Indigenous Forages of Ethiopia

Species Evaluation and Variety Development: A Historical Perspective

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Contents

List of Abbreviations and Acronyms

Acronym/ Abbreviation	
ArARC	Areka Agricultural Research Center
AxARC	Axum Agricultural Research Center
ARARI	Amhara regional agricultural research institute
BARC	Bako agricultural research center
BNF	Biological nitrogen fixation
cm	Centimeter
CIAT	Centro Internasional Agricultura Tropical (International Center for Tropical Agriculture)
CV	Coefficient of variation; cultivar
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CDD	Crop Development Department
CP	Crude protein
DZARC	Debre Zeit Agricultural Research Center
DAP	Di-ammonium phosphate
DM	Dry matter
EIAR	Ethiopian Institute of Agricultural Research
EAA	Ethiopian Agriculture Authority
Fig.	Figure
FAO	Food and Agriculture Organization
FM	Fresh matter
g	Gram
ha	Hectare
HARC	Holeta Agricultural Research Center
HuARC	HuARC Humera Agricultural Research Center
HuARC	Humera Agricultural Research Center
CIAT	International Center for Tropical Agriculture
IAR	Institute of Agricultural Research
IBPGR	International Board for Plant Genetic Resources
ICARDA	International Centre for Agricultural Research in the Dry Areas
ILCA	International Livestock Centre for Africa
ILRI	International livestock research institute
IVDMD	In-vitro dry matter digestibility
kg	Kilogram
KARC	Kulumsa Agricultural Research Center
MARC	Melkasa agricultural research center
MOA	Ministry of agriculture
m	Meter
m.a.s.l.	Meters above sea level
mm	Millimeter

MPT	Multipurpose trees
MoARD	Ministry of Agriculture and Rural Development
NCARTT	National Centre for Agricultural Research and Technology Transfer
NCIC	National Seed Industry Agency
NVRC	National Variety Release Committee
NVRSCA	Nationall Variety Release, Registration and Seed Certification Agency
N	North; Nitrogen
ORARI	Oromia regional agricultural research institute
N°	Number
NYT	National yield trial
PARC	Pawe Agricultural Research Center
PVRPSQCD	Plant variety release, protection and seed quality control directorate
%	Per cent
P	Phosphorus
q	Quintal (100 kg)
SMARC	Shire-Mytsebri Agricultural Research Center
SoRPARI	Somali region patoral agropastoral research institute
SRARI	South regional agricultural research institute
SN	Serial number
S	South
SNNPR	Southern Nations Nationalities and Peoples Region
Spp	Species (plural, many species)
Sp	Species (singular, one species)
SIDA	Swidish International Development Agencyy
Syn.	Synonymous
TC	Technical committee (of NVRC)
TARI	Tigray RegionalAgricultural Research Institute
t	Tonne (1000 kg)
TSP	Triple superphosphate
Var	Variety
VVT	Variety Verification Trial
WARC	Werer Agricultural Research Center

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Introduction

Agricultural research in Ethiopia began in the early 1960s. The earliest agricultural research center was the Debre Zeit Experiment Station, a constituent station of Alemaya College of Agriculture, Emperor Haile Selasie University. Almost at the same time, the national research system, IAR was established in 1966, by proclamation No 42/58 (1958 E.C.). The Swedish-Ethiopian regional agricultural development branch- the Arsi Rural Development Unit (ARDU) was founded in 1966 (SIDA, 1966), and became operational in 1972 (CADU, 1972). The CGIAR research institute, ILCA, was established in 1982 to promote livestock development in Africa. All these institutions did their part to improve livestock productivity through improving animal feed *inter alia*.

The scope of this review is limited to the topic of forage research in Ethiopia, with a focus on native Forage species. Therefore, the foregoing discussions do not go beyond simple presentation of stories of forage research processes, achievements, and gaps in the research, collected from published and unpublished literature found at various national and international research institutions.

From the research achievements of the pioneering institute CADU-ARDU, it is evident that wholistic, system-based research and development approaches were more fruitful than isolated single item-based approaches. Although sustenance could not be maintained for various reasons, there is evidence that improved forage crops developed by CADU have made their way to the farm gates of smallholder farmers in Arsi (ARDU, 1983). Additionally, CADU researchers have laid the groundwork for the fruitful approach of screening and developing varieties from indigenous material (Carlson, J., 1972; Thulin, M., 1972). Now, after half a century of research (with "staggering" achievements), benefits of focusing research efforts on native forages are vivid. Box 1.1 is a case in point.

A review of published and unpublished literature revealed that a total of 59 indigenous forage species (31 legumes and 28 grasses) have undergone evaluation for their forage value. Of these, 6 legume varieties and 9 grass varieties have been registered/released (NVRC, 2018). This number does not correspond to the exotic species that have been introduced and evaluated in the country since forage research began. Apart from a few species: Oats (*Avena* spp), Rhodes (*Chloris gauana*), Guinea grass (*Panicum maximum*), vetches (*Vetch* spp) Lucerne (*Medicago sativa*) desmodiums (*Desmodium intortum* and *D. uncinatum*) which remain valuable forage crops in districts of Ethiopia, other large numbers of introductions failed important selection criteria (adaptation, yield and quality). Some temperate grass species such as rye grass (*Lolium* spp) are destroyed by rust. Most of the previously selected and recommended oats varieties (Lulseged G. Hiwot, 1981), suffer from *crown rust*, although resistant varieties have been developed. Oats remain the only successful annual forage grass species. The exotic clovers (*Trifolium repens, T. pretense* and others) cannot compete with the native clover species in terms of adaptability and herbage yield.

Box 1.1: ***Desho***, the mysterious indigenous forage grass

Desho grass (*Pennisetum glaucifolium*) is an indigenous perennial grass forage variety developed from native ecotypes germplasm collected jointly by the Debre Zeit Agric Research Center (DZARC) and Areca Agricultural Research Center (AARC) of the Southern Nations Nationalities and Peoples Region (SNNPR) around Wolayta Zone. The grass is tussoky, rhizomatous, erect, up to 2 meters tall. The dense stem and foliage is glossy, so named *glousifolius*. Forage yield varies widely with soil fertility and moisture. Mean dry forage yield per harvest ranged 5.6 – 8.8 t/ha DM. While yearly (3 cuts) yield (under irrigation), ranged between 21.0 t/ha (Areka-DZF-590) to 24.59 t/ha (Kindukosha-DZF-591). At its best location (Wondo Genet) with fertile soil and abundant soil moisture, the mean DM yield ranged 25 – 39 t/ha (Solomon Mengistu *et al*, 2017; Tekalign Yirgu *et al*, 2017). Among the "pro-poor" forage technologies, three varieties of **desho** officially released by DZARC have provided hope to the smallholder farmer (Fig. 1). MoARD and NGOs have desiminated planting material almost throughout the highlands of Ethiopia. Farmers plant desho in their backyard on small plots and use the green fodder to feed lactating cows and young stock. Desho ha gained nationwide popularity. Some farmers have taken up multiplying propagation material as a business and make money by selling bunches of vegetative (stem cuttings and rhizome splits) to neigbouring farmers and even to distant areas, hundreds of kms away. The business has spread dramatically.

Fig 1. Recently released indigenous grass variety of **Desho** (*Pennisetum glaucifolium*), DZF-592

Various references in literature indicate that the screening and selection of forage materials carried out by most institutions does not go beyond simple agronomic and laboratory assessments. Advanced agronomic evaluations related to determination of nutrient requirements and selection of compatible species for grass-legume mixtures are generally lacking. Apart from a few exceptions, animal experimental evaluation of target species in the sense of grazing trials and feeding trials with penned-in herbivores is also missing. The limitation has been understandably attributed to a lack of resources (finance, facilities, and expertise).

Due to prevailing ignorance of the potential of native genetic forage resources and lack of conservation measures, many potential species are threatened with extinction year after year due to human practices: encroachment of cultivated crops, road construction, urbanization, unjustified land use that devastates the habitats of rare species. Already in the 1980s, warning reports about the eminent danger of extinction of the rarest and most potential native species were made available to the public (Solomon Mengistu, 1988; 2010b; Solomon M. and Alemayehu M, 2015). According to recent observations, incredibly large tracts of natural forest and forest margins, home to various endemic and near-endemic species, have been destroyed for arable farming and urbanization. One can imagine the magnitude of habitat destruction by comparing the present and near past (two decades ago) vegetation status of the Bale Mountains. In less than two decades, many rare and highly potential forage species have been lost due to clearing of the natural vegetation. In the face of these ongoing threats, it is outrageous to learn that a national *ex-situ* conservation practice does not yet exist.

Chapter 1: Historical Perspective of Forage Research in Ethiopia

1.1. The Institute of Agricultural Research (1966-1990)

Prior to its evolution into the present EIAR, the Institute of Agricultural Research (IAR) was established in the early 1960s by the Imperial Ethiopian Government as a fully-fledged national institution with a mandate to conduct agricultural research throughout Ethiopia (IAR, 1976). The Forage and Range Management Division of IAR conducted research in forage, rangelands, and animal nutrition since 1996, as reported in the earliest Research Progress Report (IAR, 1976). The earliest research stations of IAR included: Holetta, Sinana, and Adet (highland representatives), Bako, Assosa and Pawe (subhumid representatives), Melka Werer and Adami Tulu (low-altitude semiarid representatives). Of these, Holeta, Bako, Adami Tulu and Melka Werer were the oldest and well organized of all IAR stations, particularly in livestock research.

A review of available progress reports shows that IAR has assesssed a large number of forage accessions including grasses, legumes and fodder trees and shrubs at its various research stations. Perhaps the largest number of accessions ever introduced was that of oats, 9,000 entries were introduced and screened at Holleta, Sheno and Sinana research centers (Astate Haile, 1976; Lulseged G. Hiwot, 1987)

During the first decade of its operation, IAR placed more emphasis on the evaluation of temperate forage for the highlands (Lulseged Gebre Hiwot, 1987). The priority for the highlands is the fact that the Ethiopian highlands are one of zones with high livestock potential. The other rationale was to meet the increasing demand for improved forages by the small-scale dairy industry and state-run dairy farms, that are continually upgrading their dairy herd to higher exotic breeds through artificial insemination.

Major forage taxa that have been evaluated on the highlands include: *Medicago*, *Trifolium*, *Melilotus*, *Vicia* (legumes) *Avena*, *Dactylis*, *Festuca*, *Lolium*, *Phalaris*, *Setaria* (grasses); and fodder root crops such as swedes and fodder beet. These forage species were tested for yield both as pure stands and as grass/legume mixtures. Studies have also been conducted on their potential for establishment under unfavorable soil conditions such as poor drainage and low soil fertility, grazing management systems and methods for their integration into arable farming systems. Promising species identified for the highlands include *Vicia dasycarpa*, *Avena sativa* and fodder beet (*Beta vulgaris*) (Lulseged Gebre Hiwot and Alemu Tadesse, 1985).

Tropical forage species, imported mainly from Australia and Kenya have been tested at Bako and the surrounding stations since 1971 (Haile, Astatke, 1976). These include most of the successful commercial tropical forage species: *Setaria*, *Chloris*, *Sorghum*, *Paspalum* (grasses) *Centrocema*, *Dolichos*, *Glycine*, *Lotononis*, *Medicago*, *Macrotyloma*, *Desmodium*, *Phaseolus*, and *Stylosanthes* (legumes), *Leucaena* and *Sesbania* (browse trees).

1.2 The Arsi Rural Development Unit (ARDU) (ex-CADU)

The Arsi Rural Development Unit (ARDU), formerly known as the Chilalo Agricultural Development Unit (CADU) was established under the Ministry of Agriculture (MOA) in 1967 at Asela and was financed jointly by the Ethiopian and Swedish governments to promote agricultural development in Chilalo Awraja (District) (ARDU, 1967). In 1975, its development program comprised: research on crop and livestock production, socioeconomic studies, extension services, and building of various infrastructures.

The Crop and Pasture Section had been one of the various research and development units of ARDU. During its active operation in the past, the unit had achieved considerable successes not only in terms of identifying productive forage cultivars suited for its mandate area (the Arsi highland) but also in getting some of the selected cultivars adopted by the subsistence farmers to the extent that seeds were produced on the farmer's field, and farmer to farmer transfer of forage seed was reported (ARDU, 1983). The success was attributed to its strong extension service coupled with the comprehensive package of livestock improvement technologies, such as provision of credits, cross-bred cattle, forage seed, veterinary facilities, market facilities and infrastructure.

The major areas of ARDU's forage research program include study of indigenous species, natural pasture improvement, and introduction and evaluation of exotic forage species and associated management systems.

Collection and evaluation of indigenous forages

ARDU has been appreciated for its pioneer work in the collection and evaluation of indigenous potential forage species, which had not received significant attention until then. Several ARDUS's expatriate scientists have undertaken agro-botanical investigations on potential forage plants.

Carlson (1972) collected 39 ecotypes of six grass species including *Cenchrus ciliaris* (8 ecotypes), *Chloris gayana* (11), *Phalaris arundinaceae* (7), *Setaria sphaceleta* (1), mostly from Arsi and the surrounding areas for determination of forage yield and nutrient content. According to Carlson, considerable intra-specific variations in yield were observed for some species, and many of them had outyielded their respective exotic variety controls.

Thulin (1972) had carried out an agro-botanical investigation of leguminous species in Chilalo Awraja and come up with 90 accessions in the family Leguminosae and 300 accessions in other different families along with their descriptions of specific habitats, distribution, and apparent potentials as forages.

Froman (1974; 1975) had also undertaken similar studies on native legume and grass accessions and published two illustrated guides to taxonomic determination of both legume and grass families, including short notes on their distribution, palatability, and apparent toxicity to livestock. Thus, one would speculate that it was ARDU's initial work on native forages that prompted other institutions such as ILCA and EIAR to embark on extensive collection of potential forage taxa in Ethiopia. Furthermore, ARDU's forage crop germplasm introductions make up the bulk of elite species germplasm still circulating among research and development institutions and farmers alike.

In general, ARDU has made considerable contribution not only to forage research and development but also to the overall agricultural sector productivity in its mandate area, particularly during its first decade of active operation. Its holistic systems-oriented agricultural development packages and the strong extension services had been the salient features of its operation, which laid the foundation for crop and livestock innovations in Ethiopia. Details of forage research activities undertaken by CADU/ ARDU are available under the respective sections for genus and species.

1.3 The International Livestock Center for Africa (now, ILRI)

The International Livestock Centre for Africa (ILCA) (now ILRI) was created in 1974 as part of the network of agricultural research centers in developing countries sponsored by the Consultative Group on International Agricultural Research (CGIAR). ILCA's mandate was, according to the Center's report, to carry out research and to assist African governments in increasing livestock productivity thereby improving human welfare. Its headquarters was based in Addis Ababa (1970-2004). It had two major sub-stations (Debre Berhan and Debre Zeit) and several testing/project stations in Ethiopia. The Highland Program was one of the several programs that ILCA has launched in different eco-climatic zones of tropical Africa. The cool highlands represent an eco-climate which is somewhere between temperate and tropical in character. Justifying the research focus on the highlands Gryseels and Anderson (1983) stated that "The mild climate of the central highlands favors the introduction of higher-yielding cross-bred animals and is suitable for the cultivation of forage crops, allowing productivity increases to be achieved through livestock." To that end, the Ethiopian Highland Program was founded in 1976.

Having defined its emphasis area, ILCA embarked on forage and pasture research in 1976 as part of the Highland Program activities. Two principal research stations: Debre Berhan (2800 m.a.s.l.) and Debre Zeit (1860 m.a.s.l.) were founded both of which are located within the central highlands. In 1981, ILCA built a new building at Shola (2380 m.a.s.l.), northern Addis Ababa and was officially inaugurated in 1982 as its headquarters. Open sites in its compound were used as testing site and seed multiplication for temperate forages. In 1982, the Forage Legume Agronomy Group (FLAG) was created to extend the forage research activities (with emphasis on legumes) to the tropical lowland eco-climates. Two more satellite stations were opened in 1982/83 at Zwai (1700 m.a.s.l.) in the Rift Valley and at Soddo (1900 m.a.s.l.) (formerly under northern Sidama province, now under the Southern Nations, Nationalities and Peoples Region (SNNPR) where forage germplasm multiplication and agronomic evaluation had been carried out.

1.3.1. Debre Berhan station

Debre Berhan (2800 m.a.s.l.) represented the cool high plateaux of Ethiopia (2600-3000 m.a.s.l.). It receives about 1150 mm mean annual rainfall and has a mean annual temperature of 10 - 15 °C, which is suitable for evaluation of temperate forage species. At Debre Berhan, the forage research until 1981 focused on species adaptation, herbage yield, fallow land improvement for pasture production, and bottomlands improvement through surface drainage techniques to render them fit for growing of pasture and food crops (Abate Tedila, 1982). Several entries of temperate pasture and fodder species including clovers, medics and oats, some cereals, pulses, and potatoes were tested twice a year (during the small and big rainy seasons) for adaptability. Natural pasture improvement through over-sowing of legumes was attempted by the Highlands Program around Debre Berhan (Jutsi, *et al*, 1987) but the effort was not successful (Jutsi, *et al*, 1985).

1.3.2. Debre Zeit station

Debre Zeit station was founded in 1975 as a representative experimental site for the mid-altitude highland regions. Forage research was started there in 1977/78 crop year following a baseline study on the station carried out in 1975/76 (Ephrem Bekele, 1978). Many forage species both annuals and perennials grasses and legumes, fodder root crops and browse obtained from IAR and other seed centers were tested for their agronomic performance at the station. About 575 accessions of forages were screened in the period 1978-81 of which 372 were promoted for further evaluations such as yield, nutrient composition and management systems (Abate Tedla, 1981).

As part of its multipurpose trees (MPT) evaluation activities in sub-Saharan Africa, ILCA had been evaluating a wide range of *Sesbania* germplasm both at shola (ILCA headquarters) and at Debre Zeit (ILCA, 1988). Several accessions of *Sesbania sesban, S. goetzei, S. arborea, S. bispinosa, S.*

canabina, S. formosa, S. grandiflora, S. macrantha and *S. rostrata* were included in the trial. These were evaluated for height increase (during establishment year) and leaf dry matter yields at different cutting frequencies. The result showed that *S. sesban* accessions out-yielded all the other *Sesbania* species grown together including the control (*S. sesban*, Debre Zeit Common). The authors concluded that the highest fodder yield was obtained from plants pruned once at the end of the wet season.

1.3.3. Soddo station

The Soddo forage experiment station is in the campus of the Ministry of Agriculture Training Center, formerly known as the Wolayta Agricultural Development Unit (WADU), which was contemporary to ARDU in Arsi. In 1982, The French Agricultural Development agents conducted a limited forage trial which was later handed over to the Forage Legume Agronomy Group (FLAG) of ILCA in 1984 through bilateral research partnership with the Fourth Livestock Development Program (FLDP). Since then, many humid tropical forage species were screened for adaptability to acid soils at Soddo area, which represents the sub-humid regions of eastern and central Africa. There was significantly wide genetic base in the screening program especially in the *Stylosanthes* and *Zornia* genera. *Desmodium* species were under-sown in coffee plantations in an aim to integrate fodder with horticultural crops, which is the dominant farming system in the region. Preliminary observations showed *D. intortum* to have promise as a well adapted and high yielding fodder legume with considerable shade tolerance when undersown in coffee trees on farmers' field. Soddo station provided facilities for thesis project works for graduate students from Alemaya University, including advisory from ILCA scientists. Valuable information was generated from such thesis work like yield and feeding value of stylos (Adugna Tolera and A. N. Seid, 1994); on productivity of alfalfa on acid soils with lime amendments (Yimer Hassen and J.C. Tothill, 1994), forage potential of indigenous *Neonotonia wightii* (Larbi *et al*, 1992) and *Stylosanthes fruiticosa* (Hakiza, J. *et al*, 1988).

1.3.4. Zwai station

Zwai station is located some five kms south of Zwai town and since its foundation in 1982, has served as the major forage seed production site of ILCA. The Zwai station is ideally located near a permanent water source for a year-round irrigation. It consists of 4.5 ha of flatland, fertile alluvial soil of sandy-loam texture with a pH range of 6.5-7.5. Access to electric power for irrigation pumps was facilitated by its location around the private and state-owned horticultural farms. Thousands of entries of tropical forage grasses, legumes and browse trees had been established in permanent small plots (4x4m) where using irrigation multiple harvest of seed was possible. The warm temperature, fertile alluvial soil was ideal for quick regeneration of the various tropical grass and legume forages, including the collections from several African countries (Hanson, J. and Mengistu, S., 1991).

1.3.5. ILCA Forage Germplasm Collection and Conservation Unit

Among the various forage and pasture research activities of ILCA over the past three decades, the establishment of the forage gene bank is considered the most salient contribution to forage research and development endeavors in Africa and the world at large. Formerly the forage collections were stored in ordinary rooms, necessitating frequent regeneration of germplasm. The need for installation of a gene bank became apparent in 1982, when the germplasm acquisition grew dramatically following ILCA's extensive field collection of forage germplasm undertaken both locally and from the various African countries with financial support of the International Board for Plant Genetic Resources (IBPGR) (Kahurananga J. and Mengistu, S. 1983; 1984). Later in the mid-1980s, the germplasm collection at ILCA was reported to have grown to about 9,166 accessions of forage species, including legumes, grasses and browse, and composed of about 75% legumes and 10% each of grasses and browse with 111 genera and 341 species represented in the collection (Hanson, J. and Lazier, J., 1988). According to the report the major part of the collection was made up of experimental lines of germplasm which were either acquired from other institutions or original collections of forages from various countries in Africa, including Ethiopia, Kenya, Rwanda, Burundi, Zaire (Republic of Congo), Niger and Tanzania (Hanson, J. and Mengistu, S., 1991; Mengistu, S., 1991). Furthermore, due to FLAG being in Ethiopia and the resulting ease and economy of collection there, the largest number of ILCA collected accessions are Ethiopian, and they constitute 30% of the total collection. The gene bank maintained strong working relationship with the Centro International de Agricultura Tropical (CIAT) based at Cali in Colombia which has a large collection of legume germplasm from Central and South America, the main center of diversity of forage legumes. Besides undertaking joint expedition for *Brachiaria* germplasm in several African countries, CIAT donated about 20% of ILCA's acquisitions. Another major donor of germplasm had been the Division of Tropical Crops and Pastures (CSIRO) based in Queensland, Australia from whom ILCA has received almost 10% of its germplasm.

At present, after ILCA was unified with ILRAD (the International Laboratory for Research on Animal Diseases) to create the present ILRI (on Sept 21, 1994), the gene bank developed both in facilities and manpower and was structured under the Feed and Forage Development program. Now, the genebank in Addis Ababa conserves approximately 19,000 accessions of over 1,000 species, which is one of the most diverse collections of forage grasses, legumes and fodder tree species held in any genebank in the world. It includes the world's major collection of African grasses and tropical highland forages <https://genebank.ilri.org >.

1.4 System of disseminating research output before and after establishment of NVRSCA

Forage and pasture evaluation procedures followed conventional approaches practiced in developed countries located in the tropical and subtropical regions like Australia, whose scientists have published valuable literature, for example, Whiteman (1980) on principles of screening adequate number of acquisitions. The varieties selected were recommended to users through on-farm demonstrations (as practiced by CADU and IAR), or the recommendation was published in various journals and proceedings.

Research approaches improved after the establishment of the National Variety Release Committee (NVRC) in 1982 that prepared and issued the initial version of the guideline for release and registration of crop varieties. A series of revisions were made in 2001 and 2003, and the recent version was again revised in 2006 and officially published by MoARD and FAO in 2008 (MoARD-FAO, 2008). The guideline was implemented under the authority of the National Variety Release, Registration and Seed Certification Agency (NVRSCA) that was established under MoARD. The guideline for forage (Section 6.3 of the MoARD-FAO Guideline) suggests variety screening procedures, including, agronomic, nutritional, grazing trial and feeding trial with sheep and dairy animals. The feeding experiment is supposed to be undertaken on-station to evaluate a candidate variety, a standard check and a local control using sheep/goat (continuous trial) or lactating cows (short term/continuous). The grazing trial is suggested to be conducted using sub-divided paddocks in the target ecological zone using standard procedures of grazing trial. Standard known cultivar and candidate variety need to be compared using five animals per treatment for duration of 90 days. For perennials two years grazing experiment and for annuals one season grazing experiment would be used (MOARD-FAO, 2008).

EIAR adopted the MoARD-FAO Guideline and since its official implementation, about 77 forage varieties (grasses, 35; herbaceous legumes, 42; browse tree legumes, 14) have been released/registered (Tables 1.1a and Table 1.1b) (EAA-PVRPSQCD, 2021). On accounts of financial and facility shortages, the EIAR and NVRC authorities agreed to exempt animal feeding trial as well as grazing trial component of the forage germplasm evaluation process that would otherwise hardly be executed even by the oldest, well-organized centers of EIAR.

Table 1.1.a. Registered/released forage varieties: grass species (EAA-PVRPSQCD, 2021).

Nº	Species	Variety Designation	Common Name	Year release	Breeder Institute
	Grass species (35)				
1	*Andropogon gayanus*	Dirki ayfera (12465)	gamba grass	2009	PARC/ EIAR
2	*Avena sativa*	Dumant-DZF-583	Oats	2021	DZARC/ EIAR
3	*Avena sativa*	Bareda (ILRI-5450)	Oats	2020	MARC/ OARI
4	*Avena sativa*	Was (CI-1506)	Oats	2019	HARC/ EIAR
5	*Avena sativa*	Walqaa (SRCPx80 Ab2596)	Oats	2019	HARC/ EIAR
6	*Avena sativa*	Bate (ILRI-5453)	Oats	2018	BARC/ OARI
7	*Avena sativa*	SRCPx80 2806	Oats	2015	HARC/ EIAR
8	*Avena sativa*	SRCPx80 2291	Oats	2015	HARC/ EIAR
9	*Avena sativa*	CI-8251	Oats	2013	HARC/ EIAR
10	*Avena sativa*	Bonsa PI-79AB384	Oats	2011	SARC-OARI
11	*Avena sativa*	Bona-bas PI1660	Oats	2011	SARC-OARI
12	*Avena sativa*	CI-8237	Oats	1976	HARC/ EIAR
13	*Pennisetum purpureum*	Maralfalfa	elephant grass	2018	ELFORA Agro S.L./ HARC
14	*Pennisetum purpureum*	Bako-04 (ILRI-16804)	Elephant grass	2019	BARC/ OARI
15	*Pennisetum purpureum*	Bako-01 (ILRI-16801)	Elephant grass	2019	BARC/ OARI
16	*Pennisetum purpureum*	ILRI-16791	elephant grass	2017	HARC/ EIAR
17	*Pennisetum purpureum*	ILRI-16819	elephant grass	2017	HARC/ EIAR
18	*Pennisetum purpureum*	ILRI-16984	elephant grass	1984	ILRI
19	*Chloris gayana*	Masaba	Rhodes grass	1984	HARC, EIAR
20	*Panicum colloratum*	Colloratum	Colored guinea	1984	HARC, EIAR
21	*Phalaris aquatica*	Sirosa	Phalaris	1982	HARC, EIAR
22	*Pennisetum polystachion*	Netch sar (Chifir beqoa)	Mission grass	2014	PARC/ EIAR
23	*Panicum maximum*	Degun gezia	Guinea grass	2014	PARC/ EIAR
24	*Hyparrhenia sp*	Saari Gebremariam	thatch grass	2018	AARI-TRARI
25	*Brachiaria* (*hybrid*)	Mulato II	signal grass	2018	MARC, Melkasa
26	*Brachiaria brizantha*	Xaraes	Signal grass	2021	MARC/ EIAR
27	*Sorghum sp*	Guta (IS-38331)	Forage sorghum	2021	MARC/ EIAR
28	*Sorghum aethiopicus*	Mezrut	Forage sorghum	2017	HuARC-TARI
29	*Echnochloa* sp	Michelo	echinochloa	2017	HuARC-TARI
30	*Pennisetum sphacelatum*	Shebela sar	Wiregrass	2014	DZARC/ EIAR
31	*Cynodon aethiopicus*	DZF-265	giant star grass	2015	DZARC/ EIAR
32	*Brachiaria mutica*	DZF-483	para grass	2015	DZARC/ EIAR
33	*Pennisetum glaucifolium*	DZF-590-Areka	desho grass	2017	DZARC/ EIAR

Nº	Species	Variety Designation	Common Name	Year release	Breeder Institute
34	*Pennisetum glaucifolium*	DZF-591-Kindo Kosha 1	desho grass	2017	DZARC/ EIAR
35	*Pennisetum glaucifolium*	DZF-592-Kulumsa	desho grass	2017	DZARC/ EIAR

Source: EAA-PVRPSQCD, 2021.

Table 1.1.b. Registered/released forage varieties: herbaceous legume and browse tree legume (EAA-PVRPSQCD, 2021).

Nº	Species	Variety Designation	Common Name	Year release	Breeder Institute
	Herbaceous Legumes (28)				
1	*Lablab purpureus*	Doli-I (ILRI-11640)	Lablab	2019	MARC-EIAR
2	*Lablab purpureus*	Doli-II (ILRI-147)	Lablab	2019	MARC-EIAR
3	*Lablab purpureus*	Gedbis-17 (ILRI-14417)	Lablab	2016	BARC-OARI
4	*Lablab purpureus*	Beresa-55 (ILRI-14445)	Lablab	2016	BARC-OARI
5	*Lablab purpureus*	-	Lablab	1984	HARC-EIAR
6	*Lupinus angustifolius*	Welela (SW-001)	sweet lupine	2016	HARC/ EIAR
7	*Lupinus angustifolius*	Sanabor	sweet lupine	2014	ARARI
8	*Lupinus angustifolius*	Vitabor	sweet lupine	2014	ARARI
	Medicago sativa	Supersonic Alfalfa	Alfalfa	2021	S&W Seed Company Harvest General Trading PLC/ HARC
10	*Medicago sativa*	DZF-552	Alfalfa	2014	DZARC
11	*Medicago sativa*	Alfalfa 1086	Alfalfa	2016	Elfora Agroindustries PLC/ HARC-EIAR
12	*Medicago sativa*	Alfalfa ML-99	Alfalfa	2016	Elfora Agroindustries PLC/ HARC-EIAR
13	*Medicago sativa*	DZF-552	Alfalfa	2014	DZARC/ EIAR
14	*Sesbania dummeri*	DZF-336	sesbania	2018	DZARC/ EIAR
15	*Sesbania sesban*	DZF-405	sesbania	2018	DZARC/ EIAR
16	*Sesbania macrantha*	DZF-342	macrantha	2012	S-MARC/ TRARI
17	*Sesbania macrantha*	DZF-092	Macrantha	2012	DZARC/ EIAR
18	*Trifolium quartinianum*	-	Clover	1976	HARC/ EIAR
19	*Vicia dasycarpa*	Lana	Vetch	1976	HARC/ EIAR
20	*Vicia narbonensis*	Abdeta (IG-118)	narbon vetch	2011	SARC/ OARI
21	*Vicia sativa*	ICARDA-61509	Vetch	2012	HARC/ EIAR
22	*Vicia sativa*	Gebisa	Vetch	2011	SARC/ OARI
23	*Vicia villosa*	Lalisa (IG-6792)	Wooly vetch	2011	SARC/ OARI
24	*Vigna unguiculata*	Adulala (ILRI-9352)	Cowpea	2018	MARC/ EIAR

Nº	Species	Variety Designation	Common Name	Year release	Breeder Institute
25	*Vigna unguiculata*	Melka (ILRI-9334)	Cowpea	2018	MARC/ EIAR
26	*Vigna unguiculata*	Temesgen (12668)	Cowpea	2014	HuARC-TRARI
27	*Vigna unguiculata*	Sewinet (ITS-3 KD-596)	Cowpea	2009	PARC/ EIAR
28	*Glycine max*	Milkii (TGX1990-114FN)	Forage soybean	2021	JARC/ EIAR
	Browse Tree and Shrub Legumes (14)				
1	*Cajanus cajan*	Afrasa	pigeon pea	2021	MARC/ EIAR
2	*Cajanus cajan*	Degaga (ILRI-11575)	pigeon pea	2017	S-MARC/TARI & BARC/OARI
3	*Cajanus cajan*	Degebasa (ILRI-1652)	pigeon pea	2017	BARC/OARI
4	*Cajanus cajan*	Kibret (ILRI-11555)	pigeon pea	2014	HuARC/ TRARI
5	*Cajanus cajan*	Tsigab (ILRI-11566)	pigeon pea	2014	HuARC/ TRARI
6	*Cajanus cajan*	Dursa (ICEAP-87091)	pigeon pea	2009	MARC/ EIAR
7	*Chamaecytisus palmensis*	-	Tagasaste	1992	HARC-EIAR
8	*Chamaecytisus palmensis*	Lattu (CI-15052)	Tagasaste	2018	HARC-EIAR
9	*Sesbania macrantha*	DZF-092	Sesbania	2012	DZARC
10	*Sesbania macrantha*	DZF-342	Macrantha	2012	SARC-TRARI
11	*Sesbania dummeri*	DZF-336	Dummeri	2018	DZARC
12	*Sesbania sesban*	DZF-405	Sesbania	2018	DZARC
13	*Desmodium hirtum* var. delicatulum	Teken	Desmodium	2019	HuARC-TRARI
14	*Rhynchosia minima* var. Prostrata	Eznianchiwa	Rhynchosia	2019	HuARC-TRARI

Source: EAA-PVRPSQCD, 2021.

Chapter II: Research and Achievements on Indigenous Legumes (Family Fabaceae)

2.1 Legumes Received High Research Emphasis in Ethiopia

There two major reasons, *inter alia*, why three-fourth of the hitherto research and development efforts has been invested on leguminous forages (family Fabaceae).

2.1.1. Biological and economic benefits

The first and foremost reason for prioritizing research on legumes centers on the benefit of legumes due to their peculiar natural characteristics. Some of these biological and economic benefits that are of universal, and not peculiar to Ethiopia, include:

a) Legumes have excellent attributes of high forage yield, nutritient composition and digestibility

Legumes are cheap sources of protein for poor people. Forage legumes provide livestock with highly nutritious forage. They are superior in protein, vitamin and minerals and highly digestible even at later stage of growth, thus providing livestock with balanced diets.

Legumes are important as components in grass-legume mixed pastures. They improve the palatability and digestibility of roughages by keeping the crude protein content above the critical level of 8 % below which voluntary intake declines (Whiteman, 1980). For example, the addition of clover hay to a straw or hay ration has been indicated to increase milk yield by 20 %, and percentage digestibility in sheep from 40 % to 60 % (Mosi and Butterworth, 1983). This would mean that the nutritional quality of crop residues that make up about 50% of the total feed resources of Ethiopia can be improved by the addition of fodder legumes.

b) Suitability of legumes for soil fertility maintenance and soil conservation practices

Legumes improve soil fertility through biological nitrogen fixation (BNF) thus creating an interface between agriculture and livestock production in smallholder farming through crop rotation or intercropping. Legumes play significant role in soil conservation and management when introduced in several applications such as over- under-sowings for resilience of pasturelands and contour band plantings. For example, several indigenous forage plants such as *Trifolium acaule, T. cryptopodium, T. semipilosum, Desmodium spp, Lotononis bainesii, Mimosa pigra* and *Zornia setosa*, all of which are of mat-forming growth habit and hence have the potential for rehabilitating degraded areas. Leguminous multi-purpose trees (MPTs) (*Leucaena, Sesbania, Calliandra, Chaemacytisus*) are the focus of current research in alley farming, agroforestry and silvo-agro-pastoral systems (Thotill, J. 1987; Tothill *et al* 1989). Therefore, targeted research aimed at selecting well adapted species among potential legume species is considered as an advocated strategy in forage research and development programs.

c) Legumes provide agro-ecosystem services

Leguminous crops provide a range of agro-ecosystems services for humans, including: (1) N (protein)-rich foods, feeds, and green manures; (2) lowering of the need for fertilizer N to support crop and pasture production as the result of contributions of symbiotically fixed dinitrogen to the growth of the legume host, and the subsequent improvement of soil fertility through inputs of legume organic residues (3) improvements in soil structural characteristics (4) direct impacts on soil biology by reducing the incidence of cereal root pathogens, and/or encouraging beneficial microorganisms of species grown in rotations reducing the requirement for pesticides and other agrichemicals, encouraging systems resilience and biodiversity (6) deep-rooted perennial legumes reducing the risk of groundwater contamination by nitrate (NO_3^-), or the development of dry land salinity, due to their ability to grow and extract water all year round (Erik et al, 2012).

d) Legumes contribute to mitigation of climate change

Legumes have the potential to contribute to the mitigation of climate change by reducing fossil fuel use or by providing feedstock for the emerging bio-based economies where fossil sources of energy and industrial raw materials are replaced in part by sustainable and renewable biomass resources (Erik *et al*, 2012). Legumes have the capacity to (1) lower the emissions of the key greenhouse gases carbon dioxide (CO_2) and nitrous oxide (N_2O) compared to N-fertilized systems, (2) reduce the fossil energy used in the production of food and forage, (3) contribute to the sequestration of carbon (C) in soils, and (4) provide a viable source of biomass for the generation of biofuels and other materials in future bio-refinery concepts. Emissions of the most potent greenhouse gas, N_2O tend to be lower under legumes than N-fertilized crops and pastures, particularly when commercially relevant rates of N fertilizer are applied. The other potent greenhouse gas, methane (CH_4) emitted from enteric fermentation in ruminants' digestion process can be substantially reduced by feeding legume containing pastures that are less fibrous and digestible. Soil organic carbon (SOC) concentrations can be increased when legumes are included in pastures; the impact of forage legumes is greatest in permanent pastures and with perennial legume species (Erik *et al*, 2012).

2.1.2. Access to legumes: most research institutions are in the highlands which are rich sources of potential forage legumes

In Ethiopia, highlands above 1800 m.a.s.l. cover about 450,000 km^2 or 38% of Ethiopia or 64% of the highlands of eastern Africa or 40% of the entire highlands of tropical Africa (Getahun, A., 1978). These highlands support the largest livestock population in tropical Africa. Likewise, 85% of the 120 million Ethiopians live in the highlands. The highlands contain pastures which constitute a valuable feed resource. Previous studies estimated that 67% of the livestock feed resources of the Ethiopian highlands are from native pastures (Alemayehu Mengistu, 1985; Jahnkey and Asamenew, 1983). These highlands are rich in legume plant genetic resources in the genera: *Trifolium, Biserula, Medicago, Lotus, Melilotus, Argyrolobium, Neonotonia* and *Alysicarpus* (Gillet 1952; Froman, B., 1975a; 1975b; Thulin, 1983). The genus *Trifolium* in particular, is found in high diversity and endemism in the highlands. Cognizant of this resource, researchers both from CADU and ILCA, were highly motivated to collect, screen and develop adapted varieties for livestock feed, and improvement of soil fertility for increased cereal yields as they are well adapted to the peculiar climatic and edaphic conditions of the highlands (Carlson, 1972; Kahurananga, J., 1982). Details of the diversity and distribution of the native legumes are discussed in the next sections.

It was in recognition of the immense potential of the forage legume for forage and soil fertility improvement on the one hand, and the need to meet good quality feed requirement of the high livestock population on the other, that about more than half of the allocated resource for forage research and development has been invested on leguminous species.

2.2 Forage Legume Genetic Resources, and Germplasm Collection Activities in Ethiopia

2.2.1. Legume plant genetic resources

The family of legumes- Fabaceae with its 613 species (64 of which are endemic) is the second largest family (next to Asteraceae), and one of the most economically important plant families in Ethiopia (Thulin, 1983).

Forage germplasm collection activities undertaken both by national (Carlson, 1972; Thulin, 1972) and international institutions such as ILCA (Kahurananga, 1982) were concentrated on the highlands. This is because the vast highland area (above 1800 m.a.sl.) that covers about 450,000 km^2 or 38% of Ethiopia or 40% of the entire highlands of tropical Africa (Getahun, A, 1978) is home to many potential forage legume species. The permanent grasslands and fallow areas found in the highlands are very rich in legumes particularly clovers of the genus *Trifolium*. Out of a total of

40 *Trifolium* species found in eastern Africa 30 species are present in Ethiopia out of which 10 are endemic, being only found in Ethiopia (Gillet, 1952; Gillet *et al*, 1971; Thulin, 1983) (Appendix 1). Indeed, Ethiopia is a secondary center of origin of the genus *Trifolium* (Zohary, M., 1972; Zohary, M. and D. Heller. 1984).

2.3 Evaluation of native annual clovers (*Trifolium*) for forage yield and nutritional quality

Earlier observations in Ethiopia indicated that native clovers have potential for pasture production (CADU, 1972). CADU undertook collection of clovers in the highlands of Arsi and Bale highlands as early as the 1970s.

Similar species from east Africa tested in Australia showed promising results (Mannetje, 1964; Jones and Cook, 1981). In recognition of the immense potential of the indigenous clover species, the International ILCA embarked on evaluation of selected annual clover species in the first phase of agronomic screening (Kahurananga J., 1982). Out of the initial collections of about 601 accessions of different species of clovers collected from the Ethiopian highlands (Kahurananga, J and Mengistu, S., 1983; 1984), 22 accessions of 7 annual *Trifolium* species were evaluated for dry matter (DM) yield at Shola (ILCA's compound, 2,400 m.a.s.l.) under two levels (0 and 40 kg ha^{-1}) of phosphorus (P) fertilizer application with the aim to determine their suitability for hay production (Kahurananga, J., 1984). The DM yield ranged between 2051 kg ha^{-1} (*T. steudneri*) and 6820 kg ha^{-1} (*T. tembense*). The authors summarized the performance of the species, and this is presented in Table 2.2.

Table 2.2. Highest yield and range of DM yields (kg ha^{-1}) of fertilized and unfertilized accessions of annual *Trifolium* species grown at Shola in 1983*.

Species & N° of Accessions (Ac)	Mean DM yield		Remarks
	Fertilized (P)	Unfertilized (P)	
T. decorum Ac. 1	5872	1184	
T. decorum Ac. 2 – 5	3594 – 5572	436 – 708	Range of 5 accessions
T. quartinianum	5706	1031	
T. rueppelianum Ac. 1	3823	462	
T. rueppelianum Ac. 1 – 2	2736 – 3508	261 - 783	Range of 2 accessions
T. schimperi	2090	1125	
T. steudneri Ac. 1	2051	1174	
T. steudneri Ac. 2	5295	1186	
T. tembense Ac. 1	6820	752	
T. tembense Ac. 2 –7	3084 – 5845	741 – 694	Range of 7 accessions
T. sp.	1473	650	

*Source: adapted from Kahurananga, J. and A. Tsehay, 1984a; 1984b (*data abridged*)

The following year, a trial was conducted to determine the inter- and intra-specific DM yield and seed yield and flowering variation of five annual native *Trifolium* species (*T. steudneri, T quartinianum, T. rueppellianum, T. tembense* and *T decorum*) on clay soils at Shola with 40 kgha1 phosphorus fertilizer application (Kahurananga and Tsehay, 1984a; 1984b). The result showed that mean DM yield differences between species were less significant than those within species except for *T. rueppellianum* which exhibited less significant intraspecific differences and *T. tembense* which showed no significant differences at all. In seed yield both the interspecies and intra-species differences were significant in *T. tembense* and *T. quartinianum* but more than those within *T. steudneri* and *T. rueppellianum*. *T. decorum* never reached full flowering and therefore produced very low and insignificant yields. The best overall performance was shown by *T. steudneri* that produced 1,000 kgha^{-1} seed. *T. quartinianum* came second in overall performance (Table 2.3).

Table 2.3. Mean and range DM and seed yields and flowering time of native annual *Trifolium* species grown at Shola

Species	DM yield (t ha^{-1})	Seed yield (t ha^{-1})	Das to 50% flowering
T. steudneri	5.493 (4.45 – 6.97)	1.32 (1.11 – 1.45)	79.6 (67 - 93)
T. quartinianum	6.535	1.11	92.3 (80 - 102)
T. rueppellianum	4.819	0.313	82.2 (72 - 87)
T. tembense	5.646	0.558	89.3 (85 - 123)
T. decorum	5.428	0.037	123 (122 - 126)

Source: Kahurananga and Tsehay, 1985.

In a summary report of the yield response of native clovers to phosphorus (P) fertilizer application Kahurananga *et al* (1984), stated that whole plant weights measured from pot trials showed dramatic yield response to P. The addition of 30 kg/ha P increased DM yield of individual plants six-fold by the 12th week; root-weight threefold and twice the number of nodules. Seedling establishment was faster with the addition of N but N tended to retard inflorescence formation and the number of inflorescences per plant was reduced at the higher levels. At field level, the highest yield was 6.2 t/ha given by *T. quartinianum* at 35 kg/ha P harvested at 120 days. *T. tembense* gave 5.4 t/ha at the same fertilizer level and harvest date. DM yield responses were more pronounced in *T. tembense* than *T. rueppellianum* at increasing levels of P. In a separate experiment with P fertilizer, interspecific yield differences were slightly more significant than intraspecific ones (Kahurananga *et al*, 1984). The highest yield was given by *T. tembense* which produced 6.88 t/ha. The highest yields of *T. tembense, T. quartinianum* and *T. decorum* were significantly higher than the highest yields of *T. rueppellianum, T. schimperi*. There were no significant differences under no fertilizer treatment. The authors presented a summary table containing experimental results of DM yield, response to P and nutritional content of 7 native clover species, and this is presented in slightly modified form in Table 2.4.

Table 2.4. Top average DM yields (under 40 kg/ha P application), and some nutritional value of 7 native annual *Trifolium* grown at Shola.

Species	DM yield (t/ha)	% CP	% IVDMD	Reference
T. decorum	5.8	19.8	76.0	Kahurananga, 1982; Kahurananga & Tsehay, 1983
T. quartinianum	6.2	-	-	Akundabweni, 1984
T. rueppellianum	5.2	19.0	75.88	Kahurananga, 1982
T. schimperi	2.9	-	-	Kahurananga & Tsehay, 1983; 1984
T. steudneri	5.3	19.1	73.56	Kahurananga, 1982; Kahurananga & Tsehay, 1983
T. tembense	6.8	21.3	74.09	Kahurananga, 1982; Kahurananga & Tsehay, 1983
T. sp	1.5	-	-	Kahurananga, 1982; Kahurananga & Tsehay, 1983

Source: Adapted from: Kauranaga *et al*, 1984.

2.3.1. Evaluation of native annual clovers for integration with food crops

2.3.1.1. Annual clover undersowing in cereal crops

Earlier observations in Ethiopia indicated that native annual clovers have potential for soil improvement in highland cropping systems. Abate Tedla *et al*, (1992) conducted a study to assess the effects of clover under-sowing on grain straw, total crop residue, biomass and nutritive value of straw and fodder of several wheat varieties on highland black clay soils (*Vertisols*). Treatments included: *Trifolium steudneri*, and *Trifolium rueppellianum* sown as 1:1 mixture (for medium altitude) and *Trifolium tembense, Trifolium quartinianum* and *Trifolium steudneri* as one mixture of equal proportion. Wheat vars. Enkoy, Boohai and Gerardo were used for the mid-altitude locations. For the high altitude, bread wheat vars. Et 13, Dashen, and Har 407 were used all at the rate of 150 kg ha^{-1}. Clovers were sown in the same day as wheat at a rate of 10 kg/ha. DAP was applied at the rate of 100 kg/ha at planting. Nutritional values including Crude protein (CP), neutral detergent fiber (NDF), *in-vitro* dry matter digestibility (IVDMD) of straw and total fodder for three varieties of wheat was determined in the laboratory following standard procedures. The result indicated that clover mixtures in association with wheat varieties did not cause significant wheat grain yield reductions, but the system significantly increased the total fodder yield compared with the straw produced by wheat varieties grown in pure stands. The system also resulted in significant increases in CP and IVOMD contents of total fodder, and decreased NDF content in the wheat clover combination. The authors concluded that native clovers could grow together with wheat varieties without adversely affecting the wheat grain yield. Undersowing native clovers in wheat increased the total crop residue yield which is an advantage to Ethiopian farmers who face land constraints and so cannot allocate land to grow forages separately from food crops. Furthermore, improvement in the quality of wheat crop residue due to clovers association in the cropping would provide smallholder farmers good opportunity for their livestock in terms of better utilization of available crop residues and livestock performance during the dry season (Abate Tedila. *et al*, 1992).

In a similar study on native clovers integration into cereal cropping systems (Tekalign Mamo *et al*, 1993) a series of experiments were undertaken on highland black clay soils (*Vertisols*). The aim was to investigate the suitable date of planting wheat undersown with clovers for optimum grain and fodder yield and to assess the effect of clover undersowing on wheat grain and stover yields and total biomass production. The clovers were: *Trifolium steudneri, Trifolium quartinianum* (for lowlands), and *Trifolium rueppellianum, Trifolium tembense, and Trifolium decorum* (for highlands), sown as a mixture of equal proportion, at a seeding rate of 10 kg ha^{-1}. Sowing dates were: 1, on the same day as wheat varieties or 2, one month later than sowing wheat varieties. Wheat varieties were: Enkoy, Et-13, Dashen, Boohai, Gerardo (selected based on altitude). Fertilizer DAP was applied at the rate of 100 kg ha^{-1} at planting. The result showed that wheat varieties grown in medium altitudes had no reduction in grain yield due to the presence of clover mixture under wheat across all locations and seasons. Undersowing clovers in wheat significantly increased the amount of crop residues produced per unit area. Early planting of clovers with wheat was found to be more suitable date of planting than planting a month later. The authors concluded that clovers could grow together with food crops without adversely affecting wheat grain yield. The system can provide a high-quality crop residue in smallholder situations where livestock suffer from poor nutrition and land is a constraint to grow separately from food crops. As legumes have the capacity of fixing atmospheric N_2 it could in the long-term contribute to the maintenance of soil fertility.

Recognizing the potential of native clovers for soil fertility improvement ILCA launched a project to evaluate the effect of *Trifolium steudneri* grown in rotation with oats on upland vertisols (Weise, 1986). The clover was reported to have increased the yield of oats crop, and fixed up to 60 kg N/ha/yr. Thus, the authors concluded, clovers with their soil fertility maintenance capacity and provision of stock with high quality feed can create an important interface between the crop and livestock sectors.

2.3.1.2. Annual forage legume rotation with cereal crops (ARDU)

At ARDU, a crop rotation experiment was conducted to study the effect of indigenous legumes on subsequent cereal crops, wheat (ARDU, 1980). The highest wheat yield was obtained when wheat followed *Vicia dasycarpa*. An increment of 620 kg was obtained, i.e., 74% increment of wheat yield as compared to the monoculture (wheat after wheat) Table 2.5.

Table 2.5. The effect of indigenous forage legumes on subsequent cereal crops at Kulumsa.

Treatment	Clean wheat grain yield (kg)
Wheat after fallow	1319
Wheat after wheat	833
Wheat after *Trifolium rueppelianum*	1250
Wheat after *Melilotus altisimus*	1181
Wheat after *Vicia dasycarpa*	1458

Source: adapted from ARDU, 1980.

2.3.1.3. Fitting forages into traditional cropping systems (DZARC)

Production of conventional pastures at the level of the subsistence farming community has been a remote goal to achieve. One of the maor reasons is poor resource capacity of the farmers to adopt package of improved forage technologies including responsive animal breeds. Availability of arable land of moderate fertility is critical to promote even pro-poor fodder technologies especially in the highlands of Ethiopia, where average land holding is less than a hectare. Under such situations farmers found it difficult to allocate their arable land holdings to grow improved forage crops recommended to them. As alternative approach, researchers at DZARC identified systems of introducing short-term fodder crops into the existing cropping system without displacing or negatively affecting food and cash crops. One of such systems developed at DZARC was sequential cropping of annual legume species and short duration pulse crops such as chickpea and grasspea. The following experiment conducted at DZARC led to achieve a successful technology of introducing improved forages to the subsistence farmer (Solomon Mengistu *et al,* 2010).

Box 2.1. The experiment was conceived from field observation of the traditional crop rotation system on black clay soils (*Vertisols*) around Debre Zeit, which consists of two seasons under cereals followed by a season under pulse crop (e.g., tef-wheat-chickpea or grasspea) (Fig. 2.2). The third season under the two popular pulses: chickpea or grasspea attracted the interest of DZARC forage researchers. Chickpea is adapted to grow on residual soil moisture on heavy clay soils. Farmers plant chickpea (or grasspea) towards the end of the main rainy season (*meher*), usually from Sept. 20 to 27 (Meskerem 10 – 17 EC). The land meant for the third cycle crops literally stays idle from the start of the rains up to about mid-September. If the meher rain starts on mid June, the latest (allowing for unusual delays), there is roughly 75 – 80 days, which is good enough to produce annual forage legumes that are well adapted to black clay soils, such as *Trifolium quartinianum*, *T. steudneri*, *Vicia* and *Medicago* species (Fig. 2.3.).

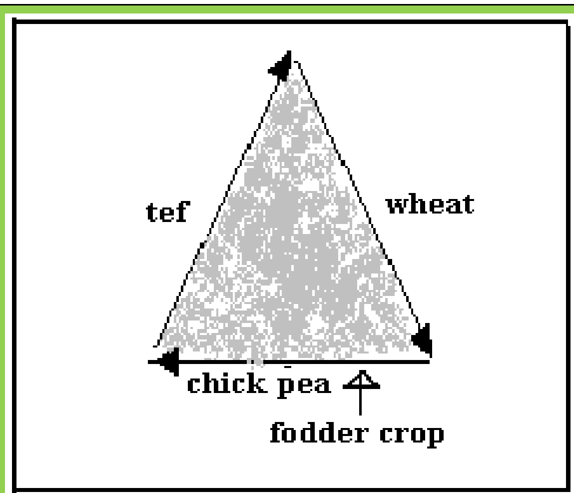


Fig. 2.2. Fitting annual forage legumes in the traditional cropping cycle in the highland *Vertisols.*

Fig.2.3. *Trifolium quartinianum*, a native annual clover selected for sequential cropping.

Taking this opportunity, long term experiment on sequential crops involving annual forage legumes and chickpea was conducted at DZARC (Solomon Mengistu *et al*, 2010). The result was encouraging (Fig. 2.6): forage DM yield of 4 – 6 t/ha (on-station) 2-4 t/ha (on-farm) plus 8 - 10 quintals of chickpea grain was produced in one season. The salient feature of the technology is that the grain yield of the food crop, chickpea was not affected because chickpea and grasspea) normally utilize the residual moisture retained in clay soils from September through to December. Additionally, the two legume crops (forage and pulse) contribute positively to the yield of the subsequent cereal crops, in this case durum wheat. Wheat yield ranged 15.36 to 25.94 quintals/ha. (Table 8, Section 2.3.1.3.). Ato Alitah (from Akaki) and other farmers from Lomme Woredas were happy to see the successful field demonstration (Fig. 2.4. and Fig. 2.5.).

Fig. 2.4. Obbo Alitah expressing his impression

Fig. 2.5. Sequential crops, planting chicpea after harvesting fodder mixture

The experiment was conducted with the aim to assess the possibility of sequential cropping of annual fodder legumes with chickpea under rain fed conditions on black clay soil (*Vertisol*) and explore the combined effect of these two legume crops on grain yield of a succeeding cereal crop (Solomon Mengistu et al, 2010). The experiment was conducted on a heavy soil (*Vertisol*) at two locations: Debre Zeit, 1800 m and at Akaki, 2200 m. The experiment consisted of crop rotation involving three phases: fodder (*Phase I*) (four annual legumes), pulse (*Phase II*) (chickpea) and cereal (*Phase III*) (durum wheat). The fodder and chickpea were grown sequentially over the main rainy season while wheat was grown in the following year, at four levels of nitrogen fertilizer.

The result of the experiment over three cycles (six years in total) from two locations is available in Solomon Mengistu *et al* (2010), which is presented phase by phase (*Phase I*, fodder; *Phase II*, chickpea; *Phase III*, wheat). For brief information, the data for one cycle and one location (Debre Zeit) is given in Table 6, Table 7 and Table 8, as follows.

Herbage yield

Herbage yield of annual forage legumes grown sequentially with chickpea ranged from 3 to 5.4 t/ha while the percent composition in the sward ranged 85.3% - 89.8% Table 2.6.

Nutrient composition

The nutritional quality of the fodder species as determined by laboratory analysis for the more critical attributes did not vary greatly among species and between locations (Table 7). The in-vitro digestibility (>40%) and crude protein (>22%) recorded for all the species was reasonably high and generally falls within the standard nutritional levels reported for tropical ruminant livestock (Kearl, 1982). The observed high nutritional quality is expectable from such early harvested fodder crops, most of which were from initial to 50% flowering at the time of harvest.

Table 2.6. Botanical composition and herbage yield of annual legume species grown sequentially with chickpea at Debre Zeit.

Species	Sward composition		Sown Legume	
	% Sown legume	% Weed	DM%	DM yield t/ha
Medicago scutellata	85.32	6.92	22.59	3.039
Trifolium quartinianum	89.76	2.19	14.18	5.384
Trifolium steudneri	85.87	6.90	17.50	4.306
Vicia dasycarpa	86.08	5.23	18.25	2.958
Statistical significance	*NS*	*NS*	*0.01*	*0.01*
C.V%	*7.64*		*17.92*	*27.07*

Source : Solomon Mengistu *et al*, 2010.

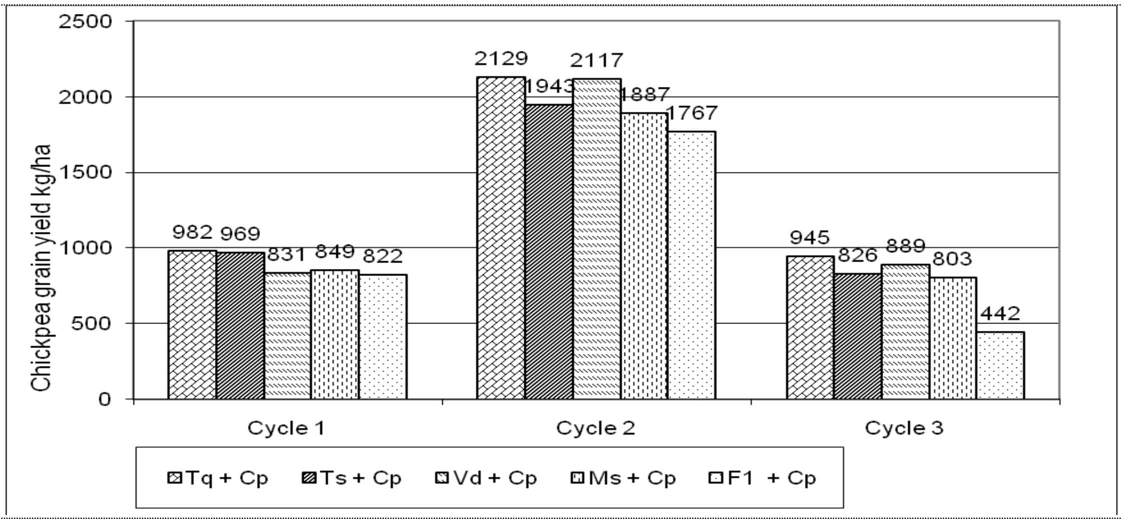
Table 2.7. Crude protein (CP) and in-vitro dry matter digestibility (IVOMD) of annual forage legume species grown as double crop with chickpea on a *Vertisol*, at Debre Zeit and Akaki sites.

Fodder species	Debre Zeit		Akaki	
	CP%	IVOMD%	CP%	IVOMD%
Trifolium quartinianum	24.10	39.63	21.49	49.64
Trifolium steudneri	26.67	41.55	26.12	72.92
Vicia dasycarpa	26.44	46.32	18.33	73.81
Mdicago scutellata	23.48	48.00	22.94	47.94

Source: adapted from Solomon Mengistu *et al*, 2010

Chickpea grain yield

Chickpea (the Phase II crop): almost uniformly over the three cycles of the experiment, within a few days after harvesting fodder crops, chickpea was planted on the vacated plots around September 10-12 EC (Debre Zeit) and September 15-20 EC (Akaki), when intermittent rain was available to initiate germination. Thereafter, the crop utilized the residual soil moisture retained by the heavy clay soil colloids of the *Vertisols*. At Debre Zeit, mean grain yield was in the range 822-982 kg ha^{-1} in *Cycle I* and there was no significant (P>0.05) difference because of the preceding fodder crops, which emplies that all the legume species had positive effect especially in biological nitrogen fixation (BNF). (Figure 2.6).



Note: LSD (alpha 0.05) for *Cycle II*= 111.3; *Cycle III*= 253.4. Designations: "T. q.+Cp" = *Trifolium quartinianum* before chickpea; "T.s+Cp" = *T. steudneri* before chickpea; "V.d+Cp" = *Vicia dasycarpa* before chickpea; "M.s+Cp" = *Medicago scutellata* before chickpea; "F1+Cp" = Fallow (partial) before chickpea.

Figure 2.6. Grain yield of chickpea var. DZ-1011 grown as double / sequential crop with fodder species for three cycles on a *Vertisol* at Debre Zeit.
Source: adapted from Solomon Mengistu *et al*, 2010.

As the third phase of the experiment, durum wheat var. Kilinto was grown. In the first cycle, the mean grain yield of var. Kilinto showed significant difference in response to the treatments in the preceding phases as well as to the nitrogen fertilizer application rates (four levels) at both Debre Zeit and Akaki sites. The mean grain ield of durum wheat ranged from 15.36 to 25.94 quintals/ha (Table 2.8).

Table 2.8. Grain yield response of durum wheat var. Kilinto to sequentially grown precursor crops of annual fodder species and chickpea in *Cycle I*, grown at 4 levels of N at Debre Zeit.

Phases I & II crops (Fodder + chickpea)	Phase III. Wheat yield (Kg/ha) at four levels of N_2 application				
	64 N*	32 N	18 N	0 N	Mean
T. quartinianum + CP	2885AB	2790BC	2385EFG	1575IJ	2409B
T. steudneri + CP	2790BC	2446DEF	2227FG	1414JK	2219C
V. dasycarpa + CP	3052A	2891AB	2559CDE	1876H	2594A
M. scutellata + CP	2672BCD	2318FG	2162G	1569IJ	2181C
ρF1 + CP	2448DEF	1698HI	1689HI	1286KL	1780D
@F2	2171G	1496IJK	1322KL	1156L	1536E
LSD (α0.05)	*235.5*				
N_2 means	2670A*2	2273B	2057C	1479D	
LSD (α0.05)	127.6				117.8
C.V. %	6.73				

* N fertilizer levels: optimum level (64 kg N/ha), sub-optimum (32 kg N/ha), low level (18 kg N/ha), & zero (without N). DMθ = dry matter herbage; *1NS = Not significant; ©CP = chickpea; ρF1= partial season fallow during phase I; @F2= fallow for full season during phases I and II. *2Means followed by similar letters are not significantly different at α 0.05.

Source: adapted from Solomon Mengistu *et al*, 2010.

The researchers concluded: "The present long-term experiment enabled to identify a number of short-duration forage legumes with attributes of tolerance to water logging; fast growth and high DM accumulation potential that confer an opportunity of growing them as double crop with late-season pulse crops such as chickpea (also possible with grass pea, data not shown). Moreover, the phenology and growth form of these crops make them well suited for conserved fodder production in which they can be raised either as pure stand or in mixture with annual fodder grass species such as oats (Solomon Mengistu, 2006). A notable feature of this food and fodder crop integration technology is that the traditional cropping cycle has not been altered. Therefore, the technology is expected to have high scope for adoption by the smallholder farmers as has been learned from an on-farm verification trials launched in three Woredas around Debre Zeit (Adaa, Lomme and Ginbicho) (data available in Kebebew Asefa *et al*, 2005; Negussie *et al*, 2008).

Finally, the researchers recommended "Further on-farm verifications of the technology at a national level should ideally include areas from the medium and higher-highland zones (1500 m altitude and above) characterized by mixed crop/livestock farming systems; where black heavy clay soils (*Vertisols*) make up a good proportion of the arable land; mean annual rainfall of at least 800 mm, with a continuous distribution of about 90 days or longer".

2.1.3.4. On-farm evaluation of annual fodder legume crops and their effects on subsequent cereal crop on highland Vertisols.

An on-farm demonstration was proposed by the DZARC researchers at two locations (Akaki and Lomme) (Kebebew Asefa *et al*, 2005; Negussie Tadese *et al*, 2008) with the obectives to: 1) assess the comparative value of three types of fodder crops, namely, pure oats, oats/vetch and oats/clover (*T. quartinianum)* mixtures as livestock feed at farmer's management level 2) assess the contribution of the fodder mixtures on a subsequent cereal crop.

Phase I and II- Fodder and pulse crops

Each of the three plots under fodder crop was split into two equal subplots. One subplot was harvested in mid September representing the fodder component of a forage-food crop double cropping system (Phase I), while the other half was allowed to grow until the oats component reached milk stage (maximum yield) and then harvested representing a full season conventional hay crop. The vacated subplot allotted for sequential/double cropping system at each farm was, as immediately as possible, sown to a subsequent crop of chickpea (Phase II) that utilizes the residual soil moisture.

Results

Phase I: Forage yield and quality

Fodder yields in the range of 2.1 to 3.2 t/ha dry matter were recorded for the eight on-farm experiments involving three types of fodder crops, the highest yield being from the oats/vetch mixture (Table 2.9). Similarly, the highest mean legume content was from the oats/vetch mixture (25.92%) compared with the oats/ *Trifolium quartinianum* mixture (18.31%), indicating that vetch had been better adapted to wider areas and hence more competitive with oats as compared with *Trifolium quartinianum*. Since a high proportion of legume in a fodder mixture is indicative of forage quality (high palatability and digestibility), for most of the areas the oats/vetch mixture seems to be a suitable fodder crop for integrated forage-cereal crops production systems.

Table 2.9. Herbage yield of fodder crops recorded for Akaki and Lomme Woredas

		Fodder yield (t/ha)		% Composition of the sward		
District	Fodder crop type	Fresh	Dry*	Grass	Legume	Weed
Lome	Oats/Quartins clover	14.328	3.224	90.08	5.58	4.35
Akaki	Oats/Quartins clover	5.878	1.137	44.79	31.04	24.18
	Mean	**10.103**	**2.180**	**67.43**	**18.31**	**14.26**
Lome	Oats/Vetch	22.833	4.590	68.99	31.01	0.00
Akaki	Oats/Vetch	9.494	1.823	76.51	20.83	2.67
	Mean	**16.164**	**3.207**	**72.75**	**25.92**	**1.33**
Lome	Oats, pure	19.434	4.103	99.40	0.00	0.60
Akaki	Oats, pure	6.729	1.515	89.94	0.00	10.06
	Mean	**13.082**	**2.809**	**94.67**	**0.00**	**5.33**
* Oven dry weight with approximately 5% moisture						

Source: adapted from Negussie Tadese, et al 2008; Kebebew Asefa *et al*, 2005.

Farmers perception

Farmers were requested to rank the fodder types based on their visual observation of the standing crop and on the palatability of the cured fodders when fed to cattle. Most farmers ranked oats/vetch mixture first and the pure oats last (Table 2.10). At Akaki, vetch did not perform as good as at Lomme, which might be due to the cold temperature prevailing at the former Woreda and hence, as expected, the farmers gave oats/vetch fodder low or comparable rank with oats/clover. Overall, the farmers appreciated the technique of high-quality fodder production on a plot of land that would stay idle over three-fourth of the growing season until the traditional sowing period of chickpea or Lathyrus. Some farmers even went beyond appreciation and asked for supply of fodder seed in quantities enough to sow hectares of land

Table 2.10. Ranking for fodder quality by participating farmers in Akaki and Lomme Woredas.

Woreda (district)	Kebele (village)	Farmer name	Sowing date (EC)	Harvest date (EC)	Fodder quality ranking (1 best – 5, least)		
					Vetch/oats	Clover/oats	Oats, pure
Lome	Dekabora	Ashebir	28/10/97	13/01/98	1	2	3
Lome	Dekabora	Shimelis	01/11/97	13/01/98	1	2	2
Lome	Tulu Rea	Solomon	28/10/97	13/01/98	1	2	3
Lome	Kelba Gode	Tamiru	01/11/97	16/01/98	1	2	3
Akaki	Gelan	Alittah	06/11/97	18/01/98	1	1	2
Akaki	Gelan	Tadele	06/11/97	18/11/98	1	1	2
Akaki	Gelan	Tolla	06/11/97	18/11/98	2	1	3
Akaki	Gelan	Shewalef	06/11/97	20/11/98	1	2	3

Source: adapted from Negussie Tadese, *et al* 2008; DZARC 2005.

Phase II: Chickpea- the second crop

The second crop- chickpea was successfully planted in mid-September on most farmers' plots of Lomme Woreda and the germination and seedling performance of the chickpea has been very good. In Akaki Woreda, most of the farmers planted the second crop of chickpea during the last week of September, since according to their justification, the rain extends up to late September, at which time the heavy clay soil stays waterlogged and difficult to plough by oxen. In both Woredas, the farmers were confident that the second crop would successfully establish since the planting operation was accomplished within the traditional sowing calendar.

Fig 2.7. Sequentially cropped annual forage legumes and chickpea on farmers' field at Lomme village. Adapted from Negussie Tadese, *et al*, 2008; Kebebew Asefa *et al*, 2005.

2.4. Evaluation of native perennial clovers for forage yield and nutritional quality

Earlier research conducted in Australia (Mannetje, 1964) and in Kenya (Strange, 1958; Bogdan, 1965a; 1965b) have shown the potential of African clovers for forage. Kenya white clover (*Trifolium semipilosum)* cultivar Safari was developed from material collected in Kenya (Jones and Cook, 1981). Initial research conducted by CADU on a few species sporadically collected in Arssi area (CADU, 1972) has shown the general magnitude of productivity of the native species and hence the need for continued research emphasis.

Contemporary to CADU, ILCA undertook screening of perennial native clover species that were collected in the second phase of germplasm collection project (Kahurananga, J. and Mengistu, S. 1983; 1984). A list of the species and varieties collected by ILCA is presented in Table 2.11.

Table 2.11. Perennial clover species germplasm collected from Ethiopian highlands

Species and variety	No of accessions Collected	Distribution
Trifolium acaule	5	Northern, central and southern highlands
T. calocephalum	13	Northern, central and southern highlands
Trifolium cryptoodium	64	Northern and central highlands
T. burchellianum var. johnstonii	41	Arsi and Bale highlands
T. burchellianum var. oblongum	8	Bale mountains
T. semipilosum (4 vars)	132	
var. brunelli		Arsi, Bale and Sidama highlands
var. glabrescens		South-western highlands

var. intermedium		Central highlands, Debresina
var. semipilosum		Northern, central and southern highlands
T. polystachyum	32	Northern, central and southern highlands
Trifolium simense	55	Northern and central highlands
Trifolium somalense	1	Southern highlands, Sidama
T. spanathum	2	Southern highlands, Arsi, Bale, Keffa
Trifolium usambarense	1	South-western highlands
Total	354*	*Additional 528 accessions of annual clovers were collected (in total 882)

Source: Kahurananga, J., 1987; 1988; Kahurananga, J. and Solomon Mengistu, 1983; 1984).

Screening of some native perennial *Trifolium* species was conducted at ILCA Headquarters in Shola, Addis Ababa in 1985 (Kahurananga J., 1988). Ninety-eight accessions of five species including *Trifolium cryptopodium* (13)*, T. burchellianum var johnstonii* (23)*, T. africanum* (2)*, T. semipilosum var semipilosum* (57) including cv Safari for comparison together with *T. repens* (European white clover; used as control) were screened for yield and persistence on a gently sloping site with seasonally waterlogged black clay soil typical of the bottomlands of the Ethiopian highlands traditionally used for hay production and grazing (Kahurananga J., 1987). The accessions were grown from pre-germinated seedlings of 7 - 9 weeks old (to achieve nearly uniform stands) which were transplanted into a well cultivated field. TSP was applied at a rate of 40 kg P ha^{-1}. Two handfuls each of sheep manure were put in the holes and mixed with soil into which seedlings were transplanted. The results showed that *T. cryptopodium* had the highest DM production followed by *T. burchellianum* var. *johnstonii*. All varieties of *T. semipilosum* had lower DM with var. *semipilosum, glabrescens*, including c.v. Safari, i*ntermedium* and *brunellii* in that order. *T. repens, T. africanum* and *T. burchellianum* var. *blongum* had the lowest DM production. Again *T. cryptopodium* and *T. burchellianum* had the best vigour or green leaf retention during the dry season. *T. semipilosum* varieties shed most of their leaves during the dry season and those which remained turned copper red (Table 2.12).

The other species which showed good productivity, and which persisted well during the dry season was *T. burchellianum* var. *johnstonii*. This characteristic is rather surprising as this species is normally distributed in moist grasslands and open glades in forests where rainfall is above 1000 mm (Gillett *et al*., 1971; Thulin, 1983). This species is found growing with *T. cryptopodium*. Its major limitation is the poor flowering and hence seed production. This was also observed in one of the early glasshouse experiments where it failed to flower altogether (Pritchard, A.J, and Mannetje L. 1967). However, in the trial (Kahurananga, 1987) there were two accessions, one from Ethiopia and the other from Tanzania which had good flowering. Kahurananga concluded that there are possibilities for selection, and that the species had good potential for use in pasture for both cattle and sheep, and it is also suitable for soil conservation.

Table 2.12. Average and range of the important observations of perennial *Trifolium* at Shola in 1985 and 1986.

Species and variety	Number of accessions	Dry season vigor (scale: 1-10)	DM weight per plant (g)	Days to first flowering	% plants in flower
T. africanum	3	4 (3-4)	69 (20-176)	192 (176-207)	60 (50-70)
T. burchellianum var. johnstonii	23	6 (4-9)	192 (11-342)	185 (182-252)	23 (0-50)
T. burchellianum var. oblongum	1	5 (5)	49 (31-71)	139 (139)	10 (10)
T. cryptoodium	13	6 (3-8)	224 (42-569)	212 (181-233)	49 (30-80)
T. repens	1	5 (5)	61 (21-160)	183 (183)	30 (30)
T. semipilosum var. brunelli	1	1 (1)	68 (4-14)	221 (221)	50 (50)
T. semipilosum var. glabrescens	12	3 (1-7)	111 (11-240)	156 (119-184)	98 (90-100)
T. semipilosum var. intermedium	2	3 (2-3)	87 (55-120)	223 (217-228)	50 (50)
T. semipilosum var. semipilosum	42	4 (1-7)	147 (41-222)	205 (166-231)	88 (40-100)
Total	98				

Source: Adapted from Kahurananga, J., 1987

The author reported that average productivity of *T. semipilosum* including var. glabrescens c.v. Safari fared poorly but still there were some accessions which did well. On the other hand, the species was reported to have excellent flowering attribute, and the pods do not shatter so easily making it more suitable for seed production. It was also reported to grow well naturally with grasses in pasture, and it is found in a very wide range of altitudes, edaphic conditions for both cattle and sheep and for soil conservation. Its spreading growth habit and stout taproot that extends deep into subsoil makes it to withstand very heavy grazing in communal natural pastures. The author remarked that the screening trial has proved that the perennial *Trifolium* species have good potential for use in pasture and that they could be used in establishing new pastures or on fallow areas including marginal areas. They could as well be useful in reseeding degraded areas. In his concluding summary report the author mentioned that it was the first time that Ethiopian perennial *Trifolium* species were being evaluated. In all the clovers showed good soil binding properties. *T. cryptopodium* in particular with its numerous mat-forming rhizomes was most outstanding. Its superior yield performance was according to the author's presumption associated with its dense rhizomatous growth. Its small leaves and short-rooted internodes make it more suitable for sheep grazing. It also grows well with good forage grasses like *Andropogon distachyos, A. amethystinus, A. abysinicus, Pennisetum thunbergii* and *P. clandestinum* (Kikuyu grass).

2.5. Evaluation of indigenous medics (genus *Medicago*)

2.5.1. Botany, distribution, and germplasm collection

Medics belong to the genus *Medicago* (that includes the perennial cultivated forage crop-*Medicago sativa*, alfalfa/ Lucerne). Medics are herbaceous legumes with trifoliate leaves looking like clovers. There are about 50 species of medics most of them Mediterranean origin. In Ethiopia, some 5 species are recorded as indigenous, most of them distributed in the northern and central highlands of Ethiopia (Thulin, 1983). All the five are annuals, found as components of upland natural pastures and as weeds of arable crops. These include: *Medicago lupulina* (black medic), *M. polymorpha* (bur clover), *M. minima, M. orbicularis* and *M. laciniata*. Out of these, the widely distributed and vigorous species *M. polymorpha* was deemed to have promise as forage and for soil fertility improvement and thus it received attention in ILCA's germplasm collection and screening program (Table 2.13).

Table 2.13. Medicago germplasm collected during 1983 – 84 by ILCA

Species	No of accessions Collected	Distribution
Medicago lupulina	1	Northern highlands, Wollo
Medicago polymorpha	12	Northern, central and Southern highlands
Medicago minima	1	Northern, central and Southern highlands
Total	14	

2.5.2. Evaluation of medics for growth vigor and herbage yield

The only medic that received research attention in Ethiopia was burr medic (*M. polymorpha*) due to its wide range of adaptation throughout the highlands of Ethiopia. Its competitiveness in the swards of native grazing lands is remarkable.

Fifty-one accessions of *Medicago polymorpha* obtained from ILRI were evaluated for earliness of emergence, plant vigor, plot cover, plant height and DM yield at HARC (HARC, 2018). The objective was to select vigorous and competitive in a natural pasture in the Ethiopian highland natural pastures, for eventual use of over-sowing lay pastures to improve herbage yield and quality. The best performing 12 accessions obtained from ILRI (previously collected in Ethiopia), plus two collections from the natural pasture at HARC campus were selected on the bases of their agronomic performance over two years (2017 - 2018). The average growth and agronomic performance is presented in Table 2.14. Further multi-locational agronomic evaluation of these short-listed accessions was planned to reselect the best 2 to 3 accessions that can be widely used to over-sow highland natural pastures (HARC, 2018).

Table 2.14. Medicago polmorpha lines selecyed for advanced agronomic evaluation at HARC.

Species / accessions	Score (on a scale of 1 - 10)			Stand Height	Maturity class
	Emergence	Plot cover	Stand vigor		
M. polymorpha, ILRI-10150	6	8	7.5	15	Intermediate
M. polymorpha, ILRI-10192	5	7.5	7.5	16	Intermediate
M. polymorpha, ILRI-16156	6	7	8	16	Intermediate
M. polymorpha, ILRI7762	7	9.5	9	22.5	Intermediate
M. polymorpha, ILRI-8468	6	9	9	20	Intermediate
M. polymorpha, ILRI-8487	5	9	9	21	Early set
M. polymorpha, ILRI8490	6	9	9	20	Early set
M. polymorpha, ILRI-8492	7	9	9	22.5	Intermediate
M. polymorpha, ILRI-8576	7	8.5	8.5	22	Intermediate
M. polymorpha, ILRI-8579	5	9	9	20.5	Intermediate
M. polymorpha, ILRI-907	6	9	8.5	15	Late set
M. polymorpha, ILRI-10136	5	8.5	7.5	20	Intermediate
M. polymorpha, HARC-01	7	8	8	26	Intermediate
M. polymorpha, HARC-02	7	9	9	23	Early set

Source: HARC, 2018

2.6. Evaluation of indigenous sesbanias (genus *Sesbania*)

2.6.1. Botany, distribution, and germplasm collection

The genus *Sesbania* **Scopoli** consisting of about 50 species distributed pan-tropically, is placed in the subfamily **Papilionoideae**, tribe **Robineae** (Gillet, 1963; 1971). The genus is divided into five subgenera *Sesbania, Agathi, Daubentonia, Pterosesbania* and *Glotidium*. The subgenera *Sesbania* and *Agathi* contain species of potential agricultural value (Evans and Rotar, 1987). Many species known as green manure and fodder crops such as *S. sesban* and *S. bispinosa* are in the subgenus *Sesbania*. The subgenus *Agathi* of southern Asia contains the tree species *S. grandiflora* and *S. formosa* (Evans, 1988)

Gillet (1963) reported 33 sesbania species to be found in Africa, most of which are distributed in eastern Africa. An international expedition to survey and collect *Sesbania* in eastern Africa (Solomon Mengistu, 1990) confirmed the region as the major centre of diversity of the genus, in that species density was the highest in eastern Africa than elsewhere where the genus is reported to occur. In Tanzania alone, 15 species occur, which is almost equal to the total number of species reported for Australia (10 spp.) (Burbidge, 1965) and North America (7 spp) (Char, 1983). This shows the richness of the eastern African region in endemic and near endemic species and varieties of *Sesbania* (Table 2.15).

Table 2.15. Taxonomy and distribution of the genus *Sesbania*[1].

Subgenus	No of spp	Representative species	Distribution
Agati	4	*S. grandiflora, S. formmosa*	Asia, N.W. Australia
Daubentonia	3	*S. drummondii, S. punicea,*	North and South America
Glottiddium	1	*S. vesicaria*	South America
Pterosesbania	2	*S. tetraptera, S. rogersii*	Africa
Sesbania	24	*S. sesban, S. bispinosa*	Africa

[1]. Source: Gillet, 1963, Evans, 1988; Thulin, 1983

Some sesbanias are perennials, a few are short-lived (1-3 years) perennials, but most are annuals. Growth-form varies from a small herb of less than a meter to a six-meter-tall tree. The tree type *Sesbania* have soft woods of varying density and thickness. Vigorous ecotypes of *S. sesban* have large stems whose circumference measure up to 60 cm (Solomon Mengistu, 1990). Most sesbania inhabit moist areas, riverbanks and fresh or alkaline lake sides. Thulin (1983) reported 10 species to be found in Ethiopia, but later explorations undertaken by ILCA for sesbania, and other browse species discovered two more species: *S. rostrata* (arial nodulating) in Gambella, Larie district, and *S. macrantha* in Gamo Gofa and in Didessa Valley (Wollega) (Solomon Mengistu, 1984a) (Table 2.16).

Table 2.16. Distribution of indigenous *Sesbania* species in Ethiopia

Species	Longevity	Distribution
Sesbania dummerii	Perennial	South-western Eth. Kefa, Illubabor
S. sesban var nubica	Perennial	Northern, central and southern Ethiopia
S. goetzei	Perennial	Southern Ethiopia, the Rift Valley
S. sericea	Perennial	Southern Ethiopia, Gamo Gofa
S. macrantha	Perennial	South-western Ethiopia, Didesa Valley
S. somalensis	Annual	Eastern Ethiopia, Ogaden
S. quadrata	Annual	Sidama upland, Harerge upland
S. pachycarpa	Annual	Nort-west Ethiopia, Sudan border
S. hepperi	Annual	Nort-west Ethiopia, Sudan border
S. leptocarpa	Annual	Eastern and southern Ethiopia, Danakil
S. tetraptera	Annual	Eastern and southern Ethiopia, Danakil
S. rostrata	Annual	Gambela, Larie flooded area

Source: Adapted from: Solomon Mengistu, 1984a.

2.6.2. Evaluation of *Sesbania* species for fodder yield, nutritional value and for soil fertility

Sesbania species have the exceptional merit of adapting to a wide range of environments, from the humid tropics to semi-arid regions and from sea level to the cool tropical highlands. Members of the subgenus **Sesbania** such as *S. macrantha, S. sesban* and *S. kenyensis* are naturalized at elevations as high as 2000 to 2300 m in eastern Africa (Solomon Mengistu, 1990) under temperatures that most promising fodder trees- *Leucaena, Calliandra, Gliricidia* and many *Acacia* species cannot survive (Brewbaker *et al*, 1990). In Ethiopia, out of the 12 species the five perennial species including *Sesbania dummerii, S. sesban var nubica, S. macrantha, S. goetzei* and *S. sericea* have potential as browse fodder, agroforestry, and silvo-pastoral systems. *S. sesban* has undergone several agronomic, nutritional, and animal evaluations by local and international research institutions in Ethiopia (Eshetu Derso *et al*, 2011; 2012).

2.6.2.1. Evaluation of four Sesbania species for fodder and green manure (MPT) at DZARC

At Debre Zeit Research Center (DZARC), four *Sesbania* species, including *S. macrantha, S. rostrata, S. quadrata* and *S. sesban* were evaluated for adaptability, dry matter yield, nutritional composition and biological nitrogen fixing potential under two soil types (Solomon Mengistu, *et al*, 2002). The result showed that *S. macrantha*'s, emergence, seedling vigour and growth, and establishment were far superior in *S. macrantha* than in the rest of the species tested together. It stood first in all the growth variables considered: it scored the highest average final height (197 cm), collar diameter (1.8 cm) and rate of growth (1.9 cm/day). In terms of DM yield on the light soil, the species exhibited contrasting total DM yield performance. Under the one-cut treatment, (cut at 105 days after sowing) (DAS), *S. macrantha* had exceptionally high total DM yield (9.091 t/ha) which was more than double of the average yields of each of the other species at similar treatment. The least total DM yield was recorded for *S. rostrata* (3.755 t/ha) which was assumed to be due to failure of nodulation, while *S. quadrata* and *S. sesban* had nearly equal average total DM yields and were intermediate between the former two species (Table 2.17).

As regards to N yield under the one-cut treatment, *S. macrantha* scored the highest total leaf N (119.2 kg/ha) followed by *S. sesban* (112.5 kg/ha). While *S. rostrata* and *S. quadrata* had nearly equal N yields (82.7 and 82.2 kg /ha respectively). Cutting twice had significant effect on the leaf N yield of all the species, resulting in higher yields in *S. macrantha* and *S. quadrata*, but reduced in *S. rostrata* and *S. sesban*, which is more of a reflection of the leaf DM yield difference of the species under a specific cutting management than a difference in tissue nitrogen *per se*.

Table 2.17. Mean dry matter yield of *Sesbania* species subjected to two cutting treatments on a light soil.

T r e a t m e n t s		**Yield**				
Species	Cutting regime	Total DM (t/ha)	leaf DM (t/ha)	stem DM (t/ha)	[2]Leaf N (kg/ha)	Leaf/ stem ratio
S. macrantha	C1[1]	9.091A*	2.837A	6.254A	119.225B	0.454G
S. macrantha	C2	4.349B	2.772A	1.577D	151.924A	1.757B
S. rostrata	C1	3.755C	1.549D	2.206C	82.685D	0.702F
S. rostrata	C2	1.038E	0.719F	0.319F	36.899F	2.251A
S. quadrata	C1	4.298B	1.794C	2.505B	82.193D	0.716F
S. quadrata	C2	3.981BC	2.194B	1.785D	112.450B	1.228D
S. sesban	C1	4.476B	1.962C	2.513B	98.435C	0.781E
S. sesban	C2	2.008D	1.233E	0.775E	66.481E	1.590C
s e		0.156	0.066	0.091	3.37	0.006
C.V. %		6.56	6.06	7.06	10.14	0.84
Mean of Spp over both cutting regime:						
S. macrantha		3.916A	6.720A	2.805A	135.574A	1.106C
S. rostrata		1.262D	2.396D	1.134D	59.792D	1.477A
S. quadrata		2.146B	4.140B	1.994B	97.322B	0.972D
S. sesban		1.644C	3.242C	1.598C	82.458C	1.185B
s e		2.333	0.111	0.047	0.065	0.004
Means of cutting (over all species):						
C1 (one cut)		5.405	2.036	3.369	95.634	0.663
C2 (two cuts)		2.844	1.729	1.115	91.939	1.707
s .e.		0.078	0.047	0.046	1.650	0.003

[T] = Treatment C1 = cut only once at 105 days after sowing (DAS); Treatment C2 = cut twice successively at 65 DAS and then after 40 days of regrowth)
1 = Cutting regimes: C1 = cut at 105 days after sowing (DAS); C2 = Combined yield of two cuts, first cut at 65 and second cut at 105 DAS (ie, after 40 days of regrowth)
2 = calculated from chemical analysis data
*Means followed by the same letter are not significantly different at P0.05

Source: adapted from Solomon Mengistu *et al,* 2002.

The nutritional composition of the four sesbania species was determined from laboratory analysis. The crude protein content data of the four sesbania species is given in Table 18. On the light soil, the species did not highly diverge in their crude protein (CP) contents. At the 105 DAS harvest, CP contents were 28.19, 35.78 and 30.94 % for *S. macrantha, S. rostrata*, and *S. quadrata,* respectively, while the check *S. sesban* at the same stage of harvest had a CP content of 33.76 % which falls within the range of values of the group. Similar trends of inter-species difference were shown both at the 65 days growth and 40 days regrowth harvests. The *In vitro* dry matter digestibility (IVDMD) of *S. macrantha* was slightly lower (60 -63 % at the 105 and 65 DAS harvests respectively) than that of the other three species, which had above 80 %. Generally, there were very little intra-species variations due to cutting stages. Except *S. rostrata* which had comparable values on both soils at all stages of cutting, the rest showed relatively lower IVDMD values on the heavy soil. This variation seems to be due to higher proportion of the less digestible leaf rachis and fine stems on the heavy soil (Table 2.18).

Table 2.18. Chemical composition (as % of DM) and *in-vitro* dry matter digestibility (IVDMD) of the leaf fraction of *Sesbania* species harvested after 105 days after planting on a light soil type.

Species	DM %	Ash	CP	NDF	ADF	Cellulose	Lignin	IVDMD
S. macrantha	93.16	9.06	28.19	35.18	22.18	13.78	7.61	62.64
S. rostrata	93.26	10.51	35.78	26.50	13.77	9.49	3.67	84.04
S. quadrata	92.58	9.40	30.94	23.36	16.42	11.35	4.48	78.37
S. sesban	92.86	10.84	33.76	28.01	15.18	10.23	4.17	70.52

Source: adapted from Solomon Mengistu, *et al* 2002

Alongside the field experiment at Debre Zeit, N fixing potential of the four species was studied on pot experiment. The three species (*S. macrantha, S. quadrata* and *S. sesban*) seeds were inoculated with a mixture of strains of sesbania *Rhizobium* bacteria inoculum, carried in peat, obtained from the University of Hawaii (USA). While the seed of *S. rostrata* was inoculated with a special bacterium, *Azorhizobium caulinodans* strain ORS 571, carried in an agar slope, received from Office de Recherch Scientific Techniques Outre-Mer (ORSTOM) (Senegal). The strain was reported to induce nodulation of both the root and stem of its host (Dreyfus *et al*, 1988). Measured parameters were nodule size, nodule count, nodule mass and nodule color for effectiveness of N fixation. The result showed that nodule size, nodule count, nodule mass was by far the highest in *S. macrantha* than in all the other three species. Inoculation resulted in higher number of nodules were recorded with inoculation than without as evidenced by the nearly equal nodule number and mass across the species except *T. rostrata*. The latter species that was expected to nodulate both on roots and stems failed to do so since according to the authors the inoculum was not viable (Table 2.19).

Table 2.19. Mean nodule number, mass, internal pigment score, and dry biomass accumulation per plant of four *Sesbania* species with inoculation on a light soil.

Species	**Nodule count**	**Fresh nodule mass (g)**	**Dry nodule mass (g)**	**Pigment Score (1 – 5)**	**Dry plant weight (g)**
S. macrantha	88.00A	4.31A	1.292A	4.0A	26.900A
S. rostrata	00.00D	0.00C	0.000C	0.0D	7.100D
S. quadrata	13.25C	0.13C	0.044C	2.0C	19.150B
S. sesban	61.13B	2.88B	0.952B	3.5B	13.651C
S.E	1.005	0.097	0.031	0.102	0.881

Source : DZARC, 1992 ; Solomon Mengistu *et al*, 2002.

2.6.2.2. Evaluation of four perennial Sesbania species for fodder and multipurpose uses (MPT) at DZARC

Three indigenous perennial sesbania: *Sesbania dummeri* (syn *S. kenyensis*), and two varieties of *S. sesban* var. nubica were evaluated for their growth characteristics, fodder yield and nutitional composition at DZARC. From field observations during germplasm collection (Solomon Mengistu, 1984a) and preliminary trials in the nursery at DZARC, they are vigorous trees with large crown and thus highly productive as fodder, wide range of adaptation and apparent suitability for integrated fodder/soil conservation and watershed management The growth form of the three species is presented in Table 2.20.

Table 2.20. Morphology and growth characteristics of three perennial *Sesbania* species under evaluation at DZARC

Characteristics	**Species / Varieties**		
	S. dummeri, DZF-336	**S. sesban, DZF-405**	**S. sesban, DZF-403**
Growth form	Branching below knee height	Erect	Erect
Growth habit	Bushy & several multiple stems	Small tree with a few prominent stems	Small tree with a few prominent stems
Longevity	Perennial	Perennial	Perennial
Propagation	Seed	Seed	Seed
Mean plant height (cm)	200	260	258
Mean Leaf yield (DM t/ha)	4.128	2.910	1.709

Source: Kebebew Asefa *et al*, 2005; Mekasha Chichaibelu, *et al*, 2015

The three *Sesbania* species were evaluated for growth characteristics, fodder DM yield, nutritional composition for five years (2013 - 2017) at four locations, namely Debre Zeit, Werer and Wondo Genet. The growth attributes measured included: plant height (in cm), plant vigor (scored on a scale of 1 to 5), Diameter at ground level (DGL), number of lateral branches at 50 cm from ground and at 100 cm from ground. The growth performance is shown in Table 2.21.

Table 2.21. Growth performance of three perennial *Sesbania* species: vigor, height, survival count over (mean over three locations)

Species & variety	**Vigor^s**	**Diameter at GL**	**Height (cm)**	**LB 50 cm**	**LB 100 cm**
Sesbani dummeri DZF-336	7.259	3.630	199.9b	9.370	15.52a
Sesbania sesban DZF-405	7.889	3.630	257.7a	5.778	11.63b
Sesbania sesban DZF-403	7.815	3.630	259.9a	8.037	11.189b
LSD at alpha 0.05	NS	NS	31.37**	NS	1.660**
CV%	13.48	19.21	17.97	19.74	17.80

^{s}Scored on a scale of 0 – 10. Abbreviations: Diam.GL= diameter at ground level; LB50cm = number of lateral branches at 50 cm; LB100= number of lateral branches at 100 cm. *means followed by the same letter are not significant at P = 0.01*, at P= 0.010**

Source : Kebebew Asefa *et al*, 2005 ; Mekasha Chichaibelu, *et al*, 2015.

The fodder yield i.e., leaf fraction of *S. dummeri* was significantly higher than the other sesbanias, *S. sesban* DZF 405 (2.91 t/ha) and *S. sesban* DZF 403 (1.71 t/ha). *S. dummeri* was also excellent in leaf-to-stem ratio (LSR) (0.1285) (Kebebew Asefa *et al*, 2005; Mekasha Chichaibelu, *et al*, 2015) (Table 2.22).

Table 2.22. Yield performance of three perennial *Sesbania* species: leaf, stem, total above ground, leaf-to- stem ratio (LSR) (mean over three locations)

Species & variety	Yield (DM t/ha)			LSR
	Leaf	Stem	Total (L+S)	
Sesbani dummeri DZF-336	4.128a	3.201b	7.329a	1.285a
Sesbania sesban DZF-405	2.910b	3.942a	6.848a	0.797b
Sesbania sesban DZF-403	1.709c	2.592c	4.301b	0.703b
LSD, ∞0.010	0.4149**	0.4691**	0.7750**	0.1243**
CV%	19.49	19.81	17.24	18.42
means followed by the same letter are not significant at P = 0.01; P= 0.010**				

Source : Kebebew Asefa *et al*, 2005 ; Mekasha Chichaibelu, *et al*, 2015.

The nutritional composition of the three sesbanias was satisfactory in terms of animal requirement. The CP ranged 30.7 – 34.8% and the IVDMD ranged 46.3 – 64.7% (Table 2.23).

Table 2.23. Nutritional analyses data for three perennial *Sesbania* Species

Variety	DM%	Ash%	OM%	NDF%	ADF%	ADL%	CP%	IVDMD%
S. dummeri, DZF-336	93.36	10.52	89.48	38.62	23.62	7.73	31.16	46.33
S. sesban, DZF-405	94.66	11.41	88.59	24.71	18.32	5.98	34.83	64.70
S. sesban, DZF-403	93.66	11.53	88.47	28.08	22.24	5.26	30.71	61.50

Source : Solomon Mengistu, *et al*, 2007.

The breeders at DZARC required registration and release of the candidate sesbania varieties they selected and developed as fodder crop varieties. Upon application submitted using standard procedures and data formats he National Variety Registration Directorate of MOARD delegated a technical committee (TC) to examine the submitted agronomic and nutritional composition data as well as physically evaluate the variety verification trials (VVT) planted on large plots (100x100 m) at six locations. To that end the TC rigorously examined the VVTs at the end of the rains in 2017. The Two varieties *S. sesban* DZF-405 and *S. dummeri* DZF-336 which performed satisfactorily in agronomic and nutritional attributes were recommended by the TC for registration and release (NVRC, 2017; 2018).

2.6.2.3. Evaluation of Sesbania macrantha ecotypes for forage yield and quality at DZARC

Sesbania macrantha is reported to be the fastest growing annual/short-lived perennial fodder legume. The growth rate and coppicing ability of *Sesbania macrantha* after repeated prunnings at various heights was reported to be excellent (Holden, S.R., et al, 1989; Lungu, S., 1987). Earlier studies conducted at DZARC on *S. macrantha* and three other sesbanias (Solomon Mengistu *et* *al*, 2002) indicated *S. macrantha* to have produced high fodder ield (total leaf and stem DM 9.1 t/ha) and high N yield (119 -152 kg/ha) in 105 days growth period. As rain-fed crop, it is most suited for the humid and sub-humid lowlands and mid-altitude areas receiving at least three months of rainfall. *S. macrantha* was found to have nodulated profusely and accumulated high amount of nitrogen in the leaf (119 -152 kg/ha), which can readily decompose and release mineral N for crop use. The study also confirmed that *S. macrantha* was more productive under irrigation where three crops per year could be produced. The species favored light soils with good drainage until establishment.

Box 2.1. *Sesbaia macrantha* a rich source of protein

Sesbania macrantha is a short-lived perennial (up to 3 years) extremely fast-growing legume with multiple woody trunks growing beyond four meters. Its natural distribution is in the sub-humid eastern Africa. In Ethiopia, it inhabits the wet woodlands of Southern and South-western regions, such as the Didesa River Valley and the open woodlands of Gamogofa. *Sesbania macrantha* has shown fast growth as observed in several mid-altitude warm regions of Ethiopia. Its fodder yield is generally superior to any of the short-term fodder legumes. Several ecotypes of *S. macrantha* evaluated at Debre Zeit Research Center for more than a decade for fodder yield, feeding value and nitrogen fixing potential, revealed impressive results. It was found to be well adapted to light soils producing high DM yields of leaf (2.8 t/ha), stem (wood) (6.3 t/ha) and total nitrogen yield (151 kg/ha) in 105 days (Solomon Mengistu *et al*, 2002; 2012). At its most favored location, Werer, (high temperature and irrigation water supply), it grew up to 5m tall, and produced 9 t/ha total DM (Fig. and Fig.).

The nutritional composition of the species was found to be within an acceptable range of livestock requirement, CP content was 28.19% and IVDMD was also high with values more than 70%. It nodulated profusely without inoculation from the native *Rhizobia* in the soil, and examination of the nodule color and mass indicated that it has a high capacity to fix nitrogen. *S. macrantha* was found to be superior in overall performance compared with other members of the genus *Sesbania*.

Highest yield was obtained at early podding stage; harvested material can be conserved as leaf hay that can be stored in sacs piled under simple shed; feeding is as easy as feeding concentrate rations (Fig. 2.8). Preliminary observations on some indicator attributes of biological nitrogen fixing potential (Solomon Mengistu *et al* 2002) revealed its promise for

Fig. 2.8. *S. macrantha* grown under irrigation at Werer Agric Res. Center (WARC).

maintenance of soil fertility and thus its prospect for use in crop rotations.

Feeding experiments with penned sheep proved S macrantha to have considerable promise as a high-quality supplementary fodder to high fiber roughage feedstuff such as tef straw (Solomon Mengistu *et al*, 2007). The daily total DM intake increased with increasing level of supplement, which may be due to increased total consumption. The intake and digestibility coefficient of nutrients and live weight gain of sheep were improved by supplementing up to 250 g of *Sesbania macrantha* leaf hay per day. This level has not caused any sign of toxicity among all the supplemented experimental animals.

Fig. 2.9. *S. macrantha* leaf hay ready for supplementary feeding

The Debre Zeit Agricultural Research Center (DZARC) evaluated *S. macrantha* ecotypes in an aim to select productive leguminous fodder varieties for strategic supplementation of livestock and thereby alleviate the animal feed crisis especially during extended drought season. Twenty-two ecotypes were screened over years and finally five ecotypes (DZF-064, DZF-449, DZF-342, DZF347 and DZF-092) were promoted for advanced trial to determine fodder yield and quality attributes over four locations (Debre Zeit, Melkasa, Werer and Wondo Genet) (Eshetu, Derso *et al*, 2011; 2012). Finally, in 2012 three varieties, namely, DZF-064, DZF-347 and DZF-092, were selected and subjected to a variety verification trial (VVT) in four locations. The VVT was examined by a technical committee (TC) delegated by the NVRC that recommended one of the candidate varieties DZF-092 for registration and release. The agronomic performance of the varieties is presented in Table 2.24 and the nutritional composition is shown in Table 2.25.

Table 2.24. Agronomic and yield performance of five *Sesbania macrantha* lines over three locations and two years.

Variety	Total fresh (t/ha)	%Leaf as fresh	%DM Leaf	%DM Stem	Leaf DM (t/ha)	Stem DM (t/ha)	L-S ratio as DM
DZF-064	26.149c	31.30	26.89	32.38a	2.126b	5.981c	0.389
DZF-092	36.953a	32.22	27.45	29.25b	3.191a	7.330b	0.458
DZF-449	27.406b	29.41	27.22	31.08ab	2.030b	6.363c	0.383
DZF-347	37.528a	30.98	27.29	30.02b	3.120a	7.958a	0.428
DZF-342	26.865bc	29.12	27.24	30.75ab	1.978b	6.061c	0.395
LSD ∞0.05	1.229	NS	NS	1.898	0.305	0.602	NS
CV%	5.92	14.38	5.47	9.23	18.29	13.33	23.18
Grand Mean	30.980	30.60	27.22	30.70	2.489	6.739	0.410

Source : Eshetu, Derso *et al*, 2011 ; 2012

Table 2.25. Chemical composition (as % of DM) and *in vitro* dry matter digestibility (IVDMD) of the leaf fraction of *Sesbania macrantha* accessions.

Variety	Rep	DM %	Ash	CP	NDF	ADF	Cellulose	Lignin	IVDMD
DZF 092	1.00	93.16	9.06	28.19	35.18	22.18	13.78	7.61	62.64
DZF 092	2.00	93.93	7.72	30.32	36.32	20.14	12.80	6.35	70.01
DZF 092	3.00	94.63	9.23	28.75	37.99	20.60	12.08	7.67	61.42
DZF 092	**Mean**	**93.91**	**8.67**	**29.09**	**36.50**	**20.97**	**12.89**	**7.21**	**64.69**
DZF 347	1.00	92.47	6.73	24.66	33.71	20.60	12.84	6.41	54.92
DZF 347	2.00	93.17	8.09	20.72	35.06	18.71	10.19	7.20	64.62
DZF 347	3.00	92.99	11.38	23.82	22.68	13.35	9.65	2.99	57.95
DZF 347	**Mean**	**92.88**	**8.73**	**23.07**	**30.48**	**17.55**	**10.89**	**5.53**	**59.16**
	Grand mean	**93.39**	**8.70**	**26.08**	**33.49**	**19.26**	**11.89**	**6.37**	**61.93**

Source : Eshetu, Derso *et al*, 2011 ; 2012

The *S. macrantha* varieties were examined by a technical committee (TC) delegated by the NVRC in 2012. The TC rigorously examined the variety verification trial (VVT) planted on large plots at four locations in 2011-2012 (2005 EC) season. Variety *S. macrantha* DZF-092, which performed satisfactorily in agronomic and nutritional attributes was recommended by the TC for registration and release.

2.6.2.4. Evaluation of Sesbania macrantha ecotypes at Shire-Mytsebri Agricultural Research Center

Shire-Mytsebri Agricultural Research Center (SMARC) of the Tigray Agricultural Research Institute (**TARI)** evaluated various forage species to select and develop and release adapted and high yielding varieties for the target regions, namely, low-moisture areas of western Tigray: Tselemt, Tahtay Koraro areas with mean annual rainfall of 500-1279 and mean annual temperature 15.8-35.6 °c. Among the potential legumes, six ecotypes of *Sesbania macrantha* obtained from EIAR center were evaluated for growth and forage yield attributes at three locations for four years. A released variety of the same species (*S. Macrantha* var. DZF-092) was included for comparison. SMARC forage researchers/ breeders applied to NVRC to evaluate and release the native grass ecotypes by submitting the candidate varieties performance data on a standard format. The NVRC delegated a technical committee to evaluate the species/ecotypes on various attributes and pass decisions on the fate of the candidate varieties: either reject or accept as forage crop variety. The average performance data on selected attributes of agronomic and nutritional content is presented in Table 2.26 and Table 2.27, respectively.

Table 2.26. Performance of candidate *S. macrantha* varieties and the check in selected agronomic attributes: fodder DM yield, **grain yield (q/ha)** and leaf-to-stem ratio (LTS) (average of three locations).

Varieties	DM yield (t/ha)	Seed (q/ha)	LTS ratio
S. macranta, DZF-342	6.61	23.48	0.578
S. macranta, DZF-347	6.40	19.85	0.659
S. macranta, DZF-092 (check)	4.39	19.16	0.736
Mean of varieties	5.80	20.83	0.658
*Nutrient analysis performed from pooled samples taken at 50% flowering.			

Source: Data submitted by breeders at SMARC

Table 2.27. Nutritional content of the candidate *S. macrantha* varieties and the check variety in selected nutritional compositions (analysis performed from pooled samples).

Varieties	Lign%	NDF%	CP%	IVDMD%
S. macranta, DZF-342	16.80	38.55	20.32	58.61
S. macranta, DZF-347	15.70	33.45	20.21	67.17
S. macranta, DZF-092 (check)	18.07	42.97	17.91	54.59
Mean of varieties	16.85	38.32	19.48	60.12

Source: Source: Data submitted by breeders of SMARC to the NVRC in 2018.

Deliberations of the TC on candidate *Sesbania macrantha* varieties (SMARC)

The candidate varieties and the check were examined by the technical committee (TC) at three testing sites of the Shire-Mytsebri Agricultural Research Center (SMARC) of the Tgray Agricultural Research Institute (TARI). A total of six experimental plots (three on station together with 2 on-farm sites for each station) that represented three ecological areas (Maytsebri, Mayadrasha and Maytemen) were visited. The stands of the candidate and the check varieties were examined for any symptoms of disease and pest attack, sensitivity to weather extremes, vigor, plot cover and stand density. Five major attributes of yield and quality (3 agronomic; 2 nutritional quality) were the bases for assessing the performance of the candidate fodder legume variety: a) *Agronomic attributes*: herbage yield (6.61 tones DM/ha); seed yield (23.48 q/ha) and Leaf-to-stem ratio 0.578) *Quality attributes*: protein content (CP 20.32%) and digestibility (IVOMD 58.61%). As the variety DZF-342 fulfilled the requirements of high yield and quality fodder crop with values well above the standard check, it was recommended for release.

2.6.2.5. Multispecies evaluation of perennial sesbania and other MPTs for response to harvesting managements

Tree legume in the genera: *Leucaena, Sesbania, Chamaecytisus, Calliandra,* and *Gliricidia* have been categorized as most important multipurpose trees (MPT) (Brewbaker *et al*, 1990; Tarawali

G. 1993). These MPTs, besides enhancing the productivity of livestock through provision of cheap protein supplement, they can also increase the firewood supply and thereby promote the use of animal dropping for fertilizer rather than for fuel. With these functions, MPTs enable smallholder farmers to increase efficient and cyclic use of feed and manure in an integrated crop-livestock production system (Tarawali, G. 1993; Tothill et al, 1989).

Recognizing the immense fodder potential of selected MPT species the Debre Zeit Agricultural Research Center (DZARC) researchers undertook a multi-species evaluation of three native sesbania species including *S. sesban* var nubica, *Sgoetzei, S. dummeri* (syn. *S. kenyensis*) and *Leucaena pallida* at Debre Zeit. The main aim of the evaluation was to determine their growth response, fodder yield, and nutrient composition in response to varied harvesting regimes, viz, cutting heights and intensities (Kebebew Asefa *et al*, 2005).

The experiment was carried out at DZARC campus for two years (2001 and 2002). **It** consisted of entire factorial combinations of the four MPTs (***viz.*** *Leucaena pallida*, *Sesbania sesban, S. kenyensis (S. dummeri)*, and *S. goetzei*); two initial cutting heights of 50 cm and 75 cm aboveground, and three cutting frequencies (*viz.*, every 2, 3 and 4 months throughout the study period).

The salient finding on the yield response (total dry biomass, and the leaf and stem fractions biomass) summarized from the report (Kebebebew Asefa *et al*, 2005) is presented in Table 2.28. Generally, significant differences were revealed among species in dry total, leaf and stem biomass yields. Cutting frequency had also significant effects on dry matter yields with increasing yield with longer frequency of cutting. On the other hand, cutting height had no significant effect on dry matter yield. In the two years period of evaluation *S. sesban* gave the highest fodder yield with almost equal proportion of leaf and stem fractions. *Leucaena pallida* was relatively slow to establish but later it progressively expanded its canopy, ranking second in fodder yield. *Sesbania dummeri (S. kenyensis)* had bushy growth habit with soft and tender twigs that can be readily browsed. *S. goetzei* (collected on beaches of alkaline lakes (Solomon Megistu, 1984a) was the least in fodder yield because it was susceptible to moisture stress and some plants died at the peak of the dry period.

Table 2.28. Total, leaf and stem fractions dry matter yield (t/ha) of four MPTs as affected by cutting heights and cutting frequency treatments

MPT species	Cutting frequency (months)	Mean dry matter yield (t/ha)					
		Total		Leaf		Stem	
		Cutting height (cm)		Cutting height (cm)		Cutting height (cm)	
		50	75	50	75	50	75
Leucaena pallida	Every two	16.274	14.871	11.569	10.578	4.705	4.293
	Every three	19.856	16.839	13.280	11.231	6.576	5.608
	Every four	32.963	23.968	19.278	14.520	13.684	9.448
Sesbania sesban	Every two	25.520	23.498	12.838	11.980	12.682	11.518
	Every three	26.516	34.385	12.471	17.212	14.045	17.174
	Every four	29.960	33.778	12.913	15.931	17.047	17.847
S. kenyensis	Every two	10.470	9.600	5.594	5.585	4.876	4.015
	Every three	10.118	13.607	5.167	7.189	4.951	6.418
	Every four	9.885	11.205	4.948	5.633	4.937	5.571
S. goetzei	Every two	7.969	6.093	5.675	4.640	2.294	1.453
	Every three	8.480	8.387	5.877	6.226	2.603	2.160
	Every four	9.021	5.930	5.442	4.109	3.579	1.821
SEM		3.94		1.89		2.21	

Source: Adapted from Kebebebew Asefa *et al*, 2005.

In terms of nutrient composition, the report (Kebebebew Asefa *et al*, 2005) stated that the species response was not significant. The average of two replicate samples gave an indication on the general picture of the CP content and IVDMD percent of the species. The CP% from different treatments varied from 13% to 26% but the variation was not consistent with the type of treatment as to draw general conclusion. Similarly, the IVDMD% varied from 40% to 76%, showing a decreasing trend with decreasing (delayed) cutting frequency.

The report (Kebebebew Asefa *et al*, 2005) concluded that owing to its fast establishment *S. sesban* was suitable for short-term plantings on moderate soil moisture. *S. kenyensis (S. dummeri)*, with its multiple stems and bushy growth habit, looked a promising fodder particularly for soils with high to excessive moisture. *S. goetzei* cannot tolerate dry period without supplementation of intermittent irrigation. Finally, *L. pallida*, a truly woody tree, seemed the best species especially for permanent plantations meant for multiple uses.

2.6.3. Studies on feeding value of sesbania

The nutritive values of *Sesbania* species in general have been shown to be excellent. The high nutritive value of *Sesbania* forage was confirmed in a supplementation study conducted at the International Livestock Centre for Africa (ILCA) (Reed *et al*, 1990). In this study, tef (*Eragrostis tef*) straw was supplemented with six experimental diets on a sheep feeding trial. The basal diet, tef straw was fed *ad libitum*. The supplemental diets were *Acacia cyanophilla* (phyllodes), *A. sieberana* (fruits), *A. seyal, S. sesban* (leaves), vetch (*Vicia dasycarpa*), noog cake (*Guizota abyssinica*) and urea to provide an intake of 1 % nitrogen. The result showed that all the offered *S. sesban*, vetch and noog cake supplements were readily consumed. Intake of tef straw was highest for sheep fed *S. sesban* and urea, *S. sesban* had high nitrogen content (4.5%) and high digestible cell wall as was evident in its low contents of indigestible neutral detergent fibre (RNDF 9.7 %) and lignin (ADL 4.3%), and low in the content of soluble phenolics (17.9%) and insoluble proanthocyanidins (0.06 %) (all values expressed as 5 % of the OM). These chemical attributes were, according to the authors (Reed *et al*, 1990), responsible for the high intake of tef straw and the high total intake by sheep supplemented with *S. sesban* leaves. The average body growth rate of sheep fed. *S. sesban* was the highest indicating that sesbania hay was by far superior to all the other supplements. Nitrogen balance in sheep showed that *Acacia cyanophylla*, had a negative nitrogen balance; the other diets ranked in a decreasing order of nitrogen balance were: *Vicia dasycarpa*, noog cake, *S. sesban, A. seyal*, *A. sieberana* and urea.

Anti-nutritional factors such as tannins and related polyphenolics in sesbania were reported to be negligible or too low (Reed *et al*, 1990) as to adversely affect palatability and digestibility in ruminants. According to the authors, the level of soluble phenolics and insoluble proanthocyanidins was 17.9 and 0.06% OM respectively. By contrast, the values for *Acacia* species were twice higher. Therefore, the authors inferred that *Sesbania* were free from the harmful anti-nutritional factors.

2.7. Evaluation of indigenous glycine (*Neonotonia wightii*)

A trial was undertaken to investigate 41 Ethiopian accessions of *Neonotonia wightii* collected around Zwai and Soddo, about 250 and 400 km south of Addis Ababa, for growth characteristics, fodder DM yield and N fixing potential (Larbi, A. *et al*, 1992). Commercial cultivars Clarence and Tinaroo were included as controls in RCBD with six replications.

The result showed that there were differences in DM yield, leafiness, and plant vigor (spread of stolon) among accessions (Appendix 3). The three native accessions had higher DM yields than Clarence and Tinaroo, probably due to variations in nodulation (Nicholas and Haydock 1971). Number of days to flowering differed among accessions and ranged from 102 – 194 days. A range of 69 – 123 days was reported for 10 exotic and native *N. wightii* accessions in Kenya. Differences in days to to flowering among accessions may partly reflect variations in temperature and photoperiod (Appendix 3).

According to Larbi *et al* (1992), native *Neonotonia* ecotypes are widely used as dry season feed supplement to milking cows in smallholder mixed farming systems in southern Ethiopia (Ochang 1985; Tanka 1986).

The authors commented that the study demonstrated for the first time the agronomic potential of *N. wightii* accessions endemic to Ethiopia. There were marked variations in DM yield and days to flowering among the *N. wightii* accessions indicate a wide range of variability from which selections can be made.

2.8. Evaluation of indigenous stylo (*Stylosanthes fruitcosa*)

2.8.1. Botany, distribution and germplasm collection

The genus *Stylosanthes* comprises 30 to 40 species (Burt *et al*., 1983; Stace and Edye, 1984), many of which are either agronomically unattractive or are of rare occurrence. *Stylosanthes* species are adapted to quite different ecological situations and range from annuals to perennials. *S. fruticosa* is regarded as an excellent forage legume in some parts of Africa. Its deep and strong tap root system makes it resistant to grazing. The prostrate forms have some value in protecting the soil against erosion.

S. fruiticosa is distributed in many countries in Africa. IBPGR reported the species to be found in 23 African countries. The largest collection of *S. fruiticosa* is held by ILCA (164), CSIRO (88), University of Florida (23) and CIAT (10), in that order (Stace and Ediye, 1984; Wiliams *et al*, 1984).

Hakiza *et al* (1985) undertook a study on a total of 93 accessions of *S. fruticosa* out of the 164 accessions collected in Ethiopia and sub-Saharan Africa and kept at ILRI's genebank. These acssesions were grown as spaced plants at Soddo research station of ILCA. From the established stands, records of 18 simple morphological and agronomic data were taken and subjected to different grouping analysis tools to come up with agro/morpho type groups to aid agronomic evaluations.

Hakiza *et al* carried out the study from a limited number of accessions collected mainly from Ethiopia and Niger (Solomon Mengistu, 1984a; 1984b). However, during germplasm collection expeditions undertaken later than 1984 in Kenya and Tanzania, some more ecotypes with diverse morphological characteristics were collected (Solomon Mengistu, 1984a; 1984b; 1984c; 1985). The material from coastal Tanzania was robust and bushy type and quite unlike the Ethiopian ecotypes. This ecotype could be the other African stylo, which Thulin (1983) speculated another similar species, *S. erecta*. As duly recommended by Hakiza *et al* (1985), future study involving these, and other additional collections will result in an exhaustive and interesting outcome.

In their conclusion and recommendation, Hakiza *et al* (1988) pointed out that the 93 accessions available for study were agronomically and morphologically diverse. Furthermore, the authors suggested that since ILCA's collections of *S. fruticosa* was from such a limited part of its geographical distribution, further collections from other African countries need to be undertaken as far as their study on the species indicated. The authors expounded their suggestions by listing the following areas of emphasis. 1) There is a need to collect and preserve genetic materials that are in danger of disappearing because of the destruction of natural vegetation. 2) There is need to increase the variability of collection from areas in relation to geographic, climatic and/or edaphic relevance. 3) There is need to collect genetic material in particular areas which in the past have been neglected or overlooked regarding collecting activities.

2.9. Evaluation of indigenous *Rhynchosia* species (genus *Rhynchosia*)

2.9.1. Taxonomy and distribution

Rhynchosia, also known as snout bean, belongs to the sub-tribe Cajaninae, tribe Phaseoleae, in the family Fabaceae. Members of the genus *Rhynchosia* are climbing, prostrate or sometimes erect herbs or subshrubs. There are about 200 species distributed worldwide in the tropics and sub-tropics. In Ethiopia, there are 24 species distributed in mid-altitude highlands and lowland grasslands and forest margins (Thulin, 1983).

One of the commonest species in the genus is *Rhynchosia minima* a perennial climbing or prostrate herb that can grow 6 to 7 feet in length. In Ethiopia, the species consists of five varieties widely distributed in grasslands and bushlands (Thulin, 1983). *R. minima* twines on tall grasses making a natural grass-legume mixed pasture in grazing lands. It is readily eaten by cattle and sheep.

2.9.2. Evaluation of Eznianchwa (*Rhynchosia minima)* at Humera Agricultural Research Center (HuARC)

Researchers from Humera Agricultural Research Center (HuARC) collected indigenous ecotypes of *Rhynchosia minima*, locally known as **Eznianchwa**, in the wooded grassland along the border with the Sudan and evaluated them for forage yield and nutritional quality at five testing sites (Banat, Maykadra, Kebabo, Dedebit and Adebay).

The growth and agronomic performance of **Eznianchwa** (*R. minima* var. prostrata) and another legume, **Teken** *(Desmodium hirtum* var. delicatulum) that was evaluated together is presented in Table 2.29 and Table 2.30.

Table 2.29. Performance of candidate varieties in selected agronomic and growth attributes (average of three locations and seven years).

Yield & Quality attributes	Varieties performance (mean over Locs & Yrs)		Remarks
	Teken (*Desmodium hirtum var delicatulum)*	**Eznianchwa** (*Rhynchosia minima var prostrata*)	
DM yield (DM t/ha)	8.224	9.645	Mean of 7 yrs & 3 Locs
Seed yield (q/ha)	10.427	9.630	Mean of 7 yrs & 3 Locs
Leaf-Stem Ratio (LSR)	0.5651	0.5436	Pooled sample
Days to 50% flowering (DTPF) (days)	62	61	Mean of 7 yrs & 3 Locs

Table 2.30. Performance of candidate varieties in selected nutritional attributes (analysis performed from pooled samples).

Quality attributes	Varieties performance (mean over Locs & Yrs)		Remarks
	Teken (*Desmodium hirtum var delicatulum)*	Eznianchwa (*Rhynchosia minima var prostrata*)	
CP%	17.25	21.57	Sampled at 50% flowering
IVOMD%	58.07	48.59	Sampled at 50% flowering
NDF%	46.98	50.75	Sampled at 50% flowering

The candidate varieties were inspected by a technical comittee (TC) delegated by the NVRC. After touring six locations nd examining the varieties performance the TC, reported that the variety (*Rhynchosia minima,* var. prostrata) was outstanding in two important yield attributes for a sound forage crop, namely, herbage (9.64 t DM/ha) and seed (9.63 q/ha) yields. In quality attributes as well, the candidate variety has acceptable values (Table 2.29). The CP content of the variety is 21.57% and the IVOMD is 48.59% (Table 30), both values being within acceptable level for good quality forage legumes. On these grounds, the TC concluded "the candidate variety **Eznianchiwa** has acceptable agronomic performance in various forage attributes of yield and quality and was observed to be free from the major forage legume diseases and pests and therefore, the variety is recommended to be considered for release".

2.10. Evaluation of indigenous *Desmodium* species (genus *Desmodium*)

2.10.1. Taxonomy and distribution

Desmodium is a genus in the family Fabaceae, tribe *Desmodieae*, sub-tribe *Desmodiinae*. There are about 300 species in tropical and temperate areas; in Ethiopia some indigenous species are found distributed in grasslands and woodlands (Thulin, 1983). Several species of *Desmodium* are good forage and are useful as living mulch and as green manure, as they can improve soil fertility via nitrogen fixation.

Two introduced species: *D. intortum* and *D. unicinatum* have undergon evaluation for forage yield and quality and both have shown wide range of environmental adaptation. Their tolerance to soil acidity and compatibility with tall grass species makes them valuable in mixes pastures, and for over-sowing degraded natural pastures.

2.10.2. Evaluation of *Teken* (*Desmodium hirtum* var. delicatulum) at Humera Agricultural Research Center (HuARC)

The Humera Research Center (HuARC) evaluated *Desmodium hirtum* ecotypes at six experimental plots (three on station together with 2 on-farm sites for each station) that represented three ecological areas (Banat, Humera, and Kebabo). The breeders were able to select a variety, named **Teken** that was registered and released as a forage crop. The fodder yield performance and nutritional composition of the variety is indicated in Table 2.29 and Table 2.30 under Section 2.9.2. that deals on *Rhynchosia*.

The candidate forage legume variety, Teken (*Desmodium hirtum* var. delicatulum*)* has outstanding performance in two important yield attributes for a sound forage crop, namely, herbage (8.22 t DM/ha) and seed (10.43 q/ha) yields (Table 2.31). The CP content (17.25%) of the variety is comparable to important cultivated forage legumes such as alfalfa. The IVOMD (58.07%) is also within acceptable level of ruminant animals' requirement.

Table 2.31. Yield attributes of Var Teken (*Desmodium hirtum* var. delicatulum)

Location	DM (t/ha)	Seed (q/ha)	LSR	Days to 50% flowering	Remarks
Banat	7.516	11.960		58	Mean, 7 yrs
Humera	8.355	10.060		67	Mean, 7 yrs
Kebabo	8.802	9.260		62	Mean, 7 yrs
Mean over locations	8.224	10.427	0.5651	62	Pooled sample

The candidate indigenous forage legume variety, ***Teken*** (*Desmodium hirtum* var. delicatulum*)* has outstanding performance in two important yield attributes for a sound forage crop, namely, herbage (8.22 t DM/ha) and seed (10.43 q/ha) yields (Table 31). The CP content (17.25%) of the variety is comparable to important cultivated forage legumes such as alfalfa. The IVOMD (58.07%) is also within acceptable level of ruminant animals' requirement. Owing to its acceptable agronomic and nutritional performance in various forage attributes of yield and quality, as shown in Table 29 and Table 30 (above under Sec. 2.9.2.), the candidate variety ***Teken*** (*Desmodium hirtum* var. delicatulum*)*, developed from local collections, was recommended for registration and release as a forage crop.

2.10.3. Evaluation of Chimero (*Desmodium dichotomum*) for forage value at Wollo University

Desmodium dichotomum, locally called *chimero*, is a native legume recognized by farmers in several districts of North and South Wollo Zones, Amhara Region, Ethiopia, as a valuable livestock feed (Hunegnaw, 2020). It is a herbaceous and self-regenerating legume growing wild and often occurs as spontaneous intercrop with sorghum and maize crops. Its growth habit is semi-erect to trailing; leaves are trifoliolate with the leaflets being mostly ovate. Leaves are hairy on both surfaces, while flowers are pink to violet and seeds are yellow to light brown. While limited research has been conducted on this species, 4.4 t DM/ha average yield has been reported as a self-grow legume with sorghum (Hunegnaw, 2020). Average nutritient composition was reported to be: 22% CP, 31% NDF, 26% ADF and 5.8% ADL, while IVDMD is 61%. Mineral concentrations were reported to be: 0.6% calcium, 0.23% phosphorus, 1.5% potassium, 0.78% magnesium, 0.01% sodium, 0.27% sulfur, 0.16% iron, 4.4 mg/kg copper, 45 mg/kg manganese and 12.3 mg/kg zinc (Hunegnaw, 2020).

Hunegnaw, A and Tewodros, A. (2022) conducted morphological characterization and grouping of 26 entries of *Desmodium dichotomum,* collected in eastern Amhara (Ethiopia) for eventual selection of promising lines as forage crops. For characterization of the entries, they used the IBPGR descriptors list. The resulting dendrogram showed 3 distinct groups of entries: Group 1 with 12 entries; Group 2 with 6 entries; and Group 3 with 8 entries. The 3 groups of entries obtained by cluster analysis showed significant quantitative morphological variation. Entries in Group 1 seemed to possess distinct attributes like early germination, rapid establishment, and vigorous growth, which suggested that these entries should need to be studied in greater depth in the field to identify desirable entries for possible variety development. Subsequently, the grouping of entries by phenotypic characteristics in the study will be used to classify the accessions into distinct morphological levels, which could be used for various breeding, collection and conservation programs. Aspects to be considered would be dry matter yields, crude protein concentration, seed production, digestibility, acceptance by livestock and longevity under cutting and grazing.

2.11. Evaluation of a group of indigenous legume taxa in a multispecies trial at CADU (*Melilotus, Mucuna, Neonotonia, Teramnus, Trifolium*)

Three climbing legume species together with two other legumes were evaluated for adaptation and herbage yield at Kulumsa in 1972-73. Out of these indigenous species *Melilotus* and *Neonotonia* stood first and second in DM yield and fast establishment and good competition with weed. They were observed to be promising as forage crop (CADU, 1973) (Table 2.32).

Table 2.32. Herbage yield performance of indigenous climbing legumes at Kulumsa in 1973.

Species	**DM yield (t/ha)**			
	Harvest 1	Harvest 2	Harvest 3	Total DM yield
Neonotonia wightii sub-sp wightii va. Longicauda	6080	190		6270
Neonotonia wightii sub-sp wightii va. Petitania	2780			2780
Mucuna melanocarpa	1120			
Teramnus labialis sub-sp labialis var. abyssinica	3530			3530
Trifolium rueppelianum	14370			14370
Melilotus altisimus	5420	1430	1230	8080

Source: CADU, 1973.

Chapter III: Research and Achievements on Indigenous Forage Grasses (Family Poaceae)

3.1. Forage grass genetic resources, and germplasm collection activities in Ethiopia

The Eastern African region with its extensive savannah grassland-herbivore ecosystem has the richest diversity of forage grass species (Clyton, 1983). The Afroalpine and Afromontane grasslands are climax and biotic type respectively, maintained by two factors: cold temperature in the alpine meadow; biotic factors (because of man's destructive activity) in the montane grasslands. This balance of plant composition in favor of herbaceous communities plays an important role for dominance of important forage plant species. In the lower altitude forest belt, the secondary grassland is dominated by the grass tribes: Andropogoneae and Paniceae and among the legume herb tribes: Trifoleae. Important grass species worth collecting include *Chloris gayana, Festuca arundinaceae, Panicum maximum, Setaria sphacelata, Pennisetum glaucifolium* and *P. reparium*. The Sudanian floristic region bordering the Sudan is more important as source of the more successful tropical forage grasses. The panicoid tribes in the genera: *Panicum, Andropogon, Brachiaria, Pennisetum* and *Setaria; among* the tribe *Cynodonteae: Chloris* and *Cynodon* occur in great diversity. However, grass species in general have not received due emphasis in forage research programs in Ethiopia.

3.2. Collection of indigenous forage grass germplasm

To date, no significant survey and collection of indigenous forage grass taxa has been attempted. As detailed in Section 2, most of the collection exercise undertaken by the national and international institutions has focused on leguminous taxa.

The only grass genus that has been adequately sampled was *Brachiaria*, which was collected during the ILCA-CIAT (International Center for Tropical Agriculture) joint expedition in Ethiopia and seven eastern and central African countries (Solomon Mengistu, 1984b; 1985; 1986). The collected germplasm proved to be a good source of genetic material for CIAT's breeding program to develop productive, tolerant to acid soils, and spittle bug resistant varieties for Latin American countries (Argel *et al*, 2007; Vendramini, J. *et al*, 2008). Varieties developed from this highly valuable African forage grass boosted livestock production in Latin America. Reports of CIAT scientists (Argel *et al*, 2007; Vendramini, J. *et al*, 2008) described that *Brachiaria* species are tropical warm season forages native to Africa (Kenya, Ethiopia, Uganda, Tanzania, Zimbabwe, Rwanda, Burundi, and Congo Republic). *Brachiaria* grasses are the most widely grown forages in tropical South America, occupying over 80 million hectares (Boddey *et al*. 2004). The Tropical Forage Program of CIAT launched a project to develop *Brachiaria* cultivars with a broad range of adaptation, high nutritive quality and forage production, and good quality seed. Cultivar (c.v.) Mulato (*Brachiaria* hybrid CIAT 36061) was the first cultivar released because of this undertaking (CIAT, 2006). Mulato is valued for its tolerance to drought, fast recovery after grazing, high plant vigor, and very good forage quality (Argel *et al*., 2007). The next cultivar developed was Mulato II, which was the result of three generations of crosses and screening conducted by the CIAT in Colombia, including original crosses between *Brachiaria ruziziensis* x *Brachiaria decumbens* cv. Basilisk (Vendramini, J. *et al*, 2008).

Further collections for other promising perennial grass species were conducted by ILCA, notably, the genera: *Panicum, Cynodon* and *Leptochloa*. (Solomon Mengistu, 1984a) In a *general collection* expedition carried out during mid-1980s, various species of legumes, grasses and browse tree species were collected in the Sudanian Floristic Region, which is a rich source of grasses. Vigorous ecotypes of *Panicum maximum* were collected in the wetter woodlands of Gambela (Solomon Mengistu, 1984a) in the form of root splits, which were subjected to agronomic evaluation at the Zwai site of ILCA (Fig. 3.10 and Fig. 3.11).

Fig. 3.10. Collecting tuft split of *Panicum maximum* in Baro River basin of Gambela

Fig. 3.11. Collecting rhizome split of *Penisetum spacelatum* in south-western Ethiopia

At CADU, Carlson, J. (1972) undertook survey and collection of germplasm of 39 ecotypes of six grass species including *Cenchrus ciliaris* (8 ecotypes), *Chloris gayana* (11), *Phalaris arundinaceae* (7), *Setaria sphaceleta* (1), mostly from Arsi and the surrounding areas for determination of forage yield and nutrient content (Table 3.1). According to Carlson, considerable intra-specific variations in yield were observed for some species, and many of them had outyielded their respective exotic variety controls.

Table 3.1. Indigenous grass species and number of accessions collected by CADU

Species	No of accessions	Altitude (m.a.s.l.) collected
Cenchrus ciliaris	8	1400 – 1700
Chloris gayana	11	1400 – 2200
Panicum coloratum	1	2400
Panicum maximum	11	1000 – 1700
Phalaris arundinaceae	7	2200 – 2700
Setaria sphacelata	1	1000 – 1500

Source: adapted from Carlson, J., 1972.

3.3. Research Activities on Grasses at Genus and Species Level

3.3.1. Evaluation of a group of indigenous grass taxa in a multispecies trial at CADU (*Chloris, Cenchrus, Panicum, Phalaris, Setaria*)

Germplasm of the various indigenous species collected by Carlson (1972) were subjected to pot trials at CADU station, Kulumsa during the small rains. Harvesting for dry matter determination was conducted twice: early and late harvest. The pot-grown species exhibited great intra-species variation in DM yield and nutrient composition especially in *chloris gayana,* and *Panicum maximum* (Carlson, J, 1972)

Some of the most promising varieties of each species were planted vegetatively as single plants in fields at different places. After three to four months, two plants of each variety were harvested and analysed for nutrient composition conducted at CADU Nutrition Laboratory. The DM yield and nutrient composition data is shown in Tables 3.2 below (an abridged summary table from Carlson, J. (1972).

According to Carlson (1972), all the Ethiopian ecotypes of *Cenchrus ciliaris, Chloris gayana, Panicum maximum, Setaria sphaceleta* and *Phalaris arundinacea* showed more vigorous growth than the control commercial varieties grown under the same conditions. He outlined as a final remark on the DM yield and nutritional composition of the more promising species:

Table 3.2. *Results of field trials, harvested after three months (Kulumsa

Species and variety	DM (kg)	LTS ratio	CP %	Fat%	Fibre %	Ash%	CHO%
Chloris gayana var. Kulumsa 1	0.18	0.39	14.22	3.28	32.48	17.86	32.16
Chloris gayana var. Kulumsa 3	0.51	0.33	13.78	3.08	31.67	16.90	34.57
Chloris gayana var. Kulumsa 4	0.82	0.52	13.73	2.58	32.31	15.75	35.63
Chloris gayana var. Kulumsa 5	0.44	0.84	13.97	2.67	28.76	17.80	36.80
Chloris gayana var. Langano 1a	0.66	0.31	13.78	3.11	32.86	16.80	33.45
Chloris gayana var. Langano 1b	0.65	0.44	13.49	3.83	35.79	17.30	29.50
Panicum maximum var. Kelata	0.70	0.50	14.06	2.09	37,29	16.92	29.64
Panicum maximum var. Langano 2	0.85	0.48	14.70	2.43	37.74	1691	28.22
Panicum maximum var. Langano 3	1.12	0.30	14.23	2.48	38.22	17.64	27.15
Panicum maximum var. Melkasa 1	0.67	0.31	13.99	2.72	37..78	16.48	29.04
Panicum maximum var. Melkasa 2	0.43	0.20	12.39	2.07	40.35	14.81	30.39
P. coloratum, Kenyan var	0.51	0.53	14.94	3.51	33.66	15.19	32.71
P. coloratum, var. Bole	0.51	0.39	14.92	2.69	34.10	15.02	33.27
Setaria sphacelata var. Melka 1	1.14	0.51	12.70	3.87	37.61	11.58	34.25
Setaria sphacelata var. Melka 2	1.30	0.32	13.40	3.76	35.33	14.11	33.33
Setaria sphacelata var. Melka 3	1.94	0.70	15.12	4.48	30.43	13.15	36.82
Phalaris arundinaceae Eth. vars	1.08	0.53	14.44	3.68	31.86	11.60	38.42
Cenchrus ciliaris Kenyan var.	19	0.265					
Cenchrus ciliaris var. Dhera 1	22	0.449					
Cenchrus ciliaris var. Dhera 2	36	0.449					
Cenchrus ciliaris var. Awash 1	15	0.204					
Cenchrus ciliaris var. Awash 2	33	0.298					
Cenchrus ciliaris var. Jaue	46	0.428					
Cenchrus ciliaris var. Langano 1	58	0.562					
Cenchrus ciliaris var. Langano 2	36	0.234					
Cenchrus ciliaris var. Melkasa	27	0.265					

*Source: abridged form of a table, Carlson, J. 1972. *(Note that DM yield is the sum of two plants; Nutrient composition is calculated as the mean of plant and stem fractions)*

Chloris gayana: six varieties were in the field trial at Kulumsa farm. The best yielding varieties were var. Kulumsa-4 and var Langano-1a. These varieties were outstanding yielders also in the pot experiment (conducted prior to the field trial). On the whole, Kulumsa-4 and the two Langano-1 varieties were regarded as promising grasses for fodder production, first most suited for pastures, the others for hay or silage.

Panicum maximum: five varieties were put in the trial at Kulumsa farm. These were among the best yielders in the pot trial (data not shown). In the field trial, the Langano varieties were the highest yielders, but there were great differences in yield between the varieties. Only small differences were found in chemical composition. Overall, four varieties are regarded as promising forages for pasture or lay cultivation.

Setaria sphaceleta and ***Phalaris arundinaceae***: Both were all found to grow very satisfactorily on the poorly drained soil at the Asela livestock farm. *S. sphaceleta* var. Melka 3 was the best in yield as well as nutritive value, but it was somewhat slow to establish. *P. arundinaceae* was equal to some of the varieties of *Setaria* in yield but better in nutritive value. It was planted as rhizome split in a natural grassland at the livestock farm, fertilized with nitrogen and phosphorus. The plants compited very well with the natural vegetation and soon became dominating. *Phalaris arundinaceae*, proved to be a very promising indigenous grass variety for fodder production and should be of value for cultivation on temporarily waterlogged soils at medium and high altitudes in the area.

Perennial grass variety trial was carried out in 1976 – 198 at Kulumsa (ARDU, 1980). Seven indigenous grass ecotypes belonging to four species were evaluated for agronomic performance. Exotic varieties of each species were included for comparison. The indigenous *Chloris gayana* collected from Langano stood third in DM yield (Table 3.3).

Table 3.3. Forage yield of indigenous grass species at Kulumsa in 1976.

Species	**DM yield (kg/ha)**
Chloris gayana var. Mbrara (exotic, check)	4750
Chloris gayana var. Masaba (exotic, check)	6978
Chloris gayana (indig. Langano)	5350
Panicum coloratum (indigenous)	5483
Panicum maximum (Indig. from Melkafite)	4756
Golden Timothy (indig. from Ketare)	5311
Golden Timothy (exotic, control)	3167

Source: ARDU, 1980.

3.3.2. Evaluation of indigenous *Panicoid* grass taxa (tribe Panicae)

3.3.2.1. Collection and evaluation of indigenous panicoid grasses at DZARC

The Debre Zeit Research Center (DZARC) undertook germplasm collection expeditions in south-western Ethiopia around Bebeka (near Bonga) to screen and develop adapted and high yielding forage crops (Mekasha Chichaibelu *et al*, 2015). The panicoid (tribe **Panicae**) grass genera *Panicum*, *Brachiaria* and *Pennisetum* were targeted for collection since these genera are among the most successful pastures that have contributed substantially to the development of livestock industries particularly in Australia, Central and South America (CIAT, 2006; Whitman, 1980). Despite their nativity to Africa (Bogdan, 1977; Clyton, 1983), they have not been exploited as sown pastures to any significance anywhere in tropical Africa. This is partly because the cultivars developed from these taxa had been bred and/or selected under different environments and production systems, which may not represent the African situations. This necessitates inclusion of indigenous ecotypes in the forage collection, selection and variety development programs under the rigors of local environments. Therefore, tapping the indigenous genetic resource was a justified move undertaken by DZARC researchers. To that end, six grass species were collected as root splits and multiplied at DZARC forage nursery plot (Mekasha Chichaibelu *et al*, 2014; 2015) (Table 3.4).

Table 3.4. Grass species collected by DZARC from south-western Ethiopia.

Sn	Species	Common name	Longevity	Growth form
1	*Panicum maximum*	Gunea grass	Perennial	Erect, tufted
2	*Pennisetum sphacelatum*	Wire grass	Perennial	Erect, rhizomatous
3	*Pennisetum trachyphyllum*		Perennial	Decumbent, rhizomatous
4	*Pennisetum unisetum*		Perennial	Erect, tufted
5	*Sorghum aethiopicum*		Annual	Errect, tufted
6	*Cynodon aethiopicus*	African giant grass	Perennial	Stoloniferous

Source: Mekasha Chichaibelu *et al*, 2014; 2015

From the preliminary observation and multiplication in the DZARC nursery plot, four of the entries were evaluated for their agronomic performance in replicated field experiment. Rhodes grass, c.v. Callide was included as a control. The result revealed that the native species were superior to the exotic control (*Chloris gayana*, c.v. callide) by almost two-fold. All the species persisted over the drought season and grew vigorously at the onset of the rains. Herbage yield and quality of the native grass species data is shown in Table 3.5.

Table 3.5. Herbage yield and quality of native panicoid (tribe **Panicae**) grass species at Debre Zeit.

Species	DM yield (t ha $^{-1}$)		Nutritional analysis	
	First season	Second season	CP%	IVDMD%
Pennisetum sphaceletum	10.465	7.00	10.14	53.65
Pennisetum unisetum	8.057	6.50	9.29	50.16
Pennisetum trachyphyllum	10.327	7.80	7.50	64.51
Panicum maximum	14.417	10.87	11.53	59.31
Chloris gayana c.v. callide (check)	8.73	5.93	9.5 0	57.36
C.V. %	7.95	20.95		

Source: Mekasha Chichaibelu *et al*, 2014; 2015

3.3.2.2. Evaluation of mission grass (Pennisetum polystachion)

Mission grass (*Pennisetum polystachion*) is a weedy annual or perennial grass, with culms up to 2 m high. It is pantropic in distribution. In 1987, ILCA undertook survey and collection of targeted wild relatives of crops and forage species in the Sahelian Africa, Niger (Mengistu, S., 1984c). Targeted species were in the genera *Pennisetum (P. americanum, P. polystachion), Andropogon* (*A. gayanus*) and *Stylosanthes* (*S. fruiticosa*). In the wetter woodland of the Sahelian Africa, *Penisetum polystachion* was found as dominant component of the herbaceous layer, forming a dense stand in combination with similar grasses *Pennisetum pedicellatum* and *Andropogon gayanus*. Describing its forage and environmental value Partridge (1986) stated that mission grass thrives in difficult conditions and is adaptable; prefers high rainfall but tolerates short drought periods. It is adapted to a wide range of soils from light sandy to waterlogged clay soil; can be grown without fertilizer. Mission grass, according to Partridge, can grow under 80% shade and on poor fertility soils. *Pennisetum polystachion* is resistant to fires. It is useful for controlling erosion on hillsides. The same author valued Mission grass as a valuable fodder, either grazed or cut to be used as hay by cattle; its nutritive value and palatability is high before seedling and drops dramatically after it; it is thus recommended to prevent flowering by 6-week cutting intervals.

In Ethiopia, it forms the fire-climax community of the herbaceous growth of the Sudanian woodland vegetation along the frontier (Ethiopia-Sudan) from Humera extending southwards up to Gambella. Researchers from Pawe Agricultural Research Center (PARC) collected germplasm of native ecotypes of *P. polystachion* and associated perennial grass *Panicum maximum* and *Hiparrhenia* sp that were evaluated together for herbage yield and nutritional value. Selected accessions of *P. polystachion* and *Panicum maximum* were developed as forage varieties under the names: **Netch Sar** and **Degun Gizia**, respectively, that were officially released in 2006. Besides its apparent forage value, the species has excellent attributes of fast establishment and consolidation on disturbed land. This attribute makes it valuable short-term pasture to rehabilitate highly degraded arid rangelands elsewhere in Ethiopia through reseeding/ over-sowing. This attribute was emphasized and duly credited during its variety verification and recommendation for release. The report of the technical committee delegated to examine the candidate species stated that the "As learned from the breeders' application document, the candidate species, *Pennisetum polystachion* was outstanding in the main forage attribute, i.e., dry matter yield; it exceeded the check (*Andropogon gayanus*) by 25.53% over locations and years. It also exceeded the check in seed yield by 70.61%, crude protein content by 3.03. It performed well in other attributes such as drought and heat tolerance and resistance to major pests and diseases of grasses. *Pennisetum polystachion* is one of the few annual grass species adapted to arid lowlands. It has fast establishment under poor fertility soils, exploits space in disturbed lands. It is also highly prolific in seed production. These attributes make it a special grass crop for rehabilitating degraded lands. Therefore, the TC recommended its registration and release". Accepting the TC report, the NVRC approved its release in 2006. The agronomic and nutritional performances data of the candidate varieties as reported by PARC is presented in Table 3.6. The details on the other released variety- **Degun Gizia** (*Panicum maximum*) is discussed under a separate section.

Table 3.6. *Major agronomic and nutritional attributes of four indigenous grass species at (PARC)

Species	Herbage DM t/ha	L_S Ratio	Seed yield (q/ha)	CP %	IVOMD %
Sembelet (*Hyparrhenia* sp.)	10.16	0.63	26.53	6.30	52.30
Netchsar (*Pennisetum polystachion*)	10.92	0.82	24.60	6.60	50.50
Panicum (*Panicum maximum*)	9.78	2.57	0.97	9.40	50.90
Andropogon gayanus	8.13	0.86	7.23	6.40	51.50
* (Data: mean over three locations & two years)					

Source: data submitted by PARC to NVRC, application for variety evaluation and release (2006).

3.3.2.3. Evaluation of wetland adaptive group of perennial grass species: Pennisetum sphacelatum Cynodon aethiopicus, Brachiaria mutica and B. decumbense

Pennisetum sphacelatum is a perennial rhizomatous grass about 1.5 m tall. It is a tussoky erect growing, leafy at young stage but later becomes woody (so named Wire Grass). It is distributed in wet woodlands and rainforest margins. Debre Zeit Agricultural Research Center (DZARC) undertook germplasm collection for six indigenous grass species *P. sphacelatum, P. unisetum, Cynodon aethiopicus, Panicum maximum, Pennisetum trachyphyllum* and *Sorghum* sp. in southern Ethiopia, near Bebeka, the Woreda famous for its coffee and tea production (Mekasha Chiaibelu *et al*, 2014; 2015). Three of the acquisitions were selected for the first phase of agronomic evaluation. These species share the wetter habitat spectrum in south-western Ethiopia. They have similar morphology and growth characteristics and growth requirements (Table 3.7).

Table 3.7. Morphology and growth characteristics of grass species evaluated at DZARC.

Characteristics	**Species/ Varieties**		
	B. mutica DZF- 483	*C. aethiopicus*	*P. sphacelatum*
Growth form	Decumbent	Erect	Erect
Growth habit	Rhizomatous	Stoloniferous	Rhizomatous
Longevity	Perennial	Perennial	Perennial
Propagation	Vegetative	Vegetative	Vegetative
Mean plant height (cm)	117	113	72
Mean forage yield (DM t/ha)	13.302	12.174	13.186
Edaphic environments	bottomlands with ample soil moisture in medium to low altitude areas		
Adaptability with irrigation	Medium and low-altitude areas anywhere		
Utilization information	- Most suited for irrigated production system -Excellent for direct grazing systems -Excellent for haying/ ensiling; multiple cuts every 3 months (irrigation)		

Source : Mekasha Chichaibelu *et al*, 2014; 2015

The growth performance and herbage yield of these panicoid perennial grasses from a national yield trial involving six grasses is shown in Table 3.8 and Table 3.9, respectively, and the nutritient composition data is given in Table 3.10.

Table 3.8. Mean Growth and yield performance over two harvests and over three locations of six perennial grass species on a National Variety Trial (NYT) in 2004EC (combined analysis over harvests and locations).

	Average of two harvests per year					Annual total DM (t/ha/y)
Species/variety name	Mean Ht (cm)	Mean DM%	Mean fresh Yield t/ha	Mean DM (t/ha)	Mean LSR	
Cynodon aethiopicus	113	31.07	37.885	11.833	0.816	23.666
Pennisetum sphacelatum	72	30.69	42.483	13.131	0.800	26.262
Brachiaria decumbens	363	29.50	18.890	5.905	0.894	11.144
Brachiaria mutica DZF 484	106	27.56	33.319	9.213	0.626	18.426
Brachiaria mutica DZF 483	117	30.40	46.499	13.669	0.712	27.337
Chloris gayana cv Masaba	118	30.09	27.299	8.644	0.817	17.289
CV%	15.80	8.41	10.48	12.20	20.02	12.73
SE	7.804	2.311	1.202	0.423	0.052	0.878

Source : Mekasha Chichaibelu *et al*, 2014 ; 2015

Table 3.9. Mean yield performance over two years and three locations of six perennial grass species on a National Variety Trial (NYT)

Species/variety name	Mean fresh Yield t/ha	Mean DM%	Mean DM yield (t/ha)	Mean LSR
Cynodon aethiopicus	37.996	32.01	12.174	0.782
Pennisetum sphacelatum	41.929	31.73	13.186	0.727
Brachiaria decumbens	18.540	30.02	5.564	0.823
Chloris gayana cv Masaba	27.783	30.26	8.506	0.775
Brachiaria mutica DZF 484	32.016	28.20	8.991	0.552
Brachiaria mutica DZF 483	45.913	29.79	13.302	0.659
CV%	14.22	11.40	17.67	26.19
SE	0.931	0.665	0.349	0.036

Source : Mekasha Chichaibelu *et al*, 2014 ; 2015

Table 3.10. Nutritient composition of grass species under agronomic evaluation at DZARC.

Sample type	DM %	Ash %	OM %	NDF %	ADF %	Hemi-cellulo-se %	Lignin %	CP %	DOM %
Brachiaria decumbens	94.08	11.51	88.49	79.8	45.69	34.11	7.47	5.72	45.51
B. mutica DZF 484	94.08	11.51	88.49	79.80	45.69	34.11	7.47	5.72	45.51
B. mutica DZF 483	95.03	15.58	84.42	76.85	32.96	55.62	5.88	9.17	40.13
Pennisetum sphacelatum	95.45	14.67	85.33	81.13	45.62	35.50	10.38	10.2	48.82
Cynodon aethiopicus	94.77	12.28	87.72	80.23	46.18	34.05	13.36	9.01	41.68
Chloris gayana var Massaba (com. check)	94.75	13.52	86.48	74.61	37.86	36.76	8.68	9.93	49.93

Source: Mekasha Chichaibelu *et al*, 2014; 2015

3.3.2.4. Evaluation of Desho grass (Pennisetum glaucifolium)

Desho (*Pennisetum glaucifolium*) is a local forage traditionaly used by Wolayta people well ahead of its evaluation and release by DZARC in collaboration with the Areca Agricultural Research Center (AARC) (Solomon Mengistu *et al*, 2017). Desho is a panicoid perennial grass endemic to the central and the southern Ethiopian highlands. Due to its fast growth and rapid ground cover, it has been locally used as cut-and-carry fodder and as gully stabilizing plantings.

In recognition of its potential as forage crop germplasm collection and screening was initiated by DZARC in collaboration with Areca Agricultural Research Center (AARC). Germplasm collection was undertaken on four desho genotypes that were sampled as root splits from selected locations that represented the natural distribution of desho, namely, three locations clustered around the medium highlands of Wolayta Zone of Southern Nations, Nationalities and Peoples Region (SNNPR): Areka, Kindokosha-1 and Kindokosha-2 and the fourth highland ecotype was collected at Kulumsa. This ecotype possibly represents grass species collections carried out a long time (45 years ago) by CADU (Carlson 1972) and became adapted to the cool highland (2200 m.a.s.l.) environment, unlike the other ecotypes.

These genotypes were evaluated for their growth characteristics, fodder yield and nutritional attributes at four locations, namely, Debre Zeit, Kulumsa, Holeta and Wondo, under supplemental irrigation (Solomon Mengistu *et al*, 2017). At each location, agronomic evaluations were carried out for DM yield leaf-to-stem ratio and for nutritional composition of samples taken at the time of harvesting for herbage yield.

Herbage yield varied with altitude, and hence temperature, abundance of supplementary irrigation and soil fertility levels. Fodder yield over locations was the highest for Kindo Kosha 1-DZF- 591 (23.59 t/ha DM followed by Areka-DZF-590 (21.70 t/ha DM). While Kulumsa DZF-592 and Kindo Kosha2-DZF 589 ranked third and fourth in DM yield, giving 20.69 and 17.00 t/ha, respectively (Table 3.11).

Table 3.11. Mean Growth and herbage DM yield performance of desho grass varieties over two years and four locations (combined analysis over locations and years)

Variety name	Mean plant height	Mean DM yield (t/ha)	Mean LSR
Pennisetum glaucifolium, Areka, DZF-590	121.7	21.698	0.465
Pennisetum glaucifolium, Kulumsa, DZF-592	86.8	20.692	0.371
Pennisetum glaucifolium, Kindu Kosha DZF-591	115.4	23.589	0.283
Pennisetum glaucifolium, kindu Kosha DZF-589	79.7	18.993	0.394
SE	120.6	1.9	0.060

Source : Solomon Mengistu *et al*, 2017

The nutritive composition of desho varieties was within satisfactory range of animal nutrition for the more important parameters. Crude protein (CP) content ranged 6.8 – 7.06% and IVDMD ranged 50.4 – 56.46% Table 3.12.

Table 3.12. Nutritient composition and digestibility of four varieties of Desho grass (*Pennisetum glaucifolium*)

Variety	**DM%**	**Ash%**	**CP%**	**NDF%**	**ADF%**	**Lignin%**	**IVDMD%**
Areka, DZF590	91.84	8.05	6.82	61.35	38.59	6.41	51.08
Kulumsa, DZF 592	92.00	7.95	7.04	64.21	38.35	6.46	56.46
Kindu Kosha 1, DZF 591	93.65	7.90	6.90	60.78	38.28	6.52	50.36
Kindu Kosha 2, DZF 589	92.37	7.94	7.06	66.84	38.21	6.49	54.33

Source : Solomon Mengistu *et al*, 2017

Overall, *Desho* varieties showed excellent performance as was evident from the agronomic performance and nutritional composition. As a result, three of the promising ecotypes have been released officially under the variety name: Kulumsa-DZF-592, Areka-DZF-590; and Kindo Kosha-1-DZF-591.

Desho has special favorable characteristics as sound forage crop, including wide range of adaptation, high yield of good quality forage; excellent for irrigated production system, and freedom from diseases and pest attack. Researchers from DZARC and collaborating research centers (Solomon Mengistu *et al*, 2017; Tekalign Yirgu *et al*, 2017) recommended desho grass varieties for cut-and-carry use as well as conventional pasture in the wetter regions of southern and south-western medium to high altitude highlands; while under supplementary irrigation conditions it can be grown elsewhere in Ethiopia, including arid and semi- arid lowlands.

3.3.2.5. Research on indigenous panicum (the genus Panicum)

The genus *Panicum* comprises tall tussocky grasses including Guinea grass, Blue panic, Colored blue,

Guinea grass (Panicum maximum / Megathyrsus maximus)

Guinea grass is extremely variable species, loosely to densely tufted, shortly rhizomatous, erect or geniculately ascending, often branched, nodes usually bearded, sometimes rooting at the lower nodes. Because of the morphological and agronomic variability, the species is treated as 2 broad non-taxonomic types:

a) Tall/medium (TM) type: tussock, mostly >1.5 m in flower; robust perennials (sometimes annuals or short-lived perennials), 1.5–3.5 m tall, with stems to about 10 mm diameter. Commonly referred to as "Guinea grass" or "giant Guinea grass".

b) Short (S) type: tussock, mostly <1.5 m in flower; perennials, 0.5–1.5 (–1.8) m tall, stems to about 5 mm diameter, commonly referred to as "panics".

Guinea grass (*Panicum maximum*) is native to Africa. It is distributed in wetter woodlands and forest margins of eastern Africa, central Africa, Southern Africa and sub-Saharan west Africa. It is introduced in tropical and subtropical countries where it has naturalized (Clayton, 1983). It is valued as long-term pasture if fertility is maintained. It is ideal for cut-and-carry, although bristly types may cause discomfort to forage collector. It is reasonably palatable when mature, providing good roughage for use in conjunction with urea molasses supplements. It has been used successfully for making silage and hay. Guinea grass grows in most soil types providing they are well-drained, moist, and fertile. Some varieties are tolerant of lower fertility and poorer drainage. Its tolerance of low soil pH and high aluminum (Al^{+++}) saturation has made it valuable pasture to reclaim acid soils in Latin America.

In Ethiopia, Guinea grass is distributed in river valleys, moist woodlands in western and southern Ethiopia. It is a component of the tall grass savannah of western Ethiopia along the frontier with the Sudan, extending from Humera to Metekel and Gambela. Luxeriant ecotypes up to four meters tall make up the dominant tall grass component of the herbaceous strata often in dense stands in association with *Pennisetum polystachion, P. pedicellatum, Brachiaria brizantha* and *Andropogon gayanus*. Wildfire during the dry season is a common ecological phenomenon that wipes out the herbaceous vegetation including the palatable and nutritious forage species. Management of this vegetation involving appropriate conservation and utilization practices would salvage the abundant forage resource in the region that could be transported to the feed-deficit areas elsewhere in Ethiopia.

Germplasm collection for potential grass species was undertaken at Pawe Research Center (PARC). Three of the more important grass species, namely: *Panicum maximum; Pennisetum polystachion;* and *Hyparrhenia* sp., were evaluated at three locations around Pawe for the purpose of variety development and registration. The agronomic performance is shown in Table 3.13.

Table 3.13. Main attributes of **Degun Gizia** (*Panicum maximum)* that justify its recommendation for release

Sn	Attribute	Priority	Performance rating
1	Mean Dry matter yield (DM): 9.8 t/ha	1	Exceeds the check at two locations
2	Mean Seed yield: 0.9 quintal/ha	4	
3	Leaf to stem ratio: 0.950		Exceeds the check
4	Crude protein (CP) content: 9.4%	5	Exceeds the check
5	Invitro DM digestibility (IVDMD): 50.9%	6	Does not exceed the check
6	Disease incidence	3	Resistant to the common disease of panicum:: head-smut (*Ustilago*)
6	Peculiar merit	7	Vigorous crop free from smuts; quite leafy as observed in the field; excellent seed recovery peculiar to this ecotype.

Source: Data submitted for variety examnation by PARC

The report of the technical committee (delegated by NVRC) that evaluated *P. maximum* as a candidate grass variety is as follows.

“The candidate forage grass variety *Panicum maximum* was observed to be outstanding in the main forage attribute, i.e., dry matter yield (9.8 t/ha). It exceeded the check Gamba grass by 16.9% over locations and years. It also exceeded the check in crude protein content by 31.97%. It also performed well in other attributes such as drought and heat tolerance and resistance to major fungal diseases of panicoid grasses, namely, smut as observed in the field. Furthermore, the candidate grass **Degun Gizia** (*Panicum maximum*) is the first in the genus *Panicum* so far forwarded for registration and release. It has acceptable agronomic performance as outlined above and was observed to be free from pathogens and pests during the field inspection. Its leaf to stem ratio is superior to most cultivated forage grasses. Therefore, the TC has recommended **Degun Gizia** for registration and release as a forage grass crop variety”.

3.3.3. Evaluation of *Hyparrhenia* spp (genus *Hyparrhenia*)

3.3.3.1. Hyparrhenia species evaluation at CADU

CADU was the first institute to collect and evaluate *Hyparrhenia* species for adaptability and forage yield potential (CADU, 1969). Collected accessions were not identified to a species level except *H. hirta*. Four of the accessions were designated by their morphology, as tall medium or short type or by site of collection. Agronomic evaluations were often conducted by lumping in various grass and legume species collected. Initially in 1969, the five accessions of *Hyparrhenia* were evaluated with *Andropogon Abyssinica, Snowdenia polystachia* and two annual legume species, *Medicago polymorpha* and *Trifolium rueppellianum*. The herbage yield of the *Hyparrhenia* accessions ranged 1.2 – 4.8 t/ha DM while the weedy, often overlooked annual grass *Snowdenia polystachia* yielded 13.8 t/ha DM. *A. abyssinica* stood second in DM yield (6.7 t/ha). The two annual legumes *Medicago polymorpha* and *T. rueppellianum* gave 3.6 and 1.3 t/ha DM respectively (Table 3.14).

Table 3.14. Herbage yield of five *Hyparrhenia* accessions/ ecotypes, and two perennial grass species (*Snowdenia polystachia* and *Andropogon abyssinica*) at Kulumsa, CADU in 1969.

Species	**DM yield (t/ha) at stages of harvest**		**Total yield (t/ha)**
	Heading	**Flowering**	
Hyparrhenia hirta	3.1		3.1
Hyparrhenia sp. No 12	1.2		1.2
Hyparrhenia sp- Kulumsa	2.9		2.9
Hyparrhenia sp medium	4.8		4.8
Hypparhenia sp. Tall	3.3		3.3
Andropogon abyssinica	6.7		6.7
Snowdenia polystachia		13.8	13.8
Medicago polymorpha		3.6	3.6
Trifolium rueppellianum	1.3		1.3

Source: CADU, 1969. 1971; 1973.

The following year in 1970, four accessions of *Hypparhenia* together with *Pennisetum clandestinum*, *Cynodon dactylon* and *Neonotonia wightii* were evaluated at Kulumsa. The herbage yield of the *Hyparrhenia* accessions ranged 14.3 – 19.1 t/ha DM while *P. clandestinum* and *C. dactylon* gave 4.9 and 6.9 t/ha DM respectively. The legume, *N. wightii* gave 9.8 t/ha DM (CADU, 1971) (Table 3.15).

Table 3.15. Herbage yield of four *Hyparrhenia* accessions and two perennial grass species grown at Kulumsa in 1970.

Species/ Variety	**DM yield (t/ha)/ harvest**			Total DM yield (t/ha)
	Flowering	Flowering	Heading	
Hyparrhenia hirta	5.2	3.7	5.4	14.3
Hyparrhenia sp	7.5	5.0	6.6	19.1
Hyparrhenia sp	5.5	4.9	7.9	18.3
Hyparrhenia sp	4.2	3.9	10.4	18.5
Cynodon dactylon	3.3		3.6	6.9
Pennisetum clandestinum	2.1	2.8		4.9
Neonotonia wightii	5.3	4.5		9.8

Source: CADU, 1969. 1971; 1973.

The same four accessions of *Hyparrhenia* were evaluated with one accession of *Panicum maximum* at Kulumsa in 1972 season (CADU, 1973). Herbage yields of the *Hyparrhenia* ranged 14,470 25,690 kg/ha dry matter per hectare. Perhaps included for comparison, *Panicum maximum* yielded 15,280 kg DM/ha (Table 3.16).

Table 3.16. Mean DM yield of *Hyparrhenia* accessions grown for two years (1969 - 1970) at Kulumsa.

Species, accessions	DM yield (kg/ha)			
	Heading	Heading	Flowering	Total DM yield
Hyparrhenia sp (medium height)	4520		13790	25,690
Hyparrhenia sp (medium height)	3460		13770	19,730
Hyparrhenia sp (tall)	2490		12290	19,730
Hyparrhenia hirta	3880	2910	7680	14,470
Panicum maximum	4770	4880	5630	15,280

Source: CADU, 1969. 1971; 1973.

3.3.3.2. Evaluation of indigenous Hyparrhenia species at PARC

At Pawe Research Center (PARC), *Hyparrhenia* species known locally sembelet, was evaluated with two other native perennial grass species: *Panicum maximum* and *Pennisetum polystachion*. According to the report of the PARC breeders, one of the candidate species, *Hyparrhenia* performed satisfactorily in DM yield exceeding the check *Andropogon gayanus* by 19.95% over locations and years. In seed yield, as well, it exceeded the check by 72.75% (Table 1). However, it performed poorly in other attributes, namely, leaf-to-stem ratio and crude protein (CP) content. The then Technical Committee (TC), delegated to examine the variety rejected the species until further evaluations were brought forward that justify its value as forage. The performance of *Hyparrhenia* and the other candidate varieties is shown in Table xxx and Table 3.17.

Table 3.17. Main attributes of native *Hyparrhenia* that justify its recommendation for release

Sn	Attribute	Priority	Performance rating
1	Mean Dry matter yield (DM): 10.16 t/ha	1	Exceeds the check by 19.95%
2	Leaf to stem ratio: 0.63		Does not Exceeds the check; less by -37.60%
3	Mean Seed yield: 26.53 quintal/ha	4	Exceeds the check by 72.75%
4	Crude protein (CP) content: 6.30%	5	Does not Exceeds the check; less by -1.59%
5	In-vitro DM digestibility (IVDMD): 52.30%	6	Exceeds the check by 1.53
6	Disease and pest incidence; nill	3	Resistant to major pests and diseases of grasses
7	Peculiar merit	7	Poor in two important agronomic characteristics: Leaf-to-Stem Ratio and CP content

Source: Data submitted by PARC to NVRC

3.3.3.3. Evaluation of indigenous Hyparrhenia species (Saari Gebremariam) at Humera (TARI)

A native perennial grass species (Saari Gebremariam) as the candidate variety, and a check grass variety (Masaba Rhodes), were observed by the technical Committee (TC) at three testing sites of Axum Agricultural Research Center. A total of six experimental plots (three on station together with 2 on-farm sites for each station) that represented three ecological areas (Rama, Adet, L/Maichew and Ahferom) were visited. The stands of the varieties were rigorously examined for any symptoms of disease and pest attack, sensitivity to weather extremes, vigor, plot cover and stand density.

Six major attributes of yield and quality (3 agronomic; 3 nutritional qualities) were the bases for assessing the performance of the candidate native perennial forage grass variety. These attributes, namely, herbage yield (tones DM/ha); seed yield (q/ha) and Leaf to Stem ratio (LTS); protein content (CP%) and digestibility (IVOMD%) are important measures for value of a forage crop. The variety performance on these attributes was extracted from the Center's breeder data which is presented in Table 3.18 and Table 3.19 for yield and Table 3.20 for nutritional attributes.

Table 3.18. Performance of candidate variety and the check in selected agronomic attributes, herbage yield (t DM/ha) (average of two locations), and leaf-to-stem ratio (LSR).

Locations	DM yield of Vars (t/ha) (mean over Yrs)			
	Saari Gebre Mariam		*Chloris gayana* var. Masaba (check)	
	DM	LSR	*DM*	LSR
Mereb Lekhe	10.57	0.71	9.52	1.23
N/Adet	6.49	0.91	3.97	1.27
Average over Locations	8.53	0.81	6.75	1.25

Source: Data submitted by AARC-TARI to NVRC

Table 3.19. Performance of candidate variety and the check variety in selected agronomic attributes, grain yield (q/ha) (average of three locations).

Locations	Grain yield of varieties (q/ha) (mean over years)		
	Saari G/M	*C. gayana* (Check)	Yield advantage
Loc 1. Mereb Lekhe	11	5.5	50
Loc 2. N/Adet	15	4.2	72
Average over Locations	9.45	4.11	61

Source: Data submitted by AARC-TARI to NVRC

The nutritional composition of the candidate species *Hyparrhenia* sp (Saari Gebremaryam) is shown in Table 3.20. The content of crude protein (CP) is 9.93% which is within the range of good pasture grass species. The IVDMD (53.34%) is also satisfactory range for forage grass crops.

Table 3.20. Performance of candidate variety and the check variety in selected nutritional attributes (analysis performed from pooled samples).

Nutrient composition at 50% flowering	Varieties performance (mean of 2 yrs)		Remarks
	Saari Gebremariam (*Hyparrhenia* sp.)	Masaba Rhodes (*Chloris gayana*)	
CP%	9.93	8.98	Sampled at 50%
IVOMD%	53.34	51.84	
NDF%	73.31	70.60	

Source: Data submitted by AARC-TARI to NVRC

The delegated TC reported "The candidate perennial grass variety, Saari Gebremariam (a local perennial *Hyparrhenia* sp) has outstanding performance in three important yield attributes for a sound forage crop, namely, herbage (8.53 t DM/ha) with a yield advantage of 24.38%, leaf to stem ratio (LSR) of 0.810 and grain yield of 9.45 q/ha. The variety has nearly double yield of herbage and grain and comparable quality performance as the check variety. The CP content (9.93%) of the variety exceeded the check (masaba Rhodes) and the value is well above the threshold level (7-8%) for a sound tropical grass forage crop. The IVOMD (53.34%) is also within acceptable level for a quality pasture grasses. Therefore, the TC recommended this important native perennial grass variety to be considered for regional release for use within the area recommended by the breeders".

3.3.4. Evaluation of forage sorghum species (the genus *Sorghum*)

3.3.4.2. Taxonomy and distribution

Sorghum is a genus of about 25 species of flowering plants in the grass subfamily Panicoideae and the tribe Andropogoneae (the same as *Andropogon* and sugarcane). Some of these species are grown as cereals for human consumption and some in pastures for animals. One species is grown for grain (*Sorghum bicolor*), while many others are used as fodder plants, either cultivated in warm climates worldwide or naturalized in pasturelands. There are two commercial varieties of forage sorghum: *S. sudanense and S. almum*. In Ethiopia, wild sorghum species and ecotypes are found in western Ethiopia along the Ethio-Sudan frontier in the humid and sub-humid woodlands of Humera in the north extending southwards to Metekel and Gambela.

3.3.4.2. Evaluation of Sorghum for forage yield and nutritient content at HuARC, TARI

Researchers at Humera Agricultural Research Center (HuARC) collected potential grass and legume species in the Sudanian woodland around Humera and screened for forage yield and quality. Among the grass germplasm collected two perennial grass species, namely, *Sorghum aethiopicum* (**Mechello**) and *Echinochloa pyramidalis* (**Mezrut**) were evaluated for growth and forage yield attributes for four years at three locations. A commercial forage grass variety, Masaba Rhodes (*Chloris gayana*) was included for comparison.

Researchers/ breeders at HuARC applied to NVRC to evaluate and release the native grass ecotypes by submitting the candidate varieties performance data on a standard format. The NVRC delegated a technical committee to evaluate the species/ecotypes on various attributes and pass decisions on the fate of the candidate varieties: reject or accept as forage crop variety.

The delegated technical committee considered five major attributes of yield and quality (3 agronomic; 2 nutritional quality) as the bases for assessing the performance of the candidate perennial forage grass varieties.

a) *Agronomic attributes*: herbage yield (tones DM/ha); seed yield (q/ha) and Leaf to Stem ratio (LTS)

b) *Quality attributes*: protein content (CP%) and digestibility (IVOMD%).

Table 3.21 and Table 3.22 show the more important agronomic and nutritional performance data of the candidate varieties extracted from the standard application document submitted by the researchers/ breeders.

Table 3.21. Performance of two native grass varieties and the check (*Chloris gayana*) in herbage and seed yields, and leaf-to-stem ratio (LSR).

Yield & LSR	Varieties performance (mean over 3 locations & 2 yrs)		
	Mezrut (*E. pyramidalis*)	Mechello (*Sorghum aethiopicum*)	Masaba Rhodes (*Chloris gayana*)
DM yield (DM t/ha)	24.44	22.27	8.3
Seed yield (q/ha)	11.35	9.58	5.63
Leaf-to-stem ratio (LSR)	1.535	1.255	0.89

Source: data submitted by Humera Agricultural Research Center (HuARC) to NVRC for variety evaluation and release (2017).

Table 3.22. Performance of two native grass varieties and the check (*Chloris gayana*) in selected nutritional attributes*.

Quality (nutrient content)	Varieties performance (samples taken at 50% flowering)		
	Mezrut (*E. pyramidalis*)	Mechello (*Sorghum aethiopicum*)	Masaba Rhodes (*Chloris gayana*)
CP%	13.88	8.76	9.30
IVOMD%	57.16	50.74	65.00
NDF%	64.55	70.21	70.60
*Nutrient analysis performed from pooled samples taken at 50% flowering.			

Source: data submitted by Humera Agricultural Research Center (HuARC) to NVRC for variety evaluation and release (2017).

TC decision on Mechelo (Sorghum aethiopicum)

The TC summarized the performance of the candidate perennial grass variety, Mechelo (*Sorghum aethiopicum*) and commented as follows: “Mechello (*Sorghum aethiopicum*) has outstanding performance in two important yield attributes for a sound forage crop, namely, herbage yield (22.27 t DM/ha) and seed yield (9.58 q/ha) yields. The candidate variety exceeded the check in most yield attributes and has comparable performance as the check in quality parameters. The CP content (8.76%) of the variety is only less by a unit than the check (Masaba Rhodes) while the IVOMD (50.74%) is higher than the check, and well above the threshold level for quality pasture grasses”. On these grounds the TC recommended the native grass variety Mechelo (*Sorghum aethiopicum*) to be considered for release.

TC decision on Mezrut (*Echnochloa pyramidalis*)

The TC summarized the performance of the candidate perennial grass variety, Mezrut (*Echnochloa pyramidalis*) and commented as follows: “Mezrut has outstanding performance in two important yield attributes for a sound forage crop, namely, herbage (24.44 t DM/ha) and seed (11.35 q/ha) yields. The variety has more than double yield and comparable quality performance as the check variety (Masaba Rhodes). The CP content (13.88%) of the variety exceeds the check (masaba Rhodes) and the value is well above the threshold level (7-8%) for a sound tropical grass forage crop. The IVOMD (57.16%) is also well above the threshold level for quality pasture grasses”. On these grounds the TC recommended the native perennial grass variety **mezrut** (*Echnochloa pyramidalis*) to be considered for releas

3.3.5. Evaluation of Cynodonteae tribe (sub-family Chloridoideae)

3.3.5.1. Evaluation of African star grass (the genus Cynodon)

The genus *Cynodon* is in the tribe Cynodonteae, sub-family Chloridoideae, largely robust, sometimes fine, stoloniferous, deep-rooted group of perennials. Stolons are often woody, and culms to 100 cms tall, and 1–3 mm in diameter near the base. It includes Bermuda grass (*Cynodon dactylon*) and the robust forms of African giant grasses: *Cynodon aethiopicus, C. nlemfuensis,* and *C. plectostachyus*. The genus is native to Africa but naturalized in North America, Latin America and Australia.

In Ethiopia, the common species *Cynodon dactylon*, known in various names: Star grass, African couch grass, Bermuda grass, is widely distributed in the Ethiopian highlands as dominant component of natural grasslands. No attempt has been made to screen and develop cultivated varieties although its forage value is recognized in native pastures. The major limitations for the negligence appear to be its sterility and hence problem of propagation, and somewhat low DM yield. While the robust form *C. aethiopicus* is not as common as *C. dactylon* and its distribution is limited to the wetter regions, including, south-western Ethiopia; the western strip of lowlands along the frontier with the Sudan, and lower courses of rivers and valleys found elsewhere within the medium highlands. Germplasm collection was initiated by ILCA in late 1980s, but the number of entries was limited to represent its wide spectrum of distribution. At the Debre Zeit Research Center, this species and affiliated perennial grasses, *Panicum* and *Pennisetum* were collected and subjected to multiplication and agronomic evaluation (Section 3.3.2.3., Tables 3.7 - 3.10). The agronomic and nutritional evaluation revealed *C. aethiopicus* to be promising as forage, so it was promoted to advanced agronomic and nutritional evaluation leading to its registration and release for wider use. For details of its performance, please refer to Tables, 3.7; 3.8; 3.9. and 3.10 under Section 3.3.2.3 (Wetland adaptive group of perennial grass species).

Chapter IV: Gaps and Future Research Directions on Forage Research and Development

4.1. Research gaps

4.1.1. Released forage varieties lack the essential final parts of agronomic evaluations

Almost across research centers there is lack of trained manpower specializing agronomy, breeding, soil science and plant protection/pathology. As a result, varieties are not evaluated for soil nutrient requirements; compatible species in mixed sowings; susceptibility/ resistance to pest and diseases and need for control measures.

4.1.2. Released forage varieties lack animal evaluation

Almost all forage varieties recommended or released lack animal response studies; grazing trials and feeding trials using penned herbivores is bypassed for reasons of capacity and financial limitations. International research institutions such as ILRI, ICARDA, CIAT, etc, with better resources could take up certain areas related to their mandate and fill the research gap that are hindering adoption of forage crop technologies.

4.1.3. Absence of applied/ on-farm/ participatory research on released or pipeline forage crops

Farmers need tangible evidence as to whether the forage technologies can be practically implemented and economically feasible enough to allocate their meagire resources.

4.2. Areas for Future Research Attention

4.2.1. Research attention to potential indigenous forage taxa

Scores of highly potential forage taxa have not received research emphasis. Some species are collected but the germplasm is lost due to keeping them in substandard stores. Some are not at all collected; their habitats are threatened with ecological degradation. A list of such valuable forage taxa that have not received due attention, is presented in Table 4.1

Table 4.1. Forage species that have not received research attention

Species	Characteristics	Potential	Status/ Threats	Immediate action
I. GRASSES				
Andropogon gayanus	Perennial, tall & leafy	Drought & heat tolerant	Not collected	Collect germplasm & evaluate
Brachiaria brizantha	Perennial, leafy	High yield, acidity tolerant	Limited collections	Collect germplasm & evaluate
Brachiaria humidicola	Perennial, leafy	High yield, acidity tolerant	Limited collections	Collect germplasm & evaluate
Brachiaria jubata	Perennial, leafy	High yield, acidity tolerant	Limited collections	Collect germplasm & evaluate
Brachiaria lachnanta	Perennial, leafy	High yield, acidity tolerant	Limited collections	Collect germplasm & evaluate
Panicum maximum	Perennial, leafy	High yield, acidity tolerant	Limited collections	Collect germplasm & evaluate
Pennisetum unisetum	Perennial, leafy	High yield, acidity tolerant	Limited collections (probably lost)	Collect germplasm & evaluate
Sorghum aethiopicum	Annual	Drought, heat, acidity tolerant	Limited collections (probably lost)	Collect germplasm & evaluate
Cynodon aethiopicum	Perennial	Excess moisture tolerant; good as bottomland pasture	Limited collections (probably lost)	Collect germplasm & evaluate
Cenchrus ciliaris	Perennial	Drought, heat, tolerant; good as grazed pasture; good for rangeland rehabilitation	Limited collections (probably lost)	Collect germplasm & evaluate
Eragrostis superba	Perennial	Drought, heat, tolerant; good as grazed pasture; good for rangeland rehabilitation	Not collected	Collect germplasm & evaluate
Leptochloa obtiusiflora	Perennial	Drought, heat, tolerant; good as grazed pasture; good for rangeland rehabilitation	Limited collections (probably lost)	Collect germplasm & evaluate
Chloris roxburghiana	Perennial	Drought, heat, tolerant; good as grazed pasture; good for rangeland rehabilitation	Not collected	Collect germplasm & evaluate
II. LEGUMES (Herbs & Trees)				
Trifolium biliniatum	Annual	Good for integration with cereals	Limited collections	Collect germplasm & evaluate
Trifolium quartinianum	Annual	Good for integration with cereals	Limited collections	Collect germplasm & evaluate

Species	Characteristics	Potential	Status/ Threats	Immediate action
Trifolium steudneri	Annual	Good for integration with cereals	Limited collections	Collect germplasm & evaluate
Trifolium polystachyum	Perennial	Good for grazing & haying	Collections lost	Collect germplasm & evaluate
Trifolium semipilosum	Perennial	Good for grazing	Limited collections	Collect germplasm & evaluate
Trifolium cryptopodium	Perennial	Good for grazing	Limited collections	Collect germplasm & evaluate
Trifolium burchellianum	Perennial	Good for grazing	Limited collections	Collect germplasm & evaluate
Neonotonia wightii	Perennial, climbing	Good for grazing & haying; good for oversowing degraded pastures	Limited collections	Collect germplasm & evaluate
Stylosanthus fruticosa	Perennial	Good for grazing & haying; good for oversowing degraded pastures	Limited collections	Collect germplasm & evaluate
Macrotyloma axillare	Perennial, climbing	Good for grazing & haying (as grass-legume mixture)	Limited collections	Collect germplasm & evaluate
S. macrantha	Small tree, 5 m tall	Leaf hay is good for supplementing roughages	Large ruminant evaluation is missing	Feeding experiment with large ruminants
Cordeuxia edulis	Small tree, 2.5 m tall	Foliage is used as fodder; seed is edible	Limited collections (held at SORPARI)	Collect germplasm & evaluate
Albizia malacophylla	Tree, 10 – 20 m tall	Good as fodder & MPT	Limited collections	Collect germplasm & evaluate

Source: Personal field observations (of the Reviewer) & literature

4.2.2. Conduct on-farm demonstration of pipeline and released forage varieties

Researchers are often perplexed at the question: “Why improved forage crops are not adopted in Ethiopia?” I (the Reviewer) have two assumptions: 1) Subsistence farmers to whom the forage technologies are targeted (more than 95% of beneficiaries) have poor resource capacity (as to the three factors of production: Land, capital, skilled labor) to be able to absorb a package of forage variety plus responsive livestock breed. For instance, the average land holding is below one hectare in the highlands (CSA, 2021), most farmers are financially subsistence to be able to purchase responsive animal breed such as a cross-bred cow (more than Birr 90,000/head). In addition, farmers are not practically taught whether forage technologies are paying such that they do not go bankrupt sooner or later by investing on such innovations.

On such grounds, one would suggest as an immediate action, on the part of researchers and development practitioners, to embark on participatory verification of a package of improved forage (released or in pipeline) plus an improved ruminant livestock breed, onfarm right at the level of the smallholder farmer. Regarding sufficient land issues, one would predict that the local government would give solutions: allocate free/ lease at the lowest possible rate/ a modified form of the current clustering system for the livestock sector. Finally, it goes without saying that the government need to substantially reduce the tax rate on livestock business for the sake of promoting and expanding this underdeveloped sector.

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Appendices

Appendix 1. Distribution of indigenous *Trifolium* species in eastern Africa

Sn	Species	Eth.	Kenya	Tanzania	Uganda
1	*Trifolium acaule*	+	+	-	-
2	*T. arvense*	+	-	-	-
3	*T. baccarini*	+	+	-	-
4	*T. biliniatum*	+	-	-	-
5	*T. burchellianum*				
	Ssp. Burchellianum				
	Ssp. johnstonii var. johnstonii	+	+	+	+
	var. oblongum	+	+	-	-
6	*T. calocephalum*	+	-	-	-
7	*T. campestre*	+	-	-	-
8	*T. cheranganiense*	-	+	-	+
9	*T. decorum*	+	-	-	-
10	*T. cryptopodium*	+	+	+	-
11	*T. elgonense*	+	+	-	-
12	*T. fragiferum*	+	-	-	-
13	*T. lanceolatum*	+	+	+	-
14	*T. lugardii*	-	+	-	+
15	*T. masaiense*				
	Ssp. Masiense	-	-	+	-
	Ssp. Morotoense	-	-	-	+
16	*T. mattirolianum*	+	-	-	-
17	*T. mauginianum*	+	-	-	-
18	*T. multinerve*	+	+	-	-
19	*T. petitianum*	+	-	-	-
20	*T. pichisermoli*	+	-	-	-
21	*T. polystachyum*				
	Var. contractum	+	+	-	-
22	*T. pseudostriatum*	-	-	+	+
23	*T. purseglovi*	-	-	-	+
24	*T. quartinianum*	+	-	-	+
25	*T. rueppellanum*	-	-	+	-
	Var. minimflorum				
	Var. rueppelianu	+	+	+	+
26	*T. schimperi*	+	-	-	-
27	*T. semipilosum*	+	+	+	+
	Var. brunellii				
	Var. glabrescens	+	+	+	+
	Var. intermedium				
	Var. semipilosum				
28	*T. simense*	+	+	+	+
29	*T. somalense*	+	-	-	-
30	*T. steudneri*	+	+	-	+
31	*T. spanathum*				
32	*T. tembense*	+	+	+	+

Sn	**Species**	**Eth.**	**Kenya**	**Tanzania**	**Uganda**
33	*T. ukingense*				
34	*T. usambarense*				
35	*T. wentzelianum*				
	Var. stolzii				
	Var. wentzelianum				
36	*T. chilaloense*				
37	*T. sp A*				
38	*T. sp B*				

Source: Kahurananga, J. 1984; Kahurananga, J. and Solomon Mengistu, 1983; 1984.

Appendix 2. Accessions of Trifolium collected from the Ethiopian highlands.

Table 1. Accessions of Trifolium seeds collected from the Ethiopian highlands from 1982-84

	Accessions from each elevation range (m)				
Species	1500	1500-2000	2000-2500	2500-3500	Total
T. acuale	-	-	-	5	5
T. arvense	-	-	2	1	3
T. baccarinni	1	26	16	8	51
T. bilineatum	-	14	16	2	32
T. burchellianum					
Var.johnstonii	-	3	11	27	41
Var. oblongum	-	-	-	8	8
T. calocephalum	-	-	-	13	13
T. cryptodium	-	-	16	48	64
T. decorum	-	6	26	12	44
T. lanceolatum	-	1	-	-	1
T. mattirolianum	2	33	10	-	45
T. multinerve	-	-	5	10	15
T. pichisermolli	-	-	15	19	34
T. polystachyum	-	7	17	8	32
T. quartinianum	-	8	13	-	21
T. rueppellianum	-	15	43	22	80
T. schimperi	-	3	16	5	24
T. semipilosum	-	6	70	56	132
T. simense	-	-	21	34	55
T. somalense	-	-	1	-	1
T. spananthum	-	-	-	2	2
T. steudneri	-	16	45	-	61
T. tembense	-	7	50	60	117
T. sp.	-	1	-	-	1
Total	**3**	**146**	**391**	**342**	**882**

Source: Adapted from Kahurananga and Mengistu (1983, 1984).

Appendix 3. DM yield of Ethiopian *Neonotonia wightii* accessions at Soddo

Table 2. DM yields (means of 2 cuts) of 41 Ethiopian Neonotonia wightii accessions at Soddo, Southern Ethiopia

ILCA No.	Yield Kg/ha	Flowering (days)	Leafiness (%)	Spread of stolon (cm)
9794	5491	136	50	76
7764	4588	120	42	54
7892	4359	102	43	85
10325	3436	147	43	45
10495	3278	136	40	49
7533	2810	139	40	68
8651	2268	119	39	41
8705	2259	176	43	75
10524	2164	158	43	46
7541	1666	140	33	44
10519	1662	159	33	38
9892	1531	157	50	33
10536	1456	170	37	41
7602	1430	147	30	45
8098	1324	118	31	26
8649	1289	132	30	36
10015	1286	165	43	44
10240	1146	166	36	27
7872	1129	114	40	20
7520	1048	108	35	20
Clarence'	964	175	37	17
7577	911	154	32	28
8281	890	154	43	17
8672	881	180	33	41
7554	834	118	33	18
7006	793	125	37	29
7751	789	111	30	25
9884	686	177	30	16
9037	659	109	28	11
Tinaroo[1]	623	156	35	14
10230	617	154	33	39
7801	617	109	30	22
8397	606	135	35	15
10226	598	137	28	17
7878	588	116	32	18
7818	585	107	23	13
6241	583	182	30	16
8392	497	162	30	21
11550	473	194	30	30
7174	465	128	33	9

9983	416	118	25	16
LSD (P<0.05)	1904	37	10	27

[1] Commercial cultivars

Source: Larbi, Asamoe et al, 1992

Appendix 4. Revised version of the National Variety Release and Registration Guideline

(Modified document: forage part retained: Section 6.3. Forage and Pasture Crops (Annuals and perennials)

Ministry of Agriculture and Rural Development (MoARD)

and

Food and Agricultural Organization (FAO)

Revised version of the National Variety Release and Registration Guidelines

Revised as per the study Report on

The establishment of an independent crop variety release and registration body in Ethiopia

June 2008

Addis Ababa, Ethiopia

6.3 Forage and Pasture Crops (Annuals and perennials)

Forage and pasture crops include wide range of crops composed of grasses and legumes each with different growth habit (creeping, erect, bunch, climbing) and different life cycle (annuals and perennial). For aspects of variety release the crops can be broadly categorized using life cycle (annual /perennial).

6.3.1. Conditions for release

- The new variety must show excellent performance in sufficient number of tests in comparison with the standard cultivar (s) grown in the ecological zone(s) where to be used.
- The variety should be tested for herbage/biomass yield on dry matter basis, quality, palatability, disease and insect reactions and other important characteristics for a minimum of two years in regional or national variety trials. For wide adaptation the variety must be tested at least in 3 to 4 locations in different agro-ecological zone where the variety is to be recommended. However, if the variety is intended for specific release the test in 2-3 locations in the same agro-ecology.
- At least two major agro-ecologies and 2-3 sites within the agro-ecologies need to be considered (one would be on-station and two on farms) for wider adaptation (national release). However, for specific adaptation (regional release) at least two sub agro-ecologies/ production belts and three sites within the sub agro-ecologies need to be considered (one would be on-station). Animal response component would be considered on-farm for annuals for one season at two site.
- The quality of the variety (crude protein, neutral detergent fiber, bioassays, and leaf to stem ratio) should be indicated. For herbaceous and tree legumes aspects of rumen degradability needs to be incorporated at national variety trial stage since total nitrogen will not indicate the quality of the variety. Under situations where resources are limited, laboratory data on quality of the variety must be provided based on analysis of pooled samples across locations.
- A variety which has got a special merit on a specified limiting factor on the existing commercial cultivars (e.g., drought, excess moisture, frost, pest etc) will be considered for release on one year trial data with additional data from the second-year trial to be conducted in the same year with the verification.
- When a candidate variety is proposed for release for its yield advantage, it should be significantly superior over the standard check.
- The variety to be released should be uniform, stable, and distinctly superior to the existing commercial cultivar(s) grown in the area in one or more characteristics important for the crop and is satisfactory in other major requirements. However, when there is no adequate number

of released cultivars of a particular crop, the NVRC may consider releasing a variety even if it is not superior to existing local cultivar, without compromising the requirements of the grower.

- The new variety should be planted along with the established improved cultivar in relatively large plots (10x10 m) at 3 to 5 sites (one on station and two on farm) on each agro-ecological zone verification trials during the anticipated year of release for assessment by TC. The verification sites (the on station and on farm) should be at least within a minimum range of ten-kilometer radius.
- For species targeted as grazed pasture, grazing trial need to be conducted using sub-divided paddocks in the target ecological zone using standard procedures of grazing trial. The standard known cultivar and candidate variety need to be compared using five animals per treatment for duration of 90 days. For perennials two years grazing experiment would be used.
- Feed utilization experiments should be included at a national variety trial stage for the best two to three candidates using pilot animals (sheep or goat) for the annual crops. For perennials animal response data will be taken at on-station at verification stage. Due consideration should be given to represent farmers practices and standard cultivar for comparison purposes in animal response trials using standard procedures.
- Biological data i.e., quantity and quality of feed, quantity and quality of animal product, data related to animal condition and body weight shall be taken. Socio-economic data would also be taken to compliment biological performance data in the verification process.
- Prior to preparing proposals for release of a variety, the researcher should consult with commodity program team leaders and other concerned researchers. The consensus reached on the merits of the variety should be communicated to the NVRC.

6.3.2 Supporting Document

- Release requests should be accompanied by complete morphological description and distinguishing characteristic of a candidate variety**. (Annex 2. FORM- 6.3)**
- The result of the assessment of the crop protection specialist (entomologist/ pathologist/herbologiest) animal nutritionist and the socio-economist should be included in the application format.
- Appropriate data to support recommendations as stipulated in conditions for release, disease reaction and other supporting data for individual locations and years should be presented in addition to the summaries. Recommendation on mode of utilization (cut and carry, grazing, hay, silage), target animal, agro ecology / farming system, mode of offer etc should be

included. Other relevant data on pooled samples across locations on important characteristics of quality. *In vitro* digestibility etc. in a regional or national variety trial should be supplied, (palatability/intake, animal responses (growth or body weight gain) should also be included.

- Three completed copies for each of the variety release request form and data of all the testing period of the variety in all tested locations and a year x location data summary of the recommended entries must be submitted to the committee chairman before May 30 each year.

6.3.3. Evaluation Procedure

The office appoints a Technical Committee (T.C.) that includes relevant specialists to report on varietal performance after examining the submitted data and evaluating verification plots. The evaluation report from the technical committee is expected to cover:

- Performance data evaluation on
- Field /performance evaluation
- Farmers views
- General comments
- Recommendation
- In any one season no more than two varieties per crop should be proposed for release under the same agro-ecological zone in the coming years unless sufficient written justification is given for such action. Moreover, a variety once rejected by the TC should not be repeatedly put in verification and proposed for release in the coming years unless sufficient written justification is given for such action.
- Variety release proposals should be submitted to the committee chairperson by May 30 of each year. Action to place a variety on the release list will be taken at the January/February and March/April meeting of the NVRC. The breeder submitting a variety for release will be called to appear in person before the NVRC to answer enquiries regarding the proposal. Decisions reached by the committee will be published or reported at the National Agricultural Research and Development Forum annually.
- Provisionally released variety should be planted in the following year on a quarter of hectare for grass and one hectare plot for legumes at two appropriate sites (research station and on farms) for final inspection by the NVRC. If not planted within the coming two years, it will lose its provisional status but could be considered as a new entry in another variety trial.
- A new variety should be assigned a permanent designation by the breeder/team (preferably a short local name) if the variety is approved for release. This is a pre-condition for release and

registration. The proposed name can be rejected by the NVRC for valid reason. A variety should not be distributed under more than one name.

- A variety recommended for repeat, if not tested within the coming two years will lose its repeat status but could be considered as a new entry in another variety trial.
- The breeder or institution responsible for developing the variety that has been approved for release would be expected to maintain an appropriate quantity of the breeder and basic seed for use in replenishing and restoring commercial seed of a variety to the desired genetic purity and supply to producers through the agency.
- An obsolete variety arising from genetic deterioration, loss of resistance to diseases, or a breakdown in resistance/tolerance to a condition the candidate cultivar was developed for will be communicated to the NVRSCA by the users (breeders, extension agent, state farms) for the appropriate action.

7. Quantities of Breeder's Seed Required

All breeders will be required to provide "Breeder's Seed for their varieties granted the status of provisional release" or "full release. Breeders are also required to provide seed to the Institute of Bio-diversity Conservation for long time storage and maintain duplicate samples at the time they get approval by the NVRSCA to release their varieties.

The quantity of breeder seed required for new release or renewal stock is indicated in Annex 1. Tables, 6.1, 6.2.1 and 6.3. These are the quantities of seed per variety and seed stock class, which authorized seed producers such as ESE, private sector, etc. should receive from the breeder. This could further be used to produce pre-basic and basic seed generation.

The quantity of the nucleus seed that the breeder should preferably keep in cold storage is shown in columns of the same tables. The breeder is responsible to ensure that this nucleus stock is 100% authentic (represent the variety as released) and viability exceeding 85%. In practice, the breeder will multiply this seed one generation to obtain seed quantity for authorized government and other users and simultaneously replace his nucleus stock in cold storage.

Obsolete varieties

An obsolete variety arising from genetic deterioration, significant yield reduction, loss of resistance to diseases, or a breakdown in resistance/tolerance to a condition the candidate cultivar was developed, poorly demanded in the market for will be communicated to the office. The NVRC identify technical team for final decision.

Definitions of key terms

Breeder: Refers to an individual or professional who works privately or in public and engaged in the development of improved varieties for release or other use.

Co operator: An individual or private or public agricultural organisation that collaborates with researcher/ institution to undertake variety testing and/or verification trial in accordance with previously made memorandum of understanding.

Breeder seed: It is seed or vegetative propagating material produced under strict control by the originating plant breeder or institution. The improved crop variety breeder seed is whose seed source is nucleus seed. The plant breeder or the originating scientific community usually multiplies it. Under Ethiopian condition, the Ethiopian Agricultural Research System (EARS) that includes Ethiopian Institute of Agricultural Research (EIAR), Higher Learning Institutes (HLI's) and Regional Agricultural Research Institutes (RARI's) are responsible in multiplying this class of seed.

Pre-basic seed: The seed type whose seed source is the breeder seed and is the next generation to the breeder seed. In Ethiopia, both the Ethiopian Agricultural Research System (EARS) and the Ethiopian Seed Enterprise (ESE) are so far responsible for multiplying this class of seed.

Basic Seed: The class of seed whose seed source is the pre-basic seed. In Ethiopia, the Ethiopian Seed Enterprise (ESE) is responsible to multiply this class of seed. Other well-organized seed companies can also take up and multiply this class of seed for certified seed growers.

Certified seed: Is the seed category produced either from pre-basic, basic or certified seed. This class of seed is used to produce grain used for food or feed or for further seed multiplication of certified seed. Please also note that, each seed class has different colored labels that are recognized almost similar in different countries or at global level.

Nucleus seed: A pure and specified number of seed and/or planting material which should be submitted to an appropriate organisation for a long-term *ex-situ* conservation.

Local cultivar: A popularly grown indigenous variety or an introduced variety, which has been under production in a certain locality.

Landraces: Early cultivated forms of a crop species, evolved from a wild population

DUS = distinctiveness, uniformity, stability

- ***Distinctiveness*** = A cultivar differs from any other one by one or more identifiable morphological, physiological, or other characters.
- ***Uniformity*** = A cultivar must demonstrate that the variations in the cultivar are describable, predictable, and commercially acceptable
- ***Stability*** = the cultivar must remain essentially unchanged about essential and distinctive characters with a reasonable degree of reliability commensurate with that of cultivars of the same type. Such a test is carried out for at least two seasons.

VCU = Value for cultivation and use. The characteristics of the new cultivar are assessed in comparison with the old cultivars and are also tested for

New Release: A newly developed variety of a given crop type which has obtained an official approval for release by the NVRC for the purpose and agro-ecology it is developed for.

Pending Release: A candidate variety might have been evaluated for release. However, the term is used when decision is delayed due to one or more reasons.

Provisional release: A variety, released provisionally until problems encountered or technical difficulties are corrected or amended during the following two seasons. The variety along with the standard check should be rechecked on two larger (1000m^2) plots.

Obsolete variety: A variety that has been in use for long time and has become less productive due to genetic deterioration, loss of resistance to diseases etc.

Standard cultivar: The latest improved variety of a given crop type against which a candidate variety is compared in any verification trail.

Specific adaptation: Refers to varieties adapted to a specific production belt or agro-climatic or soil conditions.

Wide adaptation: Refers to varieties adapted to wider of more than two production belts or address strategic problems of more than one agro-ecological zone.

Seed stock class: It is defined as contemporary description of existing varieties that includes time of release, purpose (renewal), maturity type (early, medium, and late), adaptation area (lowland/highland) etc.

Repeat status: When ever some crop varieties are evaluated, their performances can be good but with some work remaining. In such cases the verification trial is repeated a new.

Maintenance Block: A small plot of land where selected mother trees/plants are grown and monitored by the researcher/ institutions for varietal and genetic purity and serve as seed/planting materials source in future propagation of the variety.

Local Cultivar: A popularly grown indigenous variety or an introduced variety which has been under commercial production.

Introduced Cultivar: A variety introduced to be considered for release by the NVRC in the interest of commercial production.

Large Plants: A category of perennial horticultural crops having larger canopy and requiring larger inter-and intra-raw spacing.

Intermediate Plants: Perennial horticultural crops having an intermediate canopy and requiring moderately large inter-and intra-raw spacing.

Small Plants: Perennial horticultural crops with relatively smaller canopy and require narrow inter-and-intra-raw spacing.

Verification Trial: The final stage in a series of variety development trials in which few (usually 1-3) outstanding candidate varieties proposed for release are planted with the existing local or standard check for VCU and DUS for the release decision of the regulatory body.

Pedigree: A record of the ancestry of an individual, family or strain.

Hybrid: The product of a cross between genetically unlike parents.

Minimum Quantity of breeder seed requirement (Appendix 1)

Table 6.3. Minimum quantity of breeder's seed/cuttings of some forages and pastures crops required in Seed Stock.

Crop	Breeder's Seed required kg/variety ** (Kg)	Required Breeder's Nucleus seed in cold storage/ variety *** (Kg)
For small seeded (e.g., Rhodes, Trifolium)	15.0	TBA
Medium to large seeded (e.g., vetch)	30.0	TBA
Vegetative propagation	2000 cuts/root splits	TBA

List of Application Forms (Cont'd, Forage & Pasture crops) (Appendix 2)

FORM-FPC-6.3: Application for variety release /registration/ of forage and pasture crops (To be filled in triplicate)

1. Name and address of researcher/ institute responsible for developing the cultivar (s)

____

2. Research commodity ___________________________________

3. Name of crop (with Latin Name) ______________________________

4. Variety designation (breeder's reference) ________________________

5. Origin of cultivar

   Information on origin, pedigree, and mode of reproduction. (Hybrid/open pollinated, seedling/bud sprout/clone/selection/imported/unknown)

   ____

   ____

   ____

6. Recommended ecological zones of adaptation and rainfall requirement.

   ____

   ____

   ____

7. The main positive feature(s) of the variety, which makes it superior to those in current use. Also indicate shortcomings, which may restrict its use in some areas:

   ____

   ____

   ____

Consent Statement: *"Personal information including Name, Business Title, Email, Phones, Images and GPS points included in this report have been authorized in writing or verbally by the data subject"*
M. Zeleke