Journal of Animal &Plant Sciences, 2013. Vol.18, Issue 2: 2761-2774
Publication date 30/6/2013, http://www.m.elewa.org/JAPS; ISSN 2071-7024

Effect of relative proportion and density on competition between Speargrass (*Imperata cylindrical* (L.) Raeuschel) and Maize (*Zea mays* L.) in a moist savannah of Southwestern Nigeria

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Key words: Competition, Maize, Speargrass, Relative yield Total

1 SUMMARY

Speargrass (*Imperata cylindrica* (L.) Raeusch), is a major problem weed, causing severe yield losses in maize and other crops in the tropics, due it highly competitive ability over most crops. . A field study was conducted at International Institute of Tropical Agriculture (IITA) (7° 30'N, 3° 54'E), Ibadan, Nigeria between May 2001 and December 2002 to evaluate the competitive relationships between maize and speargrass grown together in replacement proportion. The trial was laid out as a randomized complete block design with the plant densities of 4, 8, 12, 16, 20, 32, 48 and 64 plants of either sole maize or speargrass per plot and in mixed proportions of 2:2, 4:4, 6:6, 8:8, 10:10, 16:16, 24:24 and 32:32 plants of maize and speargrass per plot, and replicated three times. Higher maize density caused speargrass biomass reduction of 41.0 to 55.0%. Interspecific competition caused maize grain yield reductions of 1.7 to 18.9% when speargrass densities were between 4 and 16 plants m^{-2}. Maize density beyond 8 plants m^{-2} caused grain yield loss of 7.6 to 47.9% plant^{-1} from intraspecific competition. Planting maize at densities between 50,000 and 80,000 plants/ha can enhance the relative competitive ability of maize against speargrass.

2 INTRODUCTION

Speargrass [*Imperata cylindrica* (L.) Rauesch.] is a rhizomatous, perennial grass weed, widely distributed throughout the tropics and in some warm areas of the temperate region (Holm *et al*, 1977). It has become a major problem in the production of arable crops such as maize, soybean, and root and tuber crops because most of the methods of control(hoe weeding, hand pulling and slashing) employed by farmers are not effective (Ogunyemi, 1977; Eussen *et al.*, 1976; Akobundu and Fagade, 1978). Yield loses attributed to speargrass infestation were ≥ 80% to 82% in maize (Lagoke, 1978; Lagoke and Fayemi, 1981), 78% in yam and cassava (Koch *et al.*, 1990; Udensi *et al.*, 1999; Chikoye *et al.*, 2000) and up to 41% in soybean (Avav, 2000). Control of speargrass in arable cropping system has often been very difficult due to high competitive ability of speargrass. The competitive ability, density of speargrass and the competitive ability of the crop influence the effect of speargrass competition on crop yield.

Information on competition studies of speargrass with maize is not available; most of the cases of speargrass interference reported are based on control efforts, none has critically looked at. total number of plants, proportion between/among the species, and spatial arrangement as suggested by Radosevich and Holt (1984).
of the studies on speargrass but were conducted to explore the relative aggressiveness of speargrass and certain crops in a natural vegetation of speargrass.. However, Eussen *et al*., (1976) in a pot experiment reported that maize responds to an increasing density of speargrass with a logarithm decrease in maize growth and biomass. The effect of speargrass on crop or other species depends on the density of speargrass and the associated crop or species. Quantitative study on the mechanism of competition between speargrass and maize is not well defined. Several experimental designs have been developed for quantifying competitive interactions among plants (Harper, 1977, Splitters, 1983; Radosevich and Holt, 1984). Such experimental procedures that may possibly be used to determine the degree of interaction resulting from maize and speargrass association include the replacement series and the addition series designs.With replacement series approach, the total density of species is maintained constant, while the proportion of the species is varied (Cousens, 1991; de Wit 1960; Rejmanek *et al*., 1989). On the other hand, the addition series considers an array of species densities in monoculture, total densities and proportions. Experiments using these designs have been used to determine which species is the stronger competitor, based on variables calculated from replacement series and addition series data. Among these variables, relative yield and relative yield total are frequently used to assess competiveness between species (de Wit, 1960; Hall, 1974; Snaydon, 1991).
Although several experiments have been conducted to explore the relative aggressiveness of speargrass and certain crops, few or none has been accomplished especially in West Africa and sub-Saharan Africa through the experimental manipulation of population density, proportion, or spatial arrangement. None has critically looked at maize–speargrass competition in addition series or replacement series, with the aim of evaluating effects of densities and proportions on competition of speargrass and maize under the field environment or conditions. Instead, most experimental studies and results on suppression were based on the observation of speargrass stands as they existed or as they responded to thinning, spacing or vegetation control. Therefore, the objective of the study was to evaluate the effect of relative proportions and densities of maize and speargrass, on the competitive ability and productivity of both species

3.0 MATERIALS AND METHODS

3.1 Pre-sprouting of rhizome segments in the screen house: The rhizomes used for this study were collected from naturally growing speargrass vegetation at Ijaiye (7° 35'N, 3° 55'E) in Oyo State, Southwestern Nigeria. . The rhizomes were washed to remove soil, and sectioned to about 5 cm length with one-node visible bud.The sectioned rhizomes were planted in large plastic pots of about 50 cm diameter to filled with 35 kg of sieved soil collected from the same site; and placed in screen house for 4 weeks to allow uniform sprouting of bud to occur and growth of young shoots . Minimum and maximum temperatures in the screen house were 30 °C and 35 °C. The rhizomes were presprouted because maize might germinate faster than the rhizomes.

3.2 Description of experimental site: The experiment was conducted on the research farm (Block ES21) of International Institute of Tropical Agriculture (IITA (7° 30'N, 3° 54'E),), Ibadan, in the forest/savanna transition zone of Nigeria. The site had been in fallow for about three years, except for routine mowing, and prior to the fallow period, it was cultivated to cassava. The site was dominated by *Panicum maximum* (Jacq.) at the time of the experiment. The soil type at the experimental site was loamy sand (Alfisol) with a pH of 6.7 and organic matter of <2%, 0.13% N, 3.08 mg/kg P (available), 0.34K (cmol), and soil texture of 85% sand, 5% clay, and 9% silt.

3.3 Field layout and experimental design: This study was conducted with maize and speargrass planted in a replacement proportion experiment and, the plots were laid out as a randomized complete block design and replicated three times. Each replicate had 16 treatments which includes, eight monocultures of maize (4:0, 8:0, 12:0, 16:0, 20:0, 32:0, 48:0, 64:0 per plot) and speargrass (0:4, 0:8, 0:12, 0:16, 0:20, 0:32, 0:48, 0:64 per plot), which were equivalent to 10,000, 20,000, 30,000, 40,000, 50,000; 80,000, 120,000, and 160,000 plants ha^{-1} of either of the species; and eight mixtures of maize: speargrass (2:2, 4:4, 6:6, 8:8, 10:10, 16:16, 24:24, 32:32 per plot of 2 m ×2 m). At the fourth week after pre-sprouting of the rhizomes, shoots of equal size were selected for transplanting to the field. A grid of 2 m × 2 m with 64 quadrilles of 25 × 25 cm each was used to plant both maize (cv. 'ACR 89-DMR-ESR-W' from IITA, Ibadan, Nigeria) and the sprouted speargrass rhizomes on the field on May 30, 2001 and on June 7, 2002 .The grid used for planting was superimposed on each treatment plot which was also 2 m × 2m, to ensure randomness and secondly remove the problem of spatial arrangement.(Radosevich *et al.*, 1997).The maize and speargrass were planted using the randomly chosen numbering of the grid to achieve the monoculture and mixture populations of maize and speargrass. One shoot of speargrass and two maize seeds were planted separately each in a quadrille according to the random number. Maize seedlings were thinned to one stand per hill one week after planting or transplanting.All plots were kept free of other weeds that may interfere with competition between the target species by weekly hand pulling of weeds. At one week after planting or transplanting, missing stands of both maize and speargrass seedlings were replaced to the appropriate plots to ensure that the required densities and proportions were maintained for the competition study. Basal fertilizer was applied at a recommended rate of 45 kg ha^{-1} of N, P_20_5, and K_20 at 2 WAP on 11 June 2001 and 21 June 2002, while urea at 45 kg N ha^{-1} was applied at 6 WAP, on 12 July 2001 and 19 July 2002. Both types of fertilizer were applied by broadcast to avoid disturbing the plants. Data were collected on plant height, leaf area, light interception, aboveground plant biomass, and maize grain yield. Monthly rainfall data were recorded near the experimental area (Figure 4).

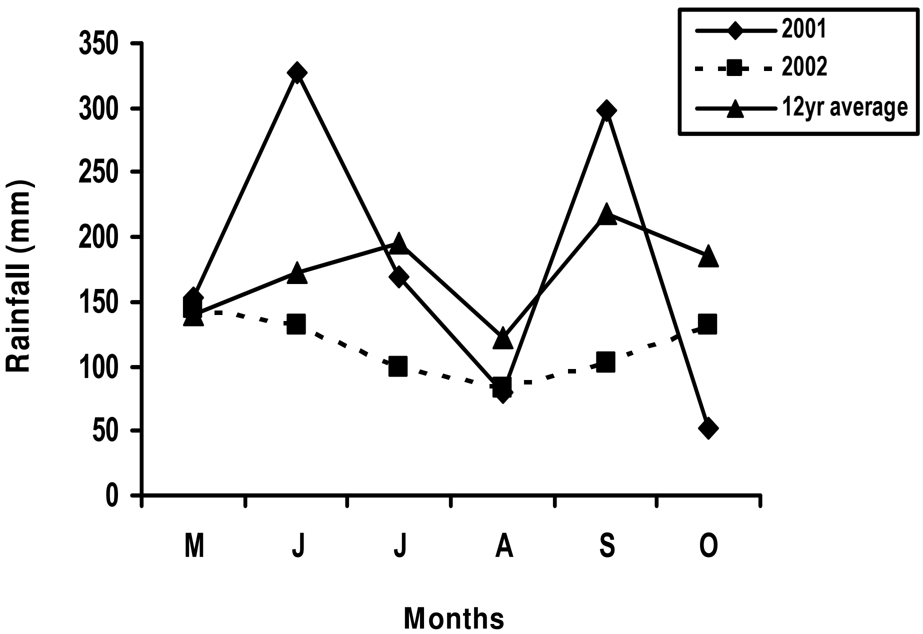

Figure 4: Monthly rainfall during 2001 and 2002 growing season, and mean monthly rainfall for 12 years.

3.4. Plant height and leaf area: Maize and speargrass height were taken in each plot by measuring ten plants at 50% maize silking (7 WAP) on 16 July 2001 and 25 July 2002. The average value of the ten plants measured represented the height per plant for each species

3.5 Light interception: Light interception as photosynthetic active radiation (PAR) was determined with 1-m long Decagon sunfleckceptometer (Decagon Devices, Inc., P O Box 835, Pullman, WA 99163 USA). Measurements of PAR at ground level and incident PAR above the maize canopy were made on a cloudless day between 11:00 and 14:00 h at 50% maize silking (7 WAP) on the same day that leaf area measurements were taken. Two diagonally crossed paired readings (four per plot) were taken from 10 cm above the ground in each plot and averaged to represent the below canopy reading. Two other readings, each one meter above the ground in the open without vegetation by each plot, were also taken and averaged to be the above canopy measurement.

The percentage of PAR intercepted (X) by the maize canopy was calculated as:

$X = [1-(B/A)] \times 100$………….. [1]

Where B is the PAR, umol m^{-2} s^{-1}, measured below the maize canopy 10 cm above the ground, A is the above maize canopy PAR reading, made in the open.

3.6 Plant biomass: Total above ground biomass of maize and speargrass were sampled from each plot at harvest on 12 September 2001 and on 17 September 2002. Maize plants were cut at the soil surface and individual plant of the total number of plants per plot weighed, and five plants selected at random were reweighed for biomass determination. Speargrass shoots in each plot were clipped at ground level and weighed, and a subsample taken for biomass determination. The average biomass value of total number of plants per plot represented the biomass per plant of each species. Samples were oven dried in a Gallenkamp oven (OVE–300 Plus Series) at 80 ^{o}C until constant mass was recorded with a digital balance (XD–4K B042809, Denver Instrument Company, USA).

3.7 Maize grain yield: Total maize ears per plant per plot were harvested for grain weight determination on the same day after total aboveground plant biomass was measured in both years. Grain weight was determined by drying harvested samples of maize ears at 65 ^{o}C for 48 hours in an oven. After shelling, moisture contents of grain samples were determined using the Tri-grain moisture tester (Model 14998 with Serial number 1170, Dickey-John Corporation Auburn, IL, 62615 USA). Grain yield in maize per hectare was computed and adjusted to 12 % moisture (moist) using the following formula.

Maize grain yield (kg ha^{-1}):

=Egwt*[(100-Moist)/88]*(10000)-------------[2]

Where Egwt=ear grain weight per plot, moist= grain moisture reading

3.9 Data analysis: ANOVA was performed using the MIXED MODEL and general linear model (GLM) procedures in the Statistical Analysis Systems software (SAS) (SAS, 1995; Littell *et al.*, 1996). In the mixed model procedure, years and replication were considered random effects in the model. Data were analyzed and presented by year. Least-square means of the individual treatment effects were compared using the contrast at P = 0.05 and standard error of the means in the LSMEANS output. Spearman's correlation analysis was performed to determine the relationship between speargrass biomass, speargrass shoot density and maize biomass, maize density, and maize grain yield.

4 RESULT

4.1 Plant shoot biomass and Light interception: In 2001, contrasts estimate indicated that the biomass of maize plants in monoculture and mixture with speargrass differed in some of the proportions. Maize biomass yield in mixture with speargrass was higher than maize biomass in monoculture. The differences were significant ($P \leq 0.05$) for maize and speargrass at the following density proportions, 2:2, 4:4, 6:6, 10:10, 16:16, and 32:32 plants per plot compared with their respective monocultures, but not for 8:8 and 24:24 plant proportions compared with the monoculture (Tables 7). Though maize plant biomass yield was high in mixture at all densities however, yield was lower as density increased beyond 20 plants per plot in both mixture and monoculture. Results for 2002 followed the same trend observed in 2001, and maize plant biomass was significantly ($P \leq 0.05$) higher in mixture than in monoculture for maize-speargrass at the following proportions, 2:2, 4:4, 10:10, 16:16, and 32:32 per plot.

When averaged over the years, maize biomass was higher in mixture than in monoculture, and the differences were significant for all densities ($P \leq 0.05$), except at 6:6, 8:8, and 24:24 plant proportions in mixture when compared with maize in monocultures at 12, 16, and 48 plant densities respectively ($P > 0.05$). Speargrass shoot biomass at all densities were higher in monoculture, than in mixture with maize in both years, except with maize and speargrass proportions at 10:10 plants each in mixture, where biomass was higher than in monoculture or sole maize density of 20:0 only in 2001 (Tables 7). Speargrass biomass in monoculture was higher, and significantly ($P \leq 0.05$) different from that of speargrass grown in mixture with maize at plant ratio of 4:4, 6:6, 8:8, 16:16, and 32:32 plants per plot in 2001, and significantly ($P=0.0002$ to 0.0125) higher than the biomass in mixture for species proportions of 2:2, 6:6, 8:8, 10:10, 16:16, and 32:32, plants per plot in 2002 (Tables 7). Averaged over the years, except with 2:2 plant species proportion, compared to the monoculture density at 4:0 plants, speargrass biomass in monoculture was higher than biomass in mixture with maize. The differences were however, significant only for significant for plant densities at 12:0, 16:0, 32:0, and 64:0 plants per plot compared to 6:6, 8:8, and 32:32 proportions in mixture ($P \leq 0.05$). Averaged over the years, lower maize densities in mixture with speargrass (2:2- 8:8 maize-speargrass per plot), reduced speargrass shoot biomass by 30% compared to pure stands of speargrass (0:4 -0:16 maize-speargrass per plot). At high maize density (10:10-32:32 maize -speargrass) in mixture, speargrass lost 47% shoot biomass compared to high speargrass density in monoculture (0:20–0:64) (Tables 7).

Percentage light interception as photosynthetic active radiation (PAR) increased significantly with increasing species proportion in the mixtures in both years (Table 7). The low densities of the species mixture (2-8 plants each of maize and speargrass) intercepted < 50% (29-47%, in 2001 and 22-40%, in 2002) of the incident PAR during the period of the study. The high densities of the species proportion in mixture (10-32 plants each of maize and speargrass in mixture) intercepted an amount of PAR > 50% (53-77%, in 2001 and 54-69% in 2002 (Table 7). Combined analysis of variance for the years indicated that higher densities of the species mixture significantly ($P<0.01$) intercepted incident PAR more than the low densities of the mixtures, mean PAR =48.9 ± 4.90 %. Maize biomass was negatively correlated with maize density in both years ($r = -0.74$, $P< 0.0001$, 2001 and $r = -0.64$, $P =0.0007$ in 2002) (Table 8).This relationship was linear ($r^2 =0.87$, $P=0.0006$, in 2001; $r^2 =0.85$, $P=0.0012$, in 2002) (Figure 5). This effect also reflected on the low biomass recorded by speargrass at high maize densities

TABLE 7: Effects of plant proportions and density on maize and speargrass shoot biomass, and PAR intercepted at Ibadan in 2001 and 2002

Mixture proportion		PAR interception		Plant shoot biomass			
				2001		2002	
Maize	Speargrass	2001	2002	Maize	Speargrass	Maize	Speargrass
-----No. per plot---		-<---------(%)------->		<----------------- (g-plant⁻¹)------------------------------->			
4	0	35.7	26.3	658.3	-	387.8	-
2	2	29.3	22.2	741.7	41.0	426.0	12.4
0	4	13.9	14.9	-	33.0	–	17.9
8	0	49.2	40.8	632.9	-	480.1	-
4	4	31.9	27.9	601.7	17.2	522.7	7.8
0	8	17.6	10.8	-	34.3	–	12.3
12	0	60.0	43.4	490.6	-	408.1	-
6	6	46.8	35.0	676.1	10.9	408.0	10.3
0	12	14.0	13.5	-	23.9	–	13.1
16	0	68.0	58.1	511.1	-	348.1	-
8	8	47.3	40.9	630.0	13.5	540.4	7.8
0	16	23.8	14.3	-	24.3	–	9.2
20	0	61.8	64.7	496.3	-	317.6	-
10	10	53.3	54.7	550.3	22.8	373.8	3.4
0	20	25.4	16.91	-	21.5	–	9.8
32	0	78.8	65.1	421.5	-	236.9	-
16	16	60.2	57.8	561.9	11.8	420.5	5.7
0	32	25.8	15.4	-	22.8	–	5.4
48	0	78.8	75.9	267.2	-	159.4	-
24	24	61.7	67.1	438.9	4.9	270.7	3.2
0	48	26.0	19.9	-	14.2	–	9.6
64	0	88.6	79.9	236.7	-	132.9	-
32	32	77.1	69.1	341.7	3.6	243.2	3.1
0	64	25.8	20.1	-	14.9		6.6
SE±		**6.56**	**3.92**	**47.9**	**3.99**	**37.7**	**1.72**

Contrast	<-------------------------------Probabilities > F				-->-
4:0 (0:4) vs 2:2	<.0001	<0.0001	0.0030	NS	0.0200	0.0004
8:0 (0:8) vs 4:4	<.0001	<0.0001	0.0017	0.0308	<.0001	NS
12:0 (0:12) vs 6:6	NS[1]	NS	0.0299	0.0053	NS	0.0099
16:0(0:16) vs 8:8	NS	0.0236	NS	0.0023	NS	0.0076
20:0 (0:20) vs 10:10	<.0001	<0.0001	0.0004	0.0635	0.0015	0.0125
32:0 (0:32) vs 16:16	<.0001	0.0005	0.0009	0.0072	0.0149	0.0002
48:0 (0:48) vs 24:24	0.0034	0.0004	NS	NS	NS	NS
64:0(0:64) vs 32:32	0.0003	<0.0001	0.0060	0.0012	<.0001	0.0002

[1]Figures in parenthesis refers to sole speargrass (or monoculture of speargrass)
[2]NS denotes not significantly different at P=0.05

Table 8. Relationship between maize and speargrass parameters at Ibadan in 2001 and 2002

Speargrass/maize	Maize plant biomass				Maize grain yield				Maize density			
	2001		**2002**		**2001**		**2002**		**2001**		**2002**	
	r	**P value**	**r**	**P value**	**r**	**P value**	**R**	**P value**	**r**	**P value**	**r**	**P value**
Shoot DW	-0.75	<.0001	-0.63	0.0008	-0.11	0.6046	-0.53	0.0075	-0.76	<.0001	-0.75	0.0001
Shoot density	-0.74	<.0001	-0.41	0.0462	-0.56	0.0038	-0.62	0.0014	0.91	<0.0001	0.83	<0.0001
Maize density	-0.74	<.0001	-0.64	0.0007	-0.55	0.0055	-0.69	0.0002	1.00	-	1.00	-

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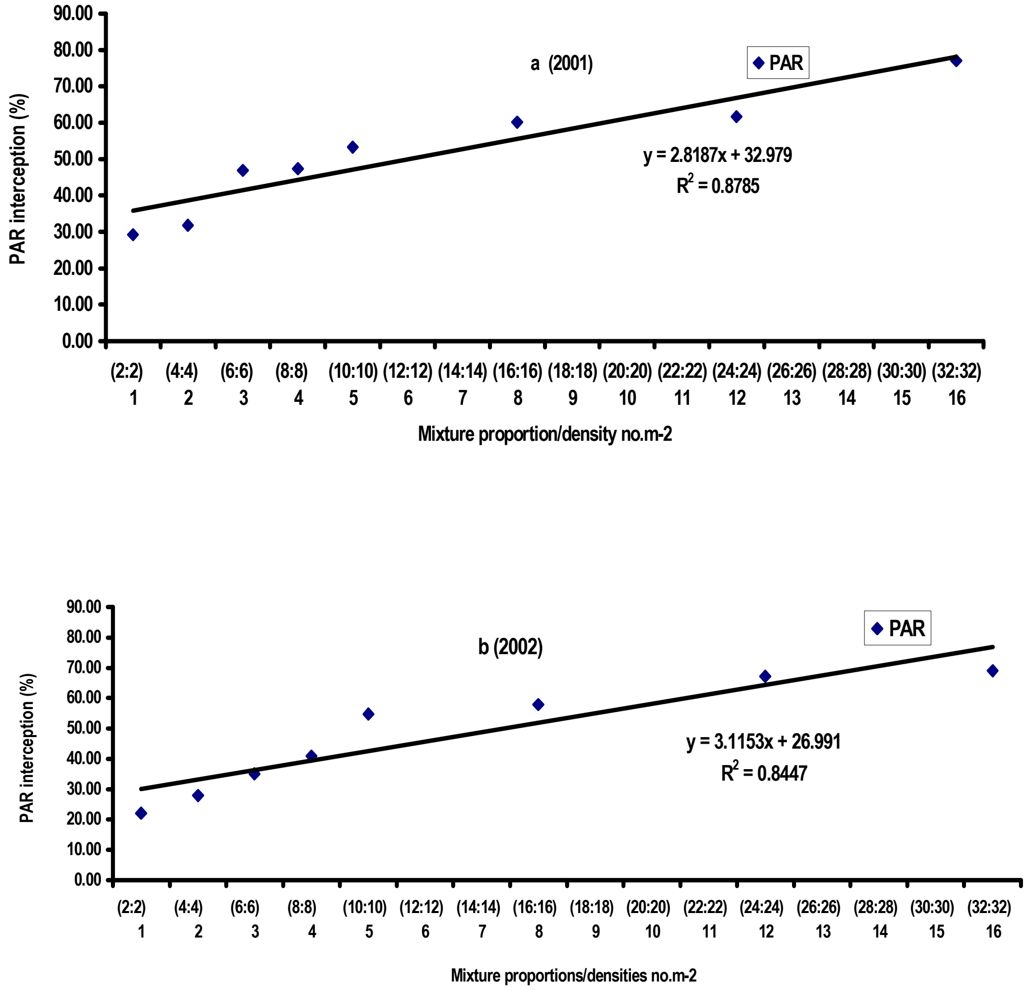

Figure 5 (a and b): Light interception as influenced by density and proportions

4.2 Grain yield kg ha^{-1}: Maize grain yield in mixture was significantly lower (about 16-52%) than the yield in monoculture (P<0.0001 to 0.0025), with species compared in replacement proportion) in 2001(Table 9). Percentage yield reduction with mixtures compared with sole was higher (≥41%) with the low densities of the maize and speargrass in a 4:4 to 10:10 mixture and 8:0-20:0 (sole) compared with the high densities of the species,) in a 16:16 to 32:32 (mixture) and 32:0 to 64:0(sole) which was lower (≥19 %) (Table 9). Maize grain yield in monoculture increased from 4:0 (1 plant m^{-2}) to 20:0 (5 plants m^{-2}) and started levelling from 32:0 (8 plants m^{-2}), after which it declined significantly at high densities of 48:0 (12 plants m^{-2})and 64:0 (16 plants m^{-2}) (Table 9).The effect on grain yield in 2002 was somehow similarities to that of 2001 (Table 9). There was a regular increase in maize grain yield from 2:2 to 8:8 species mixture, but this dropped at 10:10 species mixture below the yield at 8:8 mixtures. At 24:24 and 32:32 mixed proportions, grain yields also dropped slightly compared to the yield at 16:16 species mixture (Table 9).Maize grain yield was 23-42% higher in monoculture than in mixture at the following densities, 4:0(41.7%, P=0.0035), 8:0 (42.1%, P>0.05), 12:0 (36.7%, P<0.0001), 16:0(23.1%, P<0.0001) and 20:0(37.8%, P=0.0140) compared to 2:2 to 10:10 mixture.(Table 9). Grain yield was higher in mixture than in monoculture at these species proportions in mixture 16:16 (1.8%, P<.0001), 24:24 (32.4%, P<0.0001) and 32:32 (24.4%, P=0.0046), when compared to 32:0, 48:0, and 64:0 plants per plot in monoculture (Table 9).

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.Maize grain yield in monoculture increased as density in monoculture increased up to 32:0 monoculture density (8 plants m^{-2}), and yield dropped by 32% and 24% at 48:0 (12 plants m^{-2}) and 64:0 (16 plants m^{-2}) relative to grain yield in an 16:16 (8 plants m^{-2}) to 32:32 (16 plants m^{-2}) mixture.Averaged over the years, speargrass competition with maize reduced grain yield by23.8% (Table9).

Table 9. Effects of maize and speargrass proportions and density on maize grain yield at IITA, Ibadan in 2001 and 2002

		Maize grain yield	
Mixture proportion			
Maize	**Speargrass**	**2001**	**2002**
-----No. per plot---		<-----(kg ha^{-1})------>	
4	0	1337.5	1090.5
2	2	686.9	635.7
8	0	2957.4	2517.4
4	4	1428.5	1458.3
12	0	3623.3	3309.2
6	6	2102.8	2093.4
16	0	5074.3	4170.0
8	8	2916.8	3208.3
20	0	5710.9	4298.5
10	10	3194.9	2674.0
32	0	6849.7	4465.2
16	16	5182.6	4544.3
48	0	7013.4	3387.8
24	24	5805.5	4484.9
64	0	7282.8	3211.8
32	32	6110.6	3994.9
SE±		338.30	307.47
Contrast		<——--—Probabilities<F1———>	
4:0 (0:4) vs 2:2		<.0001	0.0035
8:0 (0:8) vs 4:4		<.0001	0.8515NS
12:0 (0:12) vs 6:6		<.0001	<.0001
16:0(0:16) vs 8:8		<.0001	<.0001
20:0 (0:20) vs 10:10		0.0025	0.0140
32:0 (0:32) vs 16:16		<.0001	<.0001
48:0 (0:48) vs 24:24		<.0001	<.0001
64:0(0:64) vs 32:32		<.0001	0.0046

[1]NS= Not significantly different at 0.05 level of probability

4.3 Plant height: Maize height measured at 7 weeks after planting (WAP) in pure stand, did not differ significantly (P>0.05) from maize height grown in mixture with speargrass, irrespective of densities in 2001 and 2002 (Table10). However, maize height was lower in mixture with speargrass in both years, except with plant densities at 16:16 species proportions in 2001, and 24:24 species proportion in 2001 and 2002, compared to pure stands of maize at 16:0 or 32:0 and 48:0 plant densities. The differences in maize height between monoculture and mixture were significant only in 2001 (P≤0.05) at plant density of 20:0 plants compared to 10:10 species proportion in mixture. Mean height of maize was 174.98 ±5.92, in 2001 and 173.76 ± 6.93 in 2002. (Table10).For speargrass, on the other hand, the overall effect was significant; generally, maximum height occurred with total population of 32 plants in 2001 and 2002 (P≤0.05). Speargrass was significantly taller only in monoculture at 0:8 plant density compared to 8:8 plant proportion in mixture in 2001 (P=0.0436) (Table 10). However, speargrass in mixture with maize at 2:2, 16:16, and 24:24 species proportions were taller in both years compared to speargrass in monoculture at 0:4 (P=0.0301, in 2002 only), 0:16 (P=0.0394, in 2001 only) and 0:48 (P>0.05) plant densities. In 2001, only shoots of speargarss planted in mixture with maize at 2:2 stands per plot has height comparable to the maximum obtained with mixture at 16:16 stands per plot. In 2002, mixtures 6:6 and 10:10 were shorter than the appropriate pure stands. Mixtures of 10:10 and 32:32 had shorter plants than their corresponding 0:20, 0:64 while pure stands of 32:0 were shorter than plant mixtures of 16:16 proportion. Similarly, speargrass grown in mixture with maize at species proportions of 8:8 plants were taller than speargrass in monoculture at 0:8 (P=0.0081) and 0:16 (P>0.05). In addition, speargrass in 6:6 mixed proportion was taller than speargrass at 0:12 density in monoculture (P=0.0365), while speargrass at 0:8 plant density in monoculture was significantly taller than speargrass grown in mixture with maize at 4:4 plant proportion only in 2002 (P=0.0070) (Table10). Mean speargrass height was 57.7 ± 4.15 in 2001 and 55.5 ± 4.55 in 2002.

TABLE 10. Effects of plant proportions and density of maize and speargrass on maize and speargrass leaf area and plant height (7 WAP) in 2001 and 2002

Proportions maize	Speargrass	**Plant height 2001**		**2002**	
-----No. per plot---		Maize	Speargrass	**Maize**	Speargrass
		<------------------ (cm plant^{-1}) ----------------. ->			
4	0	181.2	-	180.67	–
2	2	177.3	67.7	170.7	62.9
0	4	-	56.9	–	53.1
8	0	183.2	-	181.21	–
4	4	168.4	51.6	179.7	63.8
0	8	-	58.0	–	53.3
12	0	180.6	-	173.0	–
6	6	176.8	52.4	167.4	53.3
0	12	-	53.9	–	52.1
16	0	180.0	-	178.7	–
8	8	176.4	54.4	180.0	55.4
0	16	-	55.4	–	44.8
20	0	186.7	-	169.0	–
10	10	169.3	52.6	161.4	37.5
0	20	-	61.9	–	53.8
32	0	171.8	-	177.4	–
16	16	181.7	79.6	177.3	63.3
0	32	-	64.2	–	53.9
48	0	172.1	-	165.0	–
24	24	172.9	61.5	181.6	67.8
0	48	-	57.5	–	79.6
64	0	161.5	-	160.7	–
32	32	159.9	53.9	176.5	64.9
0	64	-	56.9	–	73.0
SE		5.92	4.15	6.95	4.55

Contrast	***Probabilities of F*** [1]

4:0 (0:4) vs 2:2	NS	NS	NS	0.0301
8:0 (0:8) vs 4:4	NS	NS	NS	0.0070
12:0 (0:12) vs 6:6	NS	NS	NS	0.0365
16:0(0:16) vs 8:8	NS	NS	NS	NS
20:0 (0:20) vs 10:10	0.0051	NS	NS	NS
32:0 (0:32) vs 16:16	NS	NS	NS	NS
48:0 (0:48) vs 24:24	NS	NS	NS	NS
64:0(0:64) vs 32:32	NS	NS	NS	NS

[1]NS= Not significantly different at 0.05 level of probability
– indicates where maize or speargrass is not applicable

5.0 DISCUSSION

The result from the relationship between maize biomass and maize density in this study indicates that maize responded more to density effect than to competition from speargrass. At high densities, especially in monoculture, plant biomass was reduced; this suggests that neighboring maize plants may have interfered with each other as space became limited due to overcrowding. At high density of, proportions in mixture, the effect of the associated speargrass also becomes important, though its effect on maize biomass was limiting due to the possible shading effect from the maize canopy at high densities. The greater competitive ability of maize over speargrass is related to its height, and the resultant shading effect on speargrass, which was lower in the canopy. Thus, more shading at higher proportions appears to have caused speargrass to be less competitive, especially at high densities of maize. Patterson (1980) and Santos *et al*.; (1997b), reported similar effects of reduced light availability on the competitive ability of purple nutsedge (*Cyperus rotundus*). This is clearly reflected in our observed negative correlation between maize density, maize yield per plant, and total above ground maize biomass. This same effect has been reported in a similar study for maize and proso millet (Radosevich *et al.*, 1997 in Wilson and Westra, 1991). Tokatlidis and Koutrousbas (2004) have also reported low yield potentials of maize at high density or population. Similarly, the consistent lower speargrass shoot biomass in mixture may be attributed to the shading effect of the maize canopy on the speargrass. This observation may be supported by the fact that speargrass shoot biomass was higher at low density proportions of the species mixture and lower at the high density proportions of the maize and speargrass mixture, due probably to greater neighborhood effect and intraspecific competition for the higher densities. This result is consistent with the report that maize-induced shading accounts for up to 50% reduction in weed biomass of the associated weeds (Tollenaar *et al.*, 1994). This result also showed that speargrass competition or interaction contributed to the low maize grain yield observed with some of the mixtures. One explanation for the observed trend in yield differences in mixture could be that at the low densities speargrass may not have suffered from the effect of maize canopy-induced shading, as may be the case at the high ratio of the species in mixture. This situation may have provided speargrass with an opportunity to compete more favourably with maize at low proportions than at high densities. High speargrass shoot biomass obtained at low maize density compared to the low shoot biomass at the high maize density is the evidence of shading effect. This result is consistent with earlier studies, which confirm low growth activity of speargrass in shaded condition (Eussen, 1981; Patterson, 1982). Taller speargrass plants were observed in mixture, especially at higher densities with maize. This effect could suggest etiolation, resulting from shading by the maize canopy and competition by the speargrass for light. Thus, the lower speargrass biomass observed in mixture, could be attributed to reduced PAR transmittance, because of interception by maize canopy. Previous research has also reported increased light interception at high maize density and its effect on associated weed growth (Tollenaar *et al.*, 1994; Murphy *et al.*, 1996). Speargrass being a C4 plant is likely to be less productive in terms of biomass accumulation under heavy maize canopy as provided by the high-density proportions of the mixture in this study. A similar effect of decreased total biomass of speargrass under shaded condition has been widely reported (Moosavi-nia and Dore, 1979; Patternson, 1980; Eussen, 1981; Macdicken *et* *al*., 1997) From the observation of the competitive relationship between speargrass and maize in this study, the general assumption is that in the early stage of growth, maize was more competitive; though speargrass may have picked up in later growth; maize yield was not significantly affected. The courses of development for the two species are probably not quite synchronous; hence, their peak demands may not have coincided. The maize cultivar, moreover, is an early-maturing cultivar. Speargrass, on the other hand, may not have started making demands on the environmental resources because of less rhizome biomass. Secondly, the proximity of the species may matter, because of the random planting pattern to reflect natural speargrass infestation. It is also remarkable to note that while speargrass was suppressed at a high density of mixture with maize, it did better in the lower density of the mixture, because shoots were greatly exposed to light. This suggests that, at low density, maize is likely to be more vulnerable to speargrass interference. Thus, unless speargrass is controlled, there is a distinct disadvantage to low maize density. Other weed-crop competition studies have reported similar results (Tanji *et al*., 1997).

6.0 CONCLUSION

The greater competitiveness of speargrass, as we observed, may be apparent only under conditions of relatively high speargrass infestation and long duration of competition. Slashing, often employed by farmers probably encourages higher speargrass rhizome activity, resulting in a more intense competition with associated crops. Speargrass is quite expensive to manage with a single control option. If effective control is required, integrated approach is the best option. In order to overcome constraints imposed by the unavailability of inputs and unstable economic policies in the agricultural sector, farmers should try to use or integrate a maize seeding rate that gives between 50,000 and 80,000 plants/ha. Such maize density maximizes the relative competitive ability of maize and minimizes the effect of speargrass, particularly in areas where farmers cannot afford to purchase herbicides and apply them correctly. However, the choice of seeding rate must be properly worked out, in view of intraspecific competition within the maize crop.

7.0 REFERENCE

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