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## Research Article

# **Agromorphological Traits Variability of the Ethiopian Lentil and Exotic Genotypes**

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Understanding the genetic relationships and diversity of Ethiopian lentil in relation to lentil from other countries is important in attempting to widen the genetic base of germplasm in the country. The objectives of this study were to generate information on agromorphological variability, to estimate PCV, GCV, heritability, and expected genetic advance of quantitative traits of lentil. 228 genotypes with different population types were studied for 11 agromorphological traits and rust disease severity score for two seasons (2011-2012) over three locations. The analysis of variance showed highly significant variations ( $P \le 0.01$ ) among genotypes for all characters studied. As per genetic parameter values, four groups of character were deduced. It is inferred that the exotic genotypes introduced from ICARDA showed rich genetic bases for 100-seed weight, number of seeds per plant, seed weight per plant, resistance source for rust, and high yielder in high yielding environment, where rainfall is not a major problem. Use the Ethiopian accessions for developing cultivars that could be used in double cropping and drought prone areas.

#### 1. Introduction

Lentil (Lens culinaris Medik. subsp. culinaris) is a short, slender annual cool-season food legume. The center of origin of lentil is the Near East where it was first domesticated in the Fertile Crescent around 7000 BC [1]. According to Barulina [2], two varietal types based on seed size were recognized: the small-seeded microsperma and the macrosperma with relatively large flattened pods. The largest lentil producer is India, followed by Canada and Turkey, accounting for 68% of the global production [3]. In Africa, Ethiopia, Morocco, and Tunisia are the leading producers, but 61% of the areas and 68% of the production belong to Ethiopia [4]. Lentil is an important dietary source of macro- and micronutrients for both rural and urban dwellers. It provides sufficient amounts of the most essential amino acids to meet nutrient requirements. It is a cash crop fetching the highest price in domestic market compared to all other food legumes and major cereal crops [5]. Global, African, and Ethiopian lentil productivity is about 887 kg/ha, 644 kg/ha [3], and 1168 kg/ha, respectively [6]. Biotic and abiotic factors limit lentil productivity and seed quality. The major yield gap contributing factors are insect pests, diseases, low yielding landraces grown by farmers, and the narrow genetic base [7, 8].

Prior knowledge of genetic variability and characterization of genetic resources within the germplasm available at a gene bank has an important implication for future utilization and collection activities, to identify areas of major priority for conservation and improvement programs [9]. Quantitative traits provide an estimate of genetic diversity, and various numerical taxonomic techniques have been successfully used to classify and measure the pattern of genetic diversity in germplasm, as in lentil [10, 11]. Morphological characterization is the first step in the classification and description of any crop germplasm [12]. The assessment of

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Agroecological	Sirinka	Sinana	Chefe Donsa
Range of temperature (°C)	21–32	9.3-20.9	8.9-28.3
Mean annual rainfall (mm)	876	808	851
Altitude (masl)	1850	2450	1900
Latitude	12°.11′N	7°7′N	8°44′N
Longitude	39°62′E	40°10′E	39°95′E
Soil texture	Clay soil	Clay soil	Light soil
Soil type	Eutric vertisol black soil	Pellic vertisol slightly acidic	Afisols and vertisol black soil

TABLE 1: Geographical, climatic, and soil features of the experimental sites.

genetic variability present in a given crop population can be determined by using the biometrical components such as range, variance, coefficient of variation, standard error, and heritability. The relative magnitude of these components determines the genetic properties of the population, in particular, the degree of resemblance between germplasm, that is, various determinants of the phenotype [13]. Reference [14] emphasized that the uses of the genetic coefficient of variability together with heritability and genetic advance values would determine the best picture of the amount of progress to be expected from a selection and determine the selection method to improve a character.

Several researchers investigated the diversity of economically important traits of lentil germplasm and found considerable variations [10, 11, 15–20]. Some quantitative evaluations of the Ethiopian landraces revealed potential variability for morphological traits [5, 7, 8, 21-25]. Understanding the genetic relationships and diversity of the Ethiopian lentil in relation to the germplasm from other countries is important to widen the genetic base of a germplasm. However, information is not exhaustive for different population structures of local and exotic genotypes on the genetic variability of important traits, which have economic benefit. Hence, the objectives of this study were to generate information on morphological variability and to estimate the phenotypic coefficient of variation, the genetic coefficient of variation, the heritability, and genetic advance of quantitative traits in lentil.

#### 2. Materials and Methods

2

- 2.1. Description of the Study Sites. The field experiments were conducted on a hot spot area for rust. The areas included Sirinka Agricultural Research Center (SIARC) in the northeastern part of Ethiopia for two seasons (2011 and 2012), Chefe Donsa in the central part of Ethiopia, and Sinana Agricultural Research Center (SARC) in southeastern part of Ethiopia during the 2011/12 cropping season (Table 1 and Figure 1).
- 2.2. Plant Materials. Out of the 228 genotypes considered for this study, 158 were planted for morphological evaluation at SRARC in the 2010/2011 cropping season. Of these, 104 genotypes were from the Ethiopian lentil gene pool collected from six major lentil production regions (Figure 2) and were kept by the Institute of Biodiversity Conservation (IBC).

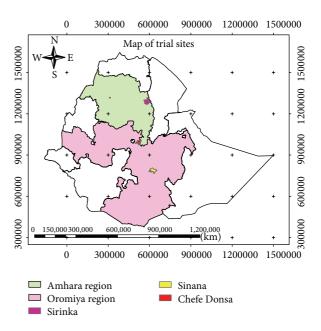


FIGURE 1: Geographical position of the experimental sites.

The accessions represent over 17% of the 618 lentil accession holdings of IBC. Rust susceptible check/EL-142/and wilt susceptible check/ILL-590/NEL 590/, as well as six commercial national released varieties (*Alemaya*, *Adaa*, *Teshale*, *Alem Tena*, *Chekol* and *Derash*), were used as a check. Ten elite breeding lines from the DebreZeit Agricultural Research Station (DZARC), Ethiopia, were included. Thirty-six parental lines and elite lines based on superiority for agronomic traits introduced from the International Center for Agricultural Research in Dry Areas (ICARDA) were included (Table 2). In the 2011/12 cropping season, 228 genotypes plus RILs were included in the study across three locations: Sirinka, Chefe Donsa, and Sinana.

2.3. Experimental Layout and Design. A randomized complete block design (RCBD) was used with three replications, in the 2010/2011 cropping season at SIARC. A unit plot comprised 2-meter length row with a plot size of (0.8 m<sup>2</sup>). Row-to row distance was 20 cm. The distance between two plots was 50 cm and the distance between two blocks was 100 cm. The genotypes were planted in the first week of July. In the 2011/12 cropping season, the experiment was carried out

TABLE 2: List of genotypes and their origin.

Source of origin	Number of genotypes	Name of genotype	Type of genotypes
Tigray	8	Acc. no. 219957, 235383, 237503, 237504, 241785, 242604, 243447	Landrace
Amhara	54	Acc. no. 36003, 36025, 36028, 36039, 36041, 36061, 36071, 36085, 36088, 36089, 36097, 36103, 36104, 36105, 36137, 36139, 36150, 36162, 36165, 36168, 207258, 207274, 207287, 207309, 212745, 215248, 215249, 223221, 228242, 229179, 229182, 229183, 231247, 235013, 235015, 235016, 235017, 236484, 236486, 236487, 237502, 238978, 238979, 241784, 241786, 243433, 243436, 243440, 243443, 244606, 244610, 244615, 244619, 244623	Landrace
Oromya	29	Acc. no. 36001, 36007, 36009, 36013, 36015, 36019, 36023, 36029, 36033, 36042, 36048, 36058, 36110, 36120, 36131, 203141, 215806, 216877, 228809, 230521, 230833, 230834, 230837, 231248, 235698, 236438, 236892, 237027, 238971	Landrace
SNNP	2	Acc. no. 36147 and Acc. No., 228243	Landrace
Somali	1	Acc. no. 230832	Landrace
DZARC	6	/ILL4225 x ILL4605/ /ILL 6821/ Alemaya, /ILL 1 x ILL 1169//ILL 6027/ ADAA, /ILL 7978/ Teshale, /Alemaya x FLIP88-41L/ Derash, /ILL 7981/ Aleme Tena and P160/ILL 2704/ /Chekol/	Improved variety
Unknown	10	Acc. no. 36134, 207260, 211062, 211078, 211110, 220120, 211131, 233349, 233973, 241782	Landrace
ICARDA	22	L-9-11, X2002S 219 /ILL 6821/, X2002S 221 /7980/, X2002S 221/FLIP 96-47 L//7979/, X2003S 195/ILL 7115/, /ILL4965 x ILL6155/FLIP-97-16L/ILL 8078/, /ILL 883 x ILL 470/FLIP-84-95L/ILL 5722/, X2003S 233 /ILL 8009/, 2003S 235, X2003S 238 /ILL 4605/, X2005S 215/ILL 6002/, 2006S 122 /FLIP 2003-43L/ /ILL 7010 x ILL 1939/ /ILL 9932/, /ILL 2573 x ILL 7537/ /FLIP 2003-62 L/ /ILL 9951/X2006S 122, /ILL 7620 x ILL 9151/ /FLIP 2003-56L/ /ILL 9945/X2006S 127, X2006S 129/F2/, X2006S 130/FLIP 93-46L/ /ILL 547/, X2006S 130/FLIP 96-46 L//ILL 7978/, X2006S 133/FLIP87-21L/ /ILL 4349 x ILL4605//ILL 6211/, X2006S 134/ILL8174/, X2002S 219 /shehor-74/ /ILL 7554/, X2003S 222/ILL 213/, X2006S 128/ILL 5480/	Parent
DARC	11	EL-142/ILL 5071/, 87S-93549XEL-1O3-3, 87s-93549XEL-03-4, Chekol X R-186-1, Chekol x R-186-2, EL-142 X R-186-3, EXOTIC #DZ/2008 AK, Chekol x R-186-8-0, ILL-358 X ILL-2573-2-2000, R-186X FLIP-86-38L, R-186XFLIP-86-38L-23	Breeding line
ICARDA	15	ILL-28501, FLIP-04-26L, FLIP-2004-37L, FLIP-2004-7L, FLIP-2006-20L, FLIP-2006-60L, FLIP-87-68L, FLIP-93-63L, FLIP-97-61L, FLIP-97-68L, /ILL 6037 x ILX 87062/ FLIP2005-24L/ ILL-10045, ILL-10680, ILL-590/NEL 590/, L-830, Precoze/ILL 4605/	Breeding line
ICARDA	70	RIL1-RIL 70	RIL

Genotypes represent different population groups of lentil germplasm such as landrace, elite breeding lines, putative parents, and recombinant inbred lines (RIL). Unknown = originated from Ethiopia but sites of collection are not mentioned. RIL = recombinant inbred line.

using the augmented design with a single row of 2 m length for each genotype planted in five blocks. Eight checks were replicated within each block. Planting was done in the first week of July at SIARC, in mid-August at Chefe Donsa and in mid-September at SARC. The recommended agronomic packages were applied for raising a successful crop.

2.4. Data Collection. Data were recorded on 10 randomly selected plants on plant basis for plant height (PH), number of pods/plant (NP), number of seeds/pod (NS), number of seeds/plant (NSPP), and seed weight/plant (SWPP), whereas days to flowering (DFF), days to maturity (DM), above ground biomass (BI), 100-seed weight in gram (SW), seed

Sources of variation	df		Mean squares									
Sources of variation	aı	DFF	DM	NP	NS	SWPP	NSPP	PH	SW	BI	SY	PSS
Replication	2	561.9	1248.1	3067.3	1.27	2.1	8980.1	379.2	0.01	6475	46675.2	0.2
Genotype	157	70.6**	408.3**	359.7**	0.3**	0.7**	859.2**	48.7**	0.99**	35878**	4645.4**	1.8**
Error	314	13.9	45.47	126.3	0.06	0.17	200.3	8.13	0.1	6140	994	0.2
CV%		6.5	7	31.9	19.9	36.8	33	8.2	12.2	27.3	37.1	9.7
Mean		57.2	95.7	35.3	1.2	1.1	42.9	34.6	2.5	286.8	84.9	5
LSD (at 5%)		6	11.1	30.5	0.4	0.6	23.4	0.5	4.6	112.7	47.9	0.8

TABLE 3: Mean squares for agromorphological traits of 158 lentil genotypes at Sirinka in the 2010/11 cropping season.

df = Degree of Freedom

DF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NS = number of seeds per pod, SWPP = Seed Weight per Plant, NSPP = Number of Seeds per Plant, PH = Plant height in cm, SW = 100-seed weight in gram, BI = Bio mass, PSS = Pod set Score

\*\*, \* = Significant at 5 % and 1% probability levels, respectively.

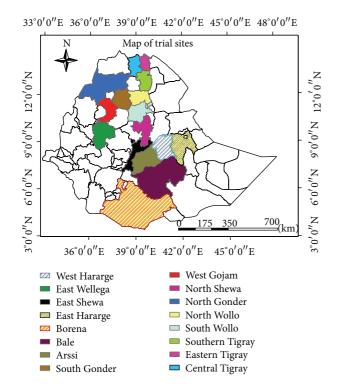


FIGURE 2: Map of Ethiopia showing areas of collection sites (shaded region) of the landrace accessions.

yield/plant (SY), pod set score (PSS) (1–9 rating scale where 1 = very poor pod setting and 9 = excellent pod setting), and rust severity scored on a 1–9 scale (1–9 rating scale where 1 = highly resistant and 9 = highly susceptible) before flowering (RSBF) and after flowering (RSAF) were recorded on plot basis according to [26].

2.5. Data Analysis. Plot mean values were calculated for all traits and used for the analysis of variance (ANOVA). The estimation of genetic parameters was analyzed using GenStat Release 13.3. [27]. Phenotypic and genotypic variances for the augmented design were computed for all traits based on the methods of [28]. The pooled analysis for augmented design was carried out according to [29, 30] using GenStat Release

15.1 [31]. The broad sense of heritability  $(h^2)$  was estimated using the genotype mean according to [14]. Consider

$$h^2 = \left[ \frac{\sigma^2 g}{\sigma^2 p} \right] \times 100. \tag{1}$$

Genetic advance (GA) for selection intensity (K) at 5% is estimated according to [14] using the formula: GA =  $(K)(\sigma p)(h^2)$ .

The genetic advance as the percentage of the mean (GAM) was estimated as per [32] formula:  $GAM = (GA/\overline{X}) * 100$ 

#### 3. Results

3.1. Analysis of Variance. Highly significant genotypic ( $P \le 0.01$ ) differences were observed for all parameters measured in the 2010/11 cropping season at Sirinka indicating that the variation was genetic. The mean square, CV, and mean values for traits of the genotype were presented in Table 3.

Moderate variabilities with an intermediate coefficient of variation (CV) among the genotypes were observed for days to 50% flowering, days to 90% maturity, plant height, and pod set score, whereas considerable variations were observed for the rest of the traits among the genotypes (Table 3).

The analysis of variance for the 2011/12 cropping season within the check showed significant variation at Sirinka, except for two traits: number of seeds/pods and number of seeds/plant (Table 4). At Chefe Donsa, days to 50% flowering, number of pods/plant, number of seeds/pods, number of seeds/plant, and seed weight/plant had nonsignificant variation within the checks (Table 5). At Sinana, all traits showed significant variability, except days to 50% flowering, days to 90% maturity, number of seeds/pods, and above ground biomass within the checks (Table 6). Consistent significant variations were noted across locations within the checks for plant height, 100-seed weight, and seed yield (Tables 4, 5, and 6).

The analysis of variance showed a highly significant variation ( $P \le 0.01$ ) for days to 50% flowering, days to 90% maturity, number of pods/plant, and number of seeds/pods within the test genotypes at Sirinka (Table 4). At Chefe Donsa, analysis depicted a highly significant variation

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LARIE 4. Mean squares for agromorn	hological traits of 778 lentil genotypes at	Sirinka in the 2011/12 cropping season.
TABLE 1. Wiedli Squares for agromorp	noingical traits of 220 lentin genotypes at	on make in the 2011/12 cropping season.

Sources of Variation	df	Mean squares									
Sources of Variation	aı	DFF	DM	NP	NS	NSPP	SWPP	PH	SW	BI	SY
Block	4	413.4**	350.5**	983.2*	0.21**	1693.6*	1.16	35.49*	0.8*	113623**	8974
Within checks	7	155.5**	504.6**	734.6*	0.1	1213.8	1.9*	37.3*	2.3**	67151*	9542*
Within test genotypes	219	91.9**	182.5**	1053.4**	0.2**	722.7	0.5	$243.0^{*}$	$0.5^{*}$	18463	2807
Between check and test genotypes	1	0.6	35.2	995.1	0.3**	5227.6**	13.2**	18.2	4.6**	437621**	110311**
Residual	35	14.1	34.1	302	0.04	546.1	0.7	13.5	0.3	24236	3801

df = degree of freedom.

DFF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NS = number of seeds per pod, SWPP = seed weight per plant, NSPP = number of seeds per plant, PH = plant height in cm, SW = 100-seed weight in gram, BI = biomass, PSS = pod set score.

Table 5: Mean squares for agromorphological traits of 228 lentil genotypes at Chefe Donsa in the 2011/12 cropping season.

Sources of variation	df		Mean squares									
Sources of variation	uı	DFF	DM	NP	NS	NSPP	SWPP	PH	SW	BI	SY	RSAF
Block	4	24.4	327.9**	664.7*	0.03	1489.4*	1.4*	12.6*	0.7**	77552**	3332*	10.3**
Within check	7	12.6	223.6*	51.6	0.04	292.6	0.4	22.0**	1.2**	23490*	3363*	17.2**
Within test genotypes	219	30.4**	133.3	184.3	0.06	495.7	0.3	15.0**	0.6**	8941	1314	4.8**
Between check and test genotypes	1	101.5**	105	988.5*	0.1	1127.8	2.3*	7.7	0.03	227174**	41227**	27.3**
Residual	35	12.1	83.4	188.2	0.06	560.1	0.4	4.5	0.1	10084	1183	2

<sup>\*\*, \* =</sup> significant at 5% and 1% probability levels, respectively.

TABLE 6: Mean squares for agromorphological traits of 228 lentil genotypes at Sinana in the 2011/12 cropping season.

Sources of vriation	df	Mean squares										
Sources of vitation	aı	DFF	DM	NP	NS	NSPP	PH	SW	BI	SY	RSBF	RSAF
Block	4	305.8**	2224*	50.9	0.04	319.6*	147.8**	1.3**	153488**	6897.6**	5.1**	16.1**
Within check	7	224.2	2473.1	76.5**	0.1	274.5*	53.7*	2.6**	30505	6842.8**	1.7*	5.9
Within test genotypes	219	10054.6**	36536	65.6**	$0.1^{*}$	256.2**	29.3	0.7**	34051	1279.1*	2.0**	4.6
Between check and test genotypes	1	0.05	121.1	124.6*	0.2	345.1	184.9**	3.0**	474202**	80244.5**	10.8**	69.1**
Residual	35	19.1	244.6	30	0.1	116.5	23	0.1	29335	823.2	0.8	3.8

RSBF; Rust disease severity score before flowering.

RSAF; Rust disease severity score after flowering.

 $(P \le 0.01)$  within test genotypes for days to 50% flowering, plant height, 100-seed weight, and rust disease severity score after flowering (Table 5), whereas at Sinana all traits revealed significant variation  $(P \le 0.05)$  except days to 90% maturity, plant height, above ground biomass, and rust disease severity score after flowering within test genotypes (Table 6).

The analysis of variance between check and test genotypes for the 2011/12 cropping season showed highly significant differences except for days to 50% flowering, days to 90% maturity, number of pods/plant, and plant height at Sirinka (Table 4). At Chefe Donsa, significant ( $P \leq 0.05$ ) variations were observed for days to 50% flowering, number of pods/plant, seed weight/plant, above ground biomass, seed yield, and rust disease severity score between checks and test genotypes (Table 5), whereas, at Sinana, significant variations were recorded between checks and test genotypes for number of pods/plant, plant height, 100-seed weight, seed yield, and rust severity score before and after flowering (Table 6). The test for homogeneity of error variance was significant across

locations because the genotypes perform differently across the three locations for yield and yield component traits. Thus, it could not make further valid inferences for the pooled ANOVA (Table 7). Besides, rust infection was severe at Sinana, mild at Chefe Donsa, and absent at Sirinka and then no combined analysis was made for this character.

The minimum and maximum values of 11 agromorphological traits analyzed for the 2010/2011 cropping season at Sirinka were presented in (Table 8). The range for days to 50% flowering was recorded from 42 to 78 days for Acc. number 36120 and breeding line (FLIP-04-26L), respectively (Table 12). The shortest maturity period was recorded (77 days) for Acc. number 36025 and the longest (138 days) for FLIP-04-26L. Parent X2003S 223 produced the minimum (1.6) number of pods/plant while the maximum (73.3 pods/plant) was noted for breeding line (R-186XFLIP-86-38L-24). The shortest plant height of 20.6 cm was recorded for breeding line (FLIP-97-61L) and the highest was 44.7 cm for Acc. number 36001. The minimum number of seeds/pod was

<sup>\*\*, \* =</sup> significant at 5% and 1% probability levels, respectively.

 $<sup>^{**}</sup>$ ,  $^{*}$  = significant at 5% and 1% probability levels, respectively.

Table 7: Mean squares of the combined analysis of variance for lentil yield and yield component traits and mean values for each location in the 2011/12 cropping season.

Sources of variation	df	DFF	DM	NP	NS	NSPP	PH	SW	BI	SY
Environment mean squares	2	754.0**	1065.0**	557.9**	17188.6**	162.1**	2028.3**	153.2**	1031.6**	343.1**
Genotype mean squares	227	3.6**	1.2 <sup>NS</sup>	$0.4^{ m NS}$	$0.01^{NS}$	$0.2^{\mathrm{NS}}$	0.9**	8.9**	$0.4^{**}$	1.1**
Residual mean squares	454	1.5	1.61	1.6	0.9	0.7	0.4	1.7	0.2	0.5
Range		41-91	60-131	12.1-298	0.4-2.6	20.6-64.3	22.7-47	0.8 - 5.1	204.5-632	19.8-172
Sirinka mean		56.4	91.4	37.4	1.2	43.77	33.9	2.7	269.8	83.2
Chefe Donsa mean		56.1	114.5	29	1.5	43.8	27.71	2.8	269.4	86.8
Sinana mean		66.3	104.6	19.2	1.9	34	40.5	2.4	521.3	44
Environment mean		64	105	30	1.6	40	36	2.5	400	60

df = degree of freedom.

6

DFF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NS = number of seeds per pod, SWPP = seed weight per plant, NSPP = number of seeds per plant, PH = plant height in cm, SW = 100-seed weight in gram, BI = biomass, PSS = pod set score.

TABLE 8: Genetic parameter estimates for agromorphological characters of lentil genotypes at Sirinka 2010/11 cropping season.

Traits	Mean	Range	GV	PV	PCV	GCV	$h^2$	GA	GAM
DFF	57.2	42-78	18.7	32.5	7.6	10	57.3	6.8	11.8
DM	95.7	77–138	119.3	164.8	11.5	13.5	72.4	19.2	20.1
NP	35.3	1.6-73.3	76.4	202.9	25	40.5	37.7	11.1	31.5
NS	1.2	0.5-2.0	0.1	0.18	22.6	30.1	56	0.4	34.8
PWPP	1.5	0.24-8.1	0.7	0.8	58.4	60.7	92.6	1.7	15.8
SWPP	1.1	0.1-3.4	0.2	0.3	36.3	51.6	48.9	0.6	52
NSPP	42.9	5.5-103.1	215.4	416.2	34.6	47.8	51.8	21.9	51
PH	34.6	20.6-44.7	13.4	21.6	10.6	13.4	62.3	6	17.3
SW	2.5	1.38-4.9	0.3	0.4	21.7	24.9	75.8	1	38.9
BI	286.8	35-767.8	9806.7	15955	34.7	44.2	61.5	160.5	56
SY	84.9	0-347.2	1192.3	2188.7	41.1	55.4	54.5	52.8	62.2
PSS	5	2-7	0.5	0.7	14	17.1	66	1.2	23.2

Triats, DFF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NS = number of seeds per pod, NSPP = number of seeds per plant, PH = plant height in cm, SW = 100-seed weight in gram, BI = above ground biomass, SY = seed yield.

recorded (0.5 seed) for landrace (Acc. number 36098) and the maximum (2 seeds) for parent line (X2003S 233/8009/). Seed weight/plant ranged from 0.1 g for parent line X2002S 219/shehor-74/7554 to 3.4 g for breeding line R-186XFLIP-86-38L-24 (Table 12). The number of seeds/plant ranged from 5.5 for landrace (Acc. number 36098) to 103.1 for lines R-186XFLIP-86-38L-24. The largest seed size was observed for parent line FLIP-2004-7L (4.9 g) while the parent line X2003S 233/8009/had a minimum seed weight of 1.4 g. The lowest biomass/plant was recorded for the parent line X2003S 223 (35 g), and the highest biomass/plant was recorded for the parent line X2006S 128/5480/(767.8 g). The lowest seed yield (0 g) was recorded for landrace X2003S 223 whereas breeding line ILL-590 showed the highest seed yield (347.2 g) (Table 12).

3.2. Phenotypic and Genotypic Coefficients of Variation. Though variability in population is an indispensable prerequisite for any improvement, it is not the only criterion for deciding as to which trait is showing the highest degree

of variability. Phenotype coefficient of variation (PCV) and genotype coefficient of variation (GCV) can help in this regard. Estimates of genetic parameter are shown in Tables 8, 9, 10, and 11. PCV and GCV values of approximately more than 20% are regarded as high, whereas values less than 10% are considered low and values in between are considered as medium [33]. Based on this delineation, high PCV and GCV values were recorded for number of pods/plant, number of seeds/pod, pod weight/plant, seed weight/plant, number of seeds/plant, 100 seed weight, above ground biomass, and seed yield. However, days to 50% flowering, days to 90% maturity, and plant height showed lower GCV and PCV values in the 2010/2011 cropping season. In the 2011/12 cropping season, similar GCV and PCV patterns were recorded across the three locations for number of pods/plant, seed weight/plant, number of seeds/plant, above ground biomass, seed yield, and rust disease score, whereas low PCV and GCV were noted for number of pods/plant, number of seeds/pods, seed weight/plant, and number of seeds/plant at Chefe Donsa.

<sup>\*\*, \* =</sup> significant at 5% and 1% probability levels, respectively.

NS = nonsignificant.

GV = genotypic variance, PV = phenotypic variance, GCV = genetic coefficient of variation, PCV = phenotypic coefficient of variation,  $h^2 = broad sense of heritability$ , GA = genetic advance, GAM = genetic advance as the percentage of the mean.

	l characters of lentil genotypes at Sirinka 2011/12 cropping season.
LARIE 9. Crenetic parameter estimates for agromorphologica	Lonaracters of lentil genotypes at Strinka 2011/12 cropping season
Tribel 7. Genetic parameter commutes for agromorphologica	i characters of femin genot, pes at off fina 2011, 12 cropping season.

Traits	Test genotype mean	Check mean	Grand mean	GV	PV	PCV	GCV	$h^2$	GA	GAM
DFF	56.3	56.3	56.3	77.4	93	15.6	17.1	83.3	16.6	29.4
DM	91.7	91.2	91.7	145.2	182	13.1	14.7	79.8	22.2	24.2
NP	35.7	45.2	35.7	714.7	1025.1	75	89.8	69.7	45.9	128.8
NS	1.2	1.3	1.2	0.1	0.2	27.6	34.3	65	0.6	49.9
NSPP	40.7	59.6	40.7	146.4	176.8	32.7	32.7	82.8	22.7	55.7
SW	2.7	3.1	2.7	0.2	0.5	18.6	27.6	45.6	0.7	24.6
PH	33.5	35.2	33.5	8.3	23.6	8.6	14.5	35	3.5	10.5
BI	245.9	392.3	245.9	5051	21656	28.9	59.8	23.3	70.6	28.7
SY	75.2	149.2	75.2	962	3429	41.2	77.8	28.1	33.9	45.1

Traits, DFF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NS = number of seeds per pod, NSPP = number of seeds per plant, PH = plant height in cm, SW = 100-seed weight in gram, BI = above ground biomass, SY = seed yield.

GV = genetypic variance, PV = phenotypic variance, GCV = genetic coefficient of variation, PCV = phenotypic coefficient of variation,  $h^2$  = broad sense of heritability, GA = genetic advance, GAM = genetic advance as the percentage of the mean.

TABLE 10: Genetic parameter estimates for agromorphological characters of lentil genotypes at Chefe Donsa 2011/12 cropping season.

Traits	Test genotype mean	Check mean	Grand mean	GV	PV	PCV	GCV	$h^2$	GA	GAM
DFF	55.9	57.3	55.9	14.9	29.3	6.9	9.7	50.6	5.6	10.1
DM	114.1	113.2	114.1	39.4	130.5	5.5	10.0	30.2	7.1	6.2
NP	26.9	35.3	26.9	4.6	185.3	7.9	50.0	2.5	0.7	2.6
NS	1.5	1.4	1.5	0.1	0.1	1.4	15.8	0.7	0.005	0.3
NSPP	41.3	50.2	41.3	2.2	502.4	3.6	53.9	0.4	0.2	0.4
SWPP	1.1	1.4	1.1	0.03	0.3	17.8	54	10.9	0.1	11.2
SW	2.8	2.7	2.8	0.5	0.6	23.7	26.2	81.8	1.3	46.6
PH	27.5	28.5	27.5	6.4	14.3	9.2	13.7	45.2	3.5	12.8
BI	262.6	305.6	262.6	2789.0	9888.0	20	37.6	28.2	57.8	22.0
SY	82.5	107.6	82.5	460.2	1427	25.7	45.3	32.3	25.1	30.5
RSAF	3.6	3.1	3.6	3.1	4.9	49.1	61.7	63.2	2.9	80.1

The lowest PCV (10%) was recorded for days to 50% flowering and the highest (60.7%) for pod weight/plant at Sirinka 2010/2011. At Sirinka 2010/2011, GCV values ranged from 7.6% for days to 50% flowering to 58.4% for pod weight/plant (Table 8). The maximum PCV and GCV recorded for number of pods/plant were 89.8 and 75, respectively, at Sirinka 2012, while the lowest PCV and GCV recorded for plant height were 14.5 and 8.6, respectively (Table 9). Days to 90% maturity and 100-seed weight showed moderate GCV. At Chefe Donsa and Sinana, values recorded for both PCV and GCV were similar with those of Sirinka (Tables 10 and 11). Traits such as number of pods/plant, seed weight/plant, 100-seed weight, above ground biomass, seed yield, and rust disease score showed relatively high PCV and GCV values across the four environments (Tables 8–11).

3.3. Heritability and Genetic Advance. The broad sense of heritability  $(H^2)$  estimates of the traits ranged from 0.4% (number of seeds/plant) to 92.6% (pod weight/plant). According to [34], heritability estimate in cultivated plants can be placed in the following categories: heritability estimate ranging from 5 to 10% low, values ranging from 10 to 30% medium, and values 30% and above as high heritability. Based on the above classification, most of the characters have shown high heritability over locations except at Chefe Donsa. At

Chefe Donsa, low heritability estimates were recorded for number of seeds/plant (0.4%), number of seeds/pods (0.7%), and number of pods/plant (2.5%) (Table 10). At Sinana, heritability estimates ranged from 18% to 88% for biomass and 100-seed weight, respectively. Days to 90% maturity, number of seeds/plant, plant height, and above ground biomass had a moderate heritability (17.7–26.1%) (Table 11), whereas seed yield, 100-seed weight, rust disease score, number of pods/plant, and number of seeds/plant scored higher heritability.

Consistently higher value of heritability was revealed for days to 50% flowering, 100-seed weight, days to 90% maturity, and plant height over locations. However, all these four characters associated with low genetic advance value (GA) because of low GCV, whereas 100-seed weight, rust severity score, and seed yield showed high heritability values coupled with high genetic advance values across locations because of high of GCV. Numbers of seeds/plant, seed weight/plant, and number of seeds/pod have intermediate GCV and heritability with a mild response to selection.

#### 4. Discussion

Morphological diversity has been used to characterize germplasm from a range of plant species and allows the assessment

Traits	Test genotype mean	Check mean	Grand mean	GV	PV	PCV	GCV	$h^2$	GA	GAM
DFF	66.04	66.8	66.1	20.7	66.6	6.9	12.4	31.1	7.9	12.1
DM	105.1	104.5	105.1	86.6	331.2	2.4	15.1	26.1	9.8	9.3
NP	19.2	20.8	19.3	33.7	63.6	30.2	41.4	52.9	8.6	44.4
NSPP	33.9	36.1	34	33.1	149.6	16.9	36	22.1	13.1	38.5
SW	2.38	2.7	2.4	0.6	0.7	32.7	35	87.1	1.51	63.2
PH	40.3	42.6	40.4	7.2	30.1	6.6	13.6	23.7	2.7	6.7
BI	505.1	619.1	509.1	6290	35625	15.6	37.1	17.7	69.9	13.8
SY	40.2	89.6	41.9	809.8	1633	67.9	96.4	49.6	45.8	109.2
RSBF	2	1.5	1.9	1.2	2	55.6	71.9	59.7	1.8	88.9
RSAF	5.8	4.6	5.7	1.2	5.1	19.5	39.4	24.5	1.2	21.1

TABLE 11: Genetic parameter estimates for agromorphological characters of lentil genotypes at Sinana 2011/12 cropping season.

of genetic diversity. The purpose of this study was to compare the genetic diversity within and among Ethiopian and exotic lentil genotypes of the Ethiopian possessions. In this paper, the characterizations of morphological variation of lentil germplasm using biometrical model was described.

As per ANOVA, highly significant phenotypic ( $P \le 0.01$ ) differences were observed for all traits measured indicating the existence of variation. The presence of highly significant variation among the genotypes for the morphological traits was indicative of the presence of high degree of genetic variation for future breeding programs through selection. Similarly, from follow-up study with the simple sequence repeat (SSR), genetic diversity analysis was a supportive evidence of the presence of a considerable variability among both local and exotic lentil genotypes of the Ethiopia germplasm (unpublished data). In agreement with this report, [21, 34–39] reported significant genetic variations among lentil landraces. On the other hand, some studies showed that no significant variation was recorded for some traits, like seed weight/plant and days to flowering [21, 38, 40].

The results recorded for coefficient of variation were comparable with [38] for days to 50% flowering (8.8), plant height (9.1), number of seeds/plant (43.2), and above ground biomass (31.5). However, [38] reported higher values *visa-vis* with this study for days to 90% maturity (19.2), pod weight/plant (47), and seed weight/plant (47.8). In agreement with this finding, [41] also noted comparable range for plant height on 3974 accessions of lentil. However, they recorded a wider range of values for 100-seed weight with an overall mean than with our records on lentil accessions. In another study, [37] reported a narrow range for yield component traits among 46 genotypes from South East Anatolia region of Turkey as opposed to our findings.

Significant variations were noted over locations among the test genotypes and within the checks with a few exceptions. In line with this study, [24] recorded the wide range of genetic variability among yield related characters in exotic lentil lines in Ethiopia. Comparable to our study, [15, 18] noted the presence of variation in characters, such as grain and straw yield, 100-seed weight, days to 50% flowering, days to 90% maturity, number of seeds/pods, plant height, pod number/peduncle, and resistance to various biotic and a biotic stresses in the lentil. Besides, the variation among

environments was significant for all morphological traits in view of diverse agro-climatic features of the test sites. Similarly, [42] also observed the greater portion of total variance was due to environment. Reference [5, 7, 23] also reported consistent regional differences among lentil landraces of Ethiopia for time to flowering and maturity, 100-seed weight, seed/pod, and plant height.

ANOVA over locations showed consistent significant variations were recorded within the checks for 100-seed weight, above ground biomass, seed yield, and rust disease score. These implied that yield increment was achieved for the last three decades, largely for 100-seed weight, above ground biomass, and seed yield of lentil genotypes. A consistent significant variation was also recorded within test genotypes over three locations for days to 50% flowering and 100-seed weight. Besides, reliable variation was noted over all locations between checks and test genotypes for above ground biomass and seed yield. Similarly, according to this (unpublished data) follow-up study, using the multivariate analysis reported that seed yield, above ground biomass, seed weight/plant, 100seed weight, rust severity score, and plant height were the major agromorphological traits contributing to variations among the genotypes.

Estimate of PCV and GVC for days to 50% flowering, days to 90% maturity, and 100-seed weight showed narrow differences, indicating a relatively low influence of the environment on these characters. Similar observation of considerable closeness between GCV and PCV for these characters made by [43] indicated low influence of environmental factors in lentil. In general, PCV values for most of the traits at Sirinka and Sinana were higher than that record noted at Chefe Donsa. In addition, the PCV was generally higher than the GCV for all characters. Consistently higher PCV values were observed across four environments for rust disease scores, seed yield, pod weight/plant, seed weight/plant, number of pods/plant, 100-seed weight, above ground plant biomass, and number of seeds/plant. Other studies showed similar high PCV and GCV for seed yield, above ground biomass, and 100-seed weight [44, 45]. In contrast, days to 50% flowering, days to 90% maturity, and plant height showed comparatively low PCV values (less than 20%) for all locations. It was observed that GCV for number of pods/plant, seed yield, rust disease score, 100-seed

TABLE 12: Means for yield and yield components of the genotypes at Sirinka 2010/11.

Genotype name	DF	DM	NP	NSS	PWPP	SWPP	NSPP	РНН	SW	BI	SY	PSS
36001	57	89	39.7	0.9	1.8	1.2	39	44.7	2.6	345.2	78	5
36003	56	91	47.8	0.7	1.9	0.9	45	38.8	2.1	315.7	59.9	6
36007	58	90	38.8	1.8	2	1.5	86	38.4	2.1	359.3	79.6	6
36009	58	90	35.6	1.3	1.4	0.9	47	39.9	1.9	294.8	60.9	5
36013	58	90	39.8	1.2	3.9	2.3	52	39.4	2.1	440.8	74	5
36015	59	98	29.7	1.9	1.9	1.2	52	41.9	2.5	545.8	128.6	5
36019	55	94	41.1	1.2	1.9	1.5	69	37	2.2	311.9	71.6	5
36023	54	84	34.5	0.6	1.6	0.6	41	36.8	2.1	237.8	30.6	5
36025	46	77	34.2	1.1	2	1.1	39	33.6	2.1	254.7	62.2	6
Alemaya	57	107	55.2	1.3	1.5	2.4	70	31.6	3.1	449.6	160.9	6
ADAA	61	128	29.1	1.7	1.9	1.3	43	40.4	2.8	249.7	45.9	4
EL-142	56	93	36.1	1.1	1.1	1	45	35.5	2	321.8	51.1	5
X2003S 222/213/	66	103	32.7	1.1	1.7	1.1	36	36	2	390.8	95.2	4
X2003S 238	55	92	32.5	1.1	2.3	1.4	40	32.2	3.8	377.4	124.8	6
36028	59	98	38.2	0.7	1.4	1.3	52	41.1	2.2	453	145.6	6
36029	57	89	39.9	1.3	2.1	1.1	49	31.8	2.3	331.6	76.7	5
36033	55	86	37.4	1	1.3	1	37	33.8	2.4	257.9	78.4	7
36039	55	88	43.5	1.2	2.1	1.2	68	33.6	2.3	181.4	60.9	5
36041	56	89	55.4	1.1	1.8	1.4	60	34.7	2.1	246.5	75.9	5
36048	57	88	52.7	0.9	1	1.3	49	35.1	1.8	280.4	89.2	5
36058	51	84	41.1	0.6	0.9	0.8	40	32.1	2.9	170.5	55.2	6
36061	54	82	36.3	0.6	0.8	0.6	22	30.5	2	163.3	30.8	6
TESHALE	56	98	26.9	1.2	2	1.3	34	33.7	3.6	372.9	119.7	5
X2006S 128/5480/	77	125	50	1.2	4.6	2	59	42.9	2.8	767.8	153.3	3
L-9-12	59	114	35.3	1.2	1.5	1.2	38	36.7	3.6	316	74	4
36071	57	91	33.1	0.9	1.5	0.9	39	41.5	2.4	406.5	104.6	6
36085	57	91	58	1.2	2	1.9	77	39.8	3	392.7	117.2	6
36088	57	95	34.4	1.1	1.2	0.9	40	37.5	3	399.6	115.3	5
36089	60	97	32.7	1.1	0.5	1.1	41	33.3	2.3	237.2	105.8	5
36097	58	98	56.4	1.1	1.7	1.5	75	34.9	2.4	288.9	86.5	4
36098	56	106	18.3	0.5	0.5	0.2	6	29.9	2.4	71.1	0.1	4
36103	53		27.5						2.5			5
		86	37.2	1.4	1.3 1.7	1	36	35.6		274.4	90.9 77.3	
36104 36105	53 56	88 87	29.7	1.1		1.3	45 33	34.9	2.7 3.1	274.5 145	41.6	6 5
				1.1	0.3	0.8		29.8				5 5
211062 Y20036 105	60	91	38.9	1.6	1.9	1.6	63	37	2	449.4	93.9	Ü
X2003S 195	72	130	35.2	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	5
X2002S 219/6821/	57	96	35.2	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	5
X2006S 129/F2	51	94	28.6	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	5
36110	57	91	40.9	1.7	2.1	1.7	68	39.8	2.2	374.5	136.5	5
36120	42	87	23.3	0.5	1	0.4	12	25.7	2.2	174	30.3	7
36131	59	92	36.3	1.6	1.2	1.4	59	37.1	2.1	369	127.4	5
36042	54	84	45.5	0.8	2.2	0.9	37	35.4	1.9	223.4	48	6
36137	59	99	33.2	1.4	1.5	0.9	44	34	2.1	251	78.6	4
36139	53	97	40.7	0.9	1.8	0.7	34	35.8	2	243.6	55.8	6
36147	60	99	48	1.1	1.8	1.2	50	38.8	2.4	331.6	97.7	6
36150	56	89	34.4	1.3	1.9	0.8	46	35.9	2.4	261.6	76.3	5
36162	57	100	34.7	1.3	2	1	43	36.6	2.3	237.1	67	5
36165	57	95	30.3	1.4	0.9	1	44	39	2.4	313.9	83.4	6
X2005S 215/6002/	57	96	34.1	0.8	1.6	1	25	40.8	3.9	329.8	101.7	5
36168	59	104	26.6	1	1.1	0.9	27	34.1	2.5	267.5	89.7	5
203141	59	90	41.1	1	1.5	1.3	42	35.4	2.3	320.5	118.4	5

Table 12: Continued.

Genotype name	DF	DM	NP	NSS	PWPP	SWPP	NSPP	PHH	SW	BI	SY	PSS
207258	58	90	50	1	1.3	1.2	47	39.1	2.6	324.7	104.2	6
207274	59	91	39.9	1.1	1.5	1.3	48	38.1	2.3	272.5	99.2	5
207260	58	94	40.9	1.2	0.9	1.1	52	38.3	2.3	340.3	92.7	5
207287	52	91	46.4	1.1	2.3	1.4	51	35.1	2.2	311.9	107.1	6
207309	57	89	36.9	1	1.3	1	35	31.8	2.3	248.1	57	5
211078	54	88	47.9	1.4	2.1	1.5	61	31	2.1	218.6	70.3	6
211131	53	87	40.7	1.7	1.4	1.8	65	32.3	2	260.4	102	6
212745	57	91	36.3	1.5	1.9	1.2	57	33.3	2.2	322.7	106.9	7
X2006S 133/6211/	53	98	18	1.3	1.2	0.7	20	30.5	3.7	135.5	36.4	5
238979	59	91	60.1	1.3	2.3	1.9	81	33	2.1	259.2	88.6	5
215248	56	87	45.5	1.2	1.5	1.2	51	31.4	2.2	237.5	71.4	5
215249	58	90	39.7	1.4	1.1	1.6	53	35.7	2.4	265.7	87	5
215806	58	91	26	1.8	0.8	0.8	35	32.9	2.5	189.6	56.8	5
216877	58	92	29.3	1.3	0.6	0.8	35	33.4	2.1	226.8	82.4	4
220120	56	91	23.6	1.3	0.7	0.6	27	37.7	2	149.7	34.9	6
223221	58	89	23.3	1.5	0.8	0.7	35	34.7	2	216.9	72.8	5
228242	59	90	34.9	1.8	1.5	1.4	65	37.3	2.2	259.5	83.5	5
228243	59	87	24.6	1.9	0.6	0.5	43	33.1	2	132.5	35.2	5
228809	53	87	32.4	0.6	1	0.7	21	35.9	2	231.1	63.9	5
219957	53	97	31.3	1.2	0.5	1	41	37.3	2.5	351.3	107.4	6
211110	59	91	38.9	1.8	1.6	1.2	62	38.4	1.8	390	96.3	5
229179	59	97	29.7	1.8	1.1	0.9	53	40.3	2.2	296.5	72.3	5
229182	59	95	40.5	1	1.1	1.1	43	41	2.2	342.6	83.3	5
229183	59	92	29.8	1.3	1	0.8	40	36	2.2	265.6	64.8	5
230521	59	93	28.7	1.3	1.2	0.7	40	38.2	1.9	366.7	99.2	5
230832	59	93	43.3	1.3	0.9	1	54	38.2	1.7	270.8	81.8	5
230833	59	93	52.6	1	1.1	1.4	60	36.9	2	327.3	91.5	5
230834	58	93	27	1.5	1	0.7	37	34.7	1.8	346.2	94.1	4
230837	58	90	44.9	0.8	1.6	1	35	35.9	1.9	402.6	118.2	4
231247	59	93	36.4	1.2	1.1	1.1	44	35.6	2.3	297.5	103.4	6
231248	58	88	42.6	0.7	1	1	29	32.2	2.4	301.5	89.7	5
X2006S 130/7547/	54	86	20.9	0.7	0.7	0.4	13	27.1	2.3	91.8	98.3	6
FLIP-2004-7L	51	99	17.6	1.6	1.4	1.3	28	32	4.9	270.8	92.8	4
233349	57	90	19.8	1.2	1.1	0.6	26	30.2	2.5	159.2	43	5
233973	57	89	30.6	1.5	1.2	1	40	31.8	2.4	252.4	143	4
X2003S 223	66	124	1.6	0.8	8.1	0.4	6	25	2.9	35	0	5
X2003S 195/7115/	57	96	35.2	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	5
235013	57	91	23.6	1.3	2.3	1.1	31	30.7	2.5	248.3	92.7	5
235015	58	91	45.4	1.1	2.2	1.2	50	35.5	2.4	199.6	66.8	5
235016	58	89	29.2	1.1	1.7	0.9	32	33.3	2.7	284.1	91.6	5
235017	58	91	38.4	1.1	1.3	0.8	42	33	2.4	196.6	66.9	5
235383	57	89	36.2	1.2	1.9	1.2	47	40.8	2.6	310	97.9	6
235698	53	88	52.1	0.8	1.4	1	40	33.6	2.2	196.8	68.3	5
236438	58	90	33.2	0.9	1.2	0.8	30	34.5	2	358.1	113.7	5
236484	57	88	52.2	1	1.7	1.4	51	33.6	2.1	273.1	87	6
X2006S 130/7978/	56	92	40.8	1	1.9	1.6	39	35.9	4.1	334.6	101.3	5
X2002S 221/7979/	46	89	20.5	0.8	0.9	0.6	18	33.3	2.3	176.6	40.7	5
X2002S 221/7980/	58	99	28.9	0.9	1.7	1.5	30	36.1	4.2	310.7	109.1	5
236486	57	88	30.5	0.9	0.8	0.9	34	35	2.2	183.4	61.9	5
236487	53	88	36	1.4	0.8	1	39	33.4	2.3	207.3	73	5
236892	58	91	36.9	1.1	1	0.9	41	37.7	2.2	240.3	59.8	5
236892	58	91	36.9	1.1	1	0.9	41	37.7	2.2	240.3	59.8	5

Table 12: Continued.

Genotype name	DF	DM	NP	NSS	PWPP	SWPP	NSPP	PHH	SW	BI	SY	PSS
237027	50	83	25.3	0.8	1.1	0.7	21	33.3	3.9	146.9	47.3	5
237502	60	90	36.8	1.2	1	0.9	44	33.8	2.1	195.5	54.1	5
237503	59	92	41.8	1.5	1.2	1.4	67	39.3	2.6	279.9	93.9	5
237504	59	92	45.4	0.9	1.8	1.1	39	36.4	2.3	227.3	76.2	5
X2003S 224	57	96	35.2	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	5
238971	58	90	31	1.5	1.1	0.9	42	32.8	2.5	262.8	80.7	5
238978	60	97	31.2	0.9	0.7	0.8	33	35.8	2.4	247.4	70.7	4
X2003S 233/8009/	51	85	19.8	2	1.4	0.4	29	27.4	1.4	75.8	30.3	2
X2006S 134/8174/	67	119	45	1.2	3.2	1.8	54	40.5	2.9	413.9	75.6	5
X2006S 127	72	124	29.1	0.9	1	0.7	28	31.7	2.2	188.8	28.7	3
241782	59	109	26.6	1.4	0.8	0.6	28	36.2	2.4	268.5	66.5	4
241784	56	90	36	1.2	1.6	1.2	41	36.5	2.6	282	98	6
241785	57	88	35.1	1	1.1	1.1	36	34.8	2.6	276	95.6	5
241786	55	87	51.3	1.2	1.4	1.7	69	35.4	2.4	391.6	145.4	5
242604	58	92	52.6	1.2	2.2	1.8	65	36.3	2.5	392.4	134.8	6
243433	59	94	32.4	0.9	1.4	1	28	32.8	2.3	241.3	73.2	5
243436	59	91	24.1	1.1	1.1	0.6	28	27.2	2.3	117.3	35	5
243440	57	94	30.7	0.7	1.1	1	20	35.8	2.3	244.1	88.5	5
243443	53	94	27.1	1.1	1.5	1	26	34.9	2.5	273.4	82.2	5
243447	53	94	26.9	1.1	2.2	1.1	26	34.7	2.7	257.9	95.7	6
X2006S 122/9932/	54	86	18.1	1	0.9	0.5	20	30.5	2.1	163.4	31.4	5
X2006S 127/9945/	51	90	27.6	0.8	1	0.5	21	28.2	2.4	206.7	42.1	4
244606	53	85	26.6	1.2	1	0.7	34	31.7	2.2	258.2	83.2	5
244610	53	85	33.8	1.3	1.5	0.9	50	34.8	2.2	222.1	86.8	5
244615	58	85	34.7	1.2	1.7	0.9	42	33.6	2.2	261.3	75.8	5
244619	58	87	33.8	1.2	1.2	0.8	32	36.7	2	227.2	65.1	5
244623	53	85	26.4	1	1.3	0.7	29	37.8	2.3	263.2	65.3	5
X2006S 122/9951/	53	88	36.3	1.3	2.1	1.1	41	33	1.8	240.1	64.6	6
X2002S 219/shehor-74/7554	46	82	10.2	0.8	0.7	0.1	8	28.8	2.5	59.7	9.1	6
ILL-590	56	87	40.7	1.3	1.2	1.1	42	35.6	3.2	468.3	347.3	6
X2003S 236	57	96	35.2	1.2	1.5	1.1	43	34.6	2.5	287.1	84.3	6
EXOTIC #DZ/2008 AK	61	115	12.2	1.2	1.5	1	16	31.8	3.3	564.3	96.4	5
R-186XFLIP-86-38L-24	60	109	73.3	1.4	1.5	3.4	103	37.1	2.8	642.9	200.9	4
FLIP-2006-60L	54	126	23	1.3	1.5	1	31	24.6	3.4	200	54.3	5
FLIP-97-68L	56	104	46.1	1.3	1.5	1.7	59	31.1	3.1	541.5	165.1	5
ILL-358 X ILL-2573-2-2000	64	112	32	1.4	1.5	1.2	46	30.4	2.9	288.1	99.5	5
FLIP-04-26L	78	138	30	1.1	1.5	1.2	26	38.1	4.2	578.8	61.2	5
ILL-28501	58	114	36.2	1.6	1.5	1.6	59	37.7	3.1	389.1	98	5
87S-93549XEL-1O3-4	47	95	33.2	1.1	1.5	1	37	27.9	2.6	215.8	81.2	5
87s-93549XEL-103-5	57	109	31.6	1.4	1.5	0.9	46	36.4	2.6	374.7	109.7	5
FLIP-2006-20L	74	124	20.4	1	1.5	0.8	21	31.8	3.2	295.8	30.9	5
Derash	57	103	55.5	1.3	1.5	2.5	71	35.6	3	446	162.2	5
ALEMETENA	50	94	25.3	1.2	1.5	1.1	33	21.9	3.6	172.2	85.6	5
Chekol x R-186-8-1	54	109	30.7	1.2	1.5	1.3	38	31.1	3.3	303	119.2	5
R-186X FLIP-86-38L	58	103	27.2	1.8	1.5	1.4	50	31.9	2.5	262.9	80.5	5
FLIP-87-68L	60	122	41	1.3	1.5	1.7	60	29.3	3.1	266	93	5
Chekol	57	98	38	1.3	1.5	1.7	54	29.3	2.3	258.1	104.8	5
ILL-10045	60	98 115	38 8.9	1.4	1.5			35.1		305.2	61.6	5 5
						0.3	10		3.1			
FLIP-97-16L	61	102	17 41.5	1.3	1.5	0.5	28	44.7	2.3	531.7	60.5	5 5
ILL-10681	63	116	41.5	1.3	1.5	1.9	53	32.1	3.3	202.2	89.7	5

DC.	10	0	1
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Genotype name	DF	DM	NP	NSS	PWPP	SWPP	NSPP	РНН	SW	BI	SY	PSS
Chekol X R-186-2	61	110	46.9	1.4	1.5	1.6	62	38.4	3.1	345.3	118.8	5
FLIP-2004-37L	63	109	32.1	1.9	1.5	1.3	50	29.1	2.5	181.8	60.1	5
FLIP-84-95L	59	129	12.4	1	1.5	0.5	13	33.2	4.1	295.2	48.6	5
EL-142 X R-186-3	58	112	66	1.4	1.5	2.4	95	37.6	2.4	437.9	156.6	2
FLIP-97-61L	63	129	44	1.4	1.5	2.1	70	20.6	3.2	135.4	46.6	4
36134	55	90	33.1	1.2	1.5	1	37	32.7	2.2	289.2	108	5
GM	57	96	35.3	1.2	1.5	1.1	43	34.6	2.5	286.8	84.9	5
SEM	2.1	3.9	6.5	0.1	0.1	0.2	8.2	1.6	0.2	45.2	18.2	0.3
SE Difference	3	5.5	9.2	0.2	0.2	0.3	11.6	2.3	0.3	64	25.7	0.4
LSD at 5%	6	10.8	18.1	0.4	0.4	0.7	22.7	4.6	0.5	125.9	50.7	0.8
CV%	6.5	7	31.9	19.9	16.5	36.8	33	8.2	12.2	27.3	37.1	9.7

DF = days to 50% flowering, DM = days to 90% maturity, NP = number of pods per plant, NSS = number of seeds per pod, PWPP = Pod weight per plant, SWPP = seed weight per plant, NSPP = number of seeds per plant, PH = plant height in cm, SW = 100-seed weight in gram, BI = biomass, SY = seed yield, PSS = pod set score.

weight, number of seeds/plant, and biological yield/plant was high in both seasons. However, traits such as days to 50% flowering, days to 90% maturity, and plant height consistently showed lower GCV values of between 2.4% and 17%. The remaining traits lack consistency and showed low to moderate GCV for number of seeds/pods, seed weight/plant, and pod weight/plant. Similar significant and considerable variation for (phenotypic and genotypic) results was reported for biological yield/plant, seed yield/plant, and 100-seed weight by [15, 35, 43, 45–48]. However, as opposed to this finding, [49, 50] reported higher GCV and PCV for days to 50% flowering but they reported the same record for days to 90% maturity and plant height. Similarly, [35] reported the minimum PCV and GCV for days to maturity and number of seeds/pod.

According to [51], most characters have showed high heritability estimate over locations except at Chefe Donsa due to severe wilt incidence. Reference [52] reported comparable high heritability estimates for all traits except for plant height and biological yield on lentil. Reference [15] similarly recorded high heritability for 100-seed weight, days to 50% flowering, and days to 90% maturity. Reference [7] also reported high heritability for seed weight and days to 50% flowering. In line with our finding, [53] reported that those days to 50% flowering showed higher heritability estimates; however, they differed in reporting with higher genetic advance. 100-seed weight, rust severity score, and seed yield showed high heritability values coupled with high genetic advance values across locations because of high GCV. Numbers of seeds/plant, seed weight/plant, and number of seeds/pods have intermediate GCV and heritability with a mild response to selection. Similar to our findings, [45] reported higher degree of PCV, GCV, and genetic advance for seed yield/plant on lentil. However, in contrast to these reports, higher PCV, GCV, and genetic advance were recorded for biological yield/plant.

The GCV along with heritability estimates provide a reliable estimate of the amount of genetic advance expected through phenotypic selection [54]. Based on the underlying

facts, four groups of traits were categorized as per the analysis: the first group included plant height, days to 50% flowering, and days to 90% maturity which have low GCV with a high heritability but they end up with low genetic advance. [42, 44] made a similar report that high heritability estimate for days to 50% flowering and days to 90% maturity with low genetic advance values on lentil. The second group of characters was above ground biomass, number of seeds/plant, and number of pods/plant with intermediate GCV, heritability, and genetic advance. However, deviated from our findings, studies by [42, 44, 45] reported high heritability and expected genetic gain estimate for above ground biomass and number of pods/plant.

The third group of characters, rust severity score, seed yield, and 100-seed weight, has higher GCV with high heritability coupled with high genetic advance as percentage of the mean. Reference [42, 44] reported high heritability estimate for seed yield and 100-seed weight coupled with higher genetic gain. High heritability for the characters indicated that these traits were less affected by environmental factors. This is indicative of the fact that these traits are mostly controlled by genetic factors and expected to respond to direct selection for traits improvement. The fourth group of characters, pod weight/plant, seed weight/plant, and number of seeds/pods, showed inconsistent GCV, heritability, and genetic advance values across locations. These findings indicated that measuring yield components in breeding program would be difficult. From our follow-up study by (unpublished data), the second and the third groups of characters responded more to selection and the most important traits that contributed to the genetic divergence of lentil. From our follow-up association study (unpublished data), these traits attributed a strong association with seed yield. Therefore, for selecting high yielding lentil genotypes, the breeder should give emphasis to higher seed weight/plant, more number of pods/plant, and plants with short to intermediate height. This observation is in accordance with [55, 56] selection based on number of pods/plant and seed weight/plant which were the most important characters that contributed to

seed yield. However, days to 90% maturity, rust disease severity score, and days to 50% flowering which otherwise had a negative phenotype correlation with seed yield had substantially negative direct effect on seed yield (unpublished data).

## 5. Conclusion

This study has described a high phenotypic diversity for important agromorphological characteristics of landraces and exotic genotypes of Ethiopia gene pool. The incidence of highly significant variation between landraces and exotic line for the majority of traits considered is a sign of the presence of a high degree of genetic variation implying the great potential of the Ethiopian germplasm in future breeding programs through selection. As per the analysis, four groups of traits were categorized. Some promising landraces were identified with superior plant characteristics, such as early flowering and early maturing accessions, wide range of genetic base for plant height, number of seeds/plant, resistance to rust, and both low and high yielding lines. Seed yield, 100-seed weight in gram, rust disease score, and total number of seeds/plant consistently showed higher GCV, heritability, and genetic advance in the lentil genotypes. All these important agromorphological characteristic traits with their associated genotypes could be successfully utilized in breeding programs that are aimed at improving the yield and the yield components of lentil. The wide genetic base that is possessed by the Ethiopian germplasm would be integrated in a breeding program and used as a parent in a recombination breeding.

In conclusion, this study has demonstrated that the exotic accessions introduced from ICARDA have a rich genetic potential for 100-seed weight, number of seeds/plant, seed weight/plant, short stature, and resistant source for rust. The Ethiopian landraces were potentials for earliness, higher number of pods/plant, and long plant height. This study has showed a high phenotypic diversity of important plant characteristics of the Ethiopian lentil germplasm. However, additional search is needed to develop a specific plant idotype for major agroecological zone to provide as a platform for local adaptation and then breed for location relevant traits, such as a biotic stresses and identification source of resistance for other major important diseases.

#### **Conflict of Interests**

The authors declare that they have no conflict of interests regarding the publication of this paper.

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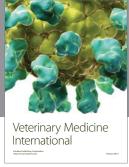
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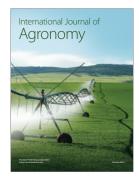
















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