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Harvesting management options for legumes intercropped in napier grass in the central highlands of Kenya

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Abstract

Ways of promoting integration of herbaceous forage legumes into a napier grass fodder system were evaluated with the aim of increasing forage quantity and quality on smallholder dairy farms in central Kenya. The herbaceous legumes *Desmodium intortum* cv. Greenleaf (ILRI 104), *Macrotyloma axillare* cv. Axillare (ILRI 6756) and *Neonotonia wightii* cv. Tinaroo (ILRI 9794) were intercropped with napier grass and evaluated for yield and quality (chemical composition and digestibility) of the fodder at 2 harvesting frequencies (8 and 16 weeks) and 2 cutting heights (0 and 10 cm above ground). Only *D. intortum* competed successfully with napier, reducing the DM yield of the grass. Due to the large forage contribution of *D. intortum* (15 750 kg/ha), the napier grass-*D. intortum* mixture had significantly higher total forage DM yield (45 910 kg/ha) than the mixture with *N. wightii* (38 840 kg/ha). Increasing the cutting interval from 8 to 16 weeks gave significantly higher grass DM yield but decreased N concentrations (from 11.3 to 8.9 g/kg DM and from 21.2 to 18.8 g/kg DM for napier and legumes, respectively) and reduced legume yields. Neutral and acid detergent fibre concentrations in grass and legume tissue increased significantly as inter-harvesting interval increased. Cutting height did not affect the yield or quality of the grass or legumes. The proportion of legume in the forage was highest during the dry season, the napier-*N. wightii* mixture being the poorest performer during that period. *D. intortum* performed consistently well and appears suitable as a companion forage legume for napier grass in central Kenya and in other areas with similar ecology.

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Introduction

In central Kenya, dairy production is a major source of smallholder farm income especially in recent years after the collapse of coffee prices. However, the predominant smallholder dairy systems are characterised by low weight gains in young stock and low milk production (Gitau *et al.* 1994). Recent farm surveys in the area have reported an average daily milk yield of 5–6 kg/animal (Gitau *et al.* 1994; Staal *et al.* 1997). The low yields are attributed to inadequate year-round feed supply, protein and energy intake, as farmers have little cash to purchase supplementary concentrate feeds. The main source of forage is napier grass (*Pennisetum purpureum*) grown in pure stands (Bayer 1990; Gitau *et al.* 1994; Mwangi 1994; Staal *et al.* 1997). Although napier grass has a high yield potential when fertilisers are applied, yields on smallholder farms are often poor (Boonman 1993) as farmers do not generally apply mineral or organic fertiliser to fodder crops.

A napier grass-forage legume mixture can improve the nutritional plane of stock as forage legumes generally have a higher nutritive value than tropical grasses and also have the ability to fix atmospheric nitrogen through their symbiotic association with rhizobia (Giller 2001). The mixture also has the potential to produce higher total dry matter yields, suppress weeds and improve soil fertility (Goldson 1977). Therefore, the integration of forage legumes into a napier grass fodder system may provide an effective means of increasing forage and dairy productivity for smallholders in central Kenya and other highland areas in Africa.

One of the major problems with grass-legume mixtures is the poor persistence of legumes in mixed swards. The persistence of legumes in mixtures is determined by the growth habits of both the legume and the grass as well as the management of the sward. Olsen and Tiharuhondi (1972) showed that *Medicago sativa* performed better than *Desmodium intortum* when grown together with the grasses *Setaria anceps*, *Chloris gayana* and *Panicum maximum*. This difference was attributed to the growth habit of the different legume species. Thomas and Sumberg (1995) suggest that the use of unsuitable legume species in mixed swards is the single most important reason why mixed swards have resulted in limited benefits in Sub-Saharan Africa. Apart from the use of unsuitable legume species, management of the mixed sward, especially harvesting frequency and cutting height, is important. In a *D. intortum*-*Setaria sphacelata* mixture, the proportion of legume DM increased from 20% to 40% when the cutting interval was increased from 3 weeks to 9 weeks (Olsen 1973). The total DM yield of the sward increased from 5.7 t/ha to 15 t/ha with the change in cutting frequency. The effect of cutting height on legume persistence is determined by its growth habit and the position of the dormant buds. Low cutting height can reduce survival and productivity of legumes (Olsen 1973), which could be associated with the proportion of lateral buds removed during defoliation.

The experiment reported here was initiated to identify legume species suitable for integration into a napier grass fodder system in central Kenya and to determine the appropriate harvesting frequency and cutting height for the mixture to maximise yields and facilitate the survival of the legumes in the mixed swards. The effect of season on the productivity of the mixture was considered, as it would be useful in the development of an annual feed budget on the smallholder farms.

Materials and methods

Study site

The study was established in April 1996 at the National Agricultural Research Centre Muguga (36.3–37.30°E, 0.30–1.30°S; 1800masl). The soil was a humic Nitosol (FAO-UNESCO 1977) with relatively high inherent fertility, *i.e.*, pH of 6.3 (1:2.5 water); organic C 3.12%; available P 41.3 mg/kg (Bray II), and total N 0.42%.

Treatments and experimental design

Napier grass was intercropped with each of the following legumes: *Desmodium intortum* cv. Greenleaf (ILRI 104), *Macrotyloma axillare* cv. Axillare (ILRI 6756) and *Neonotonia wightii* cv. Tinaroo (ILRI 9794). Napier grass (*Pennisetum purpureum* cv. Bana) was planted in April 1996 using rooted splits at a spacing of 1×1 m in 8×8 m plots. The net harvest plot was 4×4 m. Seeds of the 3 tropical herbaceous legumes were obtained from the International Livestock Research Institute (ILRI) gene bank in Addis Ababa, Ethiopia. After mechanical scarification, the seeds were drilled between the napier grass rows at the rate of 2 kg pure germinating seeds/ha. *D. intortum* was inoculated using *Bradyrhizobium* sp. "*Desmodium*" type (ILRI strain number 357), while *Bradyrhizobium* sp. "cowpea" type (ILRI strain number 364 originally TAL 169) was used for *M. axillare* and *N. wightii*. The legumes were harvested at a uniform height of 10 cm above ground in all treatments. However, the napier was subjected to a severe (0 cm above ground) or a more lenient (10 cm above ground) cutting regimen to vary competition for the legume. Similarly, 2 different cutting frequencies were tested: the recommended 8-week regrowth and a longer 16-week regrowth period.

As the establishment of legumes was slow, no harvests of the legume were made until January 1997. Therefore, while napier grass was harvested 9 times between 1996 and 1998, the legumes were harvested 7 times in the same period. The period of reporting was divided into the establishment year (April 1996–January 1997), second year (January 1997–January 1998) and third year (January 1998–May 1998).

The experiment was laid out in a $3 \times 2 \times 2$ factorial arrangement within randomised blocks replicated 3 times. Statistical analysis was carried out using the analysis of variance (ANOVA) procedures of Genstat 5 (Lawes Agricultural Trust 1997).

Sampling and chemical analysis

At harvest, sub-samples were taken from each plot and separated into grass and legume components. Dry matter (DM) yield and nitrogen and ash concentrations of the forage samples were determined following the methods of the Association of

Official Analytical Chemists (AOAC 1980). Acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin were determined using the Ankon fibre analyser (Ankon Technology Corporation, Fairport, USA). Ankon Technology F57 ash and nitrogen-free filter bags were used. Digestible organic matter was determined as organic matter loss after a 168 h incubation period during a pressure transducer assay (Theodorou *et al*. 1994).

Results

Effect of legume species on forage dry matter yield

In the establishment year, DM yield of napier grass in all 3 grass-legume associations was similar apart from the first harvest in September 1996 when the mixture with *M. axillare* produced significantly ($P < 0.05$) more grass DM than those with *D. intortum* or *N. wightii* (Table 1). By the end of Year 1, both legume and total (grass plus legume) DM yields in the *D. intortum* mixture exceeded ($P < 0.05$) those for mixtures with *M. axillare* and *N. wightii* (Table 1).

In the second year (January 1997–January 1998), napier grass yielded significantly ($P < 0.01$) less DM with *D. intortum* than with *M. axillare* or *N. wightii* in May and November 1997. However, total sward yields in the napier-*D. intortum* mixture were not significantly lower than in the other 2 mixtures. This was due to concomitantly higher *D. intortum* yields. In November 1997, total forage DM was largest ($P < 0.001$) in the napier grass-*D. intortum* mixture. Apart from the harvest

Table 1. The effect of legume species on napier grass, legume and total DM yield (averaged across cutting frequency and height).

Harvest date	Forage type	Legume species			s.e.[1]	CV (%)	Sig. level
		Desmodium	*Macrotyloma*	*Neonotonia*			
			(kg/ha)				
1996/97							
September	Napier	4000	5300	4400	330	18	*
	Legume	nh[2]	nh	nh			
	Total	4000	5300	4400	330		
November	Napier	2200	2500	3000	400	27	ns
	Legume	nh	nh	nh			
	Total	2200	2500	3000	400		
January	Napier	1500	2100	2400	360	44	ns
	Legume	3700	2200	200	430	52	***
	Total	5200	4300	2600	560	34	***
1997/98							
May	Napier	1900	3500	4600	630	32	**
	Legume	1400	620	300	340	36	*
	Total	3300	4120	4900	620	26	ns
August	Napier	6100	7470	6470	1290	17	ns
	Legume	720	670	160	174	39	ns
	Total	6820	8140	6630	1280	16	ns
November	Napier	1500	2800	2500	340	26	**
	Legume	3600	1400	530	300	29	***
	Total	5100	4200	3000	380	16	***
January	Napier	4300	5420	960	990	39	***
	Legume	1160	1040	1440	110	29	**
	Total	5460	6460	2400	1050	16	**
1998	Napier	2750	4040	3740	540	27	ns
March	Legume	2580	660	250	180	27	**
	Total	5330	4710	3980	500	19	ns
	Napier	5900	9130	7310	1470	21	ns
May	Legume	2600	610	580	490	48	***
	Total	8500	9740	7880	1510	42	ns

[1] Standard error of the difference of means, N = 12.
[2] Not harvested.

taken in January 1998, *N. wightii* produced the poorest legume DM yields. In the third year, grass and total DM yields were similar ($P > 0.05$) for all mixtures. The mixture with *D. intortum*, however, had a significantly higher legume DM yield than those with *M. axillare* and *N. wightii* at both harvests during that year (Table 1).

Cumulative DM yields over the 2-year period (April 1996–May 1998) revealed that the mixtures with *D. intortum* and *M. axillare* produced significantly more legume ($P < 0.001$) and total DM ($P < 0.05$) than the mixture with *N. wightii* (Table 2). The napier grass-*M. axillare* mixture produced 40% and 19% more grass DM than the mixtures with *D. intortum* and *N. wightii,* respectively. Cumulative total forage yield (grass plus legume) was lowest with the napier grass-*N. wightii* mixture. Although the mixtures with *D. intortum* and *N. wightii* had similar grass DM yields, the napier-*D. intortum* mixture had a higher total DM yield due to the higher yields of legume (Table 2).

Effect of harvesting frequency on yield of grass and forage legumes in a mixed sward

To enable comparison of the 2 harvesting frequencies, forage yields from the two 8-week harvests were added together and compared with the 16-week harvest taken during the same period. During the establishment year (1996–1997), only 2 harvests were taken (November and January). Harvesting at intervals of 16 weeks produced significantly more napier grass DM ($P < 0.01$) than the 8-week harvesting regimen (Table 3). The legumes were harvested only once during the establishment year so effects of harvesting interval on legume yields were not determined.

Table 2. The effect of legume species on cumulative DM yield from September 1996–May 1998.

Forage	Legume species in mixture			s.e.[1]	CV (%)	Sig. level
	Desmodium	*Macrotyloma*	*Neonotonia*			
		(kg/ha)				
Napier grass	30 150	42 260	35 380	3 330	22	*
Legume	15 760	7 200	3 460	800	27	***
Total	45 910	49 460	38 840	3 300	29	*

[1] Standard error of the difference of means.

Table 3. The effect of harvesting interval on legume, napier grass and total forage DM yield averaged over cutting heights.

Harvest	Forage type	Harvesting interval		s.e.[1]	Sig. level
		8 weeks	16 weeks		
		(kg/ha)			
1996/97					
(Nov + Jan)	Napier grass	5 800	7 300	400	**
1997/1998					
(May + Aug)	Napier grass	6 200	10 600	1 200	***
	Legume	800	1 000	200	ns
	Total	7 000	11 600	1 200	***
(Nov + Jan)	Napier grass	3 100	2 900	300	ns
	Legume	3 000	1 200	100	***
	Total	6 100	4 100	400	***
(Mar + May)	Napier grass	7 900	10 500	1 500	***
	Legume	2 100	1 500	500	ns
	Total	9 900	12 000	1 600	ns
Cumulative yield (Nov 96–May 98)	Napier grass	23 000	31 300	3 325	*
	Legume	5 900	3 700	654	***
	Total	28 900	35 000	2 694	ns

[1] Standard error of the difference of means.

After the first year, the 16-week harvesting interval gave significantly higher napier grass DM yield ($P < 0.01$) than the 8-week interval apart for the period August–January (Table 3). In contrast, legume DM yields were negatively affected by the longer harvesting frequency for August–January. On a cumulative basis, total sward yields were not significantly affected by harvesting frequency as increased ($P < 0.05$) grass yields with a longer harvesting interval were compensated for by decreased ($P < 0.01$) legume yields (Table 3).

Effect of harvesting frequency on forage quality

The 16-week harvesting interval resulted in decreased ($P < 0.05$) tissue N concentration in napier grass relative to the 8-week interval but did not significantly affect the N concentration in the legume forage (Table 4). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations in napier grass and legume tissue increased significantly with the harvesting interval (Table 4). Harvesting interval had no significant effect on acid detergent lignin (ADL) concentration or digestible organic matter in the forages (Table 4).

The effect of cutting height of napier grass on DM yield

DM yields of napier grass were significantly lower ($P < 0.001$) when cut at 10 cm compared with cutting at ground level only at the first harvest in the establishment year (September 1996) (Table 5). Apart from the harvest in November 1997, the cutting height of the grass had no significant effect on legume DM yield (Table 5).

Table 4. The effect of harvesting frequency on the chemical composition and organic matter digestibility of napier grass and average of 3 herbaceous legumes.

Parameter[1]	Napier				Legume			
	8 wk	16 wk	s.e.[2]	Sig. level	8 wk	16 wk	s.e.	Sig. level
N (g/kg DM)	11.3	8.9	0.4	*	21.2	18.8	1.6	ns
NDF (g/kg DM)	676	729	7.0	*	586	652	9.5	***
ADF (g/kg DM)	478	517	7.4	*	491	527	7.9	*
ADL (g/kg DM)	52	63	5.9	ns	144	147	6.5	ns
DML (g/kg DM)	690	692	9.4	ns	510	520	20.4	ns
DOM (g/kg)	760	758	9.2	ns	544	553	21.1	ns

[1] N = nitrogen; ADF = Acid detergent fibre; DML = Dry matter loss; ADL = Acid detergent lignin; NDF = Neutral detergent fibre; DOM = Digestible organic matter in dry matter.
[2] Standard error of the difference of means.

Table 5. The effect of napier grass cutting height on grass and legume DM yields harvested at 8-week intervals.

	Napier grass yield				Legume yield			
Cutting height	0 cm	10 cm	s.e.[1]	Sig. level	0 cm	10 cm	s.e.	Sig. level
Harvest date				(kg/ha)				
1996/97								
Sep	5260	3870	268	**	nh[2]	nh		
Nov	2730	2420	329	ns	nh	nh		
Jan	1880	1950	485	ns	2090	1983	341	ns
1997/98								
May	3180	3530	384	ns	761	784	277	ns
Aug	6270	7100	1750	ns	497	529	283	ns
Nov	2250	2250	278	ns	2170	1460	244	*
Jan	3330	3800	873	ns	1160	1260	90	ns
1998								
Mar	3730	3290	438	ns	1310	1010	147	ns
May	7920	6970	1203	ns	1580	947	402	ns

[1] Standard error of the difference of means.
[2] Legume not harvested as it was still very young.

The effect of season on forage yield

DM yield of napier grass was highly seasonal, being poor during the dry season (with only 55 mm of rain during November 1996–January 1997) and increasing substantially during the wet season (Table 6). Grass DM yield was similar (P > 0.05) for all 3 legume mixtures during the dry season. In the wet season (April–May 1997, 548 mm rain), however, grass DM yield was least in the mixture with *D. intortum* and highest when mixed with *N. wightii* (*P* < 0.01). The trend was the same in January 1998, which was for a wet period with a total of 628 mm of rain (Figure 1). *D. intortum* consistently produced more DM than the other legumes (Table 6). During the dry season (November 1996–January 1997), *D. intortum* produced at least twice as much DM as the other legumes. Although yields of *D. intortum* and *M. axillare* decreased during the wet season, *D. intortum* produced more than 1200 kg/ha at each of the harvests taken during the wet season (Table 6). The proportion of legume in the available DM was highest during the dry season, when *D. intortum* comprised 88% of the DM compared with 66% and 28% for *M. axillare* and *N. wightii,* respectively (Figure 2). The proportion of legume in the DM decreased to less than 50% for all legumes during the wet season (Figure 2).

Total forage DM (grass + legume) was similar (P > 0.05) for the 2 harvests taken during the wet season. During the dry season, total forage yield

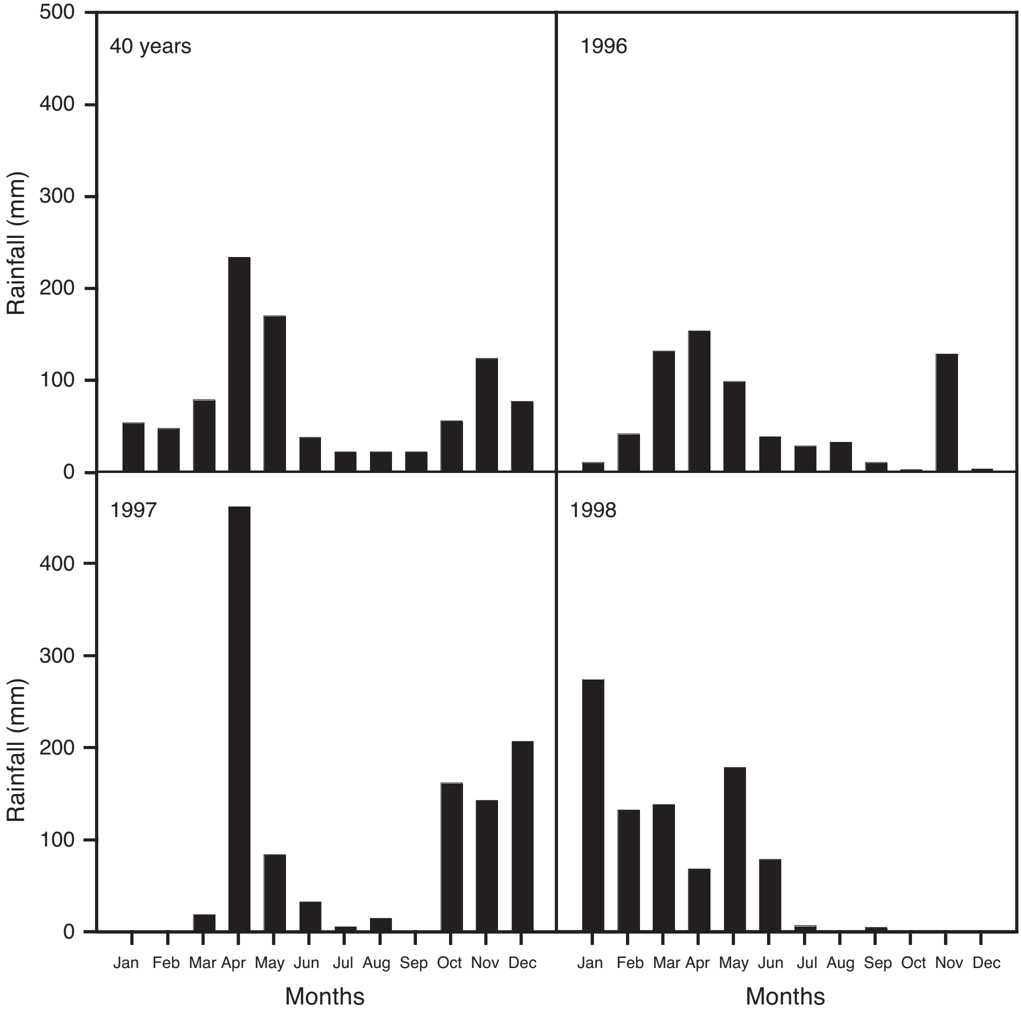

Figure 1. Monthly rainfall during the period of the study (1996–1998) and the long-term average.

Table 6. The effect of season on grass and legume DM yield from mixtures of napier grass and 3 tropical forage legumes harvested at 8-week intervals.

Legume	January 1997 (dry season)			May 1997 (wet season)			January 1998 (wet season)		
	Grass	Legume	Total	Grass	Legume	Total	Grass	Legume	Total
					(kg/ha)				
D. intortum	620	4240	4900	1910	1400	3320	2202	1248	3455
M. axillare	910	2220	3130	3510	620	4130	3293	266	3559
N. wightii	1120	240	1360	4630	300	4920	3981	258	4239
s.e.[1]	290	660	680	530	340	620	642	146	704
Sig. level	ns	***	**	**	*	ns	ns	***	ns

[1] Standard error of the difference of means.

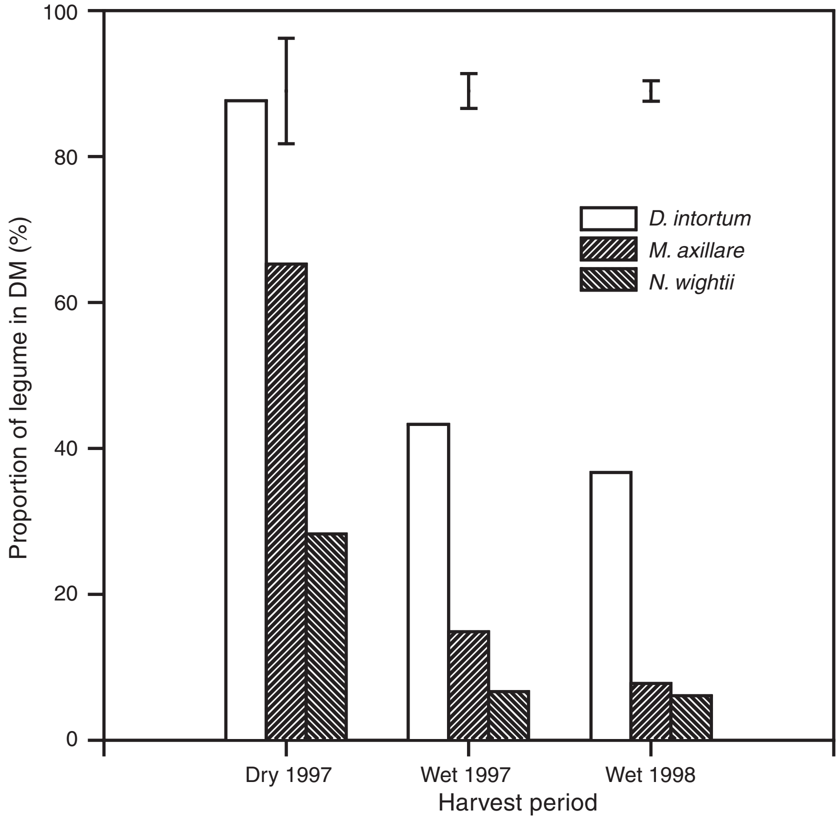

Figure 2. Proportion of legume in total (grass + legume) forage dry matter.

followed the order: grass-*D. intortum* > grass-*M. axillare* > grass-*N. wightii* (P < 0.01).

Discussion

Effect of legume species on forage DM yield

Napier grass yielded consistently less when mixed with *D. intortum* than when grown with *M. axillare* and *N. wightii*, but reduced grass yield was balanced by increased yield of *D. intortum,* which competed successfully with napier. The total sward DM yield during the establishment year of 11 400 kg/ha observed in this experiment was higher than those reported for similar napier grass-*D. intortum* mixtures in Kitale, Kenya by Thairu (1972) and Mbugua (1976). Grass yields were even greater than those reported in the Embu area of Kenya for pure stands of napier grass fertilised with 100 kg N/ha/yr (Mbugua 1976) and similar to those with 116 kg N/ha/yr in Kitale (Tiley 1989) confirming the high fertility of the soil at the Muguga site under investigation. The total forage yields of the napier mixtures with *D. intortum* and *M. axillare* were consistently higher than the 3.8 t/ha per cut reported by Anindo and Potter (1994) at the same site for pure napier grass with 40 kg N and 30 kg P/ha/yr. This suggests that the napier–legume mixtures have comparable DM productivity to a pure napier grass stand receiving at least 40 kg N/ha/yr.

Several workers have reported increased grass yield when napier grass was grown together with legumes. Mureithi *et al*. (1995) reported a 15% increase in napier grass DM yield when grown together with *Clitoria ternatea* in Kenya. Whitney and Green (1969) reported a substantial increase in napier grass DM yield when grown together with *D. intortum* or *Centrosema pubescens*. The higher yields are usually attributed to increased nitrogen supply to the grass through mineralisation of N from shed legume leaves, dead roots and decaying nodules which are of lower C:N ratio than grass residues (Whitney *et al*. 1967). Legumes also contribute to the sustainability of grasslands by adding fixed atmospheric N_2 to the system. Mwangi (1999) estimated inputs of 2–46 kg N fixed/ha/yr in these swards. The absence of a pure napier grass treatment excludes a direct comparison, but the napier grass yields can be compared with those reported in the area. *N. wightii* yielded little during the first year, so this treatment can be equated to a pure napier grass stand. Horrell (1958) reported a napier grass yield of 15 t DM/ha/yr with no N fertiliser during the establishment year, with a decline to 7 t/ha/yr during the second year. This yield is similar to the 14.9 t and 13.4 t/ha/yr from the napier grass mixtures with *N. wightii* and *M. axillare* between September 1996 and May 1997 in our study, but higher than the 9.6 t/ha/yr for the napier-*D. intortum* mixture. Although *N. wightii* yielded poorly during the establishment year, yields improved considerably during the second year. This slow establishment pattern of *N. wightii* supports findings by Bogdan (1966), who reported 0.2 t and 2.3 t/ha/yr in the first and second years, respectively, when the legume was grown together with *Panicum maximum*. Although the grass yield in the napier-*N. wightii* mixture was similar to that in the napier-*D. intortum* mixture and was comparable with napier yields reported in the area, total DM yield was lower for the *Neonotonia* mixture. Thus, the higher total forage DM yield in the mixtures reported in this study seems to be a function of DM contribution from the legume rather than a response to biologically fixed N by the grass.

The generally poorer napier grass yield when mixed with *D. intortum* than when mixed with *M. axillare* and *N. wightii* can probably be attributed mainly to competition for nutrients and water. The napier was taller than the legumes so competition for light could not have caused the lower grass DM yield in the grass mixture with *D. intortum.* On the other hand, from the performance of *D. intortum* in the mixture, it appears that this legume is relatively shade-tolerant as mentioned by Imrie *et al.* (1983).

D. intortum performed consistently well and has potential for use as a companion forage legume for napier grass in the central Kenya highlands and in other areas with similar ecology. Apart from the poor DM yield produced during the wet season, *M. axillare* also showed potential as a companion legume for napier grass. *N. wightii* consistently produced less than 500 kg/ha and therefore has little potential as a companion legume in this region.

Effect of harvesting frequency on DM yield and quality of napier grass and forage legumes in a mixed sward

The longer cutting interval resulted in higher DM yield but reduced quality, *e.g.* lower N concentration in napier grass, in agreement with earlier reports (Omaliko 1980; Woodward and Prine 1991). Woodward and Prine (1991) attributed the yield advantage associated with a longer inter-harvesting interval to the extended uninterrupted growth, which results in greater accumulation of DM through greater light interception by a canopy of greater leaf area. The longer interharvesting interval also allows for plant reserves to be replenished before the next defoliation. However, the longer cutting interval reduced legume DM yield in the mixtures by almost 60%, presumably due to shading.

Middleton (1982) reported similar changes in quality of fodder associated with increased cutting intervals, *i.e.*, decreased N concentrations and increased NDF and ADF with longer interharvest intervals. The decline in N concentration was relatively less in the legume than in the grass.

Tropical legumes have a higher crude protein concentration than tropical grasses (Antwi 1977; D'Mello and Devendra 1995) and also show a more gradual decline with plant age (Posler *et al*. 1993; Norton and Poppi 1995). Therefore, inclusion of legumes in a grass fodder system should result in feed with a higher crude protein concentration even when the interharvest intervals are long.

Effect of cutting height on grass and legume DM yield

There are conflicting reports on the response of tropical grasses to cutting height. Higher DM yield has been reported as cutting height increased (Watkins and Lewy-van Severen 1951; Middleton 1982) but the reverse has also been reported (Bryan and Sharpe 1965; Voorthuizen 1972; Middleton 1982). In general, cutting grass close to the ground removes more lateral buds, therefore slowing the recovery and growth of the plant. The lack of a significant effect of cutting height in this study might be attributed to the location of the growing points in napier grass. It seems that tillers in napier grass develop on the crown under ground, so cutting height does not affect tillering and regrowth. More importantly, in our context, reducing grass cutting height from the recommended cutting height of 10 cm above ground in the region to ground level did not promote legume recovery and performance in most cases (legumes were always cut at 10 cm height).

Effect of season on DM yield

Napier grass yield was low during the dry season and only the mixture with *N. wightii* reached a yield of 1 t/ha during this period. The grass yield was approximately 30% lower in the dry than the wet season. In contrast, *D. intortum* and *M. axillare* produced 4.2 and 2.2 t /ha DM, respectively, during the dry season. The legume DM yield in the wet season was about 12–30% of that during the dry season. Even during the wet season, when legume DM was lowest, *D. intortum* contributed 36–40% of the total sward DM yield. The decline in legume yield during the wet season, which was greater in *M. axillare* than in *D. intortum,* was probably due to the intense competition for plant nutrients by the grass and increased shading. In contrast, the better performance of the legumes in the dry season can be attributed to the reduced competition for plant nutrients by the poorly growing napier grass, as well as to the deep tap root system of the legumes (Mwangi 1999) and therefore increased ability to extract water from the deeper layers of the soil.

At the first wet season harvest, the mixture with *D. intortum* had a lower grass DM yield than the other 2 mixtures. This suggests that *D. intortum* was competing more effectively with napier grass for nutrients than the other 2 legumes. This effect of *D. intortum* on napier grass DM yield was not observed during the second wet season. Although growing together with *D. intortum* resulted in decreased napier grass DM yield, total DM yield was not reduced, as the legume DM yield compensated for the reduced grass yield. Although the grass DM yield was similar for the 3 mixtures during the dry season, the mixture with *N. wightii* had a significantly lower ($P < 0.001$) total forage DM yield, reflecting the large difference in yield of the 3 legumes during this period.

The high legume DM produced by *D. intortum* and *M. axillare* during the dry season would have a major effect on livestock performance during this period. In the region, the dry season is characterised by a severe shortage of forage and animals are mainly on poor quality crop residues, *e.g.* mainly maize stover, which is low in fermentable and metabolisable energy (Nicholson 1984; Little and Said 1987) as well as N (Abate 1990; Methu 1998). Supplementing the low quality cereal residues with legumes with a high N concentration would enhance the utilisation of these residues. Kariuki (1998) reported a higher weight gain in animals when napier grass was supplemented with *D. intortum*. Therefore, the substantial legume DM produced by *D. intortum* during the dry season would have a significant positive impact on liveweight performance and milk production of ruminants in the east African highlands.

Conclusion

Intercropping of napier grass with legumes resulted in sward DM yields comparable with those of moderately fertilised napier grass in the area. The high total sward DM yields of the mixtures were due to the contribution of legume DM to total yield and not due to higher grass yields. *D. intortum* was the most competitive of the legumes tested and reduced the yield of the associated napier grass. Importantly for animal production, *D. intortum* also produced a substantial amount of DM in the dry season. Shorter cutting intervals, *i.e.*, 8-weeks, are recommended to increase the contribution of legumes to the mixed sward. The study demonstrated that it is possible to intercrop napier grass with herbaceous legumes and highlighted the additional nutritional benefits of legumes particularly during the dry season.

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