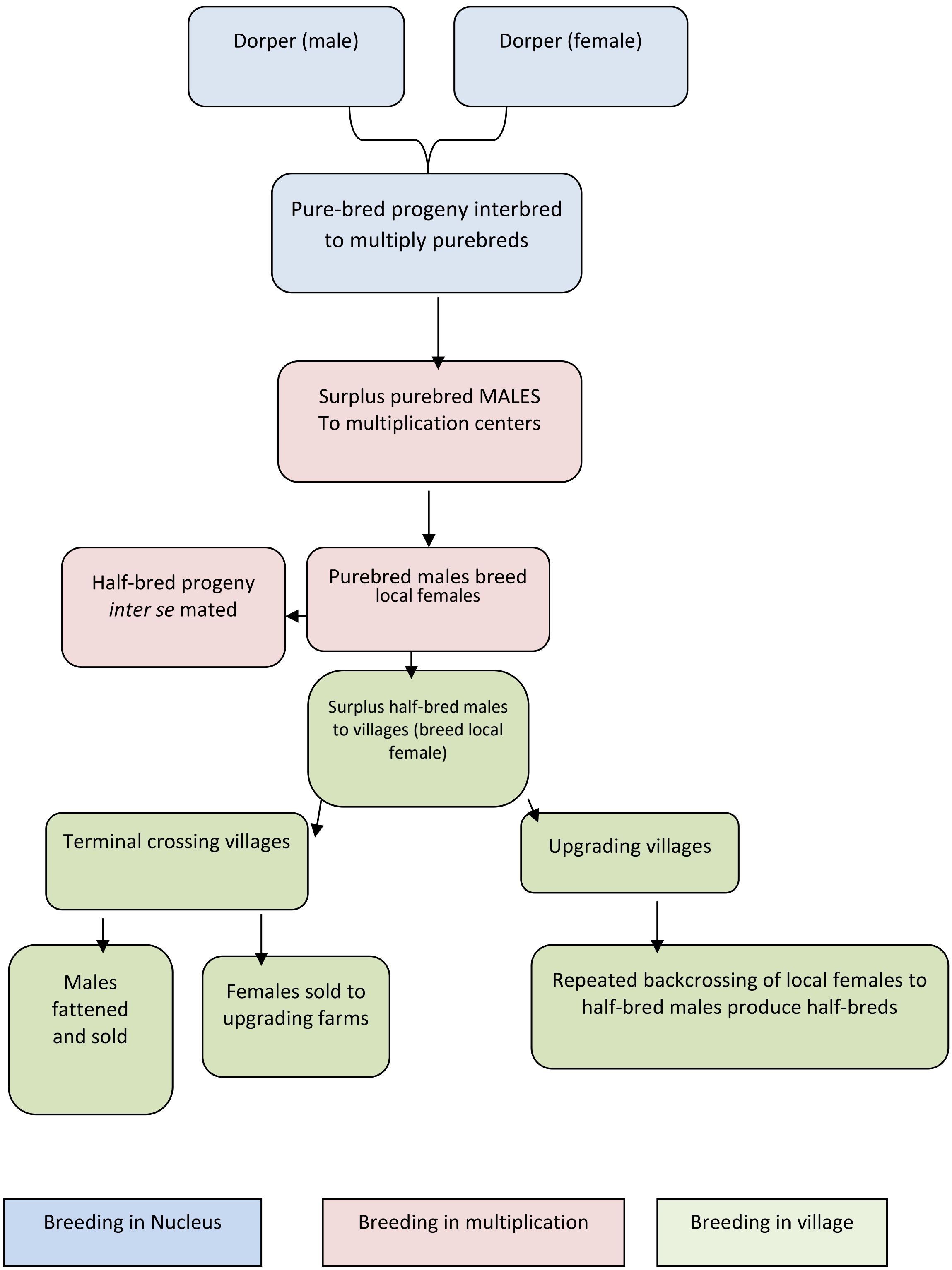
Dependent Variable: **Conception_rate** (under semi-intensive management)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	10360.69433	493.36640	6.01	<.0001
Error	146	11995.12132	82.15837		
Corrected Total	167	22355.81565			

R-Square	Coeff Var	Root MSE	CONCEPTION_RATE Mean
0.463445	11.07315	9.064125	81.85678

`

Appendix-Figure 1: Breeding scheme in nucleus center, multiplication center and at village level (Adapted from ESGPIP and crossbreeding strategy for Dorper sheep and Boer goat in Amhara region (Project on 'Developing Dorper valley 2010, ESGIP 2011).



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Appendix-Figure 2: Dorper ewes in quarantine at Brits (South Africa), adapted from ESGPIP

Appendix-Figure 3: Quarantine facility at Sebeta (Building #1), adapted from ESGPIP

Appendix-Figure 4: Photos from survey and at the spot measurement in the study sites
(Merhabete, Shewarobit , Baso & Debre-Birhan areas: *Photos by author*)

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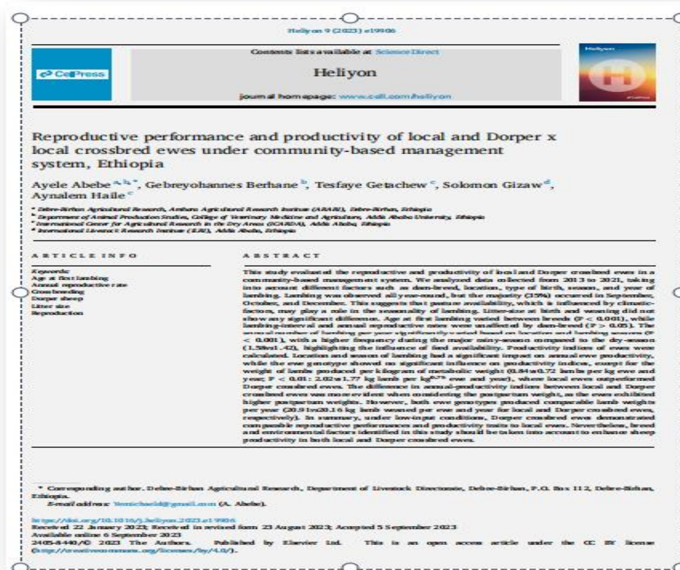

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Reproductive performance and productivity of local and Dorper x local crossbred ewes under community-based management system, Ethiopia

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ARTICLE INFO

Keywords:
Age at first lambing
Annual reproductive rate
Crossbreeding
Dorper sheep
Litter size
Reproduction

ABSTRACT

This study evaluated the reproductive and productivity of local and Dorper crossbred ewes in a community-based management system. We analyzed data collected from 2013 to 2021, taking into account different factors such as dam-breed, location, type of birth, season, and year of lambing. Lambing was observed all year-round, but the majority (35%) occurred in September, October, and December. This suggests that pasture availability, which is influenced by climatic-factors, may play a role in the seasonality of lambing. Litter-size at birth and weaning did not show any significant difference. Age at first lambing varied between breeds ($P < 0.001$), while lambing-interval and annual reproductive rates were unaffected by dam-breed ($P > 0.05$). The annual number of lambing per year significantly varied based on location and lambing seasons ($P < 0.001$), with a higher frequency during the major rainy-season compared to the dry-season (1.58vs1.42), highlighting the influence of feed availability. Productivity indices of ewes were calculated. Location and season of lambing had a significant impact on annual ewe productivity, while the ewe genotype showed no significant influence on productivity indices, except for the weight of lambs produced per kilogram of metabolic weight (0.84vs0.72 lambs per kg ewe and year; $P < 0.01$: 2.02vs1.77 kg lamb per $kg^{0.75}$ ewe and year), where local ewes outperformed Dorper crossbred ewes. The difference in annual-productivity indices between local and Dorper crossbred ewes was more evident when considering the postpartum weight, as the ewes exhibited higher postpartum weights. However, both ewe genotypes produced comparable lamb weights per year (20.91vs20.16 kg lamb weaned per ewe and year for local and Dorper crossbred ewes, respectively). In summary, under low-input conditions, Dorper crossbred ewes demonstrated comparable reproductive performances and productivity traits to local ewes. Nevertheless, breed and environmental factors identified in this study should be taken into account to enhance sheep productivity in both local and Dorper crossbred ewes.

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https://doi.org/10.1016/j.heliyon.2023.e19906
Received 22 January 2023; Received in revised form 23 August 2023; Accepted 5 September 2023
Available online 6 September 2023
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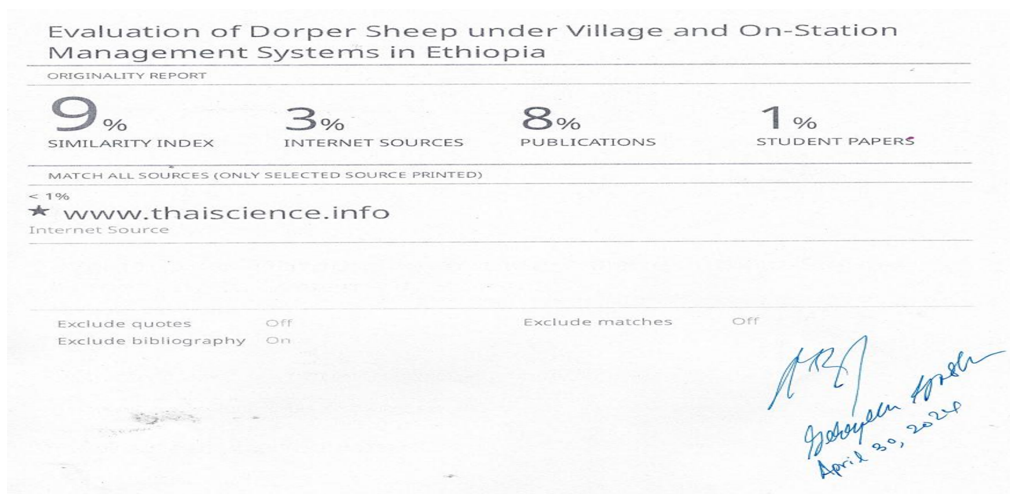

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Appendix-Figure 5: Results of plagiarism test and lists of publications