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EVALUATION OF FORAGE LEGUMES IN THE SEMI-ARID REGION OF EASTERN KENYA. 2: PERSISTENCE AND DRY MATTER PRODUCTION OF SELECTED FORAGE LEGUMES

[EVALUACIÓN DE LEGUMINOSAS FORRAJERAS EN LA REGIÓN SEMI ARIDA DE KENYA. 2: PERSISTENCIA Y PRODUCCION DE MATERIA SECA DE LEGUMINOSAS FORRAJERAS SELECCIONADAS]

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SUMMARY

Twenty forage legumes consisting of 5 short lived annuals (SLA), 5 long lived annuals (LLA) and 10 perennials were evaluated for persistence and productivity at 4 sites; Katumani, Kiboko, Mua Hills and Ithookwe within the semi-arid tropics of eastern Kenya. The legumes were sown in plots of 4 m x 4 m and after emergence, they were monitored for population and repeatedly harvested for accumulated dry matter production for a period of 3 rainy seasons comprising about one and half years. There were significant (P<0.05) difference in numbers of plants and dry matter (DM) production between legumes within the same site. Major LLA, *Lablab purpureus* cv. Rongai and *Dolichos lablab* K1002, and SLA, *Vigna unguiculata* cvv. Red Caloona and M66 had highest plant numbers at establishment in all the sites. While the LLA showed a reduced plant numbers towards the end of experiment, the SLA failed to persist beyond the second rainy season. For the perennials, although plant numbers declined after establishment, they maintained a reasonable plant population at the end of the experimental period. There was poor survival of all legumes at Kiboko compared to the other sites and *Stylosanthes scabra* cv. Fitzroy and *Rhynchosia malacophylla* K18176 showed the best survival ability across all the sites. *Vigna unguiculata* M66 and *Lablab purpureus* cv. Rongai outyielded all other the legumes in harvest 1. While M66 recorded no yield in subsequent harvest, yield for Rongai increased substantially during harvest 2 at Mua Hills, remained fairly stable at Katumani but declined drastically at Kiboko and Ithookwe. In harvests 3 and 4 yield declined at all the sites for this legume The initial growth of perennials such *Stylosanthes scabra* cv. Fitzroy, *Neonotonia wightii* K75.2366, *Desmodium intortum* cv. Greenleaf and *Rhynchosia malacophylla* K18176 were slow and were more productive from the second harvest and maintained a reasonable dry matter yield even in competition with weeds. Generally DM production was considerably reduced at the drier site of Kiboko and majority of the legumes disappeared after second harvest. By harvest 4, only 4 legumes, all perennials remained productive but yield were less than 300 kg/ha. Plant population and DM production was greatly influenced by rainfall with the wetter site of Mua Hills having the more plants surviving and highest DM production. These legumes have potential for use in the various farming of the semi-arid of eastern Kenya and there is need to investigate further how they can be integrated.

Key words: Forage legumes, plant population, dry matter production, weeds

RESUMEN

Veinte leguminosas forrajeras (5 anuales de vida corta (SLA), 5 anuales de vida larga (LLA) y 10 perenes) fueron evaluadas para persistencia y productividad en 4 localidades Katumani, Kiboko, Mua Hills e Ithookwe en la región de los trópical semi arida de Kenya. Las leguminosas fueron sembradas en parcelas de 4 x 4 m y la población fue monitoreda y repetidamente cosechada para medir producción de materia seca acumulada en tres estaciones lluviosas comprendidas en un año y medio. Existió diferencias (P<0.05) en el número de plantas y la producción de materia seca (MS) entre leguminosas en un mismo sitio. Las LLA, *Lablab purpureus* cv. Rongai y *Dolichos lablab* K1002, y las SLA, *Vigna unguiculata* cvv. Red Caloona y M66 tuvieron la mayor cantidad de plantas al establecimiento en todos los sitios. Mientras que las LLA mostraron un número reducido de plantas hacia el final del experimento, las SLA no persistieron más alla de la segunda estación lluviosa. Las perenes aún cuando disminuyeron su número después del establecimiento, mantuvieron un población aceptable al final del experimento. Se registró una pobre sobrevivencia de todas las leguminosas en Kiboko comparado con los otros sitios y *Stylosanthes scabra* cv. Fitzroy y *Rhynchosia malacophylla* K18176 presentaron la mayor sobreviviencia en todos los sitios. *Vigna unguiculata* M66 y *Lablab purpureus* cv. Rongai tuvieron las mejores producciones de MS en la primera cosecha. Mientras que M66 no registró producción en las cosechas subsecuentes, Rongai incremento substancialmente durante la segunda cosecha en Mua Hills, permaneció relativamente estable en Katumani pero declinó drásticamente en Kiboko e Ithookwe. En las cosechas tres y cuatro la producción de esta leguminosa declinó en todos los sitios. El crecimiento inicial de las perenes *Stylosanthes scabra* cv. Fitzroy, *Neonotonia wightii* K75.2366, *Desmodium intortum* cv. Greenleaf y *Rhynchosia malacophylla* K18176 fue lento y fueron más productivos a partir de la segunda cosecha, manteniendo una producción razonable de MS aún en competencia con malezas.

En general la producción de MS fue reducida en el sitio más seco (Kiboko) y la mayoría de las leguminosas desapareció después de la segunda cosecha. Para la cuarta cosecha solo 4 leguminosas, todas perenes, permanecieron productivas pero con rendimientos menores a 300 kg/ha. La población y producción de MS fue mayor durante las lluvias en Mua Hills existiendo un mayor número de plantas sobrevivientes y una mayor producción de MS. Estas leguminosas tienen el potencial de ser empleadas en varios sistemas agrícolas de la región semi árida de Kenya pero existe la necesidad de investigar sobre los mejores sistemas de integración.

Palabras clave: Leguminosas forrajeras, densidad, producción de material seca, malezas.

INTRODUCTION

Poor nutrition caused by inadequate quantity and low quality of pastures available to animals is a major constraint to livestock productivity in the semi-arid Kenya. The low and erratic rainfall (500-800 mm/year) results to low productivity of pastures while the prolonged dry season and frequent drought results to cessation of growth of native pasture plants. In the eastern semi-arid region, farmers normally graze their livestock on natural pastures primarily grasses and crop residues mainly from cereals and grain legumes after the main harvest of the grain. Both the natural pastures and crop residues are of low nutritive value (Thairu and Tessema 1987) and do not meet the animal protein requirements. This results to limited animal productivity especially during the long dry season between June and September when major feed deficit occur (Muhammad 1993).

One approach to overcome lack of high quality pasture in this region is to introduce herbaceous forage legumes since they do not feature prominently in the existing grazing system (Njarui 1990). Forage legumes have been known to be highly nutritious (Tothill 1986; Dzowela 1986) and their inclusion is likely to contribute a significant amount of N in soil thus enhance soil fertility and sustain pasture productivity. Forage legumes can be used to provide pasture needed for livestock during the dry period, supplement poor quality natural pastures and rehabilitate denuded grazing land.

In an attempt to alleviate feed resource problem, a range of several forage legumes were evaluated within the semi-arid region of eastern Kenya from 1985-1988. Legumes with forage potential were identified as adapted to the climate and soil of the region (Njarui *et al*. 1996) on their basis to withstand environmental stress and maintain high herbage material even in the dry season. However the actual yields of these legumes was not investigated and there was therefore a need to look at the dry matter productivity and survival of these legumes in this region. The objective of this work was to evaluate the productivity and persistence of selected forage legumes in the semi-arid tropics of eastern Kenya.

MATERIALS AND METHODS

Sites

The study was conducted at 4 sites (Katumani, Kiboko, Ithookwe and Mua Hills) of different climatic conditions located in the semi-arid mid-altitude eastern Kenya. The sites descriptions are given in Table 1. The elevation ranges from 975-1650 m above sea level and mean annual rainfall of between 595-1179 mm. The rainfall is bimodal, the long rains occurs from March to May and the short rains are from October to December with peak in April and November respectively. There are two distinct dry seasons, the long dry season is from June to September and a short dry spell in January to February. The soils are generally low in nitrogen and phosphorus (Okalebo *et al.* 1992).

Experimental design and treatments

Twenty forage legumes consisting of 5 annuals, 5 long lived annuals and 10 perennials were selected for evaluation (Table 2) from 155 accessions. The selection was based on ability to attain good plant population and high visual bulk rating (Njarui *et al.* 1996). Sowing was carried out on 29 and 30 October 1986 at Kiboko and Ithookwe and 4 and 5 November, 1986 at, Katumani and Mua Hills respectively. For species where seeds was not adequate for planting at all sites, a combination of different ecotypes, denoted by different CPI numbers were used for the same species at a single planting but in different replication e.g. in *Clitoria ternatea*, CPI 48337, 47187 and 49963 were planted.

Establishment technique was the same for all the experiments. The hard-seeded accessions were gently mechanically scarified with sand paper or scalpel to break the seed coat in order to facilitate water uptake. The seed were inoculated with appropriate *Rhizobium* srains (Table 2) in Gum Arabica/distilled water solution. The grass and shrub vegetation was cut back and land ploughed and harrowed prior to planting. A small chisel plough attached to a 2 wheel Honda mini-tractor marked a 4 cm deep furrow along each planting row. The furrow were dusted with Aldrin 2.5%, at a rate of 20 kg/ha to prevent ants from taking the seed away. Prior to sowing the seeds, a sample was taken and tested for germination. The sowing rate for each legume (Table 2) was usually adjusted to give a similar number of potential seedlings using the results obtained from the germination test. The seeds were hand drilled in furrows and covered lightly with a thin layer of soil. Each legume accession was planted in 8 rows, each 4 m long at 0.5 m apart in plots of 4 m x 4 m, replicated 3 times in a randomised block design. A basal fertilizer was broadcasted evenly in the whole plots at rate equivalent to; 200, 41.7, 250, 15, 10, 10, 10 and 0.36 kg/ha of triple super phosphate, muriate of potash, dolomite, manganese sulphate, borax, zinc sulphate, copper sulphate and sodium molybdate respectively. Plots were weeded during the first two wet seasons while in the third wet season the legumes were left to compete with weeds.

Table 1. Description of location, elevation, temperature, rainfall and soils for the 4 experimental sites, Katuamni, Kiboko, Mua Hills and Ithookwe.

Site	Katumani	Kiboko	Mua Hills	Ithookwe
Latitude	1° 58'S	2° 28'S	1° 46'S	1° 37'S
Longitude	37° 28'E	37° 83'E	37° 28'E	38° 02'E
Altitude (masl)	1600	975	1650	1160
Mean temperature (°C)	19.6	25.7	19.0	22.5
Mean annual rainfall (mm)	717	595	1179	1080
Soil type	Chromic luvisol	Rhodic ferasol	Red sandy earth	Red sandy earth
Soil pH	6.5	5.8	7.0	5.8

Table 2. Legume species selected for evaluation and the sowing rate

Legume species	*Rhizobium* strains	Maturity type*	Sowing rate (kg/ha)
Centrosema pascuorum cv. Cavalcade, CPI 65970	CB1923	SLA	26.1
Macrotyloma africanum CPI 24972, 60207	CB756	SLA	6.1
Macrotyloma daltonii CPI 60303	CB756	SLA	16.2
Vigna unguiculata cv. Red Caloona	CB278	SLA	82.4
Vigna unguiculata cv. M66	CB756	SLA	82.4
Alysicarpus rugosus CPI 52351/30034	CB278	LLA	4.3
Chamaecrista rotundifolia cv. Wynn	CB1483	LLA	5.3
Dolichos lablab K 1002	CB1024	LLA	89.0
Lablab purpureus cv.Rongai	CB1024	LLA	95.0
Stylosanthes hamata cv. Verano	CB82	LLA	7.1
Centrosema virginianum CQ 2747	CB1923	P	26.1
Clitoria ternatea CPI 48337, 49963, 47817	CB930	P	43.8
Desmanthus virgatus CPI 40071	CB3058	P	9.8
Desmodium intortum cv. Greenleaf	CB627	P	7.8
Macroptilium atropurpureum cv Siratro	CB756	P	9.1
Neonotonia wightii K75.2366	CB1913	P	6.8
Rhynchosia malacophylla K18176	CB756	P	10.8
Stylosanthes fruticosa CPI 41219A	CB756	P	7.1
Stylosanthes guianensis cv. Cook	CB756	P	7.1
Stylosanthes scabra cv. Fitzroy	CB756	P	7.1

[†]Identification; CPI, Commonwealth (Australia) Plant Introduction; K, Kenya; CQ or Q, Queensland numbers.
[*]Maturity type; SLA, short-lived annual; LLA, long-lived annual; P, perennial

Measurements and harvesting procedures

Plant population counts were carried out after every 3 months for the 6 inner rows in each treatment, in the first and second wet seasons. Four harvests were carried out in each experiment, and the harvest date depended on the time of planting and the seasonal conditions. Harvesting was also timed for periods when there was a reasonable growth as this would correspond closely to farmers' usage. Thus the first harvest was carried out after the short rains (SR) 1986 in January or February 1987. The second harvest took place after the long rains (LR) 1987 in July or August 1987 while the third harvest was carried out after the long dry season either in September or October 1987. After the third harvest, all the legumes in the plots were cut back and left to compete with weeds. The fourth harvest was carried out after the end of third wet season, February or March 1988 in which both the legumes and weeds (non-planted legume) were harvested and separated. For each harvest, two randomised 1 m² quadrats were cut to a height of 5-10 cm from each plot for dry matter (DM) determination. Quadrats were randomised at different position in the plot at each harvest so that the sample reflected the DM accumulation for harvests 2 and 3 while harvest 4 was for regrowth. The fresh material was weighed, sub-samples taken where necessary, dried in oven at 105°C for 48 hours and dry weight taken.

Statistical treatment

Statistical analyses, was conducted on plant numbers recorded in two dates of observations (at the establishment period and prior to the third harvest). The first date (establishment period) was chosen because it is the stage the legumes are likely to have maximum plant numbers while the second date will show persistence. Analysis was also done for DM production for all accessions for each harvest from each site separately. Analysis of variance was conducted using Statistical Analysis Systems (SAS) general linear model (SAS, 1987) and means were separated by Least Significant Difference (LSD) (Steel and Torrie, 1981).

RESULTS

Rainfall

Rainfall data for Katumani, Kiboko and Ithookwe is shown in Table 3 for 4 seasons: long rains (LR) (March-May), short rains (SR) (October-December), short dry season (January-February) and long dry season (June-September) from the time the trials commenced. The rainfall for Mua Hill was not recorded. At Katumani the LR and SR were below the long-term average. The long term average rainfall for Kiboko and Ithookwe were not available. However, the respective SR and LR at Kiboko were less than those in Katumani but for Ithookwe the rainfall were higher than at Katumani.

Table 3. Rainfall at the experimental sites during the short dry season, long rains, long dry season and short rains

	Short dry season (Jan-Feb)	Long rains (Mar-May)	Long dry season (Jun-Sep)	Short rains (Oct-Dec)
Katumani				
1986	-	-	-	311
1987	38	119.4	77.1	105.8
1988	107.3	336.6	-	-
Long term average	119	249	18	343
Kiboko				
1986	-	-	-	176.7
1987	17	140	19.1	118.3
1988	50.6	289.8	-	-
Ithookwe				
1986	-	-	-	652
1987	11	200	31.2	272.2
1988	87	332	-	-

Katumani

Persistence

Plant establishment was good during the SR 1986 and there were no significance (P<0.05) difference on plant numbers between legumes (Table 4) in November 1996. Plant numbers ranged from 5.8 to 34.5 plants/m² with *Alysicarpus rugosus* CPI 52351 and *Stylosanthes fruticosa* CPI 55843 having the lowest numbers (5.8 and 6.6 plant/m^2 respectively), *Lablab purpureus* had the highest (34.5 plants/m²), and the rest had over 15 plants/m^2. However, plant numbers declined to less than 15 plants/m² for most legumes after the second wet season in September 1987 and significant difference occurred due to death of some plants especially the annuals. Both *Lablab purpureus* cv. Rongai and *M. africanum* 24972/60207 maintained the highest numbers (18.9 plants/m²). The major perennials, *R. malacophylla* K 18176 (13.3 plants/m²), *Neonotonia wightii* K75.2366 (14 plants/m²), *S. scabra* cv. Fitzroy (17.5 plants/m²) and *Desmanthus virgatus* CPI 40071 (15.1 plants/m²) also had a high plant stand.

Legume dry matter production

There were significant (P<0.05) difference on DM yield bewteen legumes (Table 4). *Lablab purpureus* cv. Rongai had the highest yield (3433 kg/ha) during the first harvest followed by *D. lablab* K 1002 (2616 kg/ha) and *V. unguiculata* M66 (2098 kg/ha). However M66 did not produce any DM thereafter while yield for *L. purpureus* cv. Rongai and *D. lablab* K1002 declined in the second and third harvest and to zero in the fourth harvest. The perennials, *S. scabra* cv. Fitzroy and *D. intortum* cv. Greenleaf had low DM at first harvest, but accumulated more herbage in second and third harvest. Yields for *S. guianensis* cv. Cook and *N. wightii* K 75.2366 were low in harvest 1, increased in harvest 2 but declined considerably in harvest 3. In the presence of weeds DM production was generally low for all legumes, with exception to *S. scabra* cv. Fitzroy that gave moderate yield (1327 kg/ha). Dry matter production for the annuals that survived was insignificant.

Weed dry matter production

There were significant difference (P<0.05) in DM with highest recorded in treatment where cv. Rongai (1026 kg/ha) and K1002 (1026 kg/ha) were grown. In other treatments, DM production was less than 1 t/ha.

Table 4. Plant population and accumulated dry matter yield of forage legumes during the weeded and unweeded period and yield of weeds at Katumani, eastern Kenya**.**

			Dry matter yield (kg/ha)				
			Weeded period			Un-weeded period	
			Harvests				
	Plant numbers/m^2		1	2	3	4	
	24/11 1986	26/09 1987	19/01 1987	30/07 1987	30/09 1987	03/03 1988	
Legume species[†]						Legumes	Weeds
Vigna unguiculata cv. Red Caloona	29.3	0.0	250	-[‡]	-	-	*[§]
Vigna unguiculata M66	28.5	0.0	2098	-	-	-	*
Macrotyloma africanum CPI 24972/60207	19.2	18.9	895	60	-	-	661
Macrotyloma daltonii CPI 60303	21.3	10.2	1471	242	63	-	556
Centrosema pascuorum CPI 65960	23.3	2.4	399	88	-	-	525
Alysicarpus rugosus CPI 30034/52351	5.8	1.5	20	7	-	-	783
Chamaecrista rotundifolia cv. Wynn	25.8	10.6	267	1278	510	35	564
Centrosema virginianum CQ 2748	23.2	14.9	130	1226	787	48	849
Lablab purpureus cv. Rongai	34.5	18.9	3433	3263	1738	-	1026
Dolichos lablab K 1002	23.2	9.1	2610	1296	780	-	1046
Stylosanthes hamata cv. Verano	18.3	8.9	103	1186	513	139	546
Clitoria ternatea CPI 47187/49963	15.7	7.5	112	327	290	77	716
Macroptilium atropurpureum cv. Siratro	16.5	8.7	211	1372	1168	662	282
Rhynchosia malacophylla K 18176	28.5	13.3	216	1497	907	210	440
Stylosanthes scabra cv. Fitzroy	27.7	17.5	117	2575	2252	1327	132
Stylosanthes fruticosa CPI 41219A	6.6	2.9	36	1139	552	227	684
Desmanthus virgatus CPI 40071	24.5	15.1	34	460	303	123	268
Neonotonia wightii K 75.2366	23.2	14.0	171	2663	977	308	684
Stylosanthes guianensis cv. Cook	15.3	3.2	29	2142	990	139	712
Desmodium intortum cv. Greenleaf	16.3	8.6	46	2472	2465	52	713
Mean	21.3	9.3	632	1316	953	278	621
LSD (P <0.05)	ns	4.3.	521	1071	822	319	316
SE	7.6	2.1	223	527	401	154	155

[†] CPI, Commonwealth (Australia) Plant Introduction; K, Kenya; Q or CQ, Queensland numbers.
[‡]Dashes indicate not sampled or legume was not present at the time of sampling.
[§]Stars indicate where plot was not sampled for weed

Kiboko

Persistence

Plant establishment was good for some legumes and poor for others (Table 5). At the end of first wet season (Jan 1987), the highest plant numbers were recorded in two SLA; *V. unguiculata* M66 (14.7 plants/m²) and Red Caloona (12.7 plants/m²); two LLA; cv Rongai and K1002 (13.5 and 12.9 plants/m² respectively). and one perennial, *R. malacophylla* K18176 (11.8 plants/m²). *Desmodium. Intortum* cv. Greenleaf failed to establish. At the end of long dry season, (Sept 1987), plant numbers decreased considerably for all legumes and only 11 survived. *Chamaecrista rotundifolia* cv. Wynn had the highest number of plants (4.1 plants/m²) surviving.

Table 5. Plant population and accumulated dry matter yield of forage legumes during the weeded and unweeded period and yield of weeds at Kiboko, eastern Kenya..

			Dry matter yield (kg/ha)				
			Weeded period			Un-weeded period	
			Harvest				
	Plant numbers /m^2		1	2	3	4	
	01/01 1987	04/09 1987	03/02 1987	13/08 1987	11/10 1987	04/02 1988	
Legume species[†]						Legumes	Weeds
Vigna unguiculata cv Red Caloona	12.7	0.0	1248	-[‡]	-	-	*[§]
Vigna unguiculata M66	14.7	0.0	2121	-	-	-	*
Macrotyloma africanum CPI 24972	5.1	0.0	98	-	-	-	*
Macrotyloma daltonii CPI 60303	10.3	0.0	641	5	-	-	*
Centrosema pascuorum cv. Cavalcade	5.3	0.0	82	-	-	-	*
Alysicarpus rugosus CPI 30034	6.4	0.0	16	7	-	-	*
Chamaecrista rotundifolia cv Wynn	7.8	4.1	97	210	142	-	244
Centrosema virginianum CQ 2748	5.6	0.1	18	0	-	-	*
Lablab purpureus cv Rongai	13.5	1.4	1498	483	127	-	196
Dolichos lablab K1002	12.9	0.7	1388	178	-	-	*
Stylosanthes hamata cv Verano	0.3	0.4	1	-	-	-	*
Clitoria ternatea CPI 47187	7.3	2.4	98	354	112	31	163
Macroptilium atropurpureum cv Siratro	4.4	0.5	91	68	33	-	*
Rhynchosia malacophylla K18176	11.8	3.7	46	257	270	265	141
Stylosanthes scabra cv Fitzroy	7.3	3.3	11	120	118	93	92
Stylosanthes fruticosa CPI 41219A	1.8	0.6	4	22	-	29	282
Desmanthus virgatus CPI 40071	4.0	0.1	1	-	-	-	*
Neonotonia wightii K75.2366	1.5	0.0	1	-	-	-	*
Stylosanthes guianensis cv Cook	0.1	0.0	-	-	-	-	*
Desmodium intortum cv Greenleaf	0.0	0.0	-	-	-	-	*
Mean	6.6	0.9	85	414	155	104	186
LSD (P <0.05)	3.7	2.0	596	271	n.s.	ns.	Ns
SE	1.9	1.0	293	130	81	85	82

[†] CPI, Commonwealth (Australia) Plant Introduction; K, Kenya; Q or CQ, Queensland numbers.
[‡]Dashes indicate not sampled or legume was not present at the time of sampling.
[§]Stars indicate where plot was not sampled for weed

Legume dry matter production

Yields were generally low and only significantly different in the first and second harvest (Table 5). *Vigna unguiculata* M66 was the most productive (2121 kg/ha) during harvest 1 but produced no yield thereafter. *Lablab purpureus* cv. Rongai (1498 kg/ha), *D. lablab* K 1002 (1388 kg/ha) and *Vigna unguiculata* cv Red Caloona followed but the DM yield declined considerably in subsequent harvests. The other legumes including, *Stylosanthes. hamata* cv. Verano, *D. virgatus* CPI 40071 and *N. wightii* K75.2366 had very low DM yield (<500 kg/ha) in first three harvests and most failed to produce any yields thereafter. By the harvest 4, only four legumes, all perennials remained productive but the DM yield were less than 300 kg/ha.

Weeds dry matter production

Just like the legumes DM yield for weeds was poor (less than 300 kg/ha) and yield were not significantly different.

Mua Hills

Persistence

Plant establishment was good for most of the legumes during the first wet season (Dec 1986) and only 3 legumes, *N. wightii* cv. Cooper, *S. guianansis* cv Cook and *S. fruticosa* CPI 41219A had less than 10 plants/m² (Table 6). *Vigna unguiculata* M66 (36.1 plants/m²) recorded the highest number of plants and cv. Cook (3.7 plants/m²) the lowest. Plant numbers decreased for all legumes at end of the dry season (Sept 1987) but the decrease was more in annuals than perennials. For example, *V. unguiculata* Red Caloona and M66 had 36.5 and 35.8 plants/m^2 in Dec 1986 but failed to re-establsih from seed following the LR 1987 and hence there were no plant in Sept 1987. The perennials, *S. scabra* cv Fitzroy and *R. malacophylla* K18176 had 22.3 and 17.3 plants/m^2 but decreased to 17.1 and 16.1 plants/m^2 respectively at end of dry season (Sept 1987).

Table 6. Plant population and accumulated dry matter yields of forage legumes during the weeded and unweeded period and yield of weeds at Mua Hills, eastern Kenya.

			Dry matter yield (kg/ha)				
			Weeded period			Un-weeded period	
			Harvest				
	Plant numbers /m^2		1	2	3	4	
	05/12 1986	16/09 1987	30/01 1987	20/08 1987	09/10 1987	02/03 1988	
Legume species[†]						Legumes	Weeds
Vigna unguiculata cv. Red Caloona	36.5	0.0	761	-[‡]	-	-	*[§]
Vigna unguiculata M66	35.8	0.0	2312	-	-	-	*
Macrotyloma africanum CPI 24972/60207	19.8	0.0	352	172	122	-	*
Macrotyloma daltonii CPI 60303	27.6	0.5	1344	232	125	-	902
Centrosema pascuorum cv. Cavalcade	15.3	0.4	209	247	270	-	815
Alysicarpus rugosus CPI 52351/30034	12.2	0.4	88	298	-	-	723
Chamaecrista rotundifolia cv. Wynn	17.4	5.2	41	748	422	71	543
Centrosema virginianum CQ 2748	13.7	7.3	84	2766	2237	186	474
Lablab purpureus cv. Rongai	31.0	18.7	2603	11010	6020	243	1162
Dolichos lablab K1002	23.3	8.0	1198	4016	2894	-	951
Stylosanthes hamata cv. Verano	10.0	5.6	65	2959	1718	299	447
Clitoria ternatea CPI 47817/49963	12.7	7.7	104	2312	1352	229	445
Macroptilium atropurpureum cv Siratro	24.5	7.4	195	4776	3934	1157	518
Rhynchosia malacophylla K18176	17.3	16.1	196	7077	7307	1851	60
Stylosanthes scabra cv. Fitzroy	22.3	17.1	59	6508	4568	1430	133
Stylosanthes fruticosa CPI 41219A	6.7	3.4	12	1265	2143	383	391
Desmanthus virgatus CPI 40071	19.3	9.7	18	3062	2472	1310	331
Neonotonia wightii K75.2366	7.9	7.8	107	7394	5768	2291	270
Stylosanthes guianensis cv Cook	3.7	1.2	14	2674	3733	250	270
Desmodium intortum cv. Greenleaf	16.8	4.1	27	4885	4048	438	361
Mean	18.7	6.0	489	3667	2890	780	517.
LSD (P <0.05)	9.4	3.0	472	1541	1923	621	292.
SE	4.7	1.5	233	758	944	303	143

[†] CPI, Commonwealth (Australia) Plant Introduction; K, Kenya; Q or CQ, Queensland numbers.
[‡]Dashes indicate not sampled or legume was not present at the time of sampling.
[§]Stars indicate where plot was not sampled for weed

Legume dry matter production

Dry matter accumulation varied significantly ($P < 0.05$) between legume in all the harvest (Table 6) and yield were generally high at the second and third harvest for most legumes. *Lablab purpureus* cv. Rongai had the highest DM accumulation in the first and second season (2603 and 11010 kg/ha). Although yield for this legume declined at harvest 3 to 6020 kg/ha, it was among the most productive legume. The other LLA, *D. lablab* K 1002 behaved in a similar manner but had a significantly ($P < 0.05$) lower yield. The short-lived annuals, *V. unguiculata* M66 and Red Caloona had DM yield only in the first wet season with M66 (2312 kg/ha) having higher yield ($P < 0.05$) than Red Caloona (761 kg/ha).

Majority of the perennials required at least two rainy seasons to attain peak DM accumulation (see Harvest 1 and 2). However, *S. guianensis* cv. Cook and *S. fruticosa* CPI 41219A required a longer period and accumulated more DM after the long dry season (Harvest 3). In the presence of weeds (Harvest 4) *N. wightii* K75.2366 and *R. malacophylla* K18176 were the most productive. All the short-lived annuals failed to persist during this period.

Weed dry matter production

Dry matter yields from weeds were significantly higher in treatments where Rongai, K1002 and *M. daltonii* 60303 were grown than in the other treatments and least in treatment with *R. Malacophylla* K18176.

Ithookwe

Persistence

Plant establishment during the first season at this site was excellent for major annuals and relatively good for most of the other legumes (Table 7). In January, 1987, *Vigna. unguiculata* M66 (40 plants/m²) and cv. Red Caloona (38.1 plants/m²) had the highest number of plants. Only 3 legumes, *C. pascuorum* cv. Cavalcade, *S. guianensis* cv. Cook and *S. fruticosa* CPI 41219A had less than 10 plants/m², the others legumes had a plant population in excess of 10 plants/m². At the end of dry season (Sept 1987), plant numbers declined to less than 10 plants/m² in all legumes except for cv. Fitzroy and *R. malacophylla* K18176 which had 13.1 and 12 plants/m² respectively. *Vigna unguiculata* cv. Red Caloona and M66, *M. daltonii* CPI 60303 and *M. africanum* CPI 24972 recorded no plants.

Legume dry matter production

Dry matter yields were generally high for the SLA and LLA and low to moderately high for the perennials (Table 7). *Vigna unguiculata* M66 significantly ($P<0.05$) accumulated the highest DM (8360 kg/ha) in harvest 1, but none thereafter. *Lablab purpureus* cv. Rongai (5040 kg/ha) and K 1002 (3173 kg/ha) followed but yields were reduced in harvests 2 and 3. Perennial legumes with reasonable yield during harvest 2 and 3 were *M. atropurpureum* cv. Siratro (1450 and 1974 kg/ha), *R. malacophylla* K 18176 (1299 and 1666 kg/ha) and *S. scabra* cv. Fitzroy (1808 and 1702 kg/ha). Yield of Siratro and *R. malacaphylla* K 18176 either declined slightly or remained stable while cv. Fitzroy and *Neonotonia wightii* K75.2366 showed increased DM production. DM production for other legumes remained consistently low and some of the short and long-lived annuals disappeared in presence of weeds. *Stylosanthes scabra* cv Fitzroy (2714 kg/ha) had the highest DM production in harvest 4.

Weeds dry matter production

There was dense growth of weeds and in all the plots harvested, the yield was over 1 t/ha except where *Neonotonia wightii* K75.2366 (890 kg/ha) was grown. Highest yield were recorded in plot where *Stylosanthes fruticosa* CPI 41219A (2832 kg/ha) followed in treatment with cv. Rongai (1619 kg/ha).

DISCUSSION

Persistence

The study showed variation in plant establishment between legumes. Plant establishment during the first wet season was generally good in all the sites and experiments and most legumes achieved over 15 plants/m² except at Kiboko (Table 5) where only 6 legumes attained over 10 plant/m². Low plant numbers at Kiboko was however attributed to the less rainfall at this site during the establishment period. *Desmodium intortum* cv. Greenleaf failed to establish while *S. guianensis* cv. Cook and *N. wightii* K75.2366 had a poor plant population (<2 plants/m²) and persisted poorly at Kiboko. The large seeded SLA, cvv M66, Red Caloona and LLA cvv. Rongai and K1002 had consistently higher plant numbers than most of the perennials at establishment period.

Plant survival after first season varied greatly between legumes and most annuals failed to persist beyond second wet season through germination and growth of young seedlings. There was poor survival of almost all legumes at Kiboko, with *C. rotundifolia* cv. Wynn, *R. malacophylla* K18176 and *S. scabra* cv Fitzroy being the only legumes that retained significant plant numbers (3 -5 plants/m^2) 10 months after planting, an indication that they can persist in dry regions. *Stylosathes scabra* cv Fitzroy has deep tap root which allow it to access sub-soil moisture (Njarui and Wandera (in press). *Stylosanthes scabra* cv. Fitzroy, *N. wightii* K75.2366, *R. malacophylla* K18176 and *D. virgatus* CPI 40071 maintained a high plant number at Katumani, Mua hills and Ithookwe through regeneration of original plants and can be regarded as suitable for use as permanent pastures. The large seeded annuals *L. purpureus* cv. Rongai and the *Vignas* showed poor capacity to regenerate from seed probably due the big size of seed which could not be covered easily by soil in order for germination to take place. Therefore these species would require fresh replanting at beginning of every wet season if they are used for pastures. *Camaecrista rotundifolia* cv. Wynn and *M. africanum* CPI 24972/60207 are small seeded and regenerated easily from seed. This clearly shows that these two legumes had good seedling recruitment which is important for the persistence of an annual and would be suitable to this region of low and short rainfall pattern.

Table 7. Plant population and accumulated dry matter yield of forage legumes during the weeded and un-weeded period and yield of weeds at Ithookwe, eastern Kenya.

			Dry matter yield (kg/ha)				
			Weeded period			Un-weeded period	
			Harvests				
	Plant numbers /m^2		1	2	3	4	
	06/01 1987	10/10 1987	01/01 1987	11/08 1987	28/09 1987	09/02 1988	
Legume species[†]						Legumes	Weeds
Vigna unguiculata cv. Red Caloona	38.1	0.0	2832	-	-	-	*§
Vigna unguiculata M66	40.0	0.0	8360	-‡	-	-	*
Macrotyloma africanum CPI 24972	19.6	0.0	294	70	-	-	*
Macrotyloma daltonii CPI 60303	16.4	0.4	2136	245	152	-‡	*
Centrosema pascuorum cv Cavacade/CPI 65950	8.7	0.2	476	628	168	-	*
Alysicarpus rugosus CPI 52351	12.4	2.2	61	158	87	-	*
Chamaecrista rotundifolia cv Wynn	11.5	7.9	71	352	327	212	1836
Centrosema virginianum CQ 2748	16.1	3.4	114	395	262	107	1890
Lablab purpureus cv. Rongai	26.1	3.6	5040	3952	4180	-	2619
Dolichos lablab K1002	21.5	1.6	3173	2276	2075	-	*
Stylosanthes hamata cv. Verano	11.8	8.4	121	383	553	1629	1661
Clitoria ternatea CPI 47187/49963	13.5	7.0	241	225	130	412	1715
Macroptilium atropurpureum cv. Siratro	11.4	6.1	387	1450	1974	1623	1281
Rhynchosia malacophylla K18176	14.3	12.0	144	1299	1666	1389	1263
Stylosanthes scabra cv Fitzroy	15.1	13.4	34	1808	1702	2714	1159
Stylosanthes fruticosa CPI 41219A	1.6	0.8	1	102	73	172	2832
Desmanthus virgatus CPI 40071	16.7	7.5	9	110	65	193	2030
Neonotonia wightii K75.2366	13.8	6.4	94	773	745	1275	890
Stylosanthes guianensis cv Cook	2.2	1.1	11	215	128	103	2179
Desmodium intortum cv Greenleaf	12.0	1.9	3	238	210	213	1880
Mean	16.1	4.2	1180	815	853	837	1787
LSD (P <0.05)	5.2	3.0	882	720	877	871	1009
SE	19.6	42.9	45	53	62	61	34

[†] CPI, Commonwealth (Australia) Plant Introduction; K, Kenya; Q or CQ, Queensland numbers.
[‡]Dashes indicate not sampled or legume was not present at the time of sampling.
[§]Stars indicate where plot was not sampled for weed

Dry matter production

There were differences in DM yields but the pattern of DM accumulation between legumes within the same maturity group (SLA, LLA and perennials) was similar. While the SLA needed one wet season to achieve their highest DM accumulation (Harvest 1), the LLA needed one or two wet season depending on the site. This is in agreement with the earlier screening work where the visual herbage accumulation had similar trend. However DM yield of both short and LLA declined after peak accumulation and by Harvest 3 and during the unweeded period (Harvest 4) no yield was recorded in most of these legumes. Reduced accumulated DM was due to senescence, leaf fall and death of the plant at maturity. While M66 was productive at first harvest cv. Rongai maintained a high yield even in second harvest across the set of environments. This shows that these legumes can provide large quantity of forage within a short period and can be used as forage for early season livestock feeding. *Vigna unguiculata* M66, *L. purpureus* cv. Rongai and K1002 are widely used by farmers in this region as dual-purpose legume where the grain is used as human food and the residues are fed to livestock after threshing.

Although slow to establish initially the perennials grew fast during the second wet season and achieved their highest DM at either second or third harvest. *Stylosanthes scabra* cv. Fitzroy and *R. malacophylla* K18176 and *N. wightii* K75.2366 were highly competitive with weeds and this is reflected in their high yield during the unweeded period especially at the wetter site of Mua Hills and Ithookwe. The fact that these legumes can withstand weed competition makes them suitable since the unweeded period represents the normal situation in a pasture.

The perennials were found to be productive in at least two of the four sites. *Stylosanthes. scabra* cv. Fitzroy produced reasonable DM in all sites except at the drier site of Kiboko where yield were reduced. Palatability of this legume usually increases with age and therefore it can be regarded as one of the most promising pasture in the semi-arid eastern Kenya. *Desmanthus virgatus* CPI 40071 performed well only at Mua Hills while *D. intortum* cv. Greenleaf was more productive at both Katumani and Mua Hills than at Ithookwe and failed at Kiboko. These legumes can be regarded to be among the best pastures for the cooler areas within the semi-arid eastern Kenya. *Desmanthus virgatus* CPI 40071 is native to semi-arid tropics of Brazil (Date 1991) (annual rainfall 500 mm) and its poor performance at Kiboko was unexpected. Young leaves of this legume (*D. virgatus* CPI 40071) were found to be preferred than Siratro by sheep (Gardiner and Burt 1995), hence can be useful livestock feed in this region. *Neonotonia. wightii* K75.2366 and *R. malacophylla* K18176 did well in three sites, Katumani, Mua Hills and Ithookwe and accumulated high DM and could be preserved as fodder banks for dry season feeding. These legumes are native to this region and the first author has recorded them growing naturally with the natural pastures. *Macroptilium atropurpureum* cv. Siratro is widely used for pasture in Australia and compared well with the other legumes evaluated here. Dry matter production of this legume was reasonably good in both Mua Hills and Ithookwe, extremely low at Kiboko and moderate at Katumani. *Camaecrista. rotundifolia* cv. Wynn had low DM in all sites except at Katumani where it recorded slightly over 1000 kg/ha and demonstrated poor competition with weeds despite being identified as having a high visual bulk rating (Njarui *et al*. 1996). Nevertheless cv. Wynn is one of the most promising species for pasture development in sub-humid Nigeria (Tarawali 1995) and has shown good potential in other parts of tropics. Patridge and Wright (1992) have reported that inclusion of this legume in native pasture resulted to better live weight gain in cattle than natural pasture alone in Australia. The performance of *S. fruticosa* CPI 41219A was not outstanding across the sites despite the fact that the species *S. fruticosa* is native and widespread in this regions. However more collection of this species should be carried out in the semi-arid region of Kenya and it should be given consideration for further evaluation.

Dry matter yield was influenced by rainfall more than plant population and this is clearly reflected in different site where some legumes have similar plant numbers but different DM production. Generally DM production at Mua Hills was highest for all the legumes, lowest at Kiboko and moderate at Katumani and Ithookwe. This can be attributed to the higher rainfall at Mua Hills. The rainfall at Mua Hills was not recorded but it is regarded as being more wetter and than other sites (Njarui *et al.* 1996). *Vigna unguiculata* cv. Red Caloona did better at Kiboko than at the coooler sites of Katumani and Mua Hills. Due to the higher temperature this legume responded by growing faster and reached maturity quickly than the other legumes. Lablab purpureus cv. Rongai recorded exceptionally high yield (11010 kg/ha) at Mua Hills.

CONCLUSIONS

A number of legumes were found to be persistent and productive and have potential as forage in the semi-arid region of eastern Kenya. *Stylosanthes scabra* cv. Fitzroy did well in term of seedling establishment, retained high DM during the long dry season and showed possibility to persist for several years in most of the sites. *Neonotonia wightii* K75.2366 and *D. intortum* cv. Greenleaf performed well at Katumani and Mua Hills while *D. virgatus* CPI 40071, *R. malacophylla* K18176 and *S. guianensis* cv. Cook were found to be productive at Mua Hills. Further evaluation is needed to determine their long term persistence in a natural pasture, their feeding value to livestock and ways they can be integrated in the local mixed crop-livestock farming system. One option is to grow them as fodder banks for livestock supplementation during the dry period, or grow in rotation with cereals to improve soil fertility. The other legumes need to be evaluated in a different environment to identify their suitable niche. The suitability of *V. unguiculata* cv. M66 as well as *L. purpureus* cv. Rongai and *D. lablab* K1002, as suitable legumes for use in this region is confirmed.

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