Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17-21 September 1984
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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa, Canada

Kategile, J.A.


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Pasture Improvement Research in Eastern and Southern Africa

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

Editor: Jackson A. Kategile

Cosponsored by the
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.


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 pour l'Afrique orientale et méridionale (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 África oriental y meridional (Etiopía, Kenia, Tanzania, Burundi, Zambie, 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 África Oriental y Meridional (RIPADM).
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REVIEW OF RANGE AND PASTURE RESEARCH IN BOTSWANA

D.R. Chandler

Department of Agricultural Field Services, Ministry of Agriculture, P. Bag 003, Gaborone, Botswana

Abstract Although the Animal Production Research Unit's (APRU) basic research for 1970-80 has established the benefits to be obtained from an improved management system that depends upon controlled stocking rates, access to water, and fenced paddocks, little is still known about the interrelationship of traditionally kept cattle and the natural range. APRU (Ministry of Agriculture, Botswana) uses conventional parameters of livestock productivity per head that show ranch cattle superiority over the communal herds.

A minimum acceptable standard of management will improve animal productivity. But 90% of the national herd is kept communally under traditional systems and when looked at from the point of view of productivity per hectare of land, "production" being the total benefits the herd owner obtains, then a very different picture emerges. Milk production and draft power are both important contributions from the herd, and when added in terms of energy derived from grazing to the already slanted stocking rate then the productivity on a per hectare basis becomes reversed. However, the facts of rising cattle populations, together with opening up of more water points in the western Sandveld, and the realities of the commercial aspects of the Tribal Grazing Land Policy (TGLP) (1975 White Paper) all point to the need for a revision of priorities. The Ministry of Agriculture has responded to paragraph 24 of the TGLP in which responsibility for controlling stocking rates and management of the communal range is directed to cattle owners whose tenure will not change.
Communities are being sought whose rangeland can be identified for initial improved management approaches. The Ministry Fodder and Forage Committee has been established and good liaison with APRU and regions exists. By 1984 a Botswana forage and pasture seeds multiplication program will have begun, and it is hoped that at least one further pasture research officer will be appointed into APRU.

Botswana, covering an area of 582,000 km² is situated in the middle of the southern African plateau with a mean altitude of 1,000 m above sea level. It is usually described as saucer-shaped with marked topographical features mainly in the east along the line of the Hardveld, where soils capable of supporting crop production in favourable rainfall years are found. This eastern swath varies in width from 50-150 km. The central basin is covered by significant depths of Kalahari sand. In the northwest, the Okavango delta provides a separate ecosystem. The country extends from 16°S to 27°S and from 20°E to 29°E.

Rainfall averages 475 mm/year, but varies in total by as much as 50-70% from year to year. The rainfall is highest in the northeast at 650-700 mm (varies from 400-1,200), falling through the central areas to 400-550 mm (200-850), to a minimum of 150-200 mm (0-400) in the southwest. Monthly precipitation gives little guide to effective rainfall as it is considered that 10 mm or less, unless following good previous rains, never effectively penetrates. Thus, 50% of monthly precipitation or more may be ineffective. Evapotranspiration is high from December to March. Seasonal commencement and end of rains are equally unreliable, and early planted crops are just as likely to suffer from a drought period as late planted intentions never getting established.

The country may be divided into three main ecological zones: the better-watered Okavango of the northwest, the main Kalahari system, and the eastern Hardveld. The Hardveld is further subdivided into the northern deciduous forests, the north and central Mopane veld, and the southern Acacia/Combretum complex. This is of course an oversimplification. Weare and Yalala in 1971, for example, refer to vegetation plotting of the east and northeast by Henkel in 1931,
Pole-Evans in 1936, Irvine in 1945, and Adcock in 1953. De Beer in 1962 plotted 26 different vegetation types grouped within six physiognomic definitions. Weare and Yalala produced 29 vegetation types grouped under nine physiognomic definitions. Since then, Blair-Rains and McKay produced in 1968, "The survey of the Northern State Lands," and Blair-Rains and Yalala a "Survey of the Central and Southern Lands" in 1969. Aerial photography has been used since 1947, and in 1963, 103,600 km² of eastern Botswana were surveyed for land resources by Bawden and Stobbs.

They recognized 29 land systems and divided these into nine categories for agricultural potential. The Range Ecology Unit has, since 1970, mapped fluoristically most of the major zones of the country, and there is good background knowledge of the tree and grass cover. Van Ransburg (1970) identified a range of potentially useful indigenous legumes and put down a range of trial species at Morale.

In 1973, the Land Utilization Division of the Ministry of Agriculture of Botswana established recording sites on eight of the Animal Production Research Unit (APRU) ranches to monitor (a) increase in bare ground, (b) encroachment of woody shrubs or trees, and (c) detrimental changes in botanical composition of the lower layer.

Methodology was a compromise from Walker (1970) to a modified form of Parker's three-step method used by the U.S. Department of Agriculture Forest Service (1951). A recent consultancy has recommended a change in methodology that is under review (Prince 1982).

By this time, APRU was appreciating the importance of defining eroded or badly degraded areas. Range monitoring has been continuous since 1973, noting that all previous surveys had not identified trends in range succession and regression. To this end an assessment was made in 1975 to identify a simple indicator that could be used for categorizing Botswana's grazing. This was noted under "Re-Seeding and Renovation" (APRU 1975). Other relevant publications are "A Hand Book of Common Grasses in Botswana," by David I. Field (1976), and "A Hand Book of Botswana Aca-cias," by J. Timberlake in 1980.
The Morale Research Station was established in 1931 on the advice of Professor R. Lindsay Robb under Sir Russel England. It is situated south of Mahalapye 23°S, 27°E, climate, soil, and vegetation being representative of East Botswana.

Cattle weight records and botanical reports were begun in 1951. Various grazing systems were imposed to measure live weight response and effect on veld, and different stocking rates were applied. A cleared trail was added in 1953. In 1964, the methodology of botanical analysis was changed. The trails followed adjacent territory interests in continuous grazing vs. rotational grazing vs. short-duration grazing. In 1964, it was not considered possible for the design pattern to measure any changes satisfactorily.

However, McKay stated that there were no large or obvious changes to evaluate, but it was considered justifiable to continue botanical sampling, and a number of questions remained unanswered: (a) influence of stocking rate and rainfall on yield and botanical composition, (b) effect of additional supportive irrigation to counteract rainfall deficiencies on yield of herbage, and (c) addition to nonprotein nitrogen (NPN) supplementation to winter nutrition.

The changes in species composition was noted between the various stocking rates but, because of lack of homogeneity within the paddocks, no significant conclusions could be drawn. These were summarized by McKay in 1968 who recommended improved methodology and a spread of investigation across other vegetational types. Nine stations were set up within the APRU ranches during 1972.

In 1976, APRU assessed conclusions drawn from previous research work to try to identify those variable factors in the natural rangeland that had the greatest effect on animal productivity and summarized a series of conclusions and recommendations:

(a) Deficiency of phosphorus in the pasture was endemic and the benefits of supplementation proven.
(b) Low levels of crude protein and dry matter digestibility (DDM) in herbage in the dry season varied seasonally.

(c) Only breeding stock seemed to respond economically to supplementary NPN when fed in the dry season, but total DDM ingested might be an inhibiting factor at set stocking rates.

(d) There remained the need to determine nutritive value of the range of desirable species and methods of encouragement, including bush control.

(e) It was recognized that evaluation of grazing systems is a long-term program but that detailed monitoring and measurements have to be continued.

(f) Range and livestock monitoring of the western state lands started as a result of the absence of production data from the area and the assumed fragility of the ecology and signs of overgrazing around adjacent cattle water points.

It was known that by careful control of grazing pressures, better species could contribute. The need to widen the scope of investigation was evident, and by 1977 it was concluded that the possibility of introductions, legumes, grasses, and fodder crops, into the system was a major need for investigation. Range improvement was considered possible under controlled conditions and the role of introduced reseeded legumes had to be thoroughly researched. The economics, feasibility, and adoption prospects were all aspects that had to be considered in their proper place, and initially, response to fertilization was investigated for all introduced species.

However, although acknowledged that the cyclical disasters of stock losses due to drought have been rapidly replaced in the past, the possibility of a degraded range modifying or even preventing this recovery in the future is too dangerous a theory to accept complacently. The importance of meaningful research into pasture species and fodders for all eventualities has now become, therefore, an accepted tenet of animal and range research. But the spectre of drought and drought relief measures hovers in the
minds of some planners, and several consultants over the years have referred to fodder bank reserves of drought resistant species being set up.

These suggestions have not so far been taken up by government. The history of pasture research to date has to be seen, therefore, against the noncommitment of local thinking and the probability that individual effort will produce individual qualitative and quantitative biomass bonuses that will initially be slow to be generally adopted. It is still true that "shortage of grazing" is seldom perceived as the main problem of "cattle management."

**GENERAL SURVEY (BEFORE 1977)**

Before 1976/77, research work had concentrated on investigations into range productivity and botanical composition of the natural sward. The broadening of this approach only since 1977 to include pasture research has to be viewed against the background of the political history of Botswana as a reservoir of migrant labour and beef cattle. The country remains essentially an extensive beef-producing rangeland.

Yet, although it is still recorded as one of the least densely populated countries of the world, the localized skewed population increases within the variable ecosystems have created pressures upon the natural resource capability that can no longer be alleviated by time-honoured migratory processes during the cyclical periods of drought that recur with indeterminate regularity. The impact of early settler methods of simple forms of conventional "commercial production" had no impact upon the indigenous peoples. To both groups the variability of seasonal rainfall created an attitude of conservative extensive range usage with seasonal transhumance, destocking, or agistment, relieving localized drought stress conditions in bad years.

Intensification was not a word familiar to tribesmen or settlers. Dry-season water availability finally determined grazing pressures and there has been a constant move westward by larger herd owners into the more fragile Kalahari ecosystems, with overt pressure
on government to sanction more borehole drilling in these western rangelands since the 1950s. These moves were accelerated by increasing land pressures in the areas of the eastern Hardveld where a heterogeneous form of mixed farming has been practised unconsciously by the rural peoples for many years, due to profiles permitting surface water accumulation, higher overall rainfall averages, and soils at least marginally capable of supporting an arable crop.

This area also carries 70-80% of both human and livestock populations. Traditionally, chiefs delineated arable and grazing lands. There is no evidence yet that land hunger as such is a recognized problem, but the conflict between land allocation as between arable and grazing has become a reality, and in some districts has become acute. These eastern Hardveld areas contain most of the potential arable soils of the country. Since enactment of the Tribal Lands Act of 1968 and amendments of 1969 and 1970, Land Boards have taken over the powers of land allocation. Early settler uptake of freehold blocks brought no boost to arable methods, which were designed primarily to provide self-sufficiency, so far as possible, in favourable years. Climate and soils in general militate against achieving highly profitable levels of production of cash-earning grain, pulse, and oilseed crops from dryland farming.

Nevertheless, along the eastern Hardveld there is a long history of annually ploughing part of the allocated land area by the rural households, and comparisons between 1975 and 1982 aerial photography show considerable opening up of arable lands in areas that were previously available as grazing.

During the late 1960-70 period, the government also became aware of the increasing magnitude of the problem of uncontrolled opening up and abuse of watering points in the fragile Kalahari bush savanna and the increasing pressures (localized at first) of rising cattle populations competing with more lands being allocated for plowing in the eastern Hardveld areas. Thus, the policies known as LDP 1 and TGLP evolved.
LDP 1 -- Livestock Development Project

The first Livestock Development Project (LDP 1) included a pilot establishment of a ranching block in the western Sandveld financed jointly by IDA (International Development Agency) and SIDA (Swedish International Development Authority) in the Ncojane area, with individual ranches to be leased to cattle owners and a SIDA Range Ecology team to monitor influences from 1975.

The area has been subject to monitoring of cattle productivity levels by APRU, and two study areas have been used to test stocking rates and grazing systems in what is known to be a sensitive environment where cautious management is needed to sustain production.

The studies confirmed that in this kind of fragile environment stocking rates are critical, and even spread of water reticulation vital. Tentative suggestions included 20-25 ha/livestock unit (lsu) for Schmidtia-Stipagrostis range, and 30-35 ha/lsu for the poorer Aristidia-E. pallens type, which is very vulnerable. With few exceptions all ranches show serious overgrazing around water points, and concern is for degradation to become irreversible on the poorer range. The reports all confirm the need for extreme caution in opening up this fragile ecological zone.

TGLP -- Tribal Grazing Land Policy

The White Paper was produced in 1975. Its objective was to make grazing control possible and at the same time increase cattle productivity. Also, the intent was primarily intended to safeguard the interests of the large percentage of tribesmen with few or no cattle.

There was concern for control of overgrazing and decline in productivity, and zoning was proposed, regionally, to set aside certain areas for "commercial leasehold blocks for ranching by bigger herd owners" and "reserve" areas to accommodate future expansion needs of the general traditional herd, with its wide variety of herd sizes. A report of a consultancy by S. Sandford was published in July 1980, which highlighted some of the major concerns about the implementation problems of the TGLP.
APRU (Range Research) continued to evaluate three specific areas (1970): (a) measurement of animal productivity from the natural range, (b) measurement of what the natural range could supply to the grazing animal, and (c) measurement of the effect animal productivity had on the natural range. The high selectivity for crude protein by grazing stock was also evident as well as the consistently good levels of crude protein in some of the indigenous grass species.

APRU had by now established a scattered spread of ranches throughout the country with a standardized "minimum acceptable level of management" that was largely standard commercial practice, and claimed levels of animal production were significantly higher than those recovered from traditional cattle posts. There was considerable variation between ranches, however, and considerable variation between figures of dry matter production per hectare from the range (ILCA report (1981), Bostwana Working Document No. 6) (LEU Vol 2 (1982), "Production and Nutritional Value of Range Forage") (Table 1).

There had been a full recovery from the drastic fall in the cattle population due to the low rainfall cycle of the early 1960s and the annual increase was moving upward again at 4%/year (Table 2). Although it was appreciated that the implementation of the TGLP policy was likely to be slow, the conventional thinking clung to the belief that considerable improvement in livestock productivity would be possible if distribution and management could be manipulated, and the exodus of the larger herds from the overstressed eastern grazing areas would relieve this pressure.

### Table 1. Ranch cattle compared to communal herds.

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<tr>
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<th>Ranch</th>
<th>Cattle post</th>
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<tr>
<td>Calving (%)</td>
<td>74</td>
<td>46</td>
</tr>
<tr>
<td>Mortality</td>
<td>8</td>
<td>10 (12-14)</td>
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<tr>
<td>Calf weight at 7 months (kg)</td>
<td>178</td>
<td>123</td>
</tr>
<tr>
<td>Calf weight at 18 months (kg)</td>
<td>278</td>
<td>207</td>
</tr>
<tr>
<td>Cow productivity at 7 months (kg)</td>
<td>120</td>
<td>51</td>
</tr>
<tr>
<td>Cow productivity at 18 months (kg)</td>
<td>188</td>
<td>86</td>
</tr>
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Table 2. Livestock population figures.

<table>
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<tr>
<th>Year</th>
<th>Cattle ('000)</th>
<th>Sheep</th>
<th>Goats</th>
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<tr>
<td>1965 (after 4 years</td>
<td>1481</td>
<td>125335</td>
<td>335134</td>
</tr>
<tr>
<td>drought)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>2564</td>
<td>420000</td>
<td>1400000</td>
</tr>
<tr>
<td>1983</td>
<td>2818 (Commercial herd 410700)</td>
<td>164700</td>
<td>782800</td>
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Nothing of the sort has taken place, and the situation in the communal areas becomes more acute rather than being alleviated. There was also a tacit naivety in the assumption in the White Paper, namely that (a) fencing would provide the means to increase productivity, and (b) tenants would have the will to adopt improved management and adhere to recommended stocking rates.

Subsequently, the policy known as ALDEP (Arable Lands Development Programme) in 1978/79 followed as a means of providing practical assistance to the smaller, least-advantaged, rural households who would not benefit by the broad implications of TGLP. The ultimate aim was self-sufficiency in staple food-grain productions, increased productivity being achieved through the provision of a number of grant-aided packages to the arable farming families. There was a total preoccupation with the constraint of inadequate draft power, and after great debate the late acceptance of a post for a pasture/fodder production officer was largely conceded on the concept that improved nutrition of the working oxen was the objective, the post was still being debated in June 1981. The officer finally was appointed in 1983. By this time, the Integrated Farming Pilot Project (IFPP) had already been working on the basis of a need for more realistic integration of crops and livestock into what effectively is a mixed farming situation, for 2 seasons, principally on the screening of a variety of species potentially useful for introduction into the traditional systems (see the section on Assessment of Investigation Needs).  

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Recent evaluations of both TGLP and ALDEP have coincided with the current cycle of drought, and a number of internal seminars and workshops have become increasingly concerned with environmental conservation and drought strategies. In a country beset with periodic droughts, cyclical yet unpredictable, of varying degrees of impact upon the rural populations according to the severity of water shortages compared to needed demand, it is inevitable that drought strategies at least look at alternate fodder bank provision. A number of consultancies have referred to this matter in the past. Although drought-resistant species capable of accumulated production that would contribute significantly to such a fodder bank in times of stress are not usually associated with pasture research, it has to be noted that more work needs to be done in this field (there has been no formal reaction to consultancy recommendations on this subject).

Furthermore, the work already done does indicate that there is scope for investigation into quantitative bulking-up of local fodder banks of more conventional forage species planted as a rain-fed crop with supportive irrigation from any of a number of stock watering boreholes. Experience here suggests that the crop would have to be early planted to ensure against the failure of mid-season planting rains, as well as the early cut-off of the whole season.

It is significant that in spite of the proliferation of boreholes during the last 30 years this fact still holds true. Water determines the distribution of livestock populations except in times of extreme drought, when the disasters of insufficiency of herbage under conditions of minimal precipitation are felt most severely in the most heavily populated areas of the eastern Hardveld. Drought is a cyclical reality, however, and conditions the thinking of most political planners and aid donors.

It is still possible in the western Sandveld to find tracts of undergrazed land empty because of lack of water. In the east, such pockets are now small, but still exist. Large tracts of the eastern areas have been denuded temporarily of stock by their owners in the present circumstances by complete removal of edible forage.
Notwithstanding this deliberately painted picture there is scope for improvement of levels of productivity from any given unit of land, in any given season, but the degree of variability is high due to the extremes of differentiation of seasonal rainfall patterns. Also drought strategies are relevant. Annual, even monthly means of rainfall expectations have no relevance under the circumstances.

Much has been learned in the attempts to improve reliability of performance of arable cropping, and it is here that the relevance of improvement of fodder-bank potential begins to become meaningful. Enough has now been done to justify the claim that given the will, and the seed, any year can be made to produce a significant level of fodder for the ruminant animal over and above that to be expected from the natural range. The significance of variability of rainfall makes it impossible to predict which particular methodology will pay off best in any given year, except where there are guarantees of irrigation, and, hence, the need that was foreseen to explore a variety of options both of species and of times of planting as well as annual, biennial, and perennial. Methods of conservation and utilization best suited to the differing constraints of livestock owners also need to be answered, and it is unlikely that one single, simple set of solutions will evolve.

Size of herds, herd structures, family labour availability, family wealth, size of arable holding, and area customarily cultivated each year, all will influence decision-making.

METHODOLOGY IN PASTURE RESEARCH (AFTER 1976)

Transfer of an FAO pasture research range officer to the APRU team enabled a review of past work to be undertaken and the practicalities of seed availability to determine a future program. From a long checklist (180 spp) of indigenous Papilionoidea and herbage legumes, seed was collected from 12.

Of the grasses, Cenchrus occurred locally, and Panicum coloratum and Eragrostis curvula were available commercially. Urochloa mosambicensis locally occurring was cultivated in Australia. It was decided to exclude
Chloris guyana because of lack of drought tolerance. But the ALDEP pasture research officer will probably reassess Rhodes grass in the northern areas of Kasane.

Initial investigation consisted of nursery-plot establishment with evaluation of quality characteristics and further seed collection. Siratro established by Van Rensburg (1970) had survived and seed was used in compatibility trials with Cenchrus ciliaris and E. curvula using basal dressings of 400 kg/ha single supers + split three levels of nitrogen. Other survivals: Rhynchosia sublobata was still growing but failed to set seed. Only isolated plants of Neonotonia wightii survived.

**Leucaena**

Leucaena glauca is a leguminous shrub or small tree which has long been recognized as a valuable drought resistant fodder plant (Arnold 1934). Interest has recently been revived in Malawi (FAO), although trials in Zambia have been less encouraging.

Seed of four Leucaena cultivars, Peru, Cunningham, Hawaiian cross, and Hawaiian giant, were obtained from Malawi. Plots of each species, 5 x 5 m, were planted in rows 1 m apart with 10 cm spacing between plants. Compound zincated fertilizer 2.3.2 at the rate of 400 kg/ha was applied. The plots were sown in mid January and germination and establishment were good, but subsequent growth within the plots was very uneven. By mid February plants were up to 4 cm high, by mid September individual plants were 50 cm high, but the majority only 15 cm. Hawaiian giant and Cunningham are the cultivars that have made the best growth. All cultivars were slightly scorched by light frost in June and July.

Larger plots of 15 x 8 m were sown on a separate site at the same row and plant spacing, and fertilized with single superphosphate (250 kg/ha). Germination was good, but in spite of weeding, all plants had died by mid April. The soil at this site was a sandy loam with a pH of 4.9. Although all seeds were inoculated with the correct rhizobium strain at sowing, nodulation of Leucaena has not been observed. In preparation for further trials the four cultivars have been established.
in pots under greenhouse conditions for planting out at different sites.

**Cenchrus ciliaris**

Farm practice for *C. ciliaris* on the Research Farm at Content is to seed with a fertilizer distributor at the rate of 4 kg/ha. This technique was used in an attempt to establish approximately 2 ha of the grass. A basal application of 250 kg/ha of single superphosphate was applied and seed sown at the beginning of January.

On block 2 of this trial, a 3 x 3 trial to investigate the effect of P and N on establishment and growth was laid down. Treatments were: P0, no phosphate; P1, 200 kg/ha single superphosphate; P2, 400 kg/ha single superphosphate; N0, no nitrogen; N1, 150 kg/ha LAN; N2, 300 kg/ha LAN. There were four replicates in a randomized block design with a plot size 5 x 5 m. Germination and establishment were good but again weed growth was excessive and no evaluation cuts were made.

Differential rates of LAN were applied to established swards of Cenchrus on three different sites on the research farm. Treatments were single applications of LAN at the rates of 80, 120, 160, 240, and 320 kg/ha applied at the end of January. A randomized block design with three replicates per site and a plot size of 5 x 4 m was used. No significant difference in the results of an evaluation cut taken in April was shown, although an increased response up to the application of 160 kg/ha on site 3 was obtained (Table 3).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>16.6</td>
<td>15.6</td>
<td>27.3</td>
</tr>
<tr>
<td>N2</td>
<td>21.0</td>
<td>18.0</td>
<td>29.6</td>
</tr>
<tr>
<td>N3</td>
<td>15.3</td>
<td>22.0</td>
<td>40.0</td>
</tr>
<tr>
<td>N4</td>
<td>19.6</td>
<td>24.3</td>
<td>29.6</td>
</tr>
<tr>
<td>N5</td>
<td>19.0</td>
<td>24.6</td>
<td>31.6</td>
</tr>
</tbody>
</table>
Increasing Yield and Quality of Natural Grasslands

An experiment was conducted on Morapedi Ranch to study the effects of applying fertilizers to natural grasslands. The treatments were nitrogen (N) in the form of urea at 0, 50, 100, and 150 kg/ha; phosphorus (P) in the form of single superphosphate at 0 and 33.2 kg/ha; and potassium (K) in the form of muriate of potash at 0 and 26.2 kg/ha.

All combinations, 4 x 2 x 2, were arranged in a randomized block with two replications. The nitrogen was applied in three dressings: the first, together with the phosphorus and potassium on 11 November 1976, the second on 14 December 1976, and the third on 30 December 1976. The plot size was 10 x 10 m and the area harvested measured 8.3 x 8.3 m.

No weather data other than rain were recorded, but the following are estimates based on data from Sebele weather station: temperatures at noon were, in general, above 30 °C; daily loss of moisture was on average 8 mm.

The yields, expressed as oven-dried material, are shown in Table 4. Phosphorus and nitrogenous fertilizer treatments produced highly significant effects, but not potassium, so that the data in Table 4 show the average response of the grass to nitrogen in the presence or absence of phosphorus. All responses shown in Table 4 are significantly different from the control (N₀ P₀) at P < 0.01.

Table 4. Mean response of grass to nitrogen in the presence or absence of phosphorus (kg/ha oven-dry material).

<table>
<thead>
<tr>
<th></th>
<th>P₀</th>
<th>P₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₀</td>
<td>1020</td>
<td>1386</td>
</tr>
<tr>
<td>N₁</td>
<td>1578</td>
<td>2026</td>
</tr>
<tr>
<td>N₂</td>
<td>1579</td>
<td>2696</td>
</tr>
<tr>
<td>N₃</td>
<td>1558</td>
<td>3148</td>
</tr>
</tbody>
</table>

Note: Standard error of a difference between two means = 98 kg.
After harvesting, representative samples were analyzed for the following constituents: crude protein (CP), total phosphorus, and in vitro digestibility. The crude protein percentage increased as the amounts of nitrogen fertilizer were increased. None of the other fertilizers had any significant effect on the CP%. The phosphorus application increased total phosphorus content in the grass from a mean of 727 ppm, to a mean of 1,548 ppm. None of the other fertilizers had any significant effect on the phosphorus content. The differences between the grass treated with phosphorus and the untreated grass are all significantly different.

In vitro digestibility percentages are shown in Table 5. The nitrogen applications alone increased the digestibility percentages. In particular, grasses receiving the N₂ and N₃ treatments were significantly higher than the digestibility percentages of the N₀ treatment.

The fertilizer treatments brought about changes in the botanical composition of the plots. From each plot, 5 x 1 m² quadrats were cut just before harvesting. A botanical analysis on this material revealed that it was made up mainly of the following species: Brachiaria nigropedata, Anthephora pubescens, Schmidtia pappophoroides, Eragrostis spp. together with small quantities of unidentified grasses and nongrass species (forbes).

The Eragrostis spp. and the grasses grouped with them increased in weight as the quantity of nitrogen was increased. This increase was significant and rapid.

Table 5. Mean digestibility percentages in relation to N treatments.

<table>
<thead>
<tr>
<th>N Treatment</th>
<th>Digestibility percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₀</td>
<td>41.64</td>
</tr>
<tr>
<td>N₁</td>
<td>44.50</td>
</tr>
<tr>
<td>N₂</td>
<td>48.54</td>
</tr>
<tr>
<td>N₃</td>
<td>46.73</td>
</tr>
</tbody>
</table>

Note: Standard error of difference between two treatment means = 2.35%.
It would appear that there is an interaction between nitrogen and phosphorus fertilizer in the case of _Eragrostis_ species, response being limited in the absence of the latter element. A similar result occurs with _B. nigropedata_. The growth of _A. pubescens_ is depressed by the higher levels of nitrogen, whereas _S. pappophoroides_ is not depressed by the higher levels. Experiments will be done on Sebele and Morale stations in addition to that at Morapedi in the coming year.

From 1979, further work was focused on a few specific legume species, _Siratro_ and _Stylos_, and a comparison of various cultivars of _C. ciliaris_, together with some important and significant measurements of the response of _Cenchrus_ and _Eragrostis_ to various levels of application of N and P. APRU has always acknowledged that 92% of the cattle in Botswana are maintained under traditional systems of management, and a shift of emphasis has been made since 1979 to accommodate the special problems of the community-based livestock populations.

**Siratro**

For rangeland improvement purposes, attention has been concentrated on _Siratro_, _Leucaena_, and the genus _Stylosanthes_. A plant introduction nursery was established at Sebele in 1971 and one at Mahalapye in the following year. Details of these introductions and the yields obtained were given in APRU (1979). _Cenchrus_ and _Siratro_ plots have been maintained and their yields recorded.

It was noted in APRU (1980) that some success had been achieved with _Siratro_ at Musi, Morale, and Tsetseku. At these three ranches the legume was sown in strips within cleared lands. Persistence of the legume has been good at both Musi and Morale.

Plans were made to replicate this work at other ranches, but it was decided to make preliminary small-scale sowings. A series of exclosures, either 625 or 250 m², were, therefore, established on the sites shown in Table 6.
Table 6. Sites of sown fodders on APRU ranches.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of exclosures</th>
<th>Location</th>
<th>Rainfall 1 Sept. 81 - 31 Mar. 82</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>East</td>
<td>South</td>
</tr>
<tr>
<td>Sunnyside</td>
<td>2</td>
<td>25°44</td>
<td>25°06</td>
</tr>
<tr>
<td>Masiatilodi</td>
<td>2</td>
<td>25°00</td>
<td>25°02</td>
</tr>
<tr>
<td>Seleka(^a)</td>
<td>1</td>
<td>27°45</td>
<td>23°02</td>
</tr>
<tr>
<td>Lesego</td>
<td>1</td>
<td>27°19</td>
<td>21°55</td>
</tr>
<tr>
<td>Tsetseku</td>
<td>1</td>
<td>23°10</td>
<td>20°10</td>
</tr>
<tr>
<td>Morale</td>
<td>2</td>
<td>26°50</td>
<td>23°12</td>
</tr>
<tr>
<td>Masama</td>
<td>4</td>
<td>25°25</td>
<td>23°50</td>
</tr>
<tr>
<td>leupane</td>
<td>1</td>
<td>27°00</td>
<td>22°35</td>
</tr>
<tr>
<td>Nata</td>
<td>1</td>
<td>25°57</td>
<td>20°00</td>
</tr>
<tr>
<td>Dukwe</td>
<td>1</td>
<td>26°35</td>
<td>20°36</td>
</tr>
<tr>
<td>Maitengwe(^a)</td>
<td>1</td>
<td>27°25</td>
<td>20°40</td>
</tr>
<tr>
<td>Matlolakgang</td>
<td>2</td>
<td>25°10</td>
<td>23°54</td>
</tr>
<tr>
<td>Impala(^a)</td>
<td>1</td>
<td>27°35</td>
<td>21°10</td>
</tr>
<tr>
<td>Musi(^a)</td>
<td>1</td>
<td>25°04</td>
<td>25°40</td>
</tr>
</tbody>
</table>

\(^a\)Not sown because of drought.
\(^b\)na = not applicable.

A plot trial on the effects of added microelements was carried out in the 1981 dry season, but no significant effects were recorded.

The rainfall patterns were similar on all sites except Sunnyside: a drought with occasional light showers from mid-December to the end of February. Siratro was sown in replicated 1 m wide strips with differential phosphate fertilizer applications. All sowings failed because of dry conditions after sowing.

**Stylosanthes**

One introduction of *Stylosanthes scabra* sown in 1977 at Sebele made vigorous growth and is well established, but other introductions of the species on adjacent sites all failed. Both *S. scabra* and *S. hamata* should be productive under local conditions but both have proved to be extremely difficult to establish. Seedlings of both species were planted at Sunnyside, Morale, Dukwe, Nata, Motopi, and Sebele. Establishment
at all sites except Masama and Nata was good; the plants have fruited but productivity has been low and winter greenness poor.

A collection of types was obtained from CSIRO, Australia, and a smaller one from the Grasslands Research Station, Zimbabwe. These collections were sown at Morale but only one, \textit{S. scabra} cv. Fitzroy, appears to be promising because of its winter greenness.

\textbf{Leucaena leucocephala}

Details of introductory work on Leucaena are given in previous reports (APRU 1979, 1980). It was concluded from this initial work that it is possible to establish \textit{Leucaena} under low rainfall, with a minimum of cultivation and a modicum of supplementary irrigation at planting. The program has continued and objectives now are to record the yields of established plots, to extend the geographical range of small-scale plantings, to establish a second large (16 ha) \textit{Leucaena} browse paddock at Morale, and to investigate the incorporation of \textit{Leucaena} into communal farming systems.

Dry matter yields of the established observation plots at Sebele and Mahalapye were recorded together with the results from previous harvests. The established plot at Moshu (Ngamiland, Maun region) was not harvested, but it continued to thrive and it is being maintained as a seed bank.

\textbf{ASSESSMENT OF INVESTIGATION NEEDS -- 1979/80}

Several events took place at this time that moved investigational work in the direction of the far more complex problems of the communal areas. It had been stated by the pasture research officer at APRU in 1977 that the findings of past work had not been adopted by commercial or subsistence agriculturalists. In fact, a few commercial ranchers were growing some \textit{Cenchrus} for hay, and there was the odd individual who grew large areas of Lablab not just for the hay but as a green crop before maize. The few dairy farms either relied upon irrigated lucerne, or grew fodder crops for ensiling. But, in total, the assumption was right.
By January 1979, the team members of the evaluation unit of the consultants contracted through the Ministry of Agriculture to monitor and evaluate developments emanating from the TGLP (White Paper No. 2 of 1975) were all in post. A year later they called a seminar to review local knowledge and opinions, and discuss desirable avenues of inquiry, as well as summarize the major problems.

The IFPP had adjusted to the need to concentrate more upon the disorganized but real aspects of subsistence farming, which was "mixed." It had also acquired from the Tribal Land Board 5 ha of communal land for demonstration purposes.

Also in 1979 the preliminary work of the Arable Lands Development Working Group was completed and policy began to take shape. Guided by another consultancy the need to include fodder and pasture work was accepted.

The culmination of these events led to close liaison between APRU and IFPP, and the 1979-80 season saw a series of trial plots put down in the communal area. Species were entirely from available stocks within the country, but 0.5 ha of a maize nurse crop was drilled for undersowing on 20 November and after cultivation 25 different species were undersown at the end of January to coincide with the timing of majority weeding passes by local farmers. Early planted replicated plots of a number of grasses and legumes had been sown on 30 November. This early sowing of the main annual legumes being considered has set the baseline for all further considerations.

Rainfall was favourable, growth throughout was good, and high yields were obtained from the expected species -- Lablab and Velvet bean. The latter set seed earlier than Lablab. Growth and productivity from Phasey bean and Dolichos leichardt was disappointing at 25°S. Stylos failed to establish. Seca and Verana were resown without success. Pot seedlings of Seca, transplanted, survived unproductively until the first frosts. All plots were 5 x 5 m, replicated, with basal 250 kg/ha of single supers.
Siratro germinated well and covered the soil quickly. It has been subjected to alternate plot treatments of cutting at various stages of growth for 4 years, continues to seed, and is vigorous in proliferation. Glycine at Pelotshetlha survives but cannot compete. Cenchrus established well as did Teff in open plots. Establishment from undersown plots were Lablab, Leichardt, Siratro, Cenchrus, Columbus grass, Glycine, and Teff.

A much more ambitious program in 1980-81 was designed with the collaboration of APRU and the Animal Production, Ranch Extension Division of the Ministry. A wide range of species was tested at alternate planting dates, two dates of undersowing under both maize and sorghum, with three fertilizer treatments, and a range of harvesting regimens for the tested fodder species. Winter-hardy forage species were planted through a range of planting dates to assess productive/survivability without irrigation. The ultimate objective was to determine a range of differential fodders capable of becoming established and contributing at different yet critical times during the long dry season. An attempt was also made to determine the feasibility of establishing reseeded strips through the natural veld, using the quickest, simplest, and cheapest methodology.

Three sites in the grazing areas were broadcast with Siratro at 6 kg/ha onto 2 m wide disked strips; 250 kg/ha S. Supers were broadcast at the same time. The seed was mixed with 100 kg/ha LAN and bush harrowed in. Results were similar to APRU findings on ranches: unless the cattle were excluded they used the strips as tracks and destroyed emerging seedlings.

Late sowing in mid February is too late for establishment, and the degree of cultivation needs to be adjusted to soil type. But there is no doubt that Siratro can be established, and both on ranches and at IFPP, good, consistent yields have been obtained from plots and strips under controlled conditions. This investigational program will continue. Two fenced farmer plots were successfully established with Siratro, and this has persisted in spite of intensive grazing-off by goats in the dry season.
The 1980-81 program proved that both grasses and legumes can be established by undersowing of grain crops, that P at least appears to be desirable, and February sowing is less effective. The perennial legumes Siratro and Glycine benefited from the canopy effect, and both Velvet bean and Lablab purpureus as annual "intercrops" can produce good growth from January sowings and continue to vine later than open sites due to canopy protection, provided soil moisture is adequate. Protection from frost, however, is dependent upon stands of the nurse crop.

In 1981-82, the successful establishment of grasses and legumes under both sorghum and maize was repeated, but only one sowing date was used (4 February) due to lack of rainfall in late January. Part of the sorghum block was used to undersow with a range of fodder species as a test of "reinforcing" the stand for increase of biomass. This followed the very successful growth shown by the replicated plots of Columbus grass through all the subblocks of both nurse crops in the previous year. Seven different fodder species were used and mixed in subplots with four different legumes, the annuals L. purpureus and Leichardt, and the perennials Siratro and Glycine. Half of the block was cut and stooked in the last week of April and half left standing. This procedure was a repeat of the previous year and had the dual purpose of observing effect on undersown species as well as comparing yield of stover and changes in crude protein and DDM. Stooking investigations had been undertaken by APRU in 1979 at a number of sites, including IFPP, and had confirmed work elsewhere that there are significant losses in yield and quality in the standing crop from the last week of April.

These average traditional crop residue yields are important as baseline references. They have been used to compare the biomass benefits from fodders grown specifically as livestock feed in the investigational program. The average increase from reinforcing between row sowing of a fodder is 1,100 kg. Average yields are as follows: for fodders planted in January, 3,600 kg and in February, 2,600 kg; annual legumes Lablab and Velvet bean, 5,000 kg; perennial legume Siratro, 4,400 kg; and perennial grass Cenchrus, 3,800 kg.
Reinforcing fodder plots with a legume: replicated plots of eight varieties of fodders were sown at two planting dates in the 1981-82 season. Subplots were cross broadcast with Siratro, *L. purpureus*, and *D. leichardt*. Establishment and growth were variable with the Leichardt and insignificant for late plantings (February) of Lablab, but in all cases Siratro made a useful contribution to quality. Average increase in crude protein analysis of fodder hay is 2.2%. For open plot replications, the range of species tested and established are given in the appendix.

**Farmer Participation**

There is no background of conscious effort to conserve fodder either from crop residues or standing foggage for personal individual use. Fencing of individual lands under ALDEP assistance and the ongoing investigations of fodder crops have, therefore, presented a new concept to stock owners. The successful production levels at the demonstration plot in the two seasons 1979-81 produced response from local farmers, however, particularly with the harvested legume Lablab. Seven farmer plots of 20 x 20 m planted between 12 and 20 December 1981 with *L. purpureus* enjoyed good establishment and rainfall was satisfactory for growth. Two sites were oversown with a Cenchrus-Siratro mixture in late January, and three others were sown with the same mixture on adjacent plots. All Lablab plots were pulled and dried on tripods, and the farmers allowed to use the hay as they wished. The Siratro plots were grazed by goats.

The interproject meetings had established interest in fodder evaluation, and the Evaluation of Farming Systems and Agricultural Inputs Project (EFSAIP), working in a land area north of Gaborone, recruited five participating farmers in their program to plant an area of Lablab, and separate plots of millet and trudan. The project supervised planting of trial plots of Dr Saunders cowpeas and an area of Cenchrus/Siratro. Yields of fodder were obtained at four sites, but Lablab failed as did the cowpea due to infestation, except at one site.

The exercise was repeated with millet and Lablab with 11 farmers in 1982-83. At the same time, a 4 ha
plot was established for demonstration in cooperation with APRU. IFPP recruited 30 volunteers and all areas were planted to a mixture of millet/Lablab on 0.25 ha plots, with some farmers offering a larger area having a second planting of a mixed fodder seeding Columbus grass and forage sorghum in January. The season developed into an early cut-off because of the rains and general crop failure. Seventeen of the farmers had useful yields of Lablab and fodder, however, and they harvested before cattle came into the lands early onto the failed grain crops. The intent to cart home the fodder was encouraging, and again all farmers were allowed to feed it as they wished. Two farmers plowed additional plots to broadcast in 1982-83.

To encourage the concept of feeding, baled hay was used from APRU Morale to supplement the baled fodder from IFPP plots, 12 farmers were recruited, and simple pole racks built in kraals in the dry season of 1982. Eight farmers were asked to feed their work oxen and four were allowed to feed lactating and heavily pregnant cows. This group was provided with the better-quality legume hay from the demonstration plots. The Morale hay was musty and the ox feeding was not a success.

APRU combined with EFSAIP in the winter of 1983 to use the 11 farmers to provide their own stover. This was supplemented with baled stover purchased by APRU. Six animals per farm were fed, three oxen, three cows. This exercise was monitored by APRU.

In the 1983-84 season, 60 farmers at IFPP volunteered to participate. The 17 who had crops to feed the previous year were expected to plow their own plots. All new volunteers had the first 0.5 ha disked and broadcast, but the season was such that most of the work took place over the Christmas period. Second plots were planted in some cases on rains in the second week of January. Rainfall then failed. The few early planted plots began to die back in February, and farmers were encouraged to harvest what they could. A gentle rain from 21 to 23 March (44 mm) germinated some January plantings and more farmers were able to make hay in April. All grain crops had died or never been planted. The season highlighted both the versatility and the difficulties of trying to manage fodder
crops in open lands. Cattle were in very early in the arable lands, and a number of additional farmers were encouraged to cut failed and withered sorghum crops.

It is impossible at this stage to know whether the general drought stress encouraged this willingness to get out and cut and haul home some fodder, or whether the concept of providing feed at the kraal is beginning to be accepted. The coming season will see a spread of fodder options put to the farmers with much more farmer-managed planting being required. It is intended to pursue earlier reseeding of range strips, and more farmers will be encouraged to build simple feed racks inside their kraals, including railed areas for the sheep and goats.

In summarizing the results of the first three seasons of investigational work on the demonstration plots at Pelotsetilha, it is important to relate results not only to the wide range of planting dates, methods of sowing, seeding rates, mixes of grasses, fodders and legumes, as well as the alternate procedures of cutting and harvesting times, but also to the most critical of all the variables - the rainfall.

In observation trials conducted over 5 years, clearly the critical months of January and February allowed a variety of planting times, and in particular the late undersowning of a nurse crop, to be successful in the first 3 years. The argument that it would have been better to have had the frustrations of the past two seasons initially, is not accepted. Had that occurred, there is no doubt that the consensus would have been that there were very few options open to investigation. Fortuitously, circumstances have enabled a very wide range of possibilities to be examined, and best and worst expectations compared with the alternatives of quantitative and quality needs.

The period under review has seen a very real awareness develop with regard to the magnitude of the problem confronting the silent majority of the people, the small herdowners living and surviving in a communal environment that no longer provides a semblance of symbiotic equilibrium. Two successive years of drought have accelerated this awareness, but it is not yet possible to assess whether the old familiar attitude of
complacency will return if good early rains bring the rangelands back to life again.

What is absolutely certain is the fact that large numbers of cattle have died, and, unfortunately, a high percentage of those will have been the breeding females always under the most stress. Even more distressing is the inevitability that it will be the small herds that will have suffered most. The ownership of cattle is very skewed. Forty-five percent of all rural farmers own less than 10 head, and they only planted 20% of the land under cultivation, and they harvest the least (1983 Agricultural Statistics). They are truly the most disadvantaged. Statistics also show that the ratio of calves to cows is lower than the average, and females almost certainly have to be put into the yoke.

It will be argued with some truth that this large section of the community is the least able to make any proper use of the arable land for fodder and that the fodder concept is designed to assist the above-average section of the rural households. However, this is not really relevant. All share the communal grazing. This also includes the large sections of improperly utilized arable land that never comes under the plow in any given year. The area planted in 1983 was 305,000 ha, which is only 12% of the suitable arable area.

There is great potential for better use of the large interspatial areas in the land areas, and all could benefit. The provision of better-quality grazing is equally important as a measure to combat the carrying capacity and the nutritional deficiencies of the herds. Here small herds have the advantage because their needs are more easily met.

The principal need, however, is for the unit rural community to group together and tackle the problem collectively and responsibly. The Ministry of Agriculture is currently seeking ways to give assistance to such responsible leadership. Collectively, a grazing community must be helped to improve and stabilize its own natural resource. This whole pasture and fodder program is just one component of the scene.
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APPENDIX

Species planted at IFPP 1981-84 for evaluation and investigation

**Fodders**

Trudan, Fodderbank, Supergrazer, Haygrazer, Columbus grass, Sweet Sudan grass, Babala millet, Sordan. Australian importations: Millet Feedmill II, Forage sorghums: Jumbo, Sugargrazer, Speedfeed

**Grasses**

Cenchrus ciliaris, Molopo, Gayndah, USA-W. Australian, Panicum coloratum, Bambatsi, Sabi panic, Panicum maximum, Green, Gatton, Digitaria, Smutsii, Erianthe (Rhodes grass), Anthephora pubescens, Phalaris tuberosa, Kentucky Blue Fescue, Setaria, Nandi, Paspalum, plicatum, notatum, Eragrostis, Teff, Curvula, Ermelo, American leafy

**Legumes**


**Winter Forage**

Rye, polko, koolgrazer, Hybrids, Agroticum, Triticale (4), Radish, Japanese fodder, satinajina, nooitedacht