PASTURE RESEARCH AT UYOLE OVER THE LAST TWENTY YEARS

N.J. Mukurasi and T.J. Myoya

Uyole Agricultural Centre, PO Box 400, Mbeya, Tanzania

ABSTRACT

Pasture research at Uyole over the last twenty years is reviewed. Work on natural pastures was designed to find ways of increasing yield through fertilizer use, cutting management and oversowing. The pastures showed high response to applied nitrogen and best levels appeared to be 100 kg N year^{-1}. At least some 40 kg P ha^{-1} should be applied. Cutting twice per season increased yield but at the expense of quality. More frequent cutting (three to four times per season) decreased yield but quality increased. Oversowing failed without land disturbance.

A look into planted pastures appeared necessary due to the high input levels required by natural pastures and a shorter growing season. First germplasm evaluation starting with temperate species. Most of them were not successful except at higher altitudes (2900 m.a.s.l). Further evaluation involved both tropical and subtropical species with Rhodes grass as a locally adopted reference species. Several species outyielded Rhodes grass but their quality was lower. Among the legumes, Desmodium spp cv. Greenleaf and Silverleaf have shown good adaptation and are now in wide use. They mixed well with most grasses.

Among the perennial fodders, Napier grass is widely adapted and is responsive to applied nitrogen. Cutting management was similar to other grasses and combined well with the above legumes and is now in wide use as a cut and carry crop. Lupin, vetch and lablab are among the annual fodder crops that have shown to extend their growth into the dry season and thus help solve fodder shortages during the period.

INTRODUCTION

The Uyole Agricultural Centre (UAC) does research in four regions of southern Tanzania, Mbeya, Rukwa, Ruvuma and Iringa Regions. The climate is a warm temperate monsoonal climate and annual rainfall varies from 2500 mm at Kyela in Mbeya to less than 600 mm at Ismani in Iringa. The altitude changes from 560 above sea level at Kyela to 3000 on the Livingstone plateau in Makete District. Most of the pasture research described was carried out at Uyole Agricultural Centre (UAC), longitude 33°22'E latitude 8°55'S, altitude 1800 m above mean sea level, rainfall 1000 mm annual, maximum ambient temperature 24°C, mean minimum temperature 14°C, and night temperatures in June and July as low as -7°C. The soils are volcanic in origin, with a pH of 6.5. Limiting factors to agricultural crop production are a six month dry season from June to October, low air temperatures in June and July, and poor soil fertility in terms of available nitrogen, phosphorus, copper, boron and molybdenum.

RESEARCH REVIEW

Natural pasture

The original vegetation at Uyole was *Brachystegia* woodland (Mukurasi 1984), with more than 50% woody plant species standing among tall *Hyparrhenia* and *Themeda* grasses. On farmland, tree species have been removed to facilitate agricultural traffic. *Hyparrhenia* and *Themeda* grassland remains.

The effect of nitrogen (N), phosphorus (P) and potassium (K) fertilizers on this local pasture were studied for seven years between 1975 and 1981. The results of cutting management trials are summarized in Table 1. A drop in yield occurred as the number of cuts per year increased. Cutting twice a year gave the highest annual yield at all nitrogen levels.

Surveys of the botanical nature of the pasture composition revealed a decrease in natural grasses with increased number of cuts per season, while sedges and annual grasses increased. At low levels of nitrogen there was a high proportion of legumes (22%) while the reverse was true at high levels (3%). The legumes were of the short clover type. At high levels of nitrogen, Rhodes grass invaded the trial when the cutting intervals was short. With close cuttings the quality of the material increased but at the expense of yield (Table 2).

Although the potassium status of the volcanic soils in the Southern Highlands of Tanzania is adequate for field crop production (Nilson, 1974), where pasture grass is cut and removed from the site and in cropland where successive crops are planted over for several years, the amount of potassium may decrease to low levels, and require supplementation (Nye, 1966; van Wambeke, 1967). Results at UAC showed that pastures which were harvested for seven years from 1975 to 1981 responded positively to applied potassium from 1984 to 1991 (Table 3). The magnesium status in the soil was inversely correlated to the amount of available potassium.

The effects of oversowing a Rhodes grass/desmodium or a Rhodes grass/White clover mixture into existing natural pasture under different cultivation intensities was also studied. During the first year rotovation increased the amount of broad-leaved weeds. Disc-harrowing followed by broadcasting seed hand or machine gave the best stand of the mixture. The mean dry matter yield of the Rhodes grass/desmodium mixture was 6600 kg ha^{-1} while that of the Rhodes grass-White clover mixture was 4600 kg ha^{-1}. Oversowing natural grasslands without land disturbance was a failure.

Table 1. Annual dry matter yield of natural pastures (kg ha^{-1}) under different nitrogen application rates and different cutting regimes (mean of four years)

	Nitrogen application (kg N ha^{-1} $year^{-1}$)			
Cut $year^{-1}$	80	160	320	Mean
2	7800	10400	15280	11160
3	5850	8370	12580	8930
4	5760	7900	11360	8340
Mean	6470	8890	13073	
SE	±1153	±1329	±2006	

Table 2. Crude protein content (% dry matter basis) of natural grassland under different cutting regimes and rates of nitrogen application (80, 160 or 320 kg N ha^{-1})

Cuts $year^{-1}$	Cut no.	Harvest date	Crude protein		
			80 N	160 N	320 N
2	1	10/2	9.6	9.4	11.6
	2	25/5	9.6	7.6	7.7
3	1	24/1	11.6	10.7	11.8
	2	22/3	9.6	9.1	11.2
	3	25/5	9.0	8.7	8.9
4	1	6/1	13.3	15.7	23.3
	2	10/2	11.8	10.6	11.1
	3	22/3	12.3	11.6	14.3
	4	25/5	9.9	7.9	7.7

Table 3. Annual yields of natural pasture (t ha^{-1}) over the period 1984-1991 of pasture that had been cut and removed from 1975 to 1981 (N P and K at 40 kg ha^{-1} cut^{-1})

	Control	N	P	K	Mean
Yield	4.3	5.1	4.7	5.1	5.5
K status meq 100 g^{-1}	15.6	14.9	18.1	20.1	17.2
Mg status meq 100 g^{-1}	1.6	1.6	1.2	2.0	1.5
pH	6.1	6.0	6.1	6.0	6.1

Seeded Pasture

The introduction of new grasses started with temperate and sub-tropical species, as listed by Myoya and Mukurasi (1988). Most introductions were unsuccessful except for species of *Lolium* on Kitulo Plateau (2900 m above sea level). Later introductions included tropical species, such as Rhodes grass (*Chloris gayana*) cvs Pokot, Mbarara and Masaba, Nandi setaria (*Setaria anceps*), Congo signal (*Brachiaria ruziziensis*), Guinea grass (*Panicum maximum*) cv. Riversdale, Gatton and Hamil, *Urochloa*, *Paspalum* cvs Rodd's Bay and Bryan, *Cenchrus ciliaris* cvs Biloela, and Gamba grass (*Andropogon gayanus*). Initial comparisons were based on yield alone. None of the grasses outyielded Rhodes grass or setaria. However paspalum formed a good ground cover as did Congo signal.

A much wider range of grasses were introduced in 1982 and were compared with the existing Mbeya ecotype of Rhodes grass under different fertilizer regimes (Table 4). Some grasses yielded well without added nitrogen and all were equally responsive to applied nitrogen. On the basis of quality, only Rhodes grass showed an increase in crude protein with increased nitrogen application. Although some grasses outyielded Rhodes grass in terms of dry matter their quality was poor. For example *Panicum* cv. Hamil produced good yields even without added nitrogen, but the material was coarse even when young.

Detailed comparisons of grasses were first made between Nandi setaria and Rhodes grass (Table 5). The higher yield of Rhodes grass (total of three cuts per season) without nitrogen and with rates of applied nitrogen up to 120 kg ha^{-1} suggests that Rhodes grass is less demanding than Nandi setaria. At higher nitrogen rates, the difference between the two grasses disappeared.

In further studies, four cultivars of Rhodes grass (Local, Pokot, Masaba and Mbarara) were compared with Makaeni guinea, coloured guinea, Nandi setaria and Molasses grass under eight nitrogen levels, as shown in Table 6.

Table 4. Dry matter yield (kg ha^{-1}) of a range of grasses under different nitrogen regimes (mean of three years)

	Nitrogen level (kg ha^{-1})					
	0	50	100	150	200	250
Rhodes grass Mbeya ecotype	3790	5730	6200	7110	7950	8670
Buffel grass cv. Biloela	5750	6790	12120	9760	10830	9010
Setaria cv. Kazungula	4050	7070	8330	7800	7080	7850
Panicum (green panic)	4830	9330	8470	10240	7190	8310
Panicum cv. Hamil	6270	6350	8240	10010	9690	9950
Panicum cv. Riversdale	3000	5770	10380	7320	7670	8640
Signal grass cv. Basilisk	3510	7610	9860	8790	9440	13120
Paspalum cv. Rodd's Bay	3750	6180	6190	6530	6540	7630
Paspalum cv. Bryan	5140	6970	8690	8770	9730	8810

Table 5. Dry matter (DM) yield (kg ha^{-1}) and nitrogen use efficiency (kg dry matter kg $^{-1}$ N) of Rhodes grass and *Nandi setaria* at six levels of applied nitrogen

Nitrogen (kg ha^{-1} year^{-1}) (applied Nov.)	Rhodes grass		*Nandi setaria*	
	kg DM ha^{-1}	kg DM kg^{-1} N	kg DM ha^{-1}	kg DM kg^{-1} N
0	3700	-	2370	-
60	6020	39	5000	44
120	8720	42	7820	45
240	14120	43	14820	52
360	17860	39	18160	44
480	21630	37	21460	40
Means	12008	40	11605	45
SE	±7028	±2.5	±7664	±4.4

Table 6. Dry matter yield (kg ha^{-1}) of five grasses under different rates of nitrogen application (mean of two years with three harvests per season)

Nitrogen (kg ha^{-1} year^{-1})	Local Rhodes	Pokot Rhodes	Mbarara Rhodes	Masaba Rhodes	Makaeni guinea	Coloured guinea	Nandi setaria	Molasses grass
0	3490	3990	3820	4180	3650	4360	3970	4170
150	9100	9600	8280	9650	10760	8860	9500	9150
300	13500	15260	14360	13940	13360	13730	12930	12610
450	16130	16710	16880	16890	15450	15830	18100	13800
600	17850	17940	16800	17850	15100	17110	18470	16250
750	17550	17070	17430	18500	15150	16040	17050	14810
900	19160	17200	16270	16480	15210	14930	18570	16030
1050	18880	16780	16200	17750	13580	15380	17630	15530

A similar nitrogen response was obtained for all cultivars of Rhodes grass up to 450 kg N ha^{-1} year, when a mean dry matter yield of 16,600 kg ha^{-1} was obtained. On the basis of calculations of nitrogen efficiency, optimum nitrogen application rate appears to be reached about around 150-200 kg N ha^{-1} per year for all grasses.

During the 1975/76 season, chemical analyses of crude protein content and *in vitro* dry matter digestibility (IVOMD) were carried out on Pokot Rhodes, Nandi setaria, and Mbeya ecotype Rhodes grass cut at the three leaf stage (Table 7). Nandi setaria tended to contain more crude protein than the other grasses at most nitrogen levels. Variation among cuts was not expected since the cutting interval and growth stage were the same for all cuts. INVOMD not did seem to be affected by the nitrogen level. Changes in quality were not pronounced up to 150 kg ha^{-1}, implying that more nitrogen is required on the nitrogen-poor soils of Uyole.

Pokot Rhodes gave lower protein content than Mbeya Rhodes which also displayed lower INVOMD. Despite the high DM yield and quality increases noted with N application, its overall effect on DMD was negligible. Setaria had a high crude protein content at all nitrogen levels and cuts, but Rhodes grass forms a better ground cover because it spread by stolons.

The better performance of Rhodes grass led to other agronomic studies on its establishment. Poor yields were obtained when it was grown under oats as a cover crop. The best results were obtained when it was sown broadcast under maize after the second weeding when the maize was knee-high. Compared with compared machine drilling, broadcasting by hand followed by rolling promotes much earlier germination because of the shallow planting depth (Myoya, 1980).

Table 7. Crude protein content (CP, % of DM) and *in vitro* dry matter digestibility (INVOMD, %) of three grasses at different rate of nitrogen application

Nitrogen (kg ha^{-1})	Grass species	1st cut		2nd cut		3rd cut	
		CP	INVOMD	CP	INVOMD	CP	INVDMD
0	Mbeya Rhodes	9.2	57.5	-	63.3	10.6	52.9
	Pokot Rhodes	9.6	57.7	-	75.0	9.2	58.0
	Nandi Setaria	9.3	66.3	-	70.4	10.6	64.6
50	Mbeya Rhodes	8.1	59.4	8.0	54.6	7.9	63.5
	Pokot Rhodes	7.2	60.1	7.8	59.1	5.8	59.1
	Nandi Setaria	8.6	64.8	8.1	65.6	8.3	66.2
100	Mbeya Rhodes	9.4	63.3	14.2	59.3	8.0	55.8
	Pokot Rhodes	8.7	65.4	8.2	59.5	6.5	66.3
	Nandi Setaria	10.3	60.4	9.6	55.8	9.0	64.4
150	Mbeya Rhodes	11.0	63.8	13.0	53.5	15.5	53.2
	Pokot Rhodes	11.9	67.2	10.9	66.1	9.1	60.0
	Nandi Setaria	14.2	61.4	12.6	57.0	11.4	67.3
200	Mbeya Rhodes	15.7	60.0	10.5	63.2	12.1	58.9
	Pokot Rhodes	15.5	63.9	14.6	68.4	9.6	66.1
	Nandi Setaria	16.6	61.4	17.3	71.8	11.9	65.1
250	Mbeya Rhodes	17.5	64.7	18.3	69.4	13.1	57.8
	Pokot Rhodes	15.4	62.2	16.2	61.5	12.2	68.8
	Nandi Setaria	19.2	60.2	16.8	60.5	15.2	67.6
300	Mbeya Rhodes	17.0	62.0	16.9	60.4	11.3	55.8
	Pokot Rhodes	16.1	59.7	15.1	60.0	12.9	64.2
	Nandi Setaria	18.7	64.1	16.5	64.2	15.8	71.1
350	Mbeya Rhodes	17.6	61.1	17.7	59.2	12.1	53.2
	Pokot Rhodes	16.7	63.5	17.4	60.5	12.9	68.9
	Nandi Setaria	19.9	61.3	18.3	63.2	15.5	67.9

In 1973, a series of trials were initiated to study the effect of seeding rate and planting time on Rhodes grass. Seed rates of 2.5, 5.0, 10.0, and 15.0 kg ha^{-1} were used, with November, December, January and February as the planting times. During the first year, the best seeding rate was found to be 10.0 kg ha^{-1} and the best planting time February. In February, planting occurred after a two month fallow so that there was less weed competition. In subsequent years the best results were obtained from November and December planting, and differences among seed rates disappeared because of the fact that Rhodes grass spreads by stolons.

Because of the impact of adding fertilizer on the botanical composition of pastures on the slightly acid soils of Mbeya (pH 6.5), the effect of the source of nitrogen applied on the yield and botanical composition of Rhodes grass pasture was studied in 1976. Two nitrogen sources (sulphate of ammonia and calcium ammonium nitrate CAN) were applied at different nitrogen levels (0, 60, 120, 240 and 480 kg N ha^{-1} year^{-1}). A good yield response was obtained at all the fertilizer rates, with no differences in yield between them. After three years, CAN affected soil acidity slightly. The soil pH dropped by 0.3 at high rates of nitrogen supplied as CAN, by 0.2 units at when supplied as sulphate of ammonia at 60 kg N ha^{-1} and by 1.0 when supplied as sulphate of ammonia at 480 kg N ha^{-1}. A survey of the Botanical composition of the pasture trial eight years after of the treatment revealed invasion by desmodium in the low nitrogen plots whereas of Rhodes grass was still dominant in the high nitrogen plots.

Grass-legume mixture

Despite the good response to applied nitrogen shown by some grasses, the high rates recommended are unlikely to be adopted by small scale farmers. The use of legumes in pasture would help cut down the need of nitrogen fertilizer because of the legumes' capacity to fix nitrogen symbiotically but the lack of a local spreading legume means that the only alternative is the introduction of adapted types from outside.

The inclusion of legumes in pasture has been shown to increase grass yield and quality and improve animal production in many parts of the world (Humpreys, 1978). The legumes help maintain protein levels throughout the year since the decline in protein level with maturity is not as fast in legumes as in grasses. Since 1972 a number of introduced legumes have been tested at Uyole: calopo, centro, lucerne, neonotonia, puero, siratro, stylo, clitoria, white and red clover, greeenleaf and silverleaf desmodium.

Poor germination, lack of persistence, poor drought resistance and susceptibility to disease were the main causes of failure of most of the legumes. Some legumes, such as siratro, failed to form a good ground cover at Uyole, and were therefore killed by vigorous weeds or grasses. The only successful pasture legumes were silverleaf and greenleaf desmodium.

A study of the effect of Rhodes grass in mixture with both greenleaf and silverleaf desmodium was carried out over a six year period. The trial was cuts three time for each year. By the end of the six years it had been invaded by hyparrhenia. Yield and quality data from the trial are shown in Tables 8 and 9.

The yield benefits of the grass/legume mixtures declined sharply after the first year and by the sixth year yields were very poor because of invasion by of *Hyparrhenia* sp. During the first year, a chemical analysis was done on all the three cuts (Table 9). The crude protein content of the mixture was more than that of pure grass but, as expected, less than that of the pure legumes. Crude protein levels in the mixture were comparable with those of pure Rhodes grass supplied with 250 kg N ha^{-1} (Table 7). This implies a big saving in fertilizer costs can be achieved by the use of legumes since only phosphorus would need to be supplied.

Table 8. Dry matter yield (kg ha^{-1}) of Rhodes grass/legume mixtures and their components in pure stand (mean of three cuts)

	Rhodes grass	Rhodes/ greenleaf	Rhodes/ silverleaf	Greenleaf	Silverleaf
1980	11670	15580	14230	13810	11810
1981	3095	5980	5290	6760	5150
1982	4935	5330	4190	5870	4290
1983	8700	7250	6580	7340	7650
1984	4210	4130	4740	3920	5280
1985	3665	3650	3870	4100	4040
1986	6115	5420	5370	5510	5300
Means	6055	6760	6320	6760	6220
SE	±3100	±4063	±3597	±3355	±2728

Table 9. Crude protein content (% DM basis) for three successive cuts of pure Rhodes grass, Rhodes grass/desmodium mixtures and pure desmodium

	Rhodes grass	Rhodes/ greenleaf	Greenleaf	Rhodes grass	Rhodes/ silverleaf	Silverleaf
1st cut 9/1/1980	11.3	13.7	19.2	10.8	13.2	18.0
2nd cut 17/3/1980	8.8	13.3	13.9	8.5	13.5	19.2
3rd cut 18/6/1980	7.0	10.2	13.7	5.9	10.2	9.0

Fodder Crops

Research on Napier elephant grass as a fodder crop started in 1973 when a series of trials were conducted on a locally growing ecotype. Later, in 1976, other germplasm was introduced and evaluated. The locally grown Napier grass outyielded cultivars from Ghana (Gold Coast), Cameroon, Ethiopia, and Mlingano. The dry matter yield of the local Napier grass is shown in Table 10.

Cutting the local Napier grass three and four times rather than twice a season reduced overall yield by an average of 30% and 48%, respectively, whereas for natural pasture the corresponding reduction was only 20% and 25%. The crude protein content of the individual cuts of local Napier grass in 1975/76 is presented in Table 11. There was no increase in crude protein even at higher nitrogen levels. Age of the plant at the time of regrowth appeared to be more important than nitrogen level.

In another trial, the local Napier grass was mixed with silverleaf desmodium. Whereas Napier grass grown alone produced an average of 5000 kg ha^{-1} of dry matter without added nitrogen, the mixture produced 12,000 kg ha^{-1} (Myoya, 1980). For two seasons pure Napier grass grown without nitrogen contained 4.9% crude protein while the Napier grass desmodium mixture contained 12.1%. When nitrogen was applied to the Napier grass the crude protein content was 5.2%.

Maize trash is the main food crop in the Southern Highlands. In large scale dairy production it is sometimes made into silage. Research at UAC has concentrated mainly on a comparison of local and hybrid maize. Hybrid 632 gave a dry matter yield of 14,800 kg ha^{-1}, while the local maize produced only 10,000 kg ha.

Teosinte *(Zea diploperennis)* which remains in the field for more than five years, has been tested as a fodder crop and found to perform well at UAC. Without fertilizer, mean annual dry matter yields were only 1635 kg ha^{-1}, but weeded and fertilized plots produced up to 10,249 kg ha^{-1} dry matter.

Table 10. Three year mean dry matter yield (kg ha^{-1}) of local Napier grass over a three year period at three nitrogen levels and with three cutting regimes

Number of cut year^{-1}	Nitrogen application (kg N ha^{-1} year^{-1}) 80	160	320	Mean
2	10020	14450	24730	16400
3	7080	10690	16890	11550
4	5050	9200	11520	8590
Mean	7380	11450	17710	

Table 11. Crude protein content (%) of local Napier grass at three nitrogren levels (80, 160 and 320 kg N ha^{-1}) under three cutting regimes

Cuts per season	Cut no.	Harvest date	Crude protein 80 N	160 N	320 N
2	1	20/2	5.1	5.2	5.4
	2	24/6	4.7	3.7	3.6
3	1	31/1	5.3	6.2	6.7
	2	23/3	8.6	9.2	4.6
	3	24/6	5.6	4.6	5.6
4	1	15/1	6.8	9.6	7.9
	2	20/2	9.1	9.6	10.9
	3	23/3	10.9	10.1	12.9
	4	24/6	5.1	5.3	9.4

Cool season crops such as oats, vetch, lupin and *Lablab purpureus* have been shown to extend their growth into the dry season, which is a useful characteristic. Oats and lupin have been grown on a farm scale at UAC and cut as green fodder for dairy cows during the dry season.

Considerable genetic diversity occurs within oats and many cultivars (363) have been tested at UAC for their dry matter yield. Some failed to set seed and were discarded. Twenty five varieties are still undergoing selection. Differences in maturity have been observed, a characteristic which can help in planning the sequential supply of forage. In a series of trials, the best seed rate was 75 kg ha^{-1}. Application of nitrogen to oats cv. Voll produced 6800 kg ha^{-1} dry matter at 20 kg N ha^{-1} and 10,000 kg ha^{-1} dry matter at 40 Kg N ha^{-1}. The cultivar suregrain gave mean dry matter yields of 6000 kg ha^{-1} at all nitrogen levels. The major problem with the introduced cultivars was rust attack. Copper application can help counter this. Late planting reduces yield but ensures the availability of a green crop during the early part of the dry season.

White lupin (*Lupinus albus*) performs well both as a grain and a green forage crop at Uyole. Grain yields of over 3 t ha^{-1} have been achieved. Mean biomass yields of 7 t ha^{-1} dry matter after 145 days for early December and mid-April planting has been obtained (Myoya, 1980). The optimum seeding rate for a large-seeded lupin cultivar (Santgut) was found to be 80-100 kg ha^{-1}, planted with a row spacing of 50 cm. Newhand proved to be the highest yielding cultivars, with seed yields of 2.3 t ha^{-1}. The optimum rate of nitrogen application was found to be 30 kg N ha^{-1}, and of 60 kg P ha^{-1}.

Vetch, an annual trailing plant, which is normally grown with oats for support, was tested at a series of planting dates in order to provide a green crop high in protein during the dry season. Yields of the oats/vetch and of the component crops are shown in Table 12 and quality in Table 13.

Delayed planting reduced the yield of both crops in pure stand and in mixture. The overall yield of the mixture was higher than that of pure oats. Pure vetch yielded less than the mixture but the quality (crude protein content) was much higher (Table 13).

A trial in which sheep were fed on oats or oats/vetch mixture was carried out in 1987. The results are summarized in Table 14. The inclusion of vetch did not significantly improve in digestibility, possibly because of the growth stage at which it was used, and because the digestibility of the oats was already high. However, there was a decrease in crude fibre level and a slight increase in IVOMD as the amount of vetch in the mixture increased.

Interspecific hybrids of *Phaseolus coccineus* (scarlet runner bean, grown in the Uporoto Highlands of Mbeya), *Lablab purpureus* (bonavist bean) and *Phaseolus vulgaris* (common bean) have produced high yielding cultivars which are resistant to the common pests and disease found in Southern Tanzania. *Lablab* lines given fertilizer and sprayed against beanfly produced up to 9.5 t ha^{-1} vines and seed, and 1.2 t ha^{-1} clean seed. Crosses between *L. purpureus* and *P. coccineus* gave biomass yields of up to 7.5 t ha^{-1}, and seed yields of up to 2.3 t ha^{-1} without chemical control of beanfly.

A rape seed cultivar developed by crossing the cultivars Tower and Altex produced seed yields of up to 1.8 t ha^{-1}, as also observed by Harberd (1976).

Table 12. Dry matter yield (kg ha^{-1}) of pure oats, oats/vetch mixture and pure vetch

	Planting date					
	15/12	2/1	15/1	31/1	16/2	Mean
Pure oats	5560	2690	6720	2900	1780	3930
Oats/vetch	5080	3560	4940	3860	3660	4220
Pure vetch	4320	3750	3660	3170	4150	3380

Table 13. Crude protein content (% dry matter basis) of pure oats, oats/vetch mixture and pure vetch at five planting dates

	Planting date					
	15/12	2/1	15/1	31/1	16/2	Mean
Pure oats	6.9	5.4	5.9	5.0	8.6	6.3
Oats/vetch	14.0	14.5	12.1	12.2	11.5	12.9
Pure vetch	20.7	21.8	17.2	20.9	17.7	18.0

Table 14. *In vivo* and *in vitro* organic matter digestibility (%), feed intake (g feed day^{-1} $kg^{-0.75}$ body weight) and quality of pure oats and oats/vetch mixtures

	Pure oats	Mixture proportion of oats:vetch			CV (%)[1]
		90:10	80:20	70:30	
Digestibility					
In vivo OMD	68.3	64.3	64.6	68.1	6.1
IVOMD	78.5	79.0	79.6	79.5	
Feed intake	53.8	47.5	44.7	42.7	8.0
Feed quality					
CP (%)	8.1	10.0	10.3	10.7	
NDF (%)	59.3	57.2	56.4	55.0	
CDP[2]	63.2	68.9	71.3	72.8	

[1]CV, coefficient of variation; [2]CDP, crude protein digestibility calculated from the equation [100 (y-x) + xD]/y, where y is crude protein in the feed (% DM), x is the crude protein in the faeces (%) and D is dry matter digestibility.

ACHIEVEMENTS AND CONSTRAINTS

Over the last two decades the productivity of pasture has increased both at large scale and small scale farmer levels. Although farmers were initially reluctant to use fertilizer on pasture, the practice is now well accepted. The Small Scale Dairy Project in Iringa and Mbeya has made a great effort to motivate farmers to improve their pasture. However, there still many constraints that face farmers, and especially smallholder farmers. They include the lack of availability and high cost of pasture seeds, poor soil fertility, high cost of fertilizer and shortage of land. Problems of land ownership, lack of surface water in the dry season and the presence of tsetse fly in the woodland also occur and need solutions in future.

SEQUENCE OF INNOVATIONS

In Tanzania natural grasslands are usually communally grazed and few if any inputs are applied. As a result natural grassland are characterized by poor yield. The following list is a suggested sequence for the introduction of innovations to farmers to improve the productivity of their pasture.

1. *Planted pastures.* Where farmers own land, improvement in grass yield and animal production can be achieved by the use of improved pasture.

2. *Fertilizer application.* Tropical pastures show a very good response both in yield and quality to fertilizer supplementation.

3. *Fodder crops.* During the rainy season there is a surplus of herbage while in the dry season there is a shortage. Use of plants which extend their growth into the dry season, such as lablab, to supplement poor quality roughage will increase animal performance.

4. *Intensive pasture management.* The use of appropriate cutting frequencies and subsequent fertilizer applications will increase animal production.

5. *Forage Conservation.* To carry over any surplus herbage obtained in the wet season it is important that simple practices of forage conservation, such as hay making, are used.

STRATEGIES AND PRIORITIES FOR FUTURE RESEARCH

In future, more research is needed on more plant species introduction and evaluation to suit a variety of environments ranging from high to low rainfall and from tropical to sub-tropical. Simple methods of preserving green fodder as forage, especially hay making, should be investigated to encourage their general use. More cultivar improvement will be made to increase the lifespan of plant species in sown pastures. On farm research will be done to monitor species performance in terms of yield, longevity and general use.

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