EVALUATION OF DRY MATTER ACCUMULATION AND COMPETITION INDICES OF GRASS-LEGUME MIXTURES IN THE SEMI-ARID KANO NIGERIA

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ABSTRACT

An experiment was conducted from April to September 2018 at Bayero University Kano, to determine the nature of competition between *Sorghum almum* (Columbus grass) and three forage legumes namely *Cajanus cajan* (pigeon pea*), Lablab purpureus* (lablab) and *Mucuna pruriens* (velvet bean) on the basis of dry matter accumulation and competition indices. The treatments were (*Sorghum almum* sole, three legumes sole and mixtures of grass with legumes at 50:50 replicated in four blocks in randomized complete block design. Seeds of grass and legumes were sown in 3.5m *2m plots. The results showed that sole lablab produced higher (ρ <0.05) cumulative total dry matter (42.07 t ha^{-1}) than sole grass, monoculture of other legumes and mixtures. The cumulative total plant biomass and mean relative yield total of mixtures were not significantly different. Sorghum-Mucuna mixture with mean relative yield total value (1.11) appeared to be more advantageous in terms of efficient resource sharing than other mixtures. Sorghum-Mucuna mixture was recommended as the most compatible combination.

Keywords: forage yield, intercropping, mixture, monocultures, relative yield

INTRODUCTION

Livestock is an important global asset. The livestock sector employs at least 1.3 billion people and directly supports the livelihoods of 600 million poor smallholder farmers in the developing world as a source of nutrients and traction (Thornton and Gerber, 2010). Feeding forage is an efficient, low-cost strategy that is adaptable by rural farmers for increased productivity (Yousuf, 2014). However, in the dry tropics such as the savannah zone of northern Nigeria, ruminants suffer from permanent or seasonal nutritional stress due to additional loss of quality of the predominantly grass vegetation leading to incidences such as reduced feed intake, growth rate, decreased productivity, and reproductive performances (Mohammed, Gumel and Muhammad, 2015). One of the ways to minimize the aforementioned constraints to animal productivity is through the intercropping of grasses with legumes. Grass-legume mixtures are preferred over pure-grass forage stands because they often increase the herbage yield, forage digestibility; and offer balanced nutrition (Rusinovci, Aliu, Fetahu and Zeka 2016; Okukpe, *et al.*, 2011). However, maturity difference and plant height (Bibinu, Isa and Bwatanglang, 2009) amongst other factors, exert great influence on the performance of component crops in mixture. Hence, the performance of the mixture depends on its compatibility (Ibrahim, Gaffar and Wahab, 1993). The objective of the research was to determine the degree of competition between *Sorghum almum* and three forage legumes namely *Cajanus cajan, Lablab purpureus* and *Mucuna pruriens* on the basis of dry matter accumulation and competition indices with a view to establishing compatible mixtures for enhanced animal production.

MATERIALS AND METHODS

Field experiment was conducted at the orchard of the Faculty of Agriculture, Bayero University, Kano situated in the Sudan Savanna agro-ecological zone of Nigeria. It lies between latitude $10^0$33'N to $12^0$23'N and longitude $74^0$5'E to $9^0$29' E (AIEA 2007). The soil of the experimental site is characterized as sandy with moderate acidity (P^H - 6.92), N (0.15 g/kg), P (11.90 mg/kg) and K (0.28 cmol/kg). Temperature and rainfall data during the growing season (June – September, 2018) are shown in Table 1

Table 1: Mean monthly temperatures and rainfall during the growing season

Month	Temperature Max. (^{0}C)	Temperature Min. (^{0}C)	Rainfall (mm)
June	38.25	27.00	110.00
July	32.06	20.30	265.70
August	31.00	21.20	267.30
September	32.00	21.00	37.50

Treatments and experimental design

The treatments were monoculture of grass, 3 monoculture of legumes, and 3 mixtures of grass and legumes at 50:50 sowing proportion to give a total of 7 treatments replicated in 4 blocks in a randomized complete block design. The treatments were as follow;

1) *Sorghum almum* monoculture (S)
2) *Lablab purpureus* monoculture (L)
3) *Cajanus cajan* monoculture (C)
4) *Mucuna pruriens* monoculture (M)
5) *Sorghum almum* + *Cajanus cajan* at 50:50 (SL)
6) *Sorghum almum* + *Lablab purpureus* at 50:50 (SC)
7) *Sorghum almum* + *Mucuna pruriens* at 50:50 (SM)

Land preparation and field culture

The experiment was conducted from April to September 2018. The experimental field was ploughed, harrowed and made into firm and fine seedbeds. The legume seeds were scarified using hot water at 80^{0}C for 3 minutes to break post-harvest seed dormancy (Baba *et al.,* 2011). The seeds were sown in small plots measuring 3.5m*2m (7m^2). Grass-legume mixtures were sown in an alternate arrangement at inter and intra row distance of 0.5m*0.5m, similarly for legumes monoculture, while grass monoculture was sown at inter and intra row distance of 1m*0.5m respectively.

Fertilizer application and weeding

Plots containing grass-legume mixtures and legume monocultures received basal fertilizer dose of 50kg ha^{-1} of Phosphorus and Potassium fertilizer in the form of Single Super Phosphate and Muriate of Potash. Grass monoculture received 50kg ha^{-1} of NPK. Weeding was done manually as at when due.

Harvesting

Harvesting was done three times; the first harvest was done at 8th-week post planting while subsequent harvests were carried out at 6 weeks interval. Forages from the $1m^2$ quadrat sampling area from each plot were harvested manually at a stubble height of 15cm from the ground for all the species. The materials were separated into component species and weighed fresh (W_1) and oven-dried at 65^0C for 72 hours and reweighed (W_2) to estimate dry matter yield.

Competition indices

Relative yield (RY), relative yield total (RYT), relative crowding coefficient (RCC) or (k), and aggressivity index (AI) were calculated according to the following equations:

Relative yield (RY)

The relative yield of grass (RYG) = DMYGL/DMYGG (eqn1)

The relative yield of legumes (RYL) = DMYLG/DMYLL (eqn2)

Thus, the relative yield total (RYT) = (eqn1) + (eqn2) (De Wit, 1960).

Relative crowding coefficient (RCC)

Relative Crowding Coefficient Grass Component (RCCGL) = DMYGL/(DMYGG – DMYGL)

Relative Crowding Coefficient Legume Component (RCCLG) = DMYLG/(DMYLL – DMYLG) (De Wit, 1960).

Aggressivity index (AI)

Aggressivity index of grass component (AIGL) = **(**DMYGL/DMYGG**)** – **(**DMYLG/DMYLL**)**

Aggressivity index of legume component (AILG) = **(**DMYLG/DMYLL**)** – **(**DMYGL/DMYGG**)** (McGilchrist and Trenbah, 1971).

Where in the equations;

DMYGG is the DM yield of grass ‘G’ as a sole,

DMYLL is the DM yield of legume ‘L’ as a sole

DMYGL is the DM yield of grass component ‘G’ grown in a mixture with legume ‘L’

DMYLG is the DM yield of legume component 'L' grown in a mixture with grass 'G'.

Data analysis

Data were subjected to ANOVA using SAS 2009 (version 9.2). Where a significant difference exists, means were separated using Duncan's multiple range test (DMRT) at a 5% probability level.

RESULTS

Dry matter yield of grass, legumes and mixtures over three harvests

Dry matter yields of grass, legumes, total and cumulative dry matter are shown in Table 2. Dry matter yield values of grass in the SL and SM mixture in the first harvest were lower than those of the second harvest. While values of the dry matter yield of grass in the third harvest were lower than those of the second harvest in all the treatments. The legume in the SM mixture produced higher ($\rho < 0.05$) DMY (9.00 t ha-1) compared to (1.10 t ha-1) observed in SC. Dry matter yields of legumes in SL and SM mixture decreased from harvest 1 to 3. Grass monoculture out-yielded legume monocultures and mixtures in harvests 2 and 3. However, in harvest 1, L (sole Lablab) produced higher ($\rho < 0.05$) dry matter yield than other treatments except for M. Cumulative dry matter yield of grass and legume components were significantly different. The grass in SC produced higher ($\rho < 0.05$) dry matter (19.55t ha-1) than both SL (11.0 t ha-1) and SM (10.54 t ha-1). In the case of legumes, SC produced lower dry matter compared to SL and SM.

Cumulative dry matter yield of grass component was lower than those of legumes component except in SC. Cumulative total dry matter yield of L (42.07 t ha-1) was higher ($\rho < 0.05$) than those of monoculture of grass, legumes, and mixtures. Cumulative total dry matter yields of mixtures were not significantly different.

Table 2: Dry matter yield (t ha^{-1}) of grass, legume and mixtures over three harvests.

	Harvest 1			Harvest 2			Harvest 3			Cumulative		
	DMYG	DMYL	TDMY	DMYG	DMYL	TDMY	DMYG	DMYL	TDMY	DMYG	DMYL	TDMY
Sole (100%)												
S	14.70^{a}	-	14.70^{bc}	16.20^{a}	_	16.20^{a}	3.30^{a}	_	3.30^{a}	34.21^{a}	_	34.21^{b}
C	-	5.20^{bc}	5.20^{c}	_	7.00^{b}	7.00^{c}	_	2.40^{ab}	2.40^{ab}	_	14.60^{c}	14.60^{d}
L	-	24.60^{a}	24.60^{a}	_	14.80^{a}	14.80^{ab}	_	2.70^{a}	2.70^{ab}	_	42.07^{a}	42.07^{a}
M	-	18.20^{a}	18.20^{ab}	_	7.90^{ab}	7.90^{bc}	_	1.00^{bc}	1.00^{b}	_	27.10^{b}	27.10^{c}
Mixtures(50:50)												
SC	11.80^{ab}	1.10^{c}	12.90^{bc}	7.00^{b}	1.40^{b}	8.40^{bc}	0.70^{b}	0.40^{c}	1.10^{b}	19.55^{b}	2.91^{e}	22.46^{c}
SL	3.60^{b}	6.10^{bc}	9.60^{bc}	6.20^{b}	5.20^{b}	11.30^{abc}	1.30^{b}	1.00^{bc}	2.30^{ab}	11.00^{c}	12.21^{d}	23.22^{c}
SM	3.80^{b}	9.00^{b}	12.80^{bc}	5.90^{b}	3.40^{b}	9.30^{abc}	0.90^{b}	0.70^{bc}	1.60^{ab}	10.54^{c}	13.13^{d}	23.67^{c}
SEM	1.39	0.873	1.12	0.826	0.930	0.867	0.228	0.219	0.222	1.78	1.37	1.609
ρ value	0.0419	0.0001	0.007	0.005	0.014	0.069	0.011	0.039	0.104	0.004	<.0001	0.007

^{abc}Means with different superscripts within the same column are significantly different ($\rho < 0.05$). S = *Soghurm*, C = *Cajanus*, L = *Lablab*, M = *Mucuna*, DMYG = dry matter yield of grass, DMYL = dry matter yield of legumes, TDMY = total dry matter yield

Competitive indices

Relative yields and relative yield total

The average relative yields, relative yield total (RYT), and relative yields (RY) of grass and legumes are presented in Table 3. The relative yield of grass was not significantly different at harvests 1 and 2. However, SL had a higher RY ($\rho < 0.05$) than SC at harvest 3. In the case of legumes, SM had higher RY ($\rho < 0.05$) than SC at harvest 1. The relative yield of legume and relative yield total in SL and SM seems to increase with the harvest. However, the reverse was the case as far as SC is concerned. The average relative yield of legume in SM was superior ($\rho <$ 0.05) compared to SC. However, the Average relative yield of grass and average relative yield total were not significantly different. Only SM had an average relative yield total value greater than one (1.11).

Table 3: Relative yield and relative yield total of grass, legumes and their average over three harvests

	Harvest 1			Harvest 2			Harvest 3			Average		
Treatments	RYG	RYL	RYT	RYG	RYL	RYT	RYG	RYL	RYT	RYG	RYL	RYT
SC	0.83	0.22^{b}	1.05	0.44	0.19	0.63	0.30^{b}	0.17	0.47	0.52	0.19^{b}	0.71
SL	0.39	0.26^{ab}	0.64	0.42	0.52	0.94	0.46^{a}	0.62	1.08	0.42	0.46^{ab}	0.89
SM	0.37	0.52^{a}	0.88	0.38	0.55	0.92	0.35^{ab}	1.19	1.53	0.36	0.75^{a}	1.11
SEM	0.102	0.046	0.113	0.064	0.068	0.073	0.024	0.226	0.230	0.052	0.090	0.090
ρ value	0.191	0.041	0.402	0.925	0.135	0.225	0.042	0.260	0.242	0.510	0.011	0.265

^{ab}Means with different superscripts within the same column are significantly different ($\rho < 0.05$). RYG = Relative yield of grass, RYL = Relative yield of legumes, RYT = Relative yield total, SC= *Sorghum* vs *Cajanus*, SL= *Sorghum* vs *Lablab*, SM= *Sorghum* vs *Mucuna.*

Relative crowding coefficient

The relative crowding coefficient (RCC) of grass, legumes, and average over three harvests is presented in Table 4. Relative crowding coefficient values of grass were not significantly different at harvests 1 and 2. However, SL had higher (ρ <0.05) RCC (0.98) compared to SC at harvest 3. RCC of legumes and average RCC were not significantly different. The RCC of grass was generally lower compared to those of legumes at harvest 1. However, legumes had lower RCC value in harvest 2 and harvest 3 with the exception of SM (harvest 3).

Table 4: Relative crowding coefficient of grass, legumes and their average over three harvests

	Harvest 1		Harvest 2		Harvest 3		Average	
Treatments	RCCG	RCCL	RCCG	RCCL	RCCG	RCCL	RCCG	RCCL
SC	-17.16	0.28	0.77	0.24	0.51^{b}	0.21	-5.30	0.25
SL	-9.31	0.36	1.49	-2.52	0.98^{a}	-0.36	-2.28	-0.84
SM	1.11	1.83	0.94	-3.51	0.68^{ab}	1.17	0.91	-3.51
SEM	6.968	0.355	0.419	4.283	0.064	0.549	2.218	1.370
ρ value	0.599	0.213	0.773	0.434	0.043	0.553	0.553	0.549

^{ab}Means with different superscripts within the same column are significantly different (ρ <0.05). RCCG = Relative crowding coefficient of grass, RCCL = Relative crowding coefficient of legumes, SC= *Sorghum* vs *Cajanus*, SL= *Sorghum* vs *Lablab*, SM= *Sorghum* vs *Mucuna.*

Aggressivity Index

The aggressivity index (AI) of grass-legumes and average over three harvests are presented in Table 5. The grass in SC had higher AI (ρ <0.05) than the grass in SM. Similarly, legumes in SM had higher AI (ρ <0.05) than SC. AI of grass decreased from harvest 1 to 3, while the reverse was the case with respect to the legumes. Average aggressivity index values of legumes in SL and SM were higher compared to those of grass.

Table 5: Aggressivity index of grass, legumes and their average over three harvests

	Harvest 1		Harvest 2		Harvest 3		Average	
Treatments	AIG	AIL	AIG	AIL	AIG	AIL	AIG	AIL
SC	0.62[a]	-0.62[b]	0.24	-0.24	0.13	-0.13	0.33	-0.33
SL	0.14[ab]	-0.14[ab]	-0.10	0.10	-0.17	0.17	-0.04	0.04
SM	-0.15[b]	0.15[a]	-0.17	0.17	-0.84	0.84	-0.39	0.39
SEM	0.110	0.110	0.111	0.111	0.023	0.023	0.119	0.119
ρ value	0.042	0.042	0.349	0.349	0.275	0.275	0.122	0.122

[ab]Means with different superscripts within the same column are significantly different ($\rho < 0.05$). AIG =Aggressivity index of grass, AIL =Aggressivity index of legume, SC= Sorghum vs Cajanus, SL= Sorghum vs Lablab, SM= Sorghum vs Mucuna.

DISCUSSION

Dry matter yields of grass, legumes and mixtures

Dry matter yield is a measure of pasture productivity. Results of this study showed that grass and legumes species differed significantly in dry matter accumulation and their ability to sustain yield when grown sole and as intercrop. The lower dry matter yield observed in the grass (*Sorghum almum*) and *Cajanus cajan* monocultures in harvest 1 compared to harvest two could be attributed to the fact that the two species are perennial, and were in the process of establishment at harvest one (Table 2). The capacity for tillering had not been fully attained in the case of grass. At harvest 2, both *Sorghum almum* and *Cajanus cajan* were more established and thus able to utilize soil nutrients better for maximum growth. In Thailand, Pornthip *et al.* (2006) observed that *Cajanus cajan* was slow to establish but the production of dry matter yield increased over the experimental period.

Dry matter yields of Lablab and Mucuna monocultures as well as in mixtures were highest in harvest 1 and decreased with harvest (Table 2). This was probably because Lablab and Mucuna were annual legumes with rapid growth during the early establishment. In the same connection, the decrease in DMY of Lablab and Mucuna with harvest might be as a result of an upsurge of rainfall prior to the second harvest, leading to flooding affecting some portions of the experimental plots.

The lower DMY of the grass component in SL and SM at the first harvest is reflective of higher competition from the legume components as indicated by the negative aggressivity index of grass in both treatments. The increase in DMY of grass component in both treatments at harvest 2 was probably due to the contribution of soil nitrogen by the legume component through nitrogen fixation. Yihalem and Habtemariam (2012) reported that N of several legumes increased the yield of maize, sorghum, and wheat between 112 to 190, 138 to 174 and 105 to 124 percent, respectively. The general decline in the dry matter yield of all treatments at harvest 3 may be due to inadequate soil nitrogen (in the case of sole grass) following removal through the previous harvest, perhaps the legumes did not tolerate repeated defoliation and were unable to sustain forage production undercut and carry system. Similar results were observed in guinea grass and stylo (Baba *et al.*, 2011), Sesbania and crotalaria (Pornthip *et al.,* 2006).

Lablab monoculture produced high dry matter yield than grass monoculture, other legumes and mixtures. This can be attributed to the better ability of lablab to capture light (as a result of its creeping growth habit) and soil resources or a combination of the two. Mohammed, Gumel and Muhammad (2015) reported no significant difference in dry matter yields of *Sorghum almum* and Lablab monocultures. Although no significant differences were observed, the numerically higher cumulative total dry matter recorded in *Sorghum almum* - *Mucuna* and *Sorghum almum* – lablab mixtures were as a result of high yield recorded by the component legumes. Lablab and *Mucuna*, with their trifoliate leaves, have a better ability to capture light than *Cajanus*. These views are supported by a related study (Baumann, Bastiaans and Opff, 2001).

Relative yield

The higher RY of legumes observed in Lablab and *Mucuna* (Table 3) compared to grass indicated that the legumes contributed more to total dry matter accumulation in those treatments. The reverse trend seen in *Sorghum*-*Cajanus* mixture may be due to the erect growth pattern exhibited by *Cajanus* which allowed light to pass through the canopy without trapping as much for photosynthesis and thus produced less yield. The RYT values of <1 in mixtures (except in *Sorghum almum*- *Mucuna* mixture) meant that there was no advantage in intercropping the component crops. Muhammed et al (2015) reported no yield advantage in Sorghum- Lablab forage mixtures compared to sole crops.

Relative crowding co-efficient

The higher RCC of legumes (Table 4) compared to grass in almost all mixtures is indicative of the higher competitive ability of the legume compared to the grass in mixtures. This assertion is further supported by the higher dry matter yield of legumes observed in most treatments. Muhammed et al (2015) reported higher mean RCC values of Stylo in mixture with *Sorghum almum* and attributed it to higher dry matter produced by stylo compared to the grass.

Aggressivity index

The positive AI recorded by legumes (Lablab and Mucuna) (Table 5) compared to grass (negative) in this study is indicative of the higher competitive ability of the legumes compared to the grass. Tessema and Baars (2006) showed that the positive aggressivity index recorded by *Panicum* and *Chloris* in mixtures was indicative of the superior competitive ability of the grasses compared to the legumes. The least AI margin observed in the *Sorghum almum* – Lablab mixture is an indication of better compatibility.

CONCLUSION

The following conclusions were made from the study:

- The regrowth forage of monocultures and mixtures harvested at 6 weeks had herbaceous stems that could be fed on by animals or used for silage production.
- The dry matter yield of legume in Sorghum-Lablab and Sorghum-Mucuna mixtures was 76% and 78% higher than that of Sorghum-Cajanus.
- The relative yield of grass (RYG) was 64% higher than that of Cajanus. However, RYG was 9% and 52% lower than those of Lablab and Mucuna.
- Sorghum-Mucuna mixture is more advantageous in terms of efficient resource sharing than other mixtures given its higher average relative yield total value (1.11) across three harvests.

RECOMMENDATIONS

Based on the foregoing result, the establishment of the Sorghum-Mucuna mixture at 50:50 may be recommended for better compatibility taking into account the fact that this combination produced higher dry matter than other mixtures and had the highest RYT value of 1.11.

However, we wish to suggest that further research on long-term basis would be necessary to ascertain the extent of persistence of the legumes in the mixtures. The nutritional qualities of the mixtures should also be looked into in order to match compatibility with quality.

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