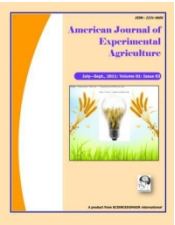

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Maize Response to Competition from Speargrass *(Imperata cylindrica* (L.) Raeuschel) Regrowth I: Species Growth Relationship, Yield and Yield Components

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Authors' contributions

This work was carried out in collaboration between all authors. Author UEU designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author OEB managed the data collection, and collation, author DC supervised the work. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Field study was conducted to evaluate the effect of speargrass shoot regrowth from previously planted rhizomes on the growth and yield of subsequent maize crop.
This study was evaluated in a Randomized Complete Block Design with three replications. The study was conducted at the International Institute of Tropical Agriculture Ibadan, Nigeria, between September 2005 and September 2006.
In this study maize and speargrass were monitored in eight monoculture densities (4, 8, 12, 16, 20, 32, 48 and 64 plants per plot and eight total densities in a mixture of 1:1 ratio of maize and speargrass (2:2-32:32) per plot.
Results suggest that both, maize and speargrass competed for the same resources. However, maize was more competitive than speargrass in 1:1 mixture. Intraspecific competition between maize plants was responsible for maize grain yield loss of about

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28.4%, while the overall interspecific competition effect from speargrass regrowth densities was responsible for a yield of about 18%. There was high and significant negative correlation between speargrass parameters and maize grain yield (r≥-0.56≤-0.78) and maize biomass per plant (r≥-0.49≤-0.67). For speargrass, interspecific competition was greater than intraspecific competition causing a speargrass biomass loss of about 35% from maize competition; while intraspecific competition accounted for about 17.9% biomass reduction. Speargrass densities of 8-16 plants m^{-2}, in mixture with maize had enormous rhizome biomass, and hence caused a grain yield reduction of 43% due to vigorous regrowth. Farmers should try to use optimum maize population that will give between 5 and 6 plants m^{-2}; this will reduce the effect of speargrass regrowth from the rhizome, especially where land preparation is by slashing.

Keywords: Competition; yield; speargrass regrowth; rhizomes; biomass.

1. INTRODUCTION

Maize [*Zea mays* (L.)] is an important food staple for more than 1 billion people in Sub-Saharan Africa, and a preferred crop of 900 million of the world poor. In most developing countries it is grown in mixture with other crops or as sole crop [1]. Aggregated production especially in West Africa has shown an increase of about 73% between the 1980s and 2000s [2]. However, this increase is due to expansion in the area under cultivation while productivity per unit area is still very low (0.5-1.0ton/ha) due to several agro ecological factors including weeds infestation. Maize is sensitive to weed competition especially in the first 3 weeks after emergence [3]. Although maize is a vigorous and tall growing plant, it is susceptible to competition from weeds, with losses greater than 30% commonly reported [4]. Maize is a high- risk crop, mainly due to the varying climatic conditions as well as inadequate management practices. Researchers indicate that maize plants are very susceptible to weed competition and yield losses are estimated at 35% to complete crop failure [5]. To obtain high crop yields weed control is very important because weed compete with maize for nutrients, soil moisture and light. Therefore, information on interaction between speargrass [*Imperata cylindrical* (L.) Raueschel] and maize will be useful for developing and implementing effective management programs. Speargrass *[Imperata cylindrical* (L.) Rauesch] is a rhizomatous perennial grass weed, widely distributed throughout the tropics and in some warm areas of the temperate region [6]. It has become a major problem in the production of arable crops such as maize, soybean, and root and tuber crops in forest transition zone of West Africa [7,8]. Most of the methods of speargrass control (hoe weeding, hand pulling and slashing) employed by rural farmers are not effective, because of its ability to infest, spread and colonize native vegetation [9,10,11,12]. Yield loses attributed to speargrass infestation in maize has been reported to be between 40 and 80% [13,14,8,15]. The density of speargrass and the competitive ability of the crop influence the effect of speargrass competition on crop yield. Most experiments on speargrass have been conducted to explore its relative aggressiveness on certain crops [15] and few have been accomplished through the experimental manipulation of population crop density, proportion, or spatial arrangement [16]. However, none have critically looked at the interaction between speargrass shoot regrowth and maize densities and proportion with the aim of evaluating effects of densities and proportions of speargrass shoot regrowth on maize under the field environment or conditions.

It is therefore the objective of this experiment to assess the competitive ability of maize against speargrass regrowth from manipulated densities

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted at the research farm of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (7°30'N, 3°54'E), in the forest/savanna transition zone. The zone is characterized by an annual rainfall that averaged 1250 and 1500mm with a bimodal distribution pattern which peaks in July and September. Before monitoring the effect of speargrass regrowth on maize, the site has been under speargrass fallow for four months. 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, 3.08mg/kg P (available), 0.34K (cmol), and soil texture of 85% sand, 5% clay, and 9% silt. The average annual temperature is 26ºC and dominant soil type is Alfisol [17,8]

2.2 Experimental Procedure and Design

The speargrass for this study was initially planted on the 25th of May 2005, and May 30th, 2006 in both addition and replacement series experiments [18] from sprouted rhizomes using a grid of 2m by 2m with 64 quadrilles of 25cm by 25cm. Its competitive effect on maize growth was monitored. Previous treatment consisted of three replicates of 16 established densities as monoculture and maize: speargrass mixtures. Eight monocultures of maize and speargrass at the following densities (4, 8, 12, 16, 20, 32, 48, 64) and eight mixtures (2:2, 4:4, 6:6, 8:8, 10:10, 16:16, 24:24, 32:32) per plot of 2m×2m were included in the experiment. All the plots were slashed immediately after harvesting of previous maize (approximately 4 months after maize planting), and maize stover and speargrass shoots packed out of the plots on September 20, 2005 and September 25, 2006 respectively. The same grid of 2 m×2m with 64 quadrilles of 25×25cm was used to replant maize (cv. 'ACR 89-DMR-ESR-W') in all the plots, which included plots previously planted to sole maize and speargrass; and plots that had maize and speargrass in mixture in September 25, 2005 and September 30, 2006. The regrowth experiment was also conducted with three replicates in a randomized complete block design. Each replicate included the same 16 treatments: eight monocultures of maize (4:0, 8:0, 12:0, 16:0, 20:0, 32:0, 48:0, 64:0 plants per plot) replanted in the same plot they were planted earlier (May 25, 2005 and May 30, 2006), while speargrass monoculture plots were allowed to regrow from the previously planted densities (0:4, 0:8, 0:12, 0:16, 0:20, 0:32, 0:48, 0:64 plants per plot) in September 25, 2005 and September 30, 2006. For the eight mixtures of maize: Speargrass, maize was also replanted into each plot that had the maize: speargrass mixture of various densities and proportions to simulate the treatment arrangement of the experiment earlier in the season. (2:2, 4:4, 6:6, 8:8, 10:10, 16:16, 24:24, 32:32 per plot). Maize seedlings were thinned to one stand per hill one week after planting. All plots were kept free of other weeds that may interfere with competition between the target species by weekly hand pulling of weeds. Basal fertilizer was applied at a recommended rate of 45 kg ha^{-1} of N, P_20_5, and K_20 at 2 weeks after planting (WAP) on October 9, 2005 and October 14, 2006, while urea at 45 kg N ha^{-1} was applied at 6 WAP, on 30 October 2005 and October 30 2006. Both types of fertilizers were applied broadcast.

2.3 Data Collection

In both years data were collected on height, leaf area and photosynthetic active radiation (PAR) of both species at 50% maize silking (7 WAP), on 15 November 2005 and 20 November 2006. Leaf area of each plant or species was determined 50% silking from an average value of five plants measured per plot with LI-3000 portable leaf area meter with head scanner PAM 1684, (LI-COR, Inc., P. O. Box 4425, Lincoln, N668504 USA). PAR interception was determined with 1-m long Decagon sunfleck ceptometer (Decagon Devices, Inc., P. O. Box 835, Pullman, WA 99163 USA) at ground level and above the maize canopy on a cloudless day between 12:00 and 14:00h. at 50% maize silking (7 WAP). An average of four reading per treatment from each replicate was used to obtain treatment mean.

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

$$X = [1 - (B/A)] \times 100 \quad \ldots\ldots\ldots\ldots [1]$$

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

Similarly data was collected on, total above ground biomass of both species by cutting at the soil surface, and below ground biomass of speargrass (rhizomes) on 27 December 2005 and on 30 December 2006. An area of $2m^{-2}$ of was harvested from each plot for the determination of total above biomass of maize and speargrass, and grain yield. Maize grain yield was adjusted to 12% moisture content using the Tri-grain moisture tester (Model 14998 with Serial number 1170, Dickey-John Corporation Auburn, IL, 62615 USA). Both maize and speargrass plant samples were oven dried in a Gallenkamp oven (OVE–300 plus Series) at 80ºC until constant mass and dry biomass was recorded with a digital balance (XD–4K B042809, Denver Instrument Company, USA).

2.4 Data Analysis

All the data collected was analyzed by year, except for correlation between maize and speargrass parameters. ANOVA was performed using the MIXED MODEL and general linear model (GLM) procedures in the Statistical Analysis Systems software (SAS) [19,20]. 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 separated 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. In addition, combined multiple correlation and regression analysis were performed to determine the relationship between speargrass and maize attributes perceived to be competitive indicators/characters.

3. RESULTS

3.1 Maize and Speargrass Biomass

In 2005, maize shoot biomass was higher in mixture with speargrass than in monoculture, but the differences were not significant (P>0.05) (Table 1). However, maize total plant biomass yield was significantly higher for 4 (P=0.0194) and 32 (P=0.0060) plants per plot in

monoculture compared to mixture yield at the same density (Table 1). Contrast estimate in 2006 indicated that maize biomass was significantly higher in mixture than in monoculture ($P \leq 0.05$) at all densities except at 6:6 plant proportions of both maize and speargrass, compared to 12:0 of maize: speargrass, ($P=0.0104$). However, in 2006 maize plant biomass was higher in monoculture at the following densities: 4 ($P \leq 0.05$), 16 ($P > 0.05$), and 32 ($P \leq 0.05$) per plot compared to their 1:1 mixed ratio (Table1). In both years, except at speargrass density of 12 plants in 2006, when compared to 6:6 maize: speargrass plant proportions ($P=0.052$) per plot; speargrass shoot biomass was significantly higher in monoculture than in mixture (Table 1) in replacement series.

Table 1. Effects of speargrass regrowth on maize and speargrass biomass

		Biomass per plant			
Proportions		Maize		Speargrass	
Maize	Speargrass	2005	2006	2005	2006
-----No. per plot---		<----------(g plant^{-1})---------- ------->			
4	0	700.86	359.42	-	-
2	2	787.00	435.33	285.56	154.64
0	4	-	-	398.70	324.24
8	0	663.33	241.64	-	-
4	4	640.83	325.50	151.74	123.60
0	8	-	-	249.46	229.32
12	0	538.53	253.97	-	-
6	6	607.56	245.28	98.55	318.17
0	12	-	-	270.44	163.28
16	0	431.11	249.26	-	-
8	8	775.83	276.92	110.73	143.29
0	16	-	-	190.98	133.89
20	0	455.88	214.85	-	-
10	10	558.60	227.45	82.67	86.96
0	20	-	-	187.72	149.35
32	0	381.93	165.68	-	-
16	16	521.12	188.04	42.00	35.88
0	32	-	-	120.49	85.19
48	0	289.23	104.17	-	-
24	24	453.82	162.40	27.00	19.34
0	48	-	-	101.72	64.87
64	0	190.40	89.88	-	-
32	32	313.54	119.43	16.33	21.29
0	64	-	-	82.44	52.07
SE±		77.4	28.6	36.96	46.78
Contrast		<----------*Probability < F1*---------->			
4:0 (0:4) vs 4:4		0.0194	0.0046	<.0001	0.0567
8:0 (0:8) vs 8:8		NS	NS	0.0645	NS
16:0(0:16)vs 16:16		NS	NS	NS	NS
32:0(0:32) vs 32:32		0.0060	0.0080	<.0001	0.0085
4:0 (0:4) vs 2:2		0.0323	0.0118	0.0006	NS
8:0 (0:8) vs 4:4		0.0296	0.0008	0.0051	NS
12:0(0:12) vs 6:6		0.0193	0.0104	0.0028	0.0521
16:0(0:16) vs 8:8		NS	0.0019	0.0022	NS
20:0 (0:20) vs 10:10		0.0211	0.0042	NS	NS
32:0 (0:32) vs 16:16		NS	0.0484	<.0001	0.0040
48:0 (0:48) vs 24:24		NS	<.0001	NS	0.0003
64:0(0:64) vs 32:32		0.0060	0.0080	<.0001	0.0085

[1]*NS denotes not significant at the 5 % level of probability;– indicates where maize or speargrass is not applicable*

All the speargrass parameters considered via density; shoot weight, rhizome weight and total dry weight as well as maize density were negatively correlated with maize biomass, respectively(r=-0.49, r=-0.45, r=-0.67, r=-0.64 and r=-0.58) (Table 2). The relationship between speargrass parameters and maize density was significant in both years except for maize density and speargrass shoot biomass in 2006 (*P*=0.0967) (Table 3). Similarly, the relationship between speargrass parameters and maize height was significant in 2005 (*P*=0.001), and significant for only speargrass rhizome biomass in 2006 (*P* =0.009) (Table 3).

Table 2. Relationship among maize and speargrass parameters at Ibadan, (means of 2005 and 2006 combined)

Speargrass/maize density	Maize biomass		Maize grain yield		Maize density	
	r	P value	r	P value	r	P value
Shoot biomass.	-0.45	0012	-0.56	<.0001	-0.74	<.0001
Shoot density	-0.49	0.0004	-0.73	<.0001	0.16	0.2817
Rhizome biomass	-0.67	<.0001	-0.78	<.0001	-0.89	<.0001
Total speargrass dwt (shoot + rhizome)	-0.64	<.0001	-0.72	<.0001	-0.86	<.0001
Maize density	-0.58	<.0001	-0.62	<.0001	1.00	-

3.2 Plant Leaf Area and Height

Leaf area of maize per plant in monoculture was not significantly different from maize leaf area grown in mixture with speargrass in both years (P>0.05), except at t the density of 8:0 maize plant per plot in comparison to 8:8 mixtures in both years (P=0.033). The effect of species competition on speargrass leaf area was significant only in 2005 (P=0.055). Speargrass leaf area per plant was consistently higher at all densities in monoculture than in mixture with maize in both years, except at 8:0 and 16:0 speargrass density per plot (Table 4). Averaged over the years, speargrass leaf area was significantly higher only at 12:0 plants density in monoculture compared to 6:6 proportion in mixture (P=0.004), and higher at 8:8 plant densities proportion in mixture compared to 16:0 plant density in monoculture (P=0.022). Maize height did not differ in monoculture and in mixture with speargrass in 2005. However, maize grown in mixture with speargrass at various species proportions were shorter except at densities of 2:2 and 24:24 where maize was taller than in monoculture (P=0.051) in 2005 (Table 4). Maize and speargrass at 8:8 and 24:24 plant proportions were significantly taller than maize at 8:0 (P=0.031) and 48:0 plant densities and proportions in 2006 (P=0.043) (Table 4). The proportions of maize and speargrass densities in mixture affected speargrass height significantly, compared to speargrass height in pure stand or monoculture in both years (P=0.05).

3.3 Maize Grain Yield (Kg Ha^{-1})

Maize grain yield was significantly higher in monoculture at all densities, compared to yields in mixture at all proportions in 2005 (*P*=0.004). Yield in both monoculture and mixture increased with increasing species densities. Differences in grain yield between monoculture and mixture were higher (≥41%) at low proportion of species in mixture (2:2–8:8), and lower (≥15–29%) at high proportion of species in mixture (16:16–32:32) (Table 5). When the interaction between maize and speargrass is averaged over densities in monoculture and species proportion in mixture, maize and speargrass association resulted in 36% maize yield

loss with replacement series analysis. Yield was also higher in monoculture, compared to mixture for the densities considered in addition series (*P*=0.001), and yield differences between monoculture and mixture were also higher (≥7–18%) at low densities, and lower (4%) at high densities (Table 5). Irrespective of the method of analysis, speargrass competition with maize in 2005 resulted in a 22% maize yield reduction. The effect of speargrass competition with maize on maize grain yield in 2006 followed the same trend as in 2005. In monoculture, maize yield increased with increasing density up to the density of 32:0 (8 plants m^{-2}) and started dropping from the density of 48:0 (12 plants m^{-2}) to 64:0 (16 plants m^{-2}) which is an indication of interference, possible resulting from neighbouring maize plants (intraspecies completion)(Table 5). Similarly, grain yield in mixture with speargrass increased with increasing species proportions in mixture, but dropped at 10:10 and 32:32 plant proportions in mixture. Maize grain yield was significantly higher in monoculture at 4:0, 12:0, 16:0, 20:0, 32:0, 64:0 (*P*=0.05) and 8:0 (P>0.05) compared to mixture with half of each species in 2006 ; and yields were lower by 5% in monoculture for 48:0 plant density compared to 24:24 proportion of the plant species in mixture (*P*=0.013) in 2006 (Table 5). Maize yield was 6.49 and 26% higher in 4:4 and 8:8 plants species mixture compared to 4:0 (*P*=0.005) and 8:0 (*P*<0.001) plant densities in monoculture in 2006 (Table 5). However, yields at 16:0 and 32:0 plants in 2006 in monoculture, were significantly higher by 24% and 32% than yields in 16:16 and 32:32 of the plant species in mixture (*P*=0.05). The overall competition effect indicates a 16% grain yield reduction in maize resulting from speargrass interaction with maize in 2006.

Table 3. Estimates of regression parameter for speargrass attributes as a linear function of maize density and maize height in a maize-speargrass competition experiment

	Maize							
	2005				2006			
	B_0[a]	B_1[b]	B_0	B_2[c]	B_0	B_1	B_0	B_2
Shoot biomass								
Estimates	109.418	-0.962	-400.03	2.667	127.494	-1.049	178.53	-0.728
Standard error	13.506	0.212	127.700	0.731	38.868	0.605	236.05	1.638
Pr > |t|	<.0001	0.0002	0.0046	0.0014	0.0034	0.0967	0.4575	0.6609
R^2	0.48		0.38		0.12		0.01	
Rhizome biomass								
Estimates	74.752	-0.674	-262.68	1.756	67.286	-0.56	-109.99	1.038
Standard error	9.559	0.150	92.506	0.534	7.338	0.114	51.828	0.359
Pr > |t|	<.0001	0.0002	0.0095	0.0033	<.0001	<.0001	0.0453	0.0086
R^2	0.48		0.33		0.52		0.27	
Total speargrass dwt.								
Estimates	184.171	-1.636	-662.72	4.423	194.78	-1.611	68.546	0.310
Standard error	22.753	0.358	216.907	1.251	36.588	0.569	244.310	1.695
Pr > |t|	<.0001	0.0001	0.0058	0.0019	<.0001	0.0097	0.7817	0.8568
R^2	0.49		0.36		0.27		0.002	

[a]B_0 is an intercept .[b]B_1 is density.[c]B_2 is height

Table 4. Effects of speargrass shoot regrowth from previous density and proportion on maize and speargrass leaf area and height at 7WAP in 2005 and 2006

		Leaf area per plant				Plant height			
Proportions		Maize		Speargrass		Maize		Speargrass	
Maize	Imperata	2005	2006	2005	2006	2005	2006	2005	2006
-----No. per plot--		----------(Cm^2 $plant^{-1}$)----------				----------(Cm $plant^{-1}$)----------			
4	0	2516.1	1639.99		-	171.0	142.4	-	-
2	2	2312.6	1909.86	178.13	256.78	191.7	165.8	47.2	79.9
0	4	-	-	285.52	307.35	-	-	60.3	84.0
8	0	2094.7	1623.89	-	-	174.3	149.3	-	-
4	4	2892.8	1679.85	174.77	289.10	180.3	151.3	50.5	74.9
0	8	-	-	222.99	285.67	-	-	49.4	83.4
12	0	2032.5	1338.87	-	-	178.8	133.8	-	-
6	6	2017.3	1448.72	207.44	263.70	176.9	136.6	59.5	74.2
0	12	-	-	242.27	294.85	-	-	67.7	83.7
16	0	2042.3	1703.50	-	-	170.7	148.3	-	-
8	8	2066.2	1615.22	254.60	286.83	163.9	151.8	60.0	79.8
0	16	-	-	234.29	282.18	-	-	67.9	87.4
20	0	2034.3	1520.68	-	-	173.3	146.5	-	-
10	10	2270.7	1369.40	236.44	190.56	163.9	126.1	50.1	68.9
0	20	-	-	376.97	277.51	-	-	70.2	89.3
32	0	2003.7	1495.48	-	-	170.9	139.8	-	-
16	16	2627.6	1705.44	192.74	263.78	169.7	137.9	59.5	73.3
0	32	--	-	362.19	278.43	-	-	74.5	84.5
48	0	1984.0	1269.15	-	-	168.3	133.7	-	-
24	24	1814.5	1433.26	181.91	211.62	172.5	142.8	58.6	82.7
0	48	-	-	265.42	237.38	-	-	63.3	82.1
64	0	1723.7	1225.56	-	-	164.3	132.9	-	-
32	32	1669.3	1326.07	148.65	238.94	164.0	134.1	60.2	82.6
0	64		-	355.21	242.56	-	-	73.3	81.5
SE±		304.03	166.27	52.08	35.90	7.3	6.2	5.0	3.9
Contrast		<--_-----_----------Probability < F^{1}----------->-							
4:0 (0:4) vs 4:4		NS	NS	NS	NS	NS	NS	NS	0.044
8:0 (0:8) vs 8:8		0.0328	0.0434	NS	NS	NS	0.031	0.007	NS
16:0(0:16)vs 16:16		NS	NS	0.0071	NS	NS	NS	0.001	0.059
32:0(0:32) vs 32:32		NS	NS	NS	NS	NS	NS	NS	NS
4:0 (0:4) vs 2:2		NS	NS	NS	0.0052	NS	NS	0.018	0.005
8:0 (0:8) vs 4:4		NS	NS	NS	NS	NS	NS	NS	0.007
12:0(0:12) vs 6:6		NS	NS	0.0053	NS	NS	NS	NS	NS
16:0(0:16) vs 8:8		NS	NS	0.0081	NS	NS	NS	0.0006	NS
20:0 (0:20) vs 10:10		NS	NS	NS	NS	NS	NS	NS	NS
32:0 (0:32) vs 16:16		NS	NS	NS	NS	NS	NS	NS	0.073
48:0 (0:48) vs 24:24		NS	NS	0.0301	NS	0.051	0.043	0.059	NS
64:0(0:64) vs 32:32		NS	NS	NS	NS	NS	NS	NS	NS

[1]*NS denotes not significant at the 5 % level of probability – indicates where maize or speargrass is not applicable*

Table 5. Effects of speargrass regrowth densities and proportions on maize grain yield at Ibadan in 2005 and 2006

Mixture proportion		Maize grain yield	
Maize	**Speargrass**	**2005**	**2006**
-----No. per plot---		**<----(Kg ha^{-1})----->**	
4	0	1499.61	944.76
2	2	882.78	654.60
8	0	2768.15	1425.76
4	4	1226.96	1010.35
12	0	3302.38	2479.37
6	6	1917.66	1228.48
16	0	3588.60	3002.78
8	8	2547.80	1926.63
20	0	4792.67	3170.40
10	10	2939.36	1614.49
32	0	5651.27	3446.82
16	16	3467.39	2295.99
48	0	5795.89	2632.43
24	24	4174.79	2755.67
64	0	6405.92	2448.74
32	32	5441.79	2333.29
SE±		420.56	254.17
Contrast		<---------Probability > F---------->	
4:0 (0:4) vs 4:4		< 0.0001	0.0049
8:0 (0:8) vs 8:8		0.0004	0.0001
16:0(0:16) vs 16:16		0.0060	0.0034
32:0(0:32) vs 32:32		0.0041	0.0193
4:0 (0:4) vs 2:2		< 0.0001	0.0403
8:0 (0:8) vs 4:4		< 0.0001	NS
12:0 (0:12) vs 6:6		0.0004	<0.0001
16:0(0:16) vs 8:8		0.0002	0.0006
20:0 (0:20) vs 10:10		0.0044	0.0396
32:0 (0:32) vs 16:16		0.0002	<0.0001
48:0 (0:48) vs 24:24		0.0011	0.0286
64:0(0:64) vs 32:32		0.0041	0.0193

3.4 Light Interception

Light interception increased with increasing species density and proportion in the mixture in both years (P=0.001), in 2005 and P=0.064, in 2006). Densities of 2-8 plants of each species in mixture intercepted ≤ 40% (13-40%) of the incident PAR in 2005, while the densities of 10-32 plants of each species in the mixture intercepted ≥ 46% (46-77%) of the incident PAR received by the canopy in 2005 (Fig. 1). However, in 2006, the PAR interception was more variable among the proportions compared to 2005. Maize-speargrass mixture at 2-8 plants of each species per plot intercepted between 35 and 53%, while for the densities at 10-32 plants of each species in mixture per plot, incident PAR interception by the canopy was between 37 and 76% in 2006 (Fig. 1). Averaged over the years, percentage PAR interception was significantly (P=0.05) different between the various densities in mixture.

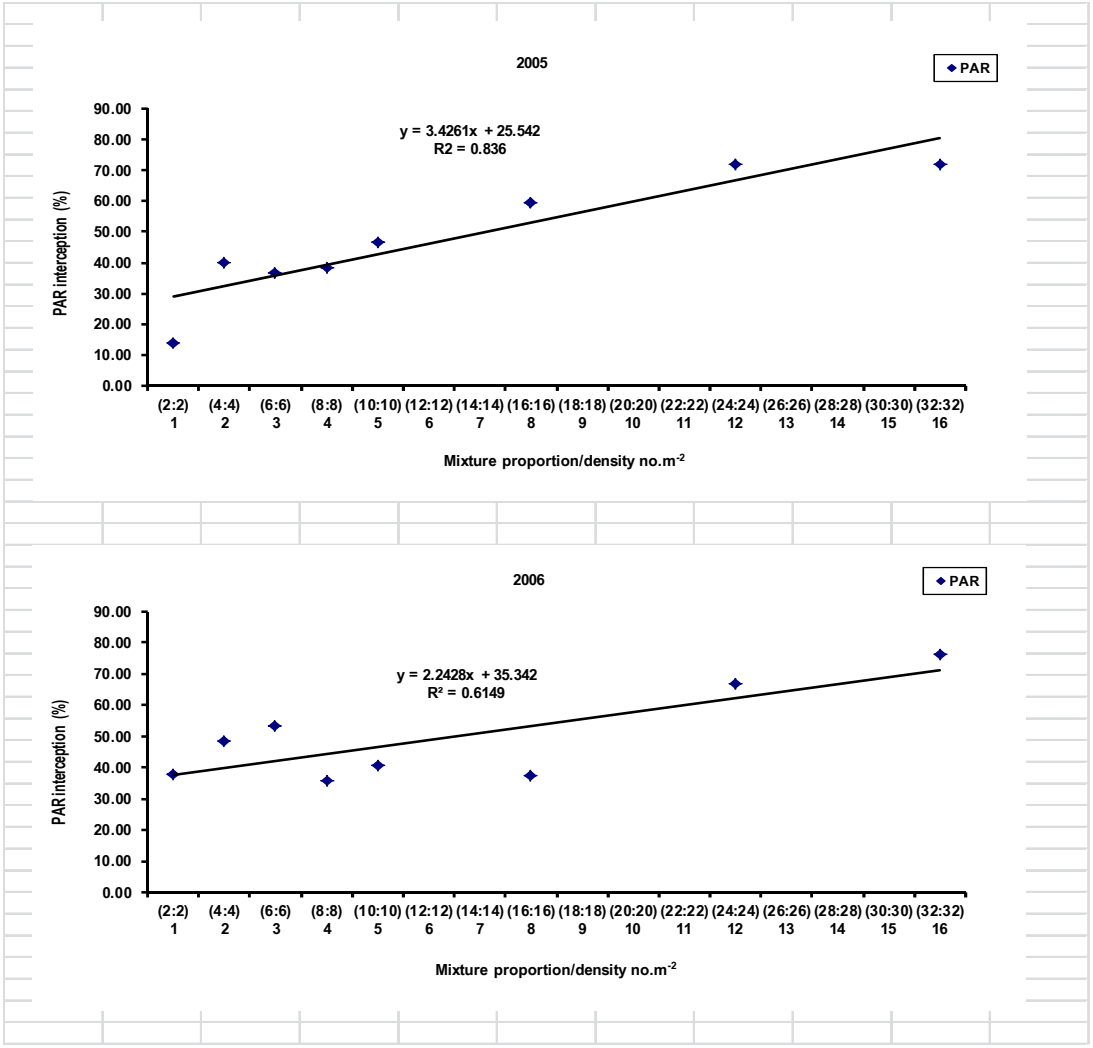

Fig. 1. Light interception by maize and speargrass proportions at various densities in 2005 and 2006

4. DISCUSSION

The effect of competition from speargrass shoot regrowth affected the growth and development of both species in pure or mixed cultures. However, maize also responded to density. The relationship between maize density and PAR in both years indicates that the slopes of the lines were positive. This means that as maize density increases, so does its ability to intercept PAR, and this in turn affects speargrass, being a shade-intolerant plant [21]. Hence the negative slope observed in the relationship between maize density and speargrass biomass in this study. The result means that increasing maize density further will result in an average increase of PAR interception by 0.35 times, and this will translate into an average loss of speargrass shoot biomass by 1.01 times, rhizomes by 0.62 times, and total biomass by 1.62 times. Thus, the competitive ability of speargrass was enhanced at a lower density of maize; this is evident in the higher speargrass biomass (≥100g per plant) at lower maize densities in mixture (2:2-8:8) compared to speargrass biomass at higher maize density (10:10-32:32) interaction in mixture (≤87g per plant). The observed antagonistic effect between maize and speargrass is attributable to severe competition for light, which is evident by the intensity of competition at high maize densities. All speargrass attributes measured were negatively related to maize density due to competition for light. These results are in agreement with similar studies that report on nutsedge competition with maize and tomato [22,23]. Similar competition for light resources between spring barley and weeds has been reported [24]. Since maize and speargrass have similar growth habits and life cycles, the two species may have been competing for the same resources and the success of speargrass in this case may be dependent on the extent of rhizome regrowth and interference.Although speargrass was established from presprouted rhizomes, maize grew taller developing a closed canopy faster than speargrass. This may have induced shade over speargrass, and reduce PAR available to speargrass. Therefore, maize limited the light received by speargrass. Previous study reported that little in height differences of two plants in time of competition can cause a lot differences in competition [25]. Change in height difference between crop and weeds has been considered as one of the most important effects of weed competition that can be favorable for crop or weeds based on species and purposed conditions [26]. Maize height irrespective of culture or proportion with speargrass averaged 172cm and 142cm at 7 WAP in 2005 and 2006 respectively; while speargrass height averaged 58.5 cm and 80.5cm at 7 WAP in 2005 and 2006 respectively. Plant leaf area at 7 WAP averaged 2131.4cm and 1519.1cm in 2005 and 2006 respectively for maize whether or not in mixture. Similarly speargrass leaf area at 7 WAP averaged 245.3cm and 262.9 cm in 2005 and 2006 respectively. Plant height and leaf area have been reported as important attributes of plants that defines growth and competitive ability in mixtures [27,28,29,30,31]. The observed differences in the competitive ability of maize and speargrass from previous reports may be attributed to differential densities and proportion of the species in competition, as well as canopy relationship of the species. This is more because the density of maize may have been fixed across all level of speargrass infestation, and also under varied management strategies. Though maize was more competitive than speargrass in 1:1 mixture in this study; the fact that speargrass shoot density was negatively correlated with maize grain yield per plant ($r=-0.73$, $P<.0001$) and maize biomass per plant ($r=-0.49$, $P=0.0004$) is also an indication of speargrass competition with maize, and this can be more intense depending on the density and proportion in competition, and duration of infestation. This result confirms to earlier studies that have reported on the competitive relationships between maize and speargrass [8,15].

5. CONCLUSION

The competitive interaction between maize and speargrass indicate that both compete for the same resources. Their competitive interaction and ability depends on the proximity, the regrowth stage, and the canopy relationship during growth association. Maize, due to taller canopies, had advantage for light competition over speargrass, and was more competitive at low densities of speargrass. The greater competitiveness of speargrass, as we observed, may be apparent only under conditions of relatively high speargrass infestation and long duration of competition. Speargrass can compete strongly with maize for light especially at high densities, and competition for light must therefore be managed to its disadvantage. Speargrass competition can be intensified if disturbance due to slashing encouraged shoot regrowth from rhizomes, because rhizome competition was found to have a greater effect on the relative performance of speargrass. Thus, speargrass densities of 8-16 plant m^{-2} in mixture had the greatest rhizome biomass and hence caused a grain yield reduction of up to 43%, due to vigorous regrowth. At this density of speargrass, farmers need to employ efficient land preparation method that will be followed by optimum plant population to avoid yield loss. 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 if effective control is required, farmers should try to use or integrate a maize seeding rate that will give the optimum population that will reduce the effect of speargrass shoot regrowth from rhizome after land preparation. Such maize population density will maximize 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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