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EFFECT OF PLANTING PATTERN OF TWO HERBACEOUS FORAGE LEGUMES IN FODDER GRASSES ON PRODUCTIVITY OF GRASS/LEGUME MIXTURE IN SEMI-ARID TROPICAL KENYA.

[EFECTO DEL PATRÓN DE SIEMBRA DE DOS LEGUMINOSAS FORRAJERAS EN PASTOS FORRAJEROS SOBRE LA PRODUCTIVIDAD DE LA MEZCLA PASTOS/LEGUMINOSA EN LA REGIÓN SEMI-ÁRIDA TROPICAL DE KENYA]

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SUMMARY

An experiment was conducted to investigate the effect of planting pattern of legumes on the growth, persistence and productivity of grass/legume mixture in the semi-arid tropical Kenya. The legumes, Seca and Siratro were planted either as single or double rows between rows of Napier grass and giant panicum. Plant population, growth and productivity of the mixture were monitored for a period of 4 wet seasons; short rains (SR) 02, long rains (LR) 03, SR 03 and LR 04 and two dry seasons (DS) 03 and DS 04. There was significantly (P<0.05) more plants that survived from double rows of legumes (15 plants m^{-2}) than from single rows (10 plants m^{-2}). Legumes planted in double rows between grass rows covered more plot than when planted in single rows with Siratro covering more plot than Seca. However, legumes planted in double rows had no significant (P<0.05) dry matter (DM) yield advantage over single rows and did not benefit or impede growth (tiller and canopy cover) of the fodder grasses. The productivity of the associated fodder grasses was not affected and hence combined total DM yield (grasses + legumes) were not significantly different. Napier grass was more vigorous, had more tillers, large canopy and consequently was more productive than Panicum. On the basis of combined DM production, Napier grass/Seca was most productive while Napier intercropped with Siratro and Panicum intercropped with either Seca and Siratro showed similarity in DM. Seca was more productive than Siratro and overall the proportion of the legume to total DM was highest during the dry season than wet season. Dry matter was highest during the SR 02 and declined progressively with seasons and was lowest during the dry seasons.

Key words: Planting pattern, herbaceous forage legumes, fodder grasses, dry matter yield, semi-arid

RESUMEN

Se realizó un experimento para investigar el efecto del patrón de siembra de la leguminosa sobre el crecimiento, persistencia y productividad de la mezcla leguminosa/pasto en la región semi-árida tropical de Kenya. Las leguminosas Seca y Siratro fueron sembradas en hilera sencilla o doble entre hileras de pasto Napier y Panicum gigante. La población, el crecimiento y la productividad de la mezcla fue monitoreada por un período de 4 estaciones húmedas, lluvias cortas (SR) 02, lluvias largas (LR) 03, SR 03 y LR 04 y dos estaciones secas (DS) 03 and DS 04. Se encontró un mayor número de plantas (P<0.05) que sobrevivieron en la doble hilera de leguminosas (15 plantas m^{-2}) que en la hilera sencilla (10 plantas m^{-2}). Leguminosas sembradas en hilera doble tuvieron una mayor cobertura, siendo Siratro el de mayor cobertura. Sin embargo, las leguminosas en hilera doble no tuvieron un mayor rendimiento de materia seca (MS) (P<0.05) y no beneficiaron ni entorpecieron el crecimiento del pasto. La productividad del pasto asociado no fue afectada por lo que el rendimiento de MS combinado (pasto + leguminosa) fue diferente. El pasto Napier fue más vigoroso tuvo más hijuelos y cobertura y consecuentemente mayor productividad. La combinación Napier/Seca fue más productiva. Napier/Siratro and Panicum/Seca o Siratro tuvieron rendimientos similares. Seca fue más productivo que Siratro. En general se observo una mayor contribución de las leguminosas al rendimiento total de la mezcla durante las épocas de seca. La producción de MS fue mayor en SR 02 y declinó progresivamente con las estaciones obteniendose el menor rendimiento durante la época seca.

Palabras clave: Patrón de siembra, leguminosas forrajeras, pastos forrajeros, producción de materia seca.

INTRODUCTION

The semi-arid region of Eastern Kenya is characterised by low rainfall (500 - 800 mm annual rainfall) which adversely affect pasture productivity. In the hilly masses, where it is relatively wet, Napier grass [*Pennisetum purpureum* (K) Schum.] and giant Panicum (*Panicum maximum* Jacq.) are increasingly becoming important cultivated fodder grasses for dairy cattle. Intercropping of fodder grasses with legumes in eastern semi arid (Njarui and Wandera, 2000), Coastal (Mureithi *et al*., 1995) and central (Mwangi *et al.*, 2004) Kenya has shown to improve dry matter yield of mixture compared to sole grasses. Incorporation of a legume in grass mixture also resulted to improved nutritive value of associated grasses in Nigeria (Shehu and Akinola, 1995) and in Rwanda (Niang *et al*., 1998).

The procedure for establishing grass/legume mixture is very important because it greatly determine the productivity. Several studies on grass/legume mixtures indicates that pasture establishment success and productivity are influenced by agronomic variables such as sowing method, relative time of planting, the component of the mixture, spacing and density of the component species. Tropical grass/legume mixtures have been successful where management is tailored to allow legume to compete favourably with grasses (Hernandez *et al*., 1995). Legumes are generally more compatible with erect bunch grasses than stoloniferous grasses (Hare *et al*., 2004). Grass/legume pastures using tree legumes instead of herbaceous species successfully retained the legume (Mureithi *et al*., 1995; Tudsri and Kaewkunya, 2002). The major challenge is to maintain the legumes in a reasonable level without affecting the productivity of grass by reducing competition for water and nutrients.

Although productive grass/legume mixtures consisting of fodder grasses and legumes including Seca (*Stylosanthes scabra* cv. Seca) and Siratro (*Macroptilium atropurpureum* cv. Siratro) have been identified in the semi-arid region of eastern Kenya (Njarui and Wandera, 2000), the major problem of such intercrop was poor persistence of legumes in the mixture. Research work on grass/legume mixtures conducted elsewhere has also recognised difficulties in achieving long term persistence of legumes in grasses (e.g. Hare *et al*., 2004). Usually the plant numbers and proportion of legume to total DM yield decline considerably over time and grasses became dominant.

In grass/legume mixture, competition for nutrients, moisture and light between plant species is very important and has a direct influence on the productivity. Reduced direct sunlight can result to reduced photosynthesis and net assimilation rate. Available moisture for plant growth in the semi-arid region of Kenya is inadequate due to low rainfall and high evaporation rate experienced and this limits plant growth and productivity. Nitrogen deficiency is also widespread in semi-arid eastern Kenya (Okalebo *et al.*, 1992) and is considered as most important in limiting yield. To overcome this, and have a successful grass/legume mixture association, it is important to maintain a legume component at reasonably high level and ensure adequate supply of N to the system without reducing the grass yield to unacceptable level. Increasing legume seeding rate is likely to improve persistence of legume in mixture but this would create competition for limited soil moisture. The experiment was therefore conducted to assess the effect of planting patterns, single or double rows of Seca and Siratro between rows fodder grasses; Napier grass cv. Bana and giant Panicum K52-129 on growth, persistence and productivity in the semi-arid region of Eastern Kenya.

MATERIAL AND METHODS

Site

The experiment was conducted from April 2002 to September 2004 at Kenya Agricultural Research Institute (KARI), Katumani Research Centre, about 75 km SE of Nairobi city, Kenya (1^{o}58'S; 37^{o}28'E). Elevation is 1600 m above sea level and the mean temperature is 19.6^{o}C. The mean annual total rainfall is 717 mm, with a bimodal pattern, the long rains (LR) occurring from March - May and the short rains (SR) from October - December with peaks in April and November, respectively. Inter-seasonal rainfall variation is large with coefficient of variation ranging between 45 - 58 % (Keating *et al*., 1992). Rainfall is unlikely from June to September hence the occurrence of long dry season (DS). Evaporation rates are high and exceed the amount of rainfall in all the months except in November in which rainfall exceeds evaporation. The land on which the experiment was established had been under natural fallow for over 3 years. Analysis of the soil from the site indicated that it was sandy clay loam with pH of 5.9 (1:2.5 soil:water); organic matter 2.33% and soil nutrients (mg kg^{-1}) P 18.40; K 688.78; Ca 822.48; Mg 203.15; and N 0.23 (%).

Experimental designs, treatments and procedures

Two legumes, Seca and Siratro were planted as single and double rows between Napier grass and giant Panicum to give 8 treatments. The treatments are summarised below:

i. Single rows of Seca between Napier grass rows
ii. Double rows of Seca between Napier grass rows
iii. Single rows of Siratro between Napier grass

rows

iv. Double rows of Siratro between Napier grass rows
v. Single rows of Seca between Panicum rows
vi. Double rows of Seca between Panicum rows
vii. Single rows of Siratro between Panicum rows
viii. Double rows of Siratro between Panicum rows

The design was randomised complete block with 3 replications in a split-split plot arrangement with the main plot being the fodder grasses, subplot the legumes and the sub-subplot the planting pattern. The sizes of the sub-subplots were 7 m x 7 m with 1 m between plots and 1.5 m between replications. Roots splits of both grasses were planted at a spacing of 1 m between and within rows in April 2002, giving 7 rows each consisting of 7 stools and overall population equivalent to 10,000 stools ha^{-1}. The single rows of legumes were drilled in the middle of the grass rows (50 cm from the rows of grasses) while in the double rows treatments, the legumes were sown at 30 cm apart and 35 cm from the rows of grasses. The Panicum splits that failed to take off were re-gapped during the SR 02 in October 2002.

The seeds of Seca and Siratro are generally hard-seeded and were gently mechanically scarified by rubbing them between two sand papers to break the seed coat in order to facilitate water uptake. The grass and shrub vegetation was cut back, land ploughed and harrowed twice to obtain a fine seedbed prior to planting using a tractor. The seeds of Seca and Siratro were drilled in furrows of about 2 cm deep and covered lightly with a thin layer of soil. Half of the recommended seed rate (Njarui *et al.,* 1996) of 3.5 and 4.5 kg ha^{-1} for Seca and Siratro respectively were used. The legumes were not inoculated with *Rhizobium* spp. at sowing, because they had shown to nodulate adequately with native *rhizobia* in the soil (Mureithi *et al*., 2003). Triple super phosphate fertilizer was applied to the legumes at a rate of 20 kg P ha^{-1} as it is a prerequisite for N fixation in the planting furrows and thereafter at the on-set of LR 03 and LR 04. The experiment was kept weed free throughout by hand weeding.

Data collection

The first rainy season (LR 02) and first dry season (DS 02) were regarded as establishment phase and the subsequent seasons up to DS 04 as the production phase. Thus establishment phase was the 20 weeks following legume seedling emergence/formation of first leaf for fodder grasses. The data recorded for the legumes were; number of plant m^{-2}, height, spread and percent plot covers at 4 weeks interval. For the fodder grasses measurements included, number of tillers per stool and percent canopy cover and were carried out at the time of legume measurement. Measurements were carried out in a pre-determined position in each plot. Plant counts for legumes were monitored within a fixed quadrat of 2 m x 2 m placed over 2 and 4 central rows for legumes planted in single and double rows, respectively. For the tiller numbers in grasses, the middle 6 stools were counted. The percent canopy cover of grasses and plot cover for legumes were determined by method of Sarrantonio (1991) and involved use of a sisal twine of 5 m long, marked in several dots at every 15 cm with a red felt pen. The string was then stretched in opposite diagonals (twice) across the plots and the number of dots that lied over or under the plant parts were counted. The percent cover of each plant species was calculated using the equation below:

$$\frac{\text{Total dots over or under plant species (first diagonal + second diagonal)}}{\text{Total possible dots in plot (first diagonal + second diagonal)}} \times 100 = \%\ \text{cover}$$

For legume spread, the diameter was measured from one edge to the other of the plants. The height was measured from the ground to the tips of plants excluding the inflorescence or flower buds. Four plants within the measurement frame were selected randomly and tagged for the measurement of height and spread and the average taken. Prior to start of the second wet season (SR 02); both grasses and legumes were harvested for dry matter (DM) yield determination (standardization cut) in October, 2002. Thereafter, they were harvested after every 8 weeks (twice per season) for a period of 4 wet seasons (SR 02, LR 03, SR 03 and LR 04) and 2 dry seasons (DS 03 and DS 04) (Table 1). In total 12 harvests were carried out although it had been anticipated that a total of 13 harvests would be realised. The last harvest (Harvest 13) was not carried because both the grasses and legumes failed to achieve much growth due to prolonged drought and were below the cutting height. Napier grass and Panicum were cut at 30 cm while Seca which has erect to semi-erect growth habit was cut at 5 - 10 cm and Siratro with its prostrate growth was cut at 10 - 15 cm above ground level using hand sickles.

Sampling for DM yield was taken from a net area of 3 m x 3 m. Nine stools of the fodder grasses in the middle rows were harvested per plot. For the single rows of legumes, three, 3 m rows of legumes were harvested but where double rows of legumes were planted between grasses, six, 3 m rows of legumes were harvested per plot. At each harvest, the herbage was separated into grass and legume components. After each sampling, the guard rows were cut to appropriate height according to the plant species and the forage removed from the plots. The fresh herbage was weighed using a spring balance of 25 kg with 0.25 kg sub-division and sub-samples taken where necessary. The sub-samples were cut into small pieces using hand sickles, put in paper bags, dried at 105°C for 48 hours in oven and dry weight taken.

Table 1. Number and date of harvests at the end of establishment and during the production phase.

Harvest	Date of harvest†	Seasons‡	Phases
Harvest 1 standardization cut	2/10/2002	LR 02/ DS 02	Establishment phase
Harvest 2	19/12/2002	SR 02	Production phase
Harvest 3	13/2/2003		
Harvest 4	9/4/2003	LR 03	
Harvest 5	4/6/2003		
Harvest 6	22/7/2003	DS 03	
Harvest 7	24/9/2003		
Harvest 8	21/11/2003	SR 03	
Harvest 9	17/1/2004		
Harvest 10	16/3/2004	LR 04	
Harvest 11	12/5/2004		
Harvest 12	3/7/2004	DS 04	
Harvest 13*	28/8/2004		

*Harvest 13 was not carried out because there was little re-growth of plant due to prolonged drought

†Plant numbers, height, spread, cover and tiller numbers were also measured at the time of harvest

‡LR = Long rains; SR = Short rains; DS = Dry season

Statistical analysis

Data on plant population, height, spread, cover, tiller numbers and DM yield were statistically evaluated by analysis of variance using Statistical Analysis Systems (SAS) general linear model (SAS, 1987) and mean separated by Least Significant Difference (LSD) (Steel and Torrie, 1981). During the production phase, all the plant measurements except the DM yield were averaged across season before analysis. For DM production, the combined total yield from 2 harvests in each season was used (Table 1). Data on total DM yield (grass + legumes) and DM yield of grasses and legume component were analysed separately by season.

RESULTS

Climatic data

The monthly rainfall and mean temperature during the experimental period together with the long term average are shown in Figure 1. The rainfall for LR 02 (April and May) was reasonably high (247 mm) compared to long term average of 3 months which is usually around 250 mm. The SR 02 (346 mm) was around the long term average with the month of December experiencing highest rainfall (180 mm). During the LR 03 season, rainfall (402 mm) was above the long term average. In SR 03, total rainfall (176 mm) was far below the long term average while the LR 04 (264 mm) were around the long term average but in both seasons the distribution was poor and not favourable for fodder grasses and legumes growth. The temperatures in almost all the months were similar to long term average with March ($21^{o}C$) and July ($17^{o}C$) being the warmest and coolest, respectively.

Legume establishment and persistence

The effect of planting pattern

At the end of establishment phase (LR 02/DS 02), mean plant numbers in both planting patterns (single and double rows) were the same; around 20 plants m^{-2} (Figure 2). From LR 03, significant difference ($P<0.05$) was apparent and the mean plant numbers in double rows were more than in single rows. However, the trend in plant changes was similar in both planting pattern and declined to 13 and 16 plants m^{-2} in LR 03 for single and double rows, respectively. The numbers remained relatively stable until SR 03 after which they increased slightly to 12 and 19 plants m^{-2} for single and double rows, respectively in LR 04 before declining again in DS 04 to 10 and 15 plants m^{-2}, respectively.

The effect of legumes

Changes in plant numbers for Seca and Siratro when intercropped with fodder grasses is shown in Figure 3. Seca maintained significantly ($P<0.05$) more plants than Siratro in all the seasons. At the end of establishment phase, plant numbers averaged 15.5 and 26 plants m^{-2} for Siratro and Seca, respectively. During the production phase, plant numbers for Seca declined to 18 plants m^{-2} in LR 03 and then remained stable until SR 03 where they increased slightly to 21 plants m^{-2} in LR 04 before declining again to 17 plants m^{-2} in DS 04. For Siratro, plant numbers declined progressively with season to 8 plants m^{-2} in DS 04.

Legume growth

The effect of planting pattern on growth of Seca and Siratro (spread and height) was negligible and not significant. Nevertheless they differed in height with Seca being consistently taller than Siratro in all seasons (10 - 34 cm between seasons) and both species were tallest in SR 02 and shortest in DS 04 (Table 2). For Siratro, height difference between seasons was relatively small (5 - 11 cm). There was a significant grass x legume interaction on plant spread. Siratro grown with Panicum spread more ($P < 0.05$) than Siratro intercropped with Napier grass and Seca intercropped with either of the grass in all the seasons (Table 3). The difference in spread between Siratro grown with Napier grass and Seca intercropped with Napier grass and Panicum was not consistent in all the seasons but Siratro tended to spread more than Seca in both grasses.

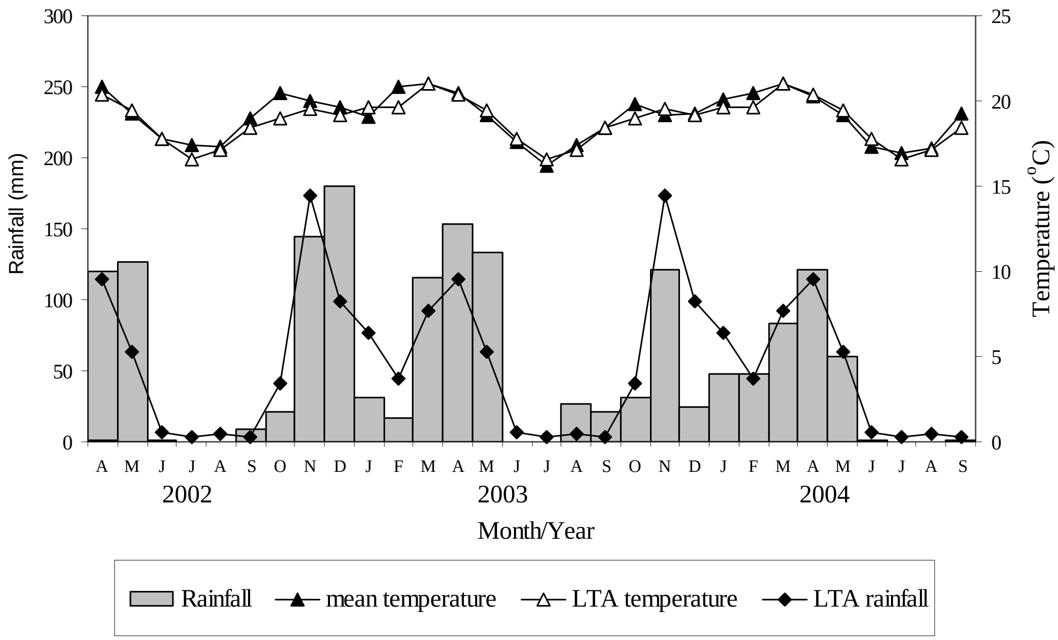

Figure 1. Total monthly rainfall and mean temperature during the experimental period, April 2002 to September 2004 at Katumani. The long term average (LTA) rainfall and temperature have been superimposed. (Source: Kenya Meteorological Department, Machakos Station).

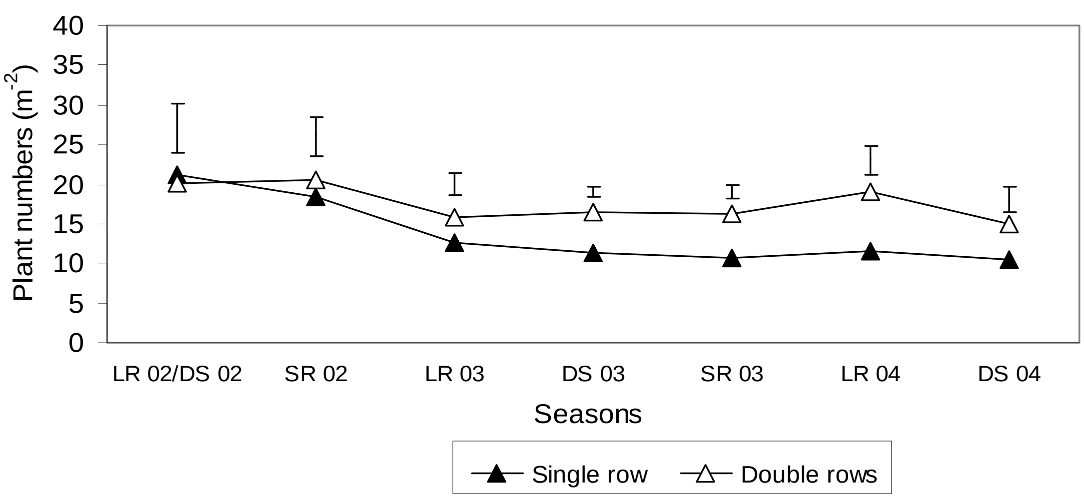

Figure 2. Effects of planting pattern on mean plant population changes of legumes over time when intercropped with fodder grasses. Mean plant numbers are average of Seca and Siratro. Bars represent the LSD, P<0.05.

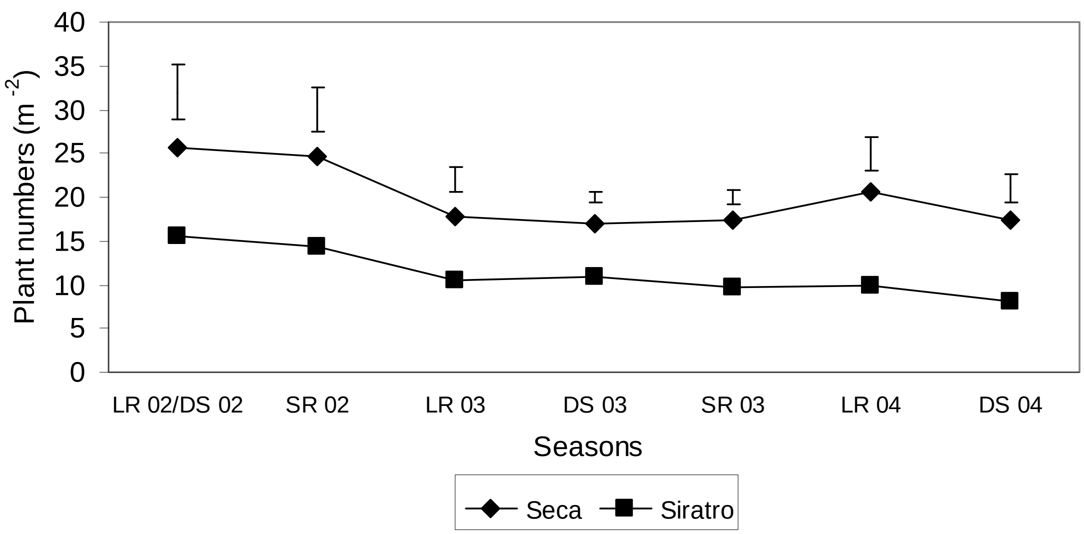

Figure 3. Mean plant population changes of Seca and Siratro over time when intercropped with fodder grasses. Mean plant numbers are averaged across planting pattern (single and double rows). Bars represent the LSD, P<0.05.

Table 2. Mean plant height changes of Seca and Siratro when intercropped with grasses following planting in April 2002.

Legumes	LR 02/DS 02	SR 02	LR 03	DS 03	SR 03	LR 04	DS 04
	Height (cm)						
Seca	32.7	34.3	28.6	14.5	14.4	30.5	9.9
Siratro	8.0	11.0	8.3	5.1	6.8	7.9	4.7
LSD (P<0.05)	2.1	1.9	1.3	1.3	1.1	1.7	0.9
CV (%)	12.0	9.4	8.2	15.0	12.3	10.2	14.3

Table 3. Effects of grass and legume on plant spread of Seca and Siratro when intercropped with Napier grass and Panicum following planting in April 2002.

Treatments	LR 02/DS 02	SR 02	LR 03	DS 03	SR 03	LR 04	DS 04
	Spread (cm)						
Napier /Seca	25.1	33.5	32.9	23.5	19.2	29.9	17.8
Napier /Siratro	-*	39.3	40.1	20.8	26.6	36.7	17.9
Panicum/Seca	45.0	48.6	39.2	23.7	19.9	25.8	16.6
Panicum/Siratro	-	66.2	53.3	31.2	42.9	60.2	26.5
LSD (P<0.05)	-	7.2	5.1	3.8	6.3	6.8	5.1
CV (%)	-	12.4	9.9	12.3	18.8	14.5	20.8

* Spread for Siratro was not measured because growth was not linear and the runners in some instance grew back towards the crown.

There were significant two - factors interactions between legume and planting pattern and between grass and legume on plot cover of legumes. The legume x planting pattern interaction on legume plot cover was significant in all the seasons except during SR 02 (Figure 4). Siratro planted in double rows had the highest cover followed by Seca planted in double rows while Siratro planted in single rows had the lowest plot cover. At the end of establishment phase (LR 02/DS 02), Siratro planted in double rows only significantly covered more plot than Seca planted in single rows. It also covered more (P<0.05) plot than all the other treatments in LR 03 and SR 03 but in LR 04 and DS 04 it was not significantly higher than Seca planted in double rows but was higher (P<0.05) than the other treatments.

Napier grass depressed growth of legumes and consequently plot cover was generally low when legumes were intercropped with Napier grass than with Panicum in most seasons (Figure 5). At the end of establishment phase and LR 03, Siratro intercropped with Panicum covered more (P<0.05) plot than the other treatments. In SR 02 and DS 03 although plot cover for Seca and Siratro intercropped with Panicum were not significantly different they were higher than when intercropped with Napier grass. In SR 03 and LR 04 Siratro intercropped with Napier grass covered lowest plot but when intercropped with Panicum it had the highest cover. Difference in plot cover between legumes during DS 04 was not significant.

Growth of grasses

The number of stools of Panicum that established was low in all treatments and averaged 47.8%, compared with 99% for the Napier grass. However after re-gapping in SR 02, all the stools established and grew well. Neither the interactions nor the main effects of legume and planting pattern had significant influence on the number of tillers and canopy cover of the fodder grasses. Treatments with single rows of legume, although marginally, tended to favour more tillers development in both fodder grasses in most seasons and consequently higher canopy cover but were not significant and therefore data is not presented. Overall mean tiller numbers of grasses when intercropped with legumes in single rows ranged between 14 - 68 while those in double rows was between 11 - 69. The canopy cover of the grasses was 29 - 55% and 22 - 50% when intercropped with legumes as single and double rows, respectively.

Napier grass produced more tillers (P<0.05) and consequently had a higher canopy cover than Panicum in all the seasons (Figure 6). Tiller numbers increased from end of establishment phase and were highest in LR 03; 84 and 43 for Napier grass and Panicum, then declined gradually across seasons and were lowest in DS 04; 3 and 1.7, respectively. Canopy cover for Panicum was low in all seasons and ranged between 13 - 38% compared with 37 - 64% for Napier grass (Figure 7).

Total dry matter production

Two factors interactions between legumes and planting pattern were not significant for DM yields. However, combined total DM yield (grasses + legumes) were marginally higher in plots where the legumes were planted in single rows than double rows in most seasons but not significantly different (data not presented). The mean yield of grasses was marginally higher where the legumes were sown in single rows than in double rows and that legumes planted in double rows out yielded those in single rows but not significantly different.

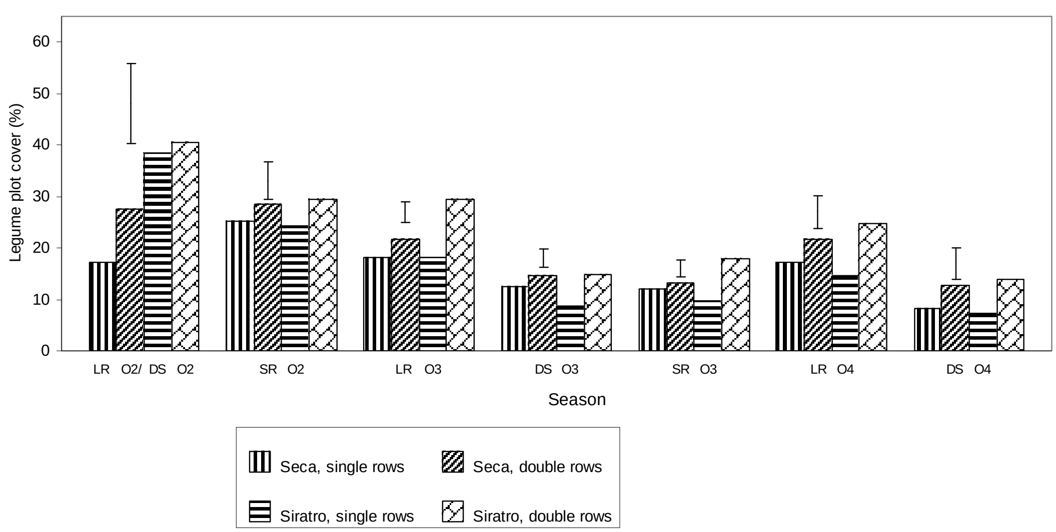

Figure 4. Effects of legumes and planting pattern on plot cover changes of Seca and Siratro over time. Bars represent the LSD, P<0.05.

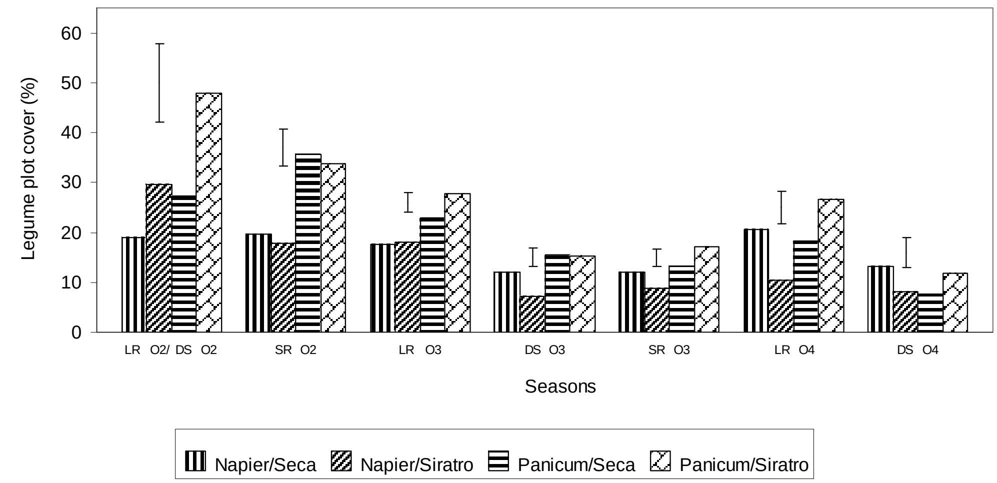

Figure 5. Effects of fodder grasses and legumes on plot cover changes of Seca and Siratro over time. Bars represent the LSD, P<0.05.

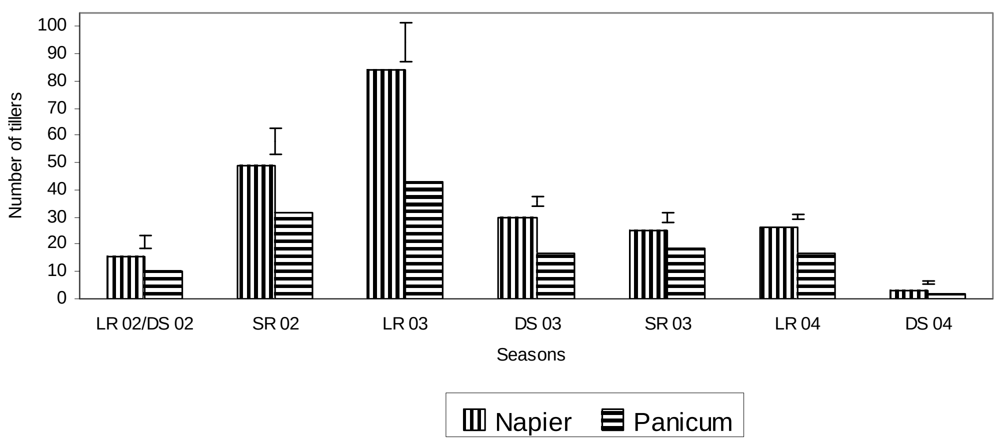

Figure 6. Mean number of tillers of Napier grass and Panicum over time when intercropped with the legumes. Bars represent the LSD, P<0.05.

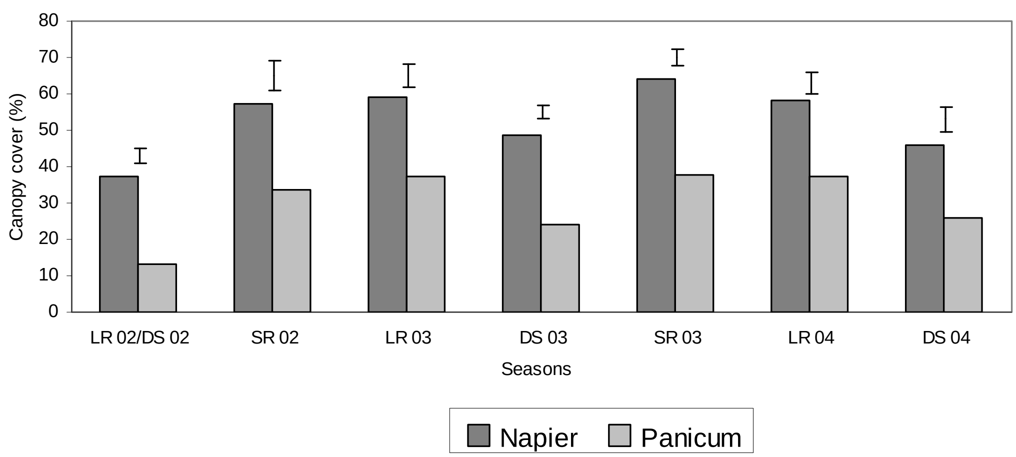

Figure 7. Mean canopy cover of Napier grass and Panicum over time when intercropped with the legumes. Bars represent the LSD, P<0.05.

There was a significant interaction between grass x legumes on DM yield and is shown in Table 4. At the end of establishment phase (LR 02/DS 02), combined total DM yield (grasses + legumes) was significantly higher in Napier grass/Seca intercrop (2223 kg ha^{-1}) than in the other treatments. During the production phase, the Napier grass/Seca intercrop remained more productive in all the seasons except in SR 02 season where the Panicum/Seca intercrop produced the highest yield (4930 kg ha^{-1}). Difference in total DM yield between Napier grass/Siratro, Panicum/Seca and Panicum/Siratro intercrops varied from season to season. For example, in LR 03 and DS 03 the yield difference were not significant, but in SR 03 the Napier grass/Siratro intercrop (1343 kg ha^{-1}) out yielded Panicum/Siratro (961 kg ha^{-1}) intercrop and Panicum/Seca (970 kg ha^{-1}) while in LR 04 the yield of Panicum/Seca (1611 kg ha^{-1}) was higher than Napier grass/Siratro (1371 kg ha^{-1}) and Panicum/Siratro (1278 kg ha^{-1}).

Napier grass had higher DM yield than Panicum in all the seasons except in SR 02 where the yield of Panicum was higher. Yield of Napier grass was highest when intercropped with Seca than Siratro but was not significant in all seasons. For Panicum, none of the legume had a significant effect on yield of Panicum than the other. Seca had a fairly stable yield when intercropped with both grasses and was more productive than Siratro in most of the seasons. Siratro was relatively more productive when intercropped with Panicum than with Napier grass. During the production phase, the highest yield for both legumes were realised during the SR 02 when they were grown with Panicum. During the season, the yields were 1608 and 598 kg ha^{-1} for Seca and Siratro and accounted for 33 and 16% of total DM yield of intercrop, respectively. Nevertheless, both legumes contributed the highest proportion to total DM yield in DS 03 although the actual yield was lower than in SR 02. In the Panicum intercrop, Seca accounted for 53% (436 kg ha^{-1}) compared to 34% (234 kg ha^{-1}) for Siratro while in Napier grass they contributed 37% (420 kg ha^{-1}) and 12% (89 kg ha^{-1}) of total yield, respectively.

DISCUSSION

Comparison of the results obtained from this study with other planting patterns reported in literature is limited because most past studies investigated on management of legumes/grasses intercrops as opposed to different planting pattern of legumes in grass intercrops as a way of maintaining and/or improving the legumes in the mixture.

Legume persistence and growth

None of the planting pattern produced more seedlings than the other at the end of first season (establishment phase). This is not surprising since the same seed rates were used at planting in both double and single rows of the legumes. However, during the production phase, legumes planted in double rows between grasses maintained higher plant numbers than in single rows indicating that double rows may give superior legume persistence in fodder grasses. This can be attributed to more space available for growth and less competition for nutrients. Establishment for Siratro (15 plants m^{-2}) was satisfactory and good for Seca (25 plants m^{-2}). Seca maintained more plant population throughout the experimental period and this may have been due to their ability to compete for growth resources. Increased plant numbers during LR 04 for Seca was due to volunteer seedlings that emerged after the rains.

Plant height was least affected by the treatments, with Seca being taller than Siratro primarily due to difference in growth habit which is genetically controlled. Siratro has a prostrate with low growth habit while Seca is semi-erect to erect (Njarui and Wandera, 2004). Spread for Siratro was greatly superior when grown with Panicum than when grown with Napier grass (Table 2) and consequently resulted to higher plot cover than the other treatments (Figure 5). Seca also showed a higher plot cover when grown with Panicum than with Napier grass; an indication that Panicum is less competitive than Napier grass. When both legumes were planted in double rows, they tended to spread in most areas than when planted in single rows and although not significantly different, the plot cover was significantly higher ($P<0.05$) in double rows of legumes than in single rows. The agronomic important is that high ground cover minimise weed invasion. This factor was not investigated in this work but is likely to be similar with other studies which showed reduced weed population where legumes were intercropped with grasses e.g. Ezenwa and Aken'ova (1998) and NARCM (2002).

Growth of fodder grasses

The planting pattern and legumes had little effect on establishment and growth of both Napier grass and Panicum. However, during this period, both legumes were small and had not developed elaborate roots to compete for either nutrients or water with the grasses. The double rows of legumes did not benefit or impede growth (tiller and canopy cover development) of the associated grasses.

Table 4. Effects of legume species on dry matter yield of grasses, legumes and total dry matter yield.

Seasons	Treatments	Dry matter yield (kg ha^{-1})		
		Grass	Legume	Total
LR 02/DS 02	Napier grass/Seca	1997	226	2223
	Napier grass/Siratro	1080	491	1571
	Panicum/Seca	364	734	1098
	Panicum/Siratro	368	764	1132
	LSD (P<0.05)	525	205	462
	CV (%)	44.5	29.8	24.8
SR 02	Napier grass/Seca	2597	592	3189
	Napier grass/Siratro	2464	281	2745
	Panicum/Seca	3322	1608	4930
	Panicum/Siratro	3086	598	3684
	LSD (P<0.05)	533	262	374
	CV (%)	14.6	26.5	8.1
LR 03	Napier grass/Seca	3029	651	3680
	Napier grass/Siratro	2525	217	2742
	Panicum/Seca	1901	996	2897
	Panicum/Siratro	2182	424	2606
	LSD (P<0.05)	630	113	584
	CV (%)	21.1	16.7	15.8
DS 03	Napier grass/Seca	714	420	1134
	Napier grass/Siratro	638	89	727
	Panicum/Seca	381	436	817
	Panicum/Siratro	458	236	694
	LSD (P<0.05)	130	80	163
	CV (%)	19.2	21.8	15.6
SR 03	Napier grass/Seca	1626	289	1915
	Napier grass/Siratro	1249	94	1343
	Panicum/Seca	690	280	970
	Panicum/Siratro	721	240	961
	LSD (P<0.05)	212	44	194
	CV (%)	16.0	18.1	12.0
LR 04	Napier grass/Seca	1728	791	2519
	Napier grass/Siratro	1202	169	1371
	Panicum/Seca	994	617	1611
	Panicum/Siratro	985	293	1278
	LSD (P<0.05)	234	111	236
	CV (%)	15.4	19.1	11.2
DS 04	Napier grass/Seca	136	0	136
	Napier grass/Siratro	103	0	103
	Panicum/Seca	63	0	63
	Panicum/Siratro	55	0	55
	LSD (P<0.05)	39	-	39
	CV (%)	35.4	-	35.4

On average stool establishment during LR 02 was low for Panicum and good for Napier grass. This was due to relatively short period of rainfall followed by a long period (4 months) of dry season (Figure 1). Between June and September only 10 mm of rainfall was recorded and the plants depended on residual moisture for growth. The stem of Napier grass is thicker and is likely to store more carbohydrate reserves for growth than that of Panicum and consequently survive better under reduced moisture than Panicum.

Napier grass was superior in growth than Panicum and this can be attributed to difference in vigour during re-growth after cutting. Tiller numbers for both grasses were highest in LR 03, remained the same in DS 03, SR 03 and LR 04 and declined sharply in DS 04 (Figure 6). The lower tiller recorded in DS 04 was due to low rainfall which resulted to unavailability of adequate water in the soil hence increasing root competition for this resource. Overall the canopy cover for each grass remained relatively the same with little variation between the wet seasons although Napier grass had significantly higher cover (Figure 7). Although tiller numbers were reduced in DS 04, though not measured it was observed the leaves were larger and broader hence little variation in canopy cover. The difference in canopy cover between Napier grass and Panicum can also be attributed to morphological characteristics. Napier grass has broad leaves and therefore has a large surface which resulted to development of a larger canopy compared to Panicum which has narrow leaves.

Dry matter yield of grasses and legumes

In both planting pattern, the grasses were aggressive and dominant component of the mixture. Several authors including Ezenwa and Aken'ova (1996) and Nyaata *et al*. (1998) also noted that in grass/legume mixtures usually the grasses dominated the mixtures. There was no marked yield advantage on grass and legume by planting double rows over single rows of legumes. The double rows tended to depress DM yield of grasses but increased the legume yield marginally. As a result the combined total DM yield (grass + legume) differences between the planting patterns were small and not significant ($P<0.05$). This result differs with those of Ezenwa *et al*. (1995) and Ezenwa and Aken'ova (1996). In an intercrop study on leucaena/gliricidia-guinea grass mixture, Ezenwa *et al*. (1995) recorded higher grass DM yield under single hedge row arrangement of legumes than under triple hedge row during the rainy season but not in dry season. They also showed that total forage (grass + tree foliage) under the single hedgerow arrangement was 28% higher than under triple hedge row. Ezenwa and Aken'ova (1996) showed higher ($P<0.05$) grass DM yield was obtained with the single than double rows of Verano (*Stylosanthes hamata* cv. Verano) planted between rows of guinea grass. On average, they recorded 12% more total (grass + legumes) forage DM yield with single rows than with double row. Nyaata *et al.* (1998) reported that, to obtain the desired ratio of 30% legume and 70% Napier grass, one or two rows of leucaena to one row of Napier grass should be used or one row of Calliandra to two or three rows of Napier grass.

Overall the total DM production of the mixture was highest in Napier grass/Seca intercrops. Highest yield were obtained in SR 02 for Panicum/Seca due to partly better rainfall distribution and good vigour since Panicum had been re-planted at beginning of SR 02. Under low rainfall DM yield were greatly reduced for both plant types but the grasses were affected more than the legumes. For example, the mean contribution of both legumes to total DM yield in SR 02 was 24 and 15% in Panicum and Napier grass intercrops but increased to 44 and 25% in DS 03, respectively. This is because the plants exploit different zones in the soil profile due to different rooting patterns. Mureithi *et al*. (1995) work in coastal lowland of Kenya found out that most roots of Napier grass were concentrated at top 30 cm soil layer and therefore are unlikely to extract water in deeper layer and are affected when it dry. Macharia *et al*. (2005) work revealed that the tap roots of Siratro and stylos extended to 95 and 85 cm depth, respectively well beyond rooting depth of most native grasses in a semi-arid environment. Nonetheless, although yield of legumes were high in SR 02 than in DS 03, contribution of legumes to total DM yield was low in SR 02 due to relatively large yield of the grasses. Both legumes were not harvested in DS 04 as they were below the 10 cm cutting height and therefore data on DM yield is not shown.

CONCLUSIONS

Legumes planted in double rows maintained higher plant population and plot cover than those planted in single rows between grasses. High plant population indicates possibility of better persistence of legume in grass intercrop while the superior cover could have agronomic advantage of reducing weed population in the intercrop. However, legumes planted in double rows between grasses did not give higher yield than legumes planted in single row and did not contribute to yield advantage of the grasses and combined total yield implying that none of the planting pattern was superior. Overall Napier grass/Seca was most productive while other intercrops showed similarity in DM yield. The contribution of legume to total DM yield was highest in the drier season than wet season with Seca being more productive than Siratro.

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