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*Full Length Research Paper*

# Grass-legume mixtures for enhanced forage production: Analysis of dry matter yield and competition indices

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**A six months field trial was conducted at the University Putra, Malaysia to evaluate dry matter yield and nature of competition between *Panicum maximum* (guinea grass) and each of the following legumes; *Stylosanthes guianensis* (stylo), *Macroptillium bracteatum* (burgundy bean), *Arachis pintoi*, and *Centrosema pubescens* (centro) in accordance with DeWit (1960) replacement principle. There were 20 treatments in all consisting of monocultures of grass, legume and grass-legume mixtures in the ratios 4:0, 3:1, 2:2, 1:3 and 0:4. The competition indices employed were relative yield total (RYT), relative crowding coefficient (RCC) or (k) and aggresivity index (AI). Guinea-stylo, guinea-*Arachis* and guinea-burgundy mixtures, irrespective of ratio combination, showed lower total dry matter yields than their respective grass monocultures. Guinea-centro (2:2) and guinea-centro (3:1), on the other hand, gave higher total dry matter yields (14.52 and 13.82 tons/ha), respectively than their grass monocultures. No significant differences were observed among mixtures; however, monocultures of legumes produced significantly lower yields ($p < 0.05$) than those of grass and mixtures. All mixtures recorded mean RYT values of greater than one (1). Guinea-stylo (GS 2:2) and guinea centro (GC 2:2) had the highest RYT values of 1.41 and 1.40 respectively. Mean k values of grasses in mixtures were higher than those of legumes except in guinea-stylo (GS 1:3) and guinea- *Arachis* (GA 1:3). Mean aggressivity index suggests that legumes were generally more aggressive at 1:3 grass-legume mixture combination, while grass gained the upper hand at 2:2 and 3:1 grass-legume proportion. Guinea-centro (GC 2:2) was recommended as the most compatible combination.**

**Key words:** Grass-legume, dry matter yield, relative yield total, relative crowding coefficient, aggressivity index.

## INTRODUCTION

Twenty three percent of the world's total area or 3.4 billion ha is permanent grasslands (FAO, 1993). The tropics account for 1.3 billion ha as either wild or cultivated fodder plants. In most developing tropical countries, animal production from pastures is low compared to developed countries. Pasture grasses (mainly C4) frequently contain crude protein levels of 8% or less which are inadequate for animal production (Humphreys, 1991). The foregoing scenario underscores the need for improved livestock production on a sustainable basis in tropical environment. Introduction of forage legumes is one of the strategies for improvement of grassland productivity. Grass-legume mixtures are a means of improving productivity compared to monocultures without any additional investment. A mixture of grass (*Chloris gayana* with the legume *Stylosanthes guianensis*) at 1:3 increased herbage dry matter yield (Onifade et al., 1994). Similarly, Berhan (2006) observed a higher dry matter yield in mixtures of *C. gayana* and *Trifolium prantese* at 50:50 seeding rates. In forage animal production system, grass-legume mixtures are preferred owing to several advantages over monocultures. Yields are generally higher in mixtures

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because of more efficient light utilization, and transfer of symbiotically fixed nitrogen to grasses (Ledgard, 1991). Gramshaw et al. (1989) observed that the establishment of grass-legume mixtures has not been much of a success in the tropics, it was hypothesized that identification of compatible grass-legume mixtures will help alleviate the problem.

The objective of the experiment was to evaluate the dry matter yield and nature of competition among four legume forages, (*Centrosema pubescens* (centro*), S. guianensis* (stylo), *Macroptillium bracteatum* (burgundy bean) and *Arachis pintoi*) in association with *Panicum maximum* (guinea grass) for plantation livestock integration considering the vast area of land that exists under plantation in Malaysia.

## MATERIALS AND METHODS

The experiment was conducted in the Agronomy field, University Putra Malaysia, located at latitude 3º 02'N longitude 101º 42'E and altitude 31 m above sea level. Total annual rainfall in the year 2010 was approximately 2832.99 mm with a monthly average of 236.08 mm. Peak rainfall was recorded in September (454.6 mm) with the least in October (56.2 mm). Mean monthly minimum and maximum temperatures were 24.13 and 33.98°C respectively while average monthly relative humidity was 93.63%. The experimental plot was previously planted with elephant grass. The soil is a clay loam with pH (5.04), N (0.04), P (29) and K (19). The land was ploughed, harrowed and rotovated prior to the commencement of the experiment.

### Experimental design

The experimental layout consisted of eighty plots each measuring 1m². Each plot was covered with plastic sheet mulch in order to check the growth of weeds within the plots. There were twenty treatments. Distances between blocks and plots were 1 and 0.5 m², respectively. The treatments consisted of *P. maximum* (guinea grass) (monoculture), *S. guianensis* (stylo) (monoculture), *M. bracteatum* (burgundy bean) ( monoculture) *C. pubescens* (centro) (monoculture) *A. pintoi* (monoculture) and mixtures of Guinea with each of the legumes in specific ratios in line with Dewit (1960) replacement principle i.e. T1 (GS 0:4), T2 (GS 1:3), T3 (GS 2:2), T4 (GS 3:1), T5 (GS 4:0), T6 (GC 0:4), T7 (GC 1:3), T8 (GC 2:2), T9 (GC 3:1), T10 (GC 4:0), T11 (GA 0:4), T12 (GA 1:3), T13 (GA 2:2), T14 (GA 3:1), T15 (GA 4:0), T16 (GB 0:4), T17 (GB 1:3), T18 (GB 2:2) T19 (GB 3:1), T20 (GB 4:0).

*P. maximum* (guinea grass) was the sole grass used in the experiment in association with four legumes, *S. guianensis* (stylo), *C. pubescens* (centro), burgundy bean, and *A. pintoi*. Legume seeds (stylo, centro and burgundy) were initially treated with hot water at 80°C for 3 min in order to break dormancy. Seeds of guinea grass, stylo, centro and burgundy were sown in jiffy pots for a period of four weeks, seedlings were then transplanted to the field. *Arachis* seedlings were raised in small polythene bags before transplanting. Sowing was done on 30 July 2010 in strict compliance with the replacement principle, thus four holes were made at each corner of the 1 m² plots, at a distance of 25 cm away from the plot margin. Much of the seedlings raised in jiffy pots could not survive beyond one week in the field. Hence vegetative method of planting was resorted to in the case of guinea, while direct seeding was done for centro, burgundy and stylo. For guinea three tillers from the cut vegetative materials were transplanted in each hole, while all legumes were later pruned to 3 stands per hole.

### Weeding

Weeding was done as and when required, first weeding was done manually, while subsequent ones were done using chemical herbicide (Roundup) at the rate of 80 m/s per 10 l of water.

### Harvesting

The first harvest was done eight weeks after sowing at 50% flowering stage of burgundy and *Arachis* and 75% flowering stage of guinea grass. Subsequent harvests were carried out at 6 weeks intervals. During each harvest, grasses and legumes were cut together on plot by plot basis at about 5 cm to the ground. Total fresh weights were taken, grasses were then separated from legumes, fresh weights of each were taken, and subsamples of each were taken wherever it was necessary. The materials were oven dried at 65°C for 72 h. The dried materials (grasses and legumes) were weighed using digital balance to determine the dry matter yield.

### Competition indices computed

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

RY= RYab =DMYab/DMYaa, RYba = DMYba/DMYbb (Ghosh et al., 2006)
RYT = DMYab/DMYaa + DMYba/DMYbb

RCC for 50:50 proportions:

RCCab = DMYab/ (DMYaa-DMYab), RCCba =DMYba/ (DMYbb-DMYba)

For mixtures different from 50:50,

RCCab = DMYab x Zba/ (DMYaa – DMYab) Zab
RCCba = DMYba X Zab/ (DMYbb – DMYba) Zba (Ghosh, 2004)
AI for 50:50 = AIab = (DMYab/DMYaa) – (DMYba/DMYbb), AIba = (DMYba/DMYbb) – (DMYab/DMYaa)

For mixtures different from 50; 50:

AIab = DMYab/ (DMYaa XZab) – DMYba/ (DMYbb x Zba)

AIba = DMYba/ (DMYbb x Zba) – DMYab/ (DMYaa x Zab) (Agegnehu et al., 2006). In the equations, the following definitions apply, ab refers to performance of Guinea (a) mixed with either stylo, *Arachis*, burgundy or centro (b), ba is the performance of either of the legume (b) mixed with guinea, aa is the performance of guinea in monoculture and bb is the performance of either of the legume as a monoculture, Z is the sown proportion or ratio.

### Statistical analysis

Dry matter yields of monocultures and mixtures were analyzed using statistical analysis systems (SAS) package. Means of dry matter yields were separated using Duncan's multiple range tests.

**Table 1.** Dry matter yields of harvest 1, 2 and 3.

| Treatment | Harvest 1 | | | Harvest 2 | | | Harvest 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | DM grass tons/ha | DM legume tons/ha | DM total tons/ha | DM grass tons/ha | DM legume tons/ha | DM total tons/ha | DM grass tons/ha | DM legume tons/ha | DM total tons/ha |
| T1 (GS 0:4) | - | 0.12 | 0.12$^{c}$ | - | 2.18 | 2.18$^{bdc}$ | - | 2.72 | 2.72$^{bcd}$ |
| T2 (GS 1:3) | 0.16 | 0.18 | 0.34$^{c}$ | 2.30 | 2.18 | 4.48$^{abc}$ | 2.32 | 1.07 | 3.39$^{abdc}$ |
| T3 (GS 2:2) | 1.83 | 0.11 | 1.94$^{ab}$ | 6.10 | 0.81 | 6.91$^{a}$ | 4.61 | 0.90 | 5.51$^{ab}$ |
| T4 (GS 3:1) | 1.44 | 0.04 | 1.48$^{abc}$ | 6.17 | 0.66 | 6.83$^{a}$ | 4.73 | 0.66 | 5.39$^{ab}$ |
| T5 (GS 4:0) | 2.39 | - | 2.39$^{a}$ | 6.26 | - | 6.26$^{a}$ | 5.78 | - | 5.78$^{ab}$ |
| T6 (GC 0:4) | - | 0.12 | 0.12$^{c}$ | - | 1.91 | 1.91$^{dc}$ | - | 1.26 | 1.26$^{cd}$ |
| T7 (GC 1:3) | 1.34 | 0.03 | 1.37$^{abc}$ | 6.21 | 0.59 | 6.80$^{a}$ | 3.86 | 0.90 | 4.76$^{ab}$ |
| T8 (GC 2:2) | 1.65 | 0.02 | 1.67$^{abc}$ | 6.73 | 0.75 | 7.48$^{a}$ | 4.53 | 0.84 | 5.37$^{ab}$ |
| T9 (GC 3:1) | 2.31 | 0.003 | 2.31$^{a}$ | 7.06 | 0.29 | 7.35$^{a}$ | 3.90 | 0.26 | 4.16$^{abc}$ |
| T10 (GC 4:0) | 1.56 | - | 1.56$^{abc}$ | 6.95 | - | 6.95$^{a}$ | 4.99 | - | 4.99$^{ab}$ |
| T11 (GA 0:4) | - | 0.30 | 0.30$^{c}$ | - | 1.27 | 1.27$^{d}$ | - | 1.02 | 1.02$^{cd}$ |
| T12 (GA 1:3) | 1.33 | 0.09 | 1.42$^{abc}$ | 5.03 | 0.69 | 5.72$^{a}$ | 4.10 | 0.91 | 5.01$^{ab}$ |
| T13 (GA 2:2) | 1.45 | 0.09 | 1.54$^{abc}$ | 6.69 | 0.58 | 7.27$^{a}$ | 4.09 | 0.86 | 4.95$^{ab}$ |
| T14 (GA 3:1) | 1.34 | 0.03 | 1.37$^{abc}$ | 6.72 | 0.55 | 7.27$^{a}$ | 5.80 | 0.46 | 6.26$^{a}$ |
| T15 (GA 4:0) | 2.03 | - | 2.03$^{ab}$ | 7.42 | - | 7.42$^{a}$ | 6.03 | - | 6.03$^{ab}$ |
| T16 (GB 0:4) | - | 0.67 | 0.67$^{bc}$ | - | 5.05 | 5.05$^{abc}$ | - | 0.61 | 0.61$^{d}$ |
| T17 (GB 1:3) | 1.19 | 0.41 | 1.60$^{abc}$ | 4.26 | 1.12 | 5.38$^{ab}$ | 3.38 | 0.85 | 4.23$^{abc}$ |
| T18 (GB 2:2) | 1.39 | 0.25 | 1.64$^{abc}$ | 3.83 | 0.97 | 4.80$^{abc}$ | 3.69 | 0.85 | 4.54$^{ab}$ |
| T19 (GB 3:1) | 2.09 | 0.05 | 2.14$^{ab}$ | 5.30 | 0.52 | 5.82$^{a}$ | 4.59 | 0.41 | 5.00$^{ab}$ |
| T20 (GB 4:0) | 2.19 | - | 2.19$^{ab}$ | 7.23 | - | 7.23$^{a}$ | 5.65 | - | 5.65$^{ab}$ |

Total dry matter values with same letters within same column are not statistically different.

## RESULTS

Dry matter yields of grasses and legumes for the three harvests are shown in Table 1. Dry matter yields of grasses, legumes and mixtures in first harvest were generally lower than those of second harvest for all treatments. Similarly, the dry matter yields of grasses in the third harvest were lower than those of second harvest. However, the difference between second harvest and third harvest in terms of legume dry matter did not follow a specific pattern. Dry matter yield from all treatments increased from the first harvest to second harvest and declined in the third harvest with treatment 1 as an exception. Grass monocultures produced higher yields than monocultures of legumes across the three harvests, on a general score, grass monocultures out yielded mixtures except in treatments T8 (GC 2:2) T 9 (GC 3:1) (harvest 1), T3 (GS 2:2), T4 (GS 3:1), T8 (GC 2:2) T9 (GC 3:1) (harvest 2), T8 (GC 2:2) and T14 (GA 2:2) (harvest 3). Highest dry matter yields were produced by T5 (GS 4:0) (2.39 tons/ha) (harvest 1), T8 (GC 2:2) (7.48 tons/ha) (harvest2) and T14 (GA 3:1) (6.26 tons/ha) (harvest 3). Total dry matter yield values (Table 2) of grass were higher than those of legumes for all mixed pasture treatments, similarly total dry matter yields of grass

**Table 2.** Total dry matter yields of grass and legume over three harvests.

| Treatment | DM grass ( tons/ha) | DM legume (tons/ha) | DM total (tons/ha) |
|---|---|---|---|
| T1 (GS 0:4) | - | 5.02 | 5.02[dc] |
| T2 (GS 1:3) | 4.78 | 3.43 | 8.21[bdac] |
| T3 (GS 2:2) | 12.54 | 1.82 | 14.36[a] |
| T4 (GS 3:1) | 12.34 | 1.36 | 13.7[a] |
| T5 (GS 4:0) | 14.43 | - | 14.43[a] |
| T6 (GC 0:4) | - | 3.29 | 3.29[d] |
| T7 (GC 1:3) | 11.41 | 1.52 | 12.93[ab] |
| T8 (GC 2:2) | 12.91 | 1.61 | 14.52[a] |
| T9 (GC 3:1) | 13.27 | 0.55 | 13.82[a] |
| T10 (GC 4:0) | 13.50 | - | 13.50[a] |
| T11 (GA 0:4) | - | 2.59 | 2.59[d] |
| T12 (GA 1:3) | 10.46 | 1.69 | 12.15[ab] |
| T13 (GA 2:2) | 12.23 | 1.53 | 13.76[a] |
| T14 (GA 3:1) | 13.86 | 1.04 | 14.90[a] |
| T15 (GA 4:0) | 15.48 | - | 15.48[a] |
| T16 (GB 0:4) | - | 6.33 | 6.33[bdc] |
| T17 (GB 1:3) | 8.83 | 2.38 | 11.21[abc] |
| T18 (GB 2:2) | 8.91 | 2.07 | 10.98[abc] |
| T19 (GB 3:1) | 11.98 | 0.98 | 12.96[ab] |
| T20 (GB 4:0) | 15.07 | - | 15.07[a] |

Means with same letters within same column are not statistically different.

monocultures produced higher yields than mixtures except in T8 (GC 2:2) (14.52 tons/ha) and T9 (GC 3:1) (13.82 tons/ha). The differences between grass monocultures and mixtures were not significant, also, no significant differences were observed among mixtures in terms of total dry matter yield. Monocultures of legumes gave significantly lower yields ($p < 0.05$) than those of grass and mixtures. Treatment 15 (GA 4:0) resulted in the highest total dry matter yield (15.48 tons/ ha). Among the mixtures, T14 (GA 3:1) (14.90 tons/ha) produced the highest total dry matter yield followed by T8 (GC 2:2) (14.52 tons/ha). T2 (GS 1:3) (8.21 tons/ha) produced the least.

The relative yield total and relative yields of grass and legumes are presented in Table 3. Relative yield total measures the extent to which components of a mixture share common resources. Relative yield values of grass in mixtures were higher than those of legumes across the three harvest except in treatments T2 (GS 1:3), T3 (GS 2:2) T17 (GB 1:3) (harvest 1), T2 (GS 1:3) (harvest 2), T12 (GA 1:3), T13 (GA 2:2) T17 (GB 1:3), T18 (GB 2:2) (harvest 3). Relative yield of legumes in guinea-centro and guinea-*Arachis* mixtures increased with harvest while that in guinea-stylo mixtures decreased. No definite pattern was observed in guinea-burgundy mixtures indicating that the legumes in guinea-centro and guinea-*Arachis* became more persistent with time. This is buttressed by the consistent reduction in the relative yield values of grass in guinea-centro mixtures especially treatment T8 (GC 2:2) and T9 (GC 3:1). Mean relative yield values (Table 4) of grass over 3 harvests were higher than those of legumes except for T2 (GS 1:3), T17 (GB 1:3) and T18 (GB 2:2). Mean relative yield values of grass increased with increase proportion of grass in mixtures, similar pattern was observed for the legumes in mixtures. Mean relative yield total values were generally greater than 1 for all treatments, highest values were recorded in T3 (GS 2:2) (1.41) and T8 (GC 2:2) (1.40). Mixtures with 2:2 grass-legume combination had higher mean relative yield total values except in guinea burgundy mixtures. Graphs of mean relative yield of grass and legumes against their sown proportion are shown in Figures 1 to 4.

Relative crowding coefficient (k value) for harvest 1, 2 3 are presented in Table 5. Total K values of grass were higher than those of legumes across the three harvests except for T17 (GB 1:3) (harvest 1), T2 (GS 1:3) (harvest 2), T12 (GA 1:3), and T13 (GA 2:2) (harvest 3). Higher k values of grass signify superior competitive ability of grass over legumes and vice versa where k values of legumes were found to be higher. Similarly, mean k values (Table 6) of grass were higher than those of legumes with T2 (GS 1:3) and T12 (GA 1:3) as exceptions.

Total aggressivity index values for harvest 1, 2 and 3 are shown in Table 7. Legumes were consistently more aggressive than grass at ratio 1:3 grass-legume mixtures across all harvest (T7 harvest 1 exclusive), similarly

**Table 3.** Relative yields of grass, legume and total for harvest 1, 2 and 3.

| Treatment | Harvest 1 | | | Harvest 2 | | | Harvest 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | RY grass | RY legume | RY total | RY grass | RY legume | RY total | RY grass | RY legume | RY total |
| T1 (GS 0:4) | - | - | - | - | - | - | - | - | - |
| T2 (GS 1:3) | 0.07 | 1.53 | 1.60 | 0.37 | 1.00 | 1.37 | 0.40 | 0.39 | 0.79 |
| T3 (GS 2:2) | 0.76 | 1.00 | 1.76 | 0.98 | 0.37 | 1.35 | 0.80 | 0.33 | 1.13 |
| T4 (GS 3:1) | 0.60 | 0.32 | 0.92 | 0.99 | 0.30 | 1.29 | 0.82 | 0.24 | 1.06 |
| T5 (GS 4:0) | - | - | - | - | - | - | - | - | - |
| T6 (GC 0:4) | - | - | - | - | - | - | - | - | - |
| T7 (GC 1:3) | 0.86 | 0.27 | 1.13 | 0.89 | 0.31 | 1.20 | 0.77 | 0.71 | 1.48 |
| T8 (GC 2:2) | 1.06 | 0.16 | 1.22 | 0.97 | 0.39 | 1.36 | 0.91 | 0.67 | 1.58 |
| T9 (GC 3:1) | 1.48 | 0.02 | 1.50 | 1.02 | 0.15 | 1.17 | 0.78 | 0.20 | 1.00 |
| T10 (GC 4:0) | - | - | - | - | - | - | - | - | - |
| T11 (GA 0:4) | - | - | - | - | - | - | - | - | - |
| T12 (GA 1:3) | 0.66 | 0.31 | 0.97 | 0.68 | 0.54 | 1.22 | 0.68 | 0.89 | 1.57 |
| T13 (GA 2:2) | 0.72 | 0.32 | 1.04 | 0.90 | 0.46 | 1.36 | 0.68 | 0.84 | 1.52 |
| T14 (GA 3:1) | 0.66 | 0.11 | 0.77 | 0.91 | 0.43 | 1.34 | 0.96 | 0.45 | 1.41 |
| T15 (GA 4:0) | - | - | - | - | - | - | - | - | - |
| T16 (GB 0:4) | - | - | - | - | - | - | - | - | - |
| T17 (GB 1:3) | 0.54 | 0.62 | 1.16 | 0.59 | 0.22 | 0.81 | 0.60 | 1.39 | 1.99 |
| T18 (GB 2:2) | 0.63 | 0.38 | 1.01 | 0.53 | 0.19 | 0.72 | 0.65 | 1.40 | 2.05 |
| T19 (GB 3:1) | 0.95 | 0.08 | 1.03 | 0.73 | 0.10 | 0.83 | 0.81 | 0.67 | 1.48 |
| T20 (GB 4:0) | - | - | - | - | - | - | - | - | - |

**Table 4.** Mean relative yields of grass, legume and total over three harvests.

| Treatment | RY grass | RY legume | RY total |
|---|---|---|---|
| T1 (GS 0:4) | - | - | - |
| T2 (GS 1:3) | 0.28 | 0.97 | 1.25 |
| T3 (GS 2:2) | 0.84 | 0.57 | 1.41 |
| T4 (GS 3:1) | 0.8 | 0.29 | 1.09 |
| T5 (GS 4:0) | - | - | - |
| T6 (GC 0:4) | - | - | - |
| T7 (GC 1:3) | 0.84 | 0.43 | 1.27 |
| T8 (GC 2:2) | 0.99 | 0.41 | 1.4 |
| T9 (GC 3:1) | 1.09 | 0.12 | 1.21 |
| T10 (GC 4:0) | - | - | - |
| T11 (GA 0:4) | - | - | - |
| T12 (GA 1:3) | 0.67 | 0.58 | 1.25 |
| T13 (GA 2:2) | 0.76 | 0.54 | 1.3 |
| T14 (GA 3:1) | 0.84 | 0.33 | 1.17 |
| T15 (GA 4:0) | - | - | - |
| T16 (GB 0:4) | - | - | - |
| T17 (GB 1:3) | 0.57 | 0.74 | 1.31 |
| T18 (GB 2:2) | 0.6 | 0.65 | 1.25 |
| T19 (GB 3:1) | 0.83 | 0.28 | 1.11 |
| T20 (GB 4:0) | - | - | - |

grass was found to be persistently more aggressive than the legumes at ratio 2:2 and 3:1 grass-legume combination with the exception of T3 (GS 2:2) (harvest 1), T13 (GA 2:2) T17 (GB 1:3) and T18 (GB 2;2) ( harvest

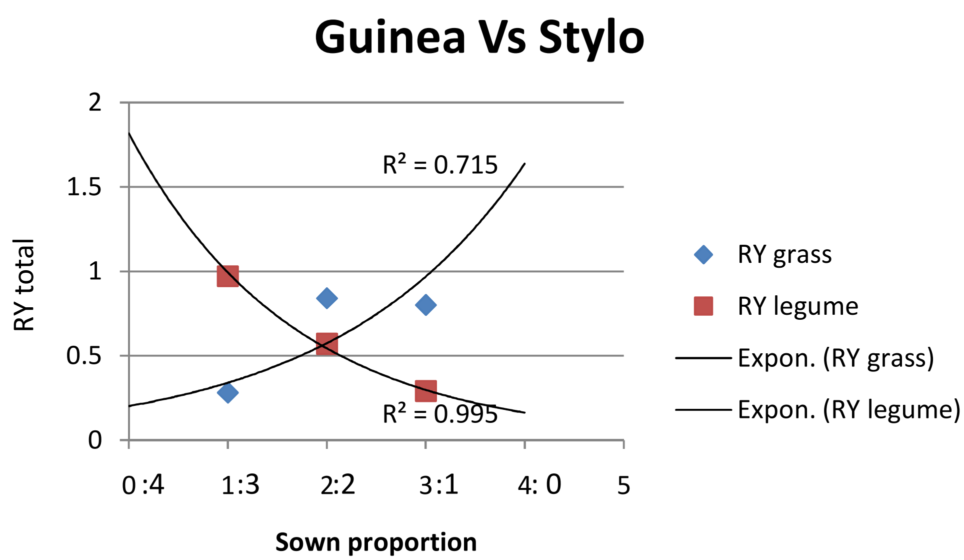


**Figure 1.** Graph of relative yield of guinea and stylo against sown proportion.

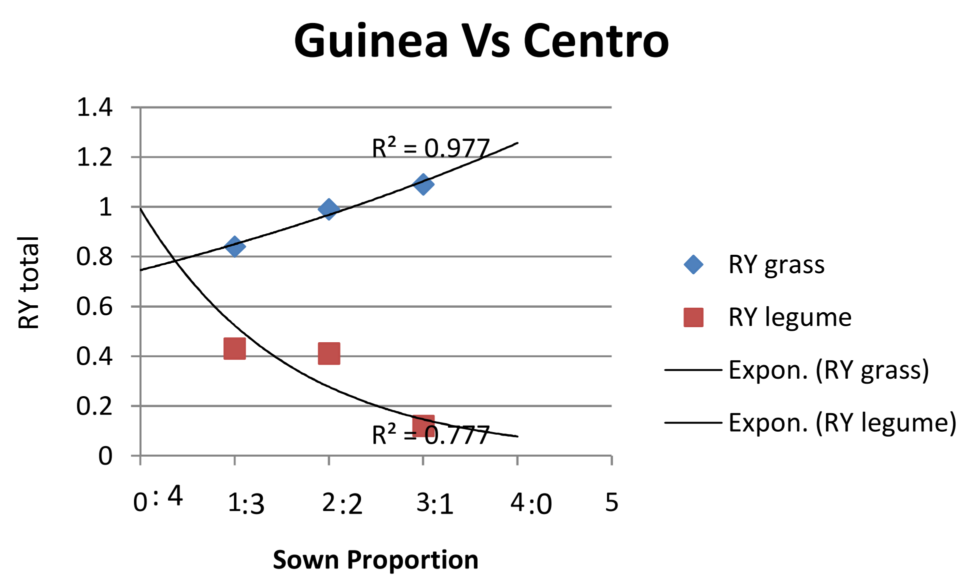


**Figure 2.** Graph of relative yield of guinea and centro against sown proportion.

3). Aggressivity of grass towards legume in T8 (GC 2:2), T9 (GC 3:1) and T19 (GB 3:1) decreased with time suggesting that the legumes became better established over time and thus more competitive. Mean aggressivity index (Table 6) of both grass and legumes reveals that grass was more aggressive than legumes in all treatments with 3:1 and 2:2 grass-legume combination (T 18 GB 2:2, exclusive) while legume became more aggressive in all 1:3 grass-legume mixture treatments and also T18 (GB 2;2). All mixture components with negative values indicate less aggressivity.

## DISCUSSION

Dry matter production is a function of the nature of competition among the various species in a mixture. Dry matter yields of grass and legume monocultures as well as mixtures were generally lowest at first harvest compared to harvest 2 and 3. This may be attributed to the fact that both grass and legumes were in the process of establishment, the capacity for tillering had not been fully attained in the case of grass, and almost all legumes were slow in establishment except burgundy. Centro did

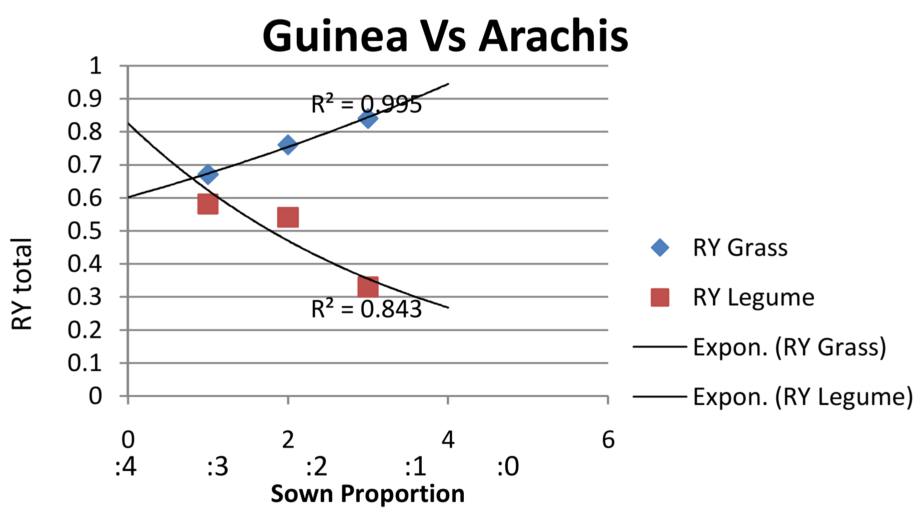


**Figure 3.** Graph of relative yield of guinea and *Arachis* against sown proportion.

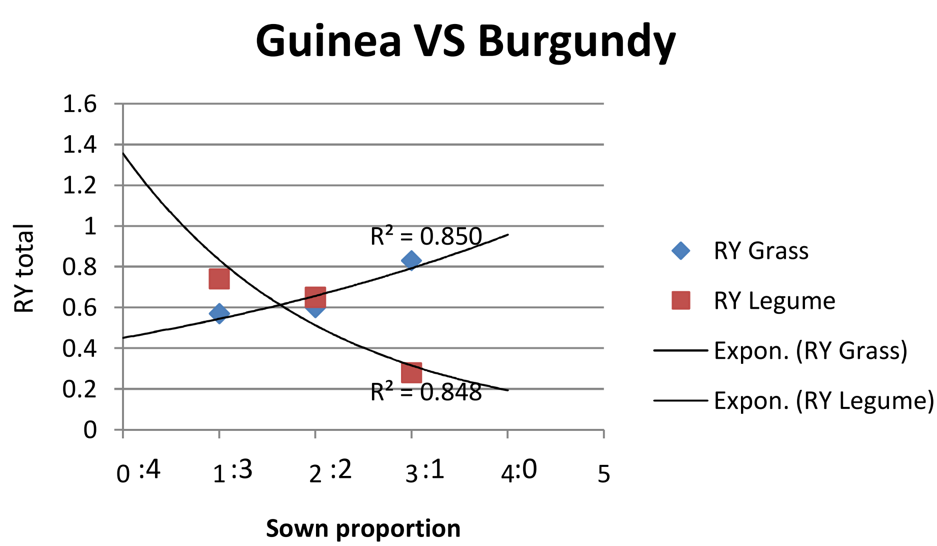


**Figure 4.** Graph of relative yield of guinea and burgundy against sown proportion.

not establish well up to the first harvest as could be seen from the dry matter figures. The higher dry matter yields of grass compared to legumes in monocultures and mixtures could be due to vigorous nature of grass growth and its ability to rapidly utilize the nitrogen in the soil which is released following cultivation (Tessema and Baar, 2006). The rapid establishment of the grass may have had a profound effect on the root system that enabled it to extract growth resources from the soil (Kechero, 2008). The higher total dry matter yields obtained for all treatments in harvest 2 compared to 1 may be seen in the light of the fact that at harvest 2 both grass and legumes were relatively more established and thus able to utilize soil resources better for maximum growth. The increase in dry matter yields of grass in mixtures was probably due to contribution of soil nitrogen by the legume component through nitrogen fixation. Mu and McGechan (1999) reported that the amount of nitrogen fixed in white clover-grass mixture had been estimated to be as high as 680 kgN/ha/yr although 50 to 250 kgN/ha/yr is more commonly achieved. The general decline in the dry matter yield of virtually all treatments from harvest 2 to 3 was caused more by a reduction in the dry matter yield of grass component. This may be due to inadequate soil nitrogen following removal through previous harvest, the s upposed contribution of the legume notwithstanding. Moreover, harvest 2 was followed by a period of consistent rainfall leading to flooding affecting a sizeable portion of the experimental n plots. Data on total dry matter yields indicate that grass monocultures produced higher yields than mixtures and monocultures of legumes. However, T8 (GC 2:2) and T9 (GC 3:1) gave higher total dry matter yields than the grass monoculture, this concurs with the result of Berhan (2006) who observed a higher dry matter yield in mixtures of *C. gayana* and *T. prantese* at 50:50 seeding ratio. Kechero (2008) also found that 3:1 mixture of Rhode grass and legume produced the highest dry matter yield.

The higher relative yield total values of grass observed in most of the treatments across the harvest as compared to legumes indicates that the grass contributed more to the total yield in those treatments. The reverse trend seen in some of the treatments with ratio 1:3 grass-legume mixture may be due to higher population of legumes resulting in higher competition for soil resources than the grass. Relative yield total value one suggest partial or no competition among species in the mixtures, probably made possible by the contribution of the legume to the environment of the grass via nitrogen fixation (Tessema and Baar, 2006) or simply the mixtures avoided competition due to different rooting pattern which may have avoided the uptake of resources from the same soil strata (Trenbath, 1974). Relative yield total of less than one connotes a situation where one species is or both are more affected than might be expected when there is crowding for the same space. Furthermore, competition in replacement series involving plant species which posses allelophathic activities may result in relative yield total of less than 1 (Eussen, 1979). Mean relative yield total values of all mixture treatments were greater than 1 which indicates the advantages of mixtures. Tessema and Baar (2006) reported that relative total yields of mixtures were greater than 1. Diriba (2002) also recorded relative total yield values of greater than 1 in *Panicum coloratum*-stylo mixtures. The almost highest mean total relative yield value recorded in T8 (GC 2:2) (1.4) suggests that total dry matter yield produced by mixture was higher than the respective grass monoculture.

Relative crowding coefficient (k value) measures the relative competitive ability of one species over another in a mixture. The higher total k value of grass observed in most treatments across the three harvests indicates the superior competitive ability of grass over legume. This agrees with the findings of Tessema and Baar (2006). Higher k values of legumes than grass observed in some of the treatments may be due to the higher proportion of the legumes in the mixtures which could out perform the grass thus making it less competitive. Mean k values of grass and legumes also followed a similar trend.

Aggresivity index measures the aggressiveness of one species towards another in a mixture. The more aggressive nature of grass at 2:2 and 3:1 grass-legume combination as well as that of legume at 1:3 grass- legume observed across harvests in most of the treatments suggest that either of the species may concede to the other in a lopsided seeding ratio that favors one against the other. The decrease in grass aggressivity towards legume with time observed in T8 (GC 2:2) and T9 (GC 3:1) indicates the development of a more compatible grass- legume mixture. Mean aggressivity index serves to confirm the trend in the 3 harvests. The dry matter yield of legumes in mixtures in aggregate terms is in the order stylo>burgundy>arachis>centro. Stylo was clearly the most productive of all the legumes, while centro recorded the least dry matter yield. However the lower yield produced by centro was compensated by higher dry matter yield of grass (guinea) in the guinea-centro mixtures. This suggests that centro was the most tolerant of all the legumes in the presence of grass. Moreover, the aggregate dry matter yield of grass in mixtures was in the order guinea-centro>guinea-arachis>guinea-burgundy>guinea-stylo. Based on the fact that guinea-centro mixtures 2:2 and 3:1 yielded more than their monocultures coupled with higher aggregate relative yield total observed in guinea-centro mixtures, one might suggest centro as the most suitable legume for grass-legume mixture.

## Conclusion

The essence of establishing grass-legume mixtures is to primarily improve the quality of the associated grass which usually contains crude protein below the level required for maintenance and animal production during a particular period of the year ( typical of tropical grasses), and also, to ensure yield stability through enhanced forage production. The result of the experiment revealed that guinea-centro (2:2 and 3:1) produced higher total dry matter yields than their respective monocultures. Mean relative total yield values were observed to be higher in guinea-Stylo (2:2) and guinea-centro (2:2) respectively. Aggressivity of grass towards legume in treatments 8 and 9 (GC 2:2 and GC 3:1) respectively decreased with harvest. Based on the foregoing result, the establishment of guinea-centro mixture at ratio 2:2 may be recommended for better compatibility taking into account the facts that this ratio produced higher dry matter yield than the corresponding grass monoculture among mixtures, the relative stability of the legume component as shown by the declining aggressivity of grass with harvest and also its almost highest RYT value of 1.4. 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. Moreover the nutritional qualities of the mixtures should be looked into in order to match compatibility with quality.

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