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Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17–21 September 1984

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Pasture Improvement Research in Eastern and Southern Africa

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Editor: Jackson A. Kategile

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Southern African Development Coordination Committee, Gaborone, Botswana,
and the
International Development Research Centre, Ottawa, Canada

Abstract: The proceedings contains reviews by national scientists on pasture research done primarily in Eastern and Southern Africa (Ethiopia, Kenya, Tanzania, Burundi, Zambia, Zimbabwe, Swaziland, Lesotho, Botswana, Mozambique, and Madagascar). The application of the results obtained and lessons learned are highlighted and used in setting of national priorities for research areas for the future. Critical reviews on current pasture research methodologies are included in the proceedings. The research methods discussed are germ-plasm collection, storage, and dissemination; and germ-plasm introduction and evaluation, nutritive evaluation of pastures, grazing experiments, and range monitoring. Specific guidelines on methodologies are outlined and these are useful to pasture agronomists, animal nutritionists, and range-management scientists.

Two case studies of pasture-research regional networks in Asia and Latin America were presented and discussed. A strategy for future pasture research coordinated through a regional Pastures Network for Eastern and Southern Africa (PANESA) was discussed and agreed upon.

Résumé: Dans les actes ci-joints, des scientifiques de divers pays analysent la recherche entreprise sur les pâturages en Afrique orientale et australe (Éthiopie, Kenya, Tanzanie, Burundi, Zambie, Zimbabwe, Lesotho, Botswana, Mozambique et Madagascar). L'utilisation des résultats obtenus et les connaissances acquises sont mises en lumière, puis utilisées pour établir les priorités nationales en matière de recherche. Les actes comportent une analyse critique des méthodes de recherche actuelles sur les pâturages : rassemblement, entreposage et diffusion du matériel génétique; mise à l'essai et évaluation de ce matériel; expériences de pâturage; évaluation nutritive des pâturages et exploitation rationnelle de ceux-ci. On présente des lignes directrices précises sur les méthodes à suivre, qui seront utilies aux agronomes en charge des pâturages, aux spécialistes de la nutrition animale et aux scientifiques responsables de la gestion des pâturages.

Deux études de cas ont fait l'objet d'une présentation suivie d'une discussion : il s'agit des réseaux régionaux de recherche sur les pâturages en Asie et en Amérique latine. Après discussion, on a convenu d'une stratégie de la recherche sur les pâturages, dans les années à venir; la coordination de cette stratégie sera assurée par une section régionale du Pastures Network for Eastern and Southern Africa (PANESA).

Resumen: En las actas se recogen ponencias presentadas por científicos de diferentes países sobre las investigaciones en pastos que se han realizado principalmente en el Africa oriental y meridional (Etiopía, Kenia, Tanzania, Burundi, Zambia, Zimbabwe, Suazilandia, Lesotho, Botswana, Mozambique y Madagascar). Se destaca la aplicación de los resultados y experiencias obtenidos, muy útiles para determinar las prioridades de las investigaciones futuras en las diferentes naciones. En las actas se recogen también ponencias críticas sobre las metodologías empleadas actualmente en las investigaciones sobre pastos. Se analizan los siguientes métodos de investigación: recogida, almacenamiento, diseminación, introducción y evaluación de germoplasma; evaluación del valor nutricional de los pastos; experimentos de pastoreo; y control de dehesas. Se resumen directrices y metodologías específicas de gran utilidad para agrónomos especializados en pastos, expertos en nutrición animal y científicos especializados en gestión de dehesas.

Se presentan y analizan dos estudios de casos de las redes regionales de investigación en Asia y Latinoamérica. Se discutió y aprobó una estrategia para realizar investigaciones sobre pastos en el futuro que serán coordinadas por la Red de Investigaciones sobre Pastos para Africa Oriental y Meridional (RIPAOM).

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COLLECTION AND PRELIMINARY FORAGE EVALUATION OF SOME ETHIOPIAN TRIFOLIUM SPECIES

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Abstract *Between 1982 and 1984 a total of 882 seed accessions of native Trifolium species were collected from the Ethiopian highlands for screening. Initial observations gave yields of up to 6.3 t/ha. Subsequently, three experiments were carried out to assess yield response to P. The best yields were obtained from* T. tembense *(6.8 t/ha),* T. quartinianum *(6.2 t/ha),* T. decorum *(5.7 t/ha), and* T. steudneri *(5.3 t/ha) at 35 and 40 kg/ha P, which were about six times the yields obtained without P. There were no significant species differences without P. At the same time, laboratory analyses on some of the above species gave values of 73.56-74.09% dry matter digestibility (DMD), 19.1-21.3% crude protein (CP). In 1982, a sheep digestibility trial showed that incremental levels of Trifolium in teff and wheat straw significantly increased digestibility. These studies have shown that Ethiopian clovers have good potential for forage production in highland areas with moderate levels of P application.*

Insufficient and poor-quality livestock feed are some of the major constraints contributing to poor livestock productivity. In tackling the enormous shortfall in the livestock feed resources, ILCA is focusing on the use of forage legumes. Not only do legumes provide highly nutritious forage, they also improve soil fertility through biological nitrogen fixation (BNF), thus creating an interphase between agriculture and livestock production in peasant farming through crop rotation or intercropping.

ILCA has programs in the different ecoclimatic zones of tropical Africa. The Highland Program is appropriately located in Ethiopia. These cool highlands present an ecoclimate that is somewhere between temperate and tropical in character. There are large areas with black clay acidic soils subject to seasonal waterlogging and low in available phosphorus and there are incidences of frost at certain times of the year. Initially, it was intended to obtain forages adapted to these conditions that ILCA started the collection and evaluation of native clovers. Since then collection has extended to lowland areas including browse species to look for species that could be adapted to the tropical savannah.

Initially, priority was given to Trifolium because the genus contains several important forage species and preliminary screening in Kenya and later work in Australia indicated the good forage potential of African Trifolium species (Strange 1958; Mannetje 1964). The African clovers are concentrated in the cool highlands and Ethiopia with its massive highland area totaling 490,000 km^2 or 43% of the total for Africa contains 28 Trifolium species (9 of them endemic) out of a total of 40 found in eastern Africa (Gillet et al. 1971, Getahun 1978, Thulin 1983).

Therefore, ILCA's aim was to collect sufficiently variable forage germ plasm from as many environments of the diverse Ethiopian highlands as possible to evaluate their forage potential because initial observations elsewhere in Ethiopia had been favourable (CADU 1972). Nutritional values were also analyzed.

This paper presents observations and experiments carried out from 1981 to the beginning of 1984 on seed collection, DM yield response to P application and nutritive value of Ethiopian clovers by members of the Forage Legume Agronomy Group (FLAG), the Highlands Programme, and the Nutrition Laboratory. The results demonstrate the role of native germ-plasm collection in forage production.

METHODS

Forage Germ-Plasm Collection

Seed collection started sporadically in 1980 and systematic work began in 1982. Exploratory missions were undertaken during the peak of flowering for annuals in August/September, except in the Agaw Medir area of Gojam where flowering was in November, to identify suitable collecting localities. The collection season for annuals was usually between October and November in most areas and December in Agaw Medir, whereas the perennials were usually collected between December and January. Collections were made at 10-km intervals along predetermined routes and also whenever large populations were found. In this way, both wider coverage and sufficient seeds of large populations were obtained for immediate screening. In some cases, the same area was visited twice because of different seed maturation dates even within the same species. Two teams were fielded to different areas at the same time to have wider coverage of material collected at the same ripening period (Kahurananga and Mengistu 1983, 1984).

Yield

In 1981, seeds of T. tembense, T. rueppellianum, and T. decorum were all collected from Shola, Addis Ababa, and T. steudneri, collected from Debre Zeit (1,800 m altitude, rainfall 800 mm rainfall) were planted in plots at Shola for preliminary observations (Kahurananga 1982).

Between 1982 and 1983 three experiments were conducted on the yield response of Ethiopian clovers to P application. All the trials were conducted at Shola (9° 02'N 38° 42'E) at an altitude of 2,380 m. The soil is seasonally water-logged black clay that cracks extensively during the dry season. Soil analysis indicated pH 5.8, 22 ppm N and 8.68 ppm P. Total rainfall in 1982 was 1,100 mm with 683 mm falling during the experimental period between July and October. There was more rainfall in 1983 totaling 1,328 mm with 920 mm falling during the experimental period between May and October. The average maximum and minimum temperatures were 21°C and 11°C, respectively.

The first experiment was conducted during 1982 and 1983. The purpose was to determine the DM yield response of T. tembense and T. rueppellianum to 0, 5, 10, 20, and 35 kg of P ha^{-1} applied as triple superphosphate (TSP) and harvested at 90, 105, 120, and 135 days. The seeding rate was 8 kg ha^{-1} in rows 40 cm apart. Planting was at the beginning of the long rains in July 1982. During 1983, the planting was split into two dates, one during the short rains and the other during the long rains and included T. quartinianum in addition to the other species. Harvesting was done at the same dates mentioned using a wooden frame and samples were taken for estimation of DM yield (Akundabweni 1984).

The second experiment was conducted in 1983. A total of 22 accessions of six annual Trifolium spp. were grown and fertilized at 0 and 40 kg of P ha^{-1}. The clovers were planted at a seeding rate of 10 kg ha^{-1} in rows 20 cm apart in July. The clover accessions were collected from altitudes ranging from 1,850 m - 3,040 m and average rainfall (annual) from 800 mm to 1,500 mm with clay or clay loam soils typically of pH 5.8. Harvesting was done at 50% flowering and samples of estimation of DM were taken as in the preceeding experiment. (Kahurananga and Tsehay 1983).

The third experiment was also conducted in 1983, and T. tembense, T. rueppellianum, and T. steudneri were grown with 0/0, 9/10, and 27/30 kg ha^{-1} N/P applied as diammonium phosphate (DAP) and 10 and 30 kg of P ha^{-1} applied as TSP. Planting was in July at a seed rate of 10 kg ha^{-1} in rows 40 cm apart. Sampling was done at 6, 12, and 18 weeks whereby 20 plants/plot for the first two harvests and 10 plants for the third were dug out, washed, and material separated into aerial parts, roots, nodules, inflorescences, and seeds (Jutzi and Haque 1984).

Nutritional Evaluation

Plant samples were taken during the initial observations at Shola in 1981 and analyzed for CP and digestibility. Also, hay comprised of about 30% T. tembense was fed to milking cows to determine the effect on milk yield.

In 1983, systematic experiments were run by the Nutrition Department. A total of 20 Ethiopian highland sheep in four groups of five were fed on rations containing T. tembense with teff straw, wheat straw, oat hay, or maize stover with the clover constituting 0%, 20-27%, 35%, 50-55%, and 100% (Mosi and Butterworth 1983).

Also in 1983, T. tembense hay was fed in different mixtures with teff straw to growing heifers and their growth compared to that of heifers fed teff straw mixed with nug (Guizotia abyssinica) and their economic returns assessed (Olayiwole, personal communication).

RESULTS

Forage Germ-Plasm Collection

A total of 17 collecting missions were carried out between November 1982 and February 1984, during which a total of 882 accessions of Trifolium species were collected (Table 1) out of an overall total of 1,617. The majority of the clovers were collected from altitudes above 2,000 m. The perennial Kenya White Clover, T. semipilosum was the most commonly collected consituting 15% of the clover accessions closely followed by the annual T. tembense, which constituted 13%. On the other extreme, only one accession each of T. lanceolatum and T. somalense were obtained. The last two are rare but endemic. In all, a total of 22 species, seven of them endemic, were collected in Ethiopia.

Initial Yield Observations

All four species tried at Shola in 1981 grew well. The best yield was given by T. tembense which produced up to 6.3 t ha^{-1}. T. rueppellianum also yielded well giving 5.2 t ha^{-1} (Kahurananga 1982).

Yield Response to P

In the first experiment, P had a very significant effect on the yields of all the three species (P 0.001). The highest yield was 6.2 t ha^{-1} given by T. quartinianum at 35 kg of P ha^{-1} harvested at 120 days. T. tembense gave 5.4 ha^{-1} at the same P fertilizer level

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

Species	Accessions from each elevation range (m)				Total
	1500	1500-2000	2000-2500	2500-3500	
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).

and harvest date. DM yield increases were more pronounced in T. tembense than T. rueppellianum at increasing levels of P (Akundabweni 1984).

Similarly, the fertilizer effect was very significant in the second experiment ($P<0.001$). There were significant differences between accessions ($P<0.01$). Interspecific yield differences were slightly more significant than intraspecific ones ($P<0.1$). The highest yield was given by T. tembense ILCA 8501, which produced 6.8t ha^{-1}, whereas the control from the same species ILCA 5774 produced 5.8 t ha^{-1}. The highest yields of T. tembense, T. quartinianum, and T. decorum were significantly higher than the highest yields of T. rueppellanum, T. schimperi and an unidentified species ($P<0.01$). There were no significant differences under no fertilizer treatment (Kahurananga and Tsehay 1983). Maximum yields of each species are shown in Table 2.

Even in the third experiment, where whole individual plants were measured, there were significant responses to P application. The addition of 30 kg of P ha^{-1} increased DM yield of individual plants six-fold by the 12th week; root-weight three-fold, 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 inflorescenses per plant was reduced at the higher levels (Jutzi and Haque 1984).

Nutritional Value

The results of laboratory analysis are given in Table 2. CP ranged from 19 to 21.3% and in vitro DMD ranged from 73.6 to 75.9%. Hay composed of 30% T. tembense increased milk yield of lactating cows by about 10% (Kahurananga 1982). In the digestibility trials with sheep, preliminary results show that incremental levels of Trifolium in teff and wheat straw increased overall digestibility (Mosi and Butterworth 1983). The results of the trial comparing the effect of Trifolium and nug Guizotia abyssinica meal are still being analyzed, but indications show favourable economic returns with clover (Olayiwole personal communication).

DISCUSSION

Native Germ Plasm

ILCA has now accumulated valuable germ plasm of hitherto uncollected Ethiopian clovers. This is especially

true in the case of endemic species, namely, T. decorum, T. mattirolianum, T. pichisermollii, T. schimperi, T. calocephalum, and T. spananthum. Also, T. semipilosum varieties intermedia and brunelli are confined to Ethiopia. Even with the other species found throughout eastern Africa, Ethiopian ecotypes or land races represent new material.

The forage germ-plasm collection activities have given practical experience to staff. Practical problems, such as differential seed maturation dates in the same species and localities, same maturation dates in different localities, differences between annuals and perennials, sampling procedures, mixed species, recognition of species, how much field data is necessary, handling of collected material, and storage and data processing and allocation of time to different activities, only become apparent with experience.

Potential Use

The trials at Shola have clearly demonstrated that some of the annual clovers from the Ethiopian highlands have good potential for hay production on sites with acidic soils subject to seasonal water-logging with moderate inputs of P fertilizer. The most promising species are T. tembense, T. quartinianum, T. decorum, T. steudneri, and T. rueppellianum. The first and last two species showed promise in preliminary screening in Kenya (Strange 1958). Similarly, T. tembense and T. ruepellianum each gave top yields of 6.3t/ha^{-1} in preliminary observations in Ethiopia (CADU 1972). The yields of the other two species were evaluated for the first time. These results are comparable to Vetch, Vicia villosa ssp. dasycarpa, an annual exotic forage legume adapted to the Ethiopian highlands from which average yields of up to 5.2t ha^{-1} have been obtained (Haile 1979).

All the clovers tested showed a dramatic response to P, thus indicating that they are adapted to moderate levels of P found in some sites in the bottomlands. The response shown by T. tembense tend to suggest that incremental yields could be obtained at levels of P above 40 kg ha^{-1}.

Table 2. Top average dry matter yields, chemical composition, and in vitro DM digestibility of seven annual Ethiopian Trifolium species grown at Shola, Addis Ababa in 1981-83.

Species	DM yield (t ha-1)	Phosphorus Input (kg ha-1)	% Crude Protein	% in vitro DM digestibility	Source
T. decorum	5.8	40	19.8	76.00	Kahurananga (1982); Kahurananga and Tschay (1983)
T. quartinianum	6.2	35	-	-	Akundabweni (1984)
T. rueppellianum	5.2	Barn site	19.0	75.88	Kahurananga (1982)
T. schimperi	2.9	40	-	-	Kahurananga and Tschay (1983)
T. steudneri	5.3	40	19.1	73.56	Kahurananga (1982); Kahurananga and Tschay (1983)
T. tembense	6.8	40	21.3	74.09	Kahurananga (1982); Kahurananga and Tschay (1983)
T. sp.	1.5	40	-	-	Kahurananga (1982); Kahurananga and Tschay (1983)

Clovers collected from different parts of the highlands nodulated well at Shola where similar species naturally occur, which means that Ethiopian species are not specific in their rhizobial requirements. It remains to be seen if these clovers will modulate effectively in other parts of East Africa where similar species occur and vice versa. However, African Trifolium species are known to be very specific in their rhizobial requirements (Norris and Mannetje 1964). Therefore, the use of native clovers from Ethiopia or elsewhere from the highlands of eastern Africa outside their normal habitats would most probably require inoculation with appropriate rhizobia as is the case with Kenya white clover in Australia (Jones 1981).

The high nutritive value of the Ethiopian clovers means that they can be blended with low-quality grass hay to improve overall feed quality. It has been shown by the nutrition experiments that a maintenance roughage of 40-50% digestibility could be increased to a production ration of 60% digestibility with the addition of Trifolium with the latter consituting 30% (Mosi and Butterworth 1983). This high-quality could then be used for increasing milk production in cows.

Introduction into Smallholder Farming Systems

Annual forage legumes could fit into peasant farming systems either through intercropping or crop rotation. In large areas of the Ethiopian highlands where low-growing cereals, namely teff, Erogrostis tef; wheat, Triticum aestivum; barley, Hordeum vulgare; and oats, Avena sativa are grown, clovers could be introduced by crop rotation. This is the system farmers are used to as is the case when they grow horse beans, Vicia faba; chick-peas, Cicer arietinum; field peas, Pisum sativum; and lentils, Lens esculentum. Intercropping could be introduced in those areas of the highlands with taller cereals such as sorghum, Sorghum vulgare, and maize, Zea mays.

Furthermore, Trifolium introduction would find easier acceptance where farmers are already aware of its nutritive value and contribution to soil fertility. The Agaw Medir of Gojam is such a place. T. decorum grows there extensively in dense swards where it is grazed after flowering. The clover falls into a natural crop

rotation with teff, barley, wheat, finger millet, Eleusine coracana; and nug. In this area, the clover plays a very strategic role in boosting grain yield through biological nitrogen fixation. Soil samples taken during seed collection from this area gave persistently high levels of N. This confirms earlier observations where results of a countrywide soil survey gave consistently high N values for soils from Agaw Medir (Murphy 1965).

Finally, the success of introducing forages into African peasant farming systems will ultimately depend on financial returns. The statement that "... cultivation of high quality herbage plants in the tropics can meet with success only if the cost of their establishment and maintenance is justified by an adequate return. To make a planted or sown pasture pay, the animal that grazes it should have the potential to match the quality of the herbage." (Bogdan 1966) could not be more true. In our context, it means that high quality forage could only be grown where there is a profitable dairy enterprise as has been amply demonstrated in different parts of eastern and southern Africa. A dairy enterprise is an absolute prerequisite for forage cultivation in Africa.

The results obtained by ILCA at Shola have shown that native legumes have an important role to play in improving forage production. A collaborative collecting mission between ILCA and CIAT will be completed soon in Kenya and it is hoped that missions will be arranged with national governments to the remaining countries in the near future. The acquired material would then be tested at different sites within eastern and southern Africa through the proposed forage network.

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