

Original Research Article

Maize response to competition from speargrass (*Imperata cylindrica* (L.) Raeuschel) regrowth from planted rhizomes I: Species Growth relationship, Yield and Yield components

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 rhizomes were previously planted 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 in May 2005 and May 2006. .The speargrass regrowth experiment was initiated in September 2005 and 2006 respectively after the previous maize harvest. All plots that had maize or speargrass either as monoculture or in mixture with each other were slashed and subsequently replanted with maize maintaining the previous maize densities earlier planted; while all plots previously planted to speargrass either in monoculture or in mixture with maize were allow to regrow from the previously planted densities.

Our Results of this study suggest that both maize and speargrass competed for the same resources. However, maize was more competitive than speargrass in 1:1 mixture in this study. Intraspecific competition between maize plants was responsible for maize grain yield loss of about 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 ($r \geq -0.56 \leq -0.78$) and maize biomass per plant ($r \geq -0.49 \leq -0.67$). 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 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. Such maize population density will maximize the relative competitive ability of maize, reduce intraspecific competition and minimizes the effect of speargrass regrowth after land preparation, particularly in areas where farmers cannot afford to purchase herbicides and apply them correctly.

Key words: Competition, maize, yield, speargrass regrowth, rhizomes, biomass

1. INTRODUCTION

Maize is an important food staple for than 1 billion people in Sub-Saharan Africa, and a preferred crop of 900 million of world poor. In most developing countries it is

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

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

56

57 **2. MATERIAL AND METHODS**

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59 **2.1 Description of study site**

60 The experiment was conducted at the research farm of International Institute of
61 Tropical Agriculture (IITA), Ibadan, Nigeria (7° 30'N, 3° 54'E), in the forest/savanna
62 transition zone. The zone is characterized by an annual rainfall that averaged 1250
63 and 1500 with a bimodal distribution pattern which peaks in July and September. .

64 Before monitoring the effect of speargrass regrowth on maize, the site was under
65 speargrass fallow for four months. The soil type at the experimental site was loamy
66 sand (Alfisol) with a pH of 6.7 and organic matter of <2%, 0.13% N, 3.08 mg/kg P
67 (available), 0.34K (cmol), and soil texture of 85% sand, 5% clay, and 9% silt. The
68 average annual temperature is 26°C and dominant soil type is Alfisol [17, 8]

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70 **2.2 Experimental procedure and design**

71 The speargrass for this study was initially planted on the 25th of May 2005, and May
72 30th, 2006 in both addition and replacement series experiments [18] from sprouted
73 rhizomes using a grid of 2 m by 2m with 64 quadrilles of 25 cm by 25 cm; and its
74 competitive effect monitored on maize growth. This previous treatment consisted
75 of three replicates of 16 established densities as monoculture, which included eight
76 monocultures of maize and speargrass at the following densities (4, 8, 12, 16, 20,
77 32, 48, 64) and eight mixtures of maize: speargrass (2:2, 4:4, 6:6, 8:8, 10:10, 16:16,
78 24:24, 32:32) per plot of 2 m ×2 m. All the plots were slashed immediately after
79 harvesting previous maize (approximately 4 months after planting the maize), and
80 maize stover and speargrass shoots packed out of the plots on September 20, 2005

81 and September 25, 2006 respectively. The same grid of 2 m × 2 m with 64
 82 quadrilles of 25 × 25 cm was used to replant maize (cv. 'ACR 89-DMR-ESR-W') in
 83 all the plots, which included plots previously planted to sole maize and speargrass;
 84 and plots that had maize and speargrass in mixture on 13 September 25, 2005
 85 and September 30, in 2006. The regrowth experiment was also conducted with
 86 three replicates in a randomized complete block design. Each replicate included the
 87 same 16 treatments: eight monocultures of maize (4:0, 8:0, 12:0, 16:0, 20:0, 32:0,
 88 48:0, 64:0 per plot) replanted in the same plot they were planted earlier (May 25,
 89 2005 and May 30, 2006), while speargrass monoculture plots were allowed to
 90 regrow from the previously planted densities (0:4, 0:8, 0:12, 0:16, 0:20, 0:32, 0:48,
 91 0:64 per plot) in September 25, 2005 and September 30, 2006. For the eight
 92 mixtures of maize: speargrass, maize was also replanted into each plot that had the
 93 maize: speargrass mixture of various densities and proportions to simulate the
 94 treatment arrangement of the experiment earlier in the season (2:2, 4:4, 6:6, 8:8,
 95 10:10, 16:16, 24:24, 32:32 per plot). Maize seedlings were thinned to one stand per
 96 hill one week after planting. All plots were kept free of other weeds that may
 97 interfere with competition between the target species by weekly hand pulling of
 98 weeds. Basal fertilizer was applied at a recommended rate of 45 kg ha⁻¹ of N, P₂O₅,
 99 and K₂O at 2 weeks after planting (WAP) on October 9, 2005 and October 14,
 100 2006, while urea at 45 kg N ha⁻¹ was applied at 6 WAP, on 30 October 2005 and
 101 October 30 2006. Both types of fertilizers were applied broadcast.

102 2.3 Data Collection

103 In both years data were collected on height, leaf area and photosynthetic active
 104 radiation (PAR) of both species at 50% maize silking (7 WAP), on 15 November
 105 2005 and 20 November 2006. Leaf area of each plant or species was determined at

106 50% silking from an average value of five plants measured per plot with LI-3000
 107 portable leaf area meter with head scanner PAM 1684, (LI-COR, Inc., P. O. Box
 108 4425, Lincoln, N668504 USA). PAR interception was determined with 1-m long
 109 Decagon sunfleck ceptometer (Decagon Devices, Inc., P O Box 835, Pullman, WA
 110 99163 USA) at ground level and above the maize canopy on a cloudless day
 111 between 12:00 and 14:00 h. at 50% maize silking (7 WAP).—An average of four
 112 reading per treatment from each replicate was used to obtain treatment mean.

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

$$114 \quad X = [1 - (B/A)] \times 100 \dots\dots\dots [1]$$

115 Where, B is the PAR, $\mu\text{mol m}^{-2} \text{ s}^{-1}$, measured below the maize canopy 10 cm above
 116 the ground, A is the above maize canopy PAR reading, made in the open.

117 Similarly data was collected on, total above ground biomass of both species by
 118 cutting at the soil surface, and below ground biomass of speargrass (rhizomes) on
 119 27 December 2005 and on 30 December 2006. An area of 2m^2 of was harvested
 120 from each plot for the determination of total above biomass of maize and
 121 speargrass, and grain yield. — Maize grain yield was adjusted to 12% moisture
 122 content using the Tri-grain moisture tester (Model 14998 with Serial number 1170,
 123 Dickey-John Corporation Auburn, IL, 62615 USA). Both maize and speargrass
 124 plant samples were oven dried in a Gallenkamp oven (OVE–300 plus Series) at 80
 125 °C until constant mass was recorded with a digital balance (XD–4K B042809,
 126 Denver Instrument Company, USA).

127 **2.4 Data Analysis**

128 All the data collected was analyzed by year, except for correlation between maize
 129 and speargrass parameters. ANOVA was performed using the MIXED MODEL and
 130 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.

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141 3. RESULTS

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143 3.1 Maize and Speargrass biomass

144 In 2005, maize shoot biomass was higher in mixture with speargrass than in
145 monoculture, but the differences were not significant ($P > 0.05$) (Table 1). However,
146 maize total plant biomass yield was significantly higher for 4 ($P = 0.0194$) and 32
147 ($P = 0.0060$) plants per plot in monoculture compared to mixture yield at the same
148 density (Table 1). Contrast estimate in 2006 indicated that maize biomass was
149 significantly higher in mixture than in monoculture ($P \leq 0.05$) at all densities except at
150 6:6 plant proportions of both maize and speargrass, compared to 12:0 of maize:
151 speargrass, ($P = 0.0104$). However, maize plant biomass was higher in monoculture
152 at the following densities: 4 ($P \leq 0.05$), 16 ($P > 0.05$), and 32 ($P \leq 0.05$) per plot
153 compared to their 1:1 mixed ratio in 2006 (Table1). All the speargrass parameters
154 considered via density; shoot weight, rhizome weight and total dry weight as well as
155 maize density were negatively correlated with maize biomass, respectively ($r = -0.49$,
156 $r = -0.45$, $r = -0.67$, $r = -0.64$ and $r = -0.58$) (Table 2). In both years, except at

157 speargrass density of 12 plants in 2006, when compared to 6:6 maize: speargrass
 158 plant proportions ($P=0.052$) per plot; speargrass shoot biomass was significantly
 159 higher in monoculture than in mixture (Table 1) in replacement series. The
 160 relationship between speargrass parameters and maize density was significant in
 161 both years except for maize density and speargrass shoot biomass in 2006
 162 ($P=0.0967$) (Table 3). Similarly, the relationship between speargrass parameters
 163 and maize height was significant in 2005 ($P=0.001$), and significant for only
 164 speargrass rhizome biomass in 2006 ($P=0.009$) (Table 3).

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

Proportions		Biomass per plant			
		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

<-----Probability < F1----->				
Contrast				
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

[†]NS denotes not significant at the 5 % level of probability;

– indicates where maize or speargrass is not applicable

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	-

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178 **Table 3. Estimates of regression parameter for speargrass attributes as a linear function of**
 179 **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	127.49	-1.049	178.53	-0.728
					4			
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	244.31	1.695
							0	
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	

180 ^aB₀ is an intercept .

181 ^bB₁ is density.

182 ^cB₂ is height.

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187 **3.2 Plant leaf area and height**

188 Leaf area of maize per plant in monoculture was not significantly different from
 189 maize leaf area grown in mixture with speargrass in both years ($P>0.05$), except at t
 190 the density of 8:0 maize plant per plot in compared to both species at 8:8 mixtures
 191 in both years ($P=0.033$). The effect of species competition on speargrass leaf area
 192 was significant only in 2005 ($P=0.055$). Speargrass leaf area per plant was
 193 consistently higher at all densities in monoculture than in mixture with maize in both
 194 years, except at 8:0 and 16:0 speargrass density per plot (Table 4). Averaged over
 195 the years, speargrass leaf area was significantly higher only at 12:0 plants density in
 196 monoculture compared to 6:6 proportion in mixture ($P=0.004$), and higher at 8:8
 197 plant densities proportion in mixture compared to 16:0 plant density in monoculture
 198 ($P=0.022$). Maize height did not differ in monoculture and in mixture with speargrass
 199 in 2005.—However, maize grown in mixture with speargrass at various species
 200 proportions were shorter except at densities of 2:2 and at 24:24 species proportion
 201 where maize was taller than in monoculture ($P=0.051$) in 2005 (Table 4). Maize and
 202 speargrass at 8:8 and 24:24 plant proportions were significantly taller than maize at
 203 8:0($P=0.031$) and 48:0 plant densities and proportions in 2006 ($P=0.043$) (Table 4).
 204 The proportions of maize and speargrass densities in mixture affected speargrass
 205 height significantly, compared to speargrass height in pure stand or monoculture in
 206 both years ($P=0.05$).

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TABLE4. 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		Imperata		Maize		Imperata	
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
<-----Probability < F¹----->									
Contrast									
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

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

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217 3.3 Maize grain yield (kg ha⁻¹)

218 Maize grain yield was significantly higher in monoculture at all densities, compared
 219 to yields in mixture at all proportions in 2005 ($P=0.004$). Yield in both monoculture
 220 and mixture increased with increasing species densities. Grain yield differences
 221 between monoculture and mixture were higher ($\geq 41\%$) with low densities (2:2–8:8)
 222 proportion of species in mixture, and lower (≥ 15 –29%) with high densities (16:16–
 223 32:32) proportion of species in mixture (Table 5). When the interaction between
 224 maize and speargrass is averaged over densities in monoculture and species
 225 proportion in mixture, maize and speargrass association resulted in 36% maize yield
 226 loss with replacement series analysis. Yield was also higher in monoculture,
 227 compared to mixture for the densities considered in addition series ($P=0.001$), and
 228 yield differences between monoculture and mixture were also higher (≥ 7 –18%) at
 229 low densities, and lower (4%) at high densities (Table 5). Irrespective of the method
 230 of analysis, speargrass competition with maize in 2005 resulted in a 22% maize
 231 yield reduction. The effect of speargrass competition with maize on maize grain
 232 yield in 2006 followed the same trend as in 2005. In monoculture, maize yield
 233 increased with increasing density up to the density of 32:0 (8 plants m⁻²) and started
 234 dropping from the density of 48:0 (12 plants m⁻²) to 64:0 (16 plants m⁻²) which is an
 235 indication of interference, possible resulting from neighbouring maize plants
 236 (intraspecies completion)(Table 5). Similarly, grain yield in mixture with speargrass
 237 increased with increasing species proportions in mixture, but dropped at 10:10 and
 238 32:32 plant proportions in mixture. Maize grain yield was significantly higher in
 239 monoculture at 4:0, 12:0, 16:0, 20:0, 32:0, 64:0 ($P=0.05$) and 8:0 ($P>0.05$)
 240 compared in mixture with half of each species in 2006 ; and yields were lower by
 241 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 were 6.49 and 26% higher in 4:4 and 8:8 of the plants species in 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 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
s			
-----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

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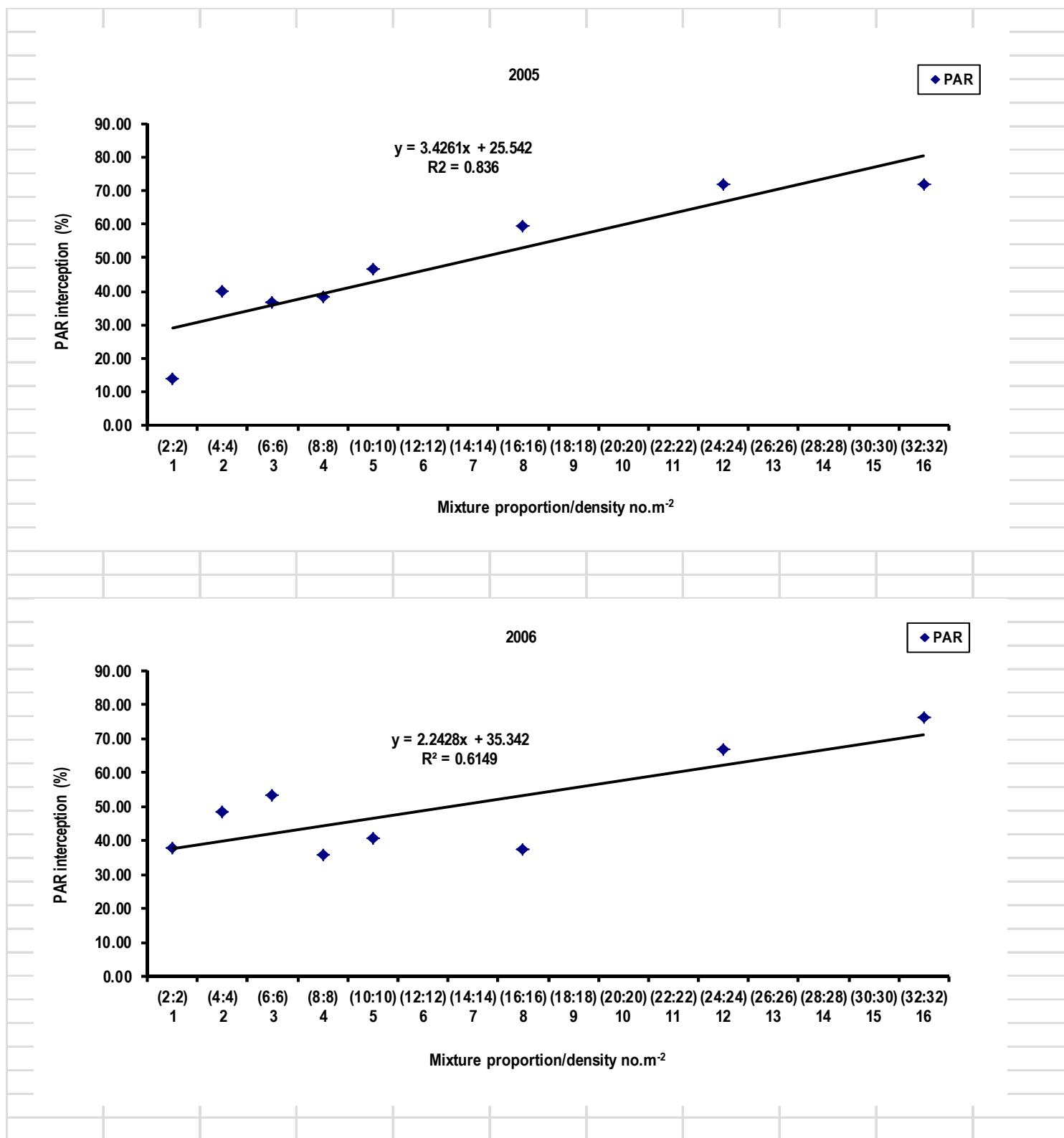
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259 3.4 Light interception

260 Light interception increased with increasing species density and proportion in the
 261 mixture in both years ($P=0.001$, in 2005 and $P=0.064$, in 2006). Densities of 2-8
 262 plants of each species in mixture intercepted $\leq 40\%$ (13-40%) of the incident PAR in
 263 2005, while the densities of 10-32 plants of each species in the mixture intercepted
 264 $\geq 46\%$ (46-77%) of the incident PAR received by the canopy in 2005(Fig.1).
 265 However, in 2006, the PAR interception was more variable among the proportions
 266 compared to that of 2005. Maize-speargrass mixture at 2-8 plants of each species
 267 per plot intercepted between 35 and 53%, while for the densities at 10-32 plants of
 268 each species in mixture per plot, incident PAR interception by the canopy was
 269 between 37 and 76% in 2006 (Fig. 1). Averaged over the years, percentage PAR
 270 interception was significantly ($P=0.05$) different between the various densities in
 271 mixture.

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273



275 4. DISCUSSION

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277 The effect of competition from speargrass shoot regrowth ~~competition~~ affected the
 278 growth and development of both species in ~~pure~~ or mixed cultures. However, maize
 279 also responded to density. The relationship between maize density and PAR in
 280 both years indicates ~~that the slopes of the lines were positive. This means that as~~
 281 ~~maize density increases, so does its ability to intercept PAR,~~ and this in turn affects
 282 speargrass, being a shade-intolerant plant [8, 21]. Hence the negative slope
 283 observed in the relationship between maize density and speargrass biomass in this
 284 study. ~~The result means that increasing maize density further will result in an~~
 285 ~~average~~ increase of PAR interception by 0.35 times, and this will translate into an
 286 average loss of speargrass shoot biomass by 1.01 times, rhizomes by 0.62 times,
 287 and total biomass by 1.62 times. Thus, the competitive ability of speargrass was
 288 enhanced at a lower density of maize; this is evident in the higher speargrass
 289 biomass (≥ 100 g per plant) at lower maize densities in mixture (2:2-8:8) compared
 290 to speargrass biomass at higher maize density (10:10-32:32) interaction in mixture
 291 (≤ 87 g per plant). The observed antagonistic effect between maize and speargrass
 292 is attributable to severe competition for light, which is evident by the intensity of
 293 competition at high maize densities. All speargrass attributes measured were
 294 negatively related to maize density due to competition for light. These results are in
 295 agreement with similar studies that report on nutsedge competition with maize and
 296 tomato [22, 23]. Similar competition for light resources between spring barley and
 297 weeds has been reported [24]. Since maize and speargrass have similar growth
 298 habits and life cycles, the two species may have been competing for the same
 299 resources and the success of speargrass in this case may be dependent on the

300 extent of rhizome regrowth and interference. Although speargrass was established
 301 from presprouted rhizomes, maize grew taller and developed a closed canopy faster
 302 than speargrass. This may have induced shade over speargrass, and reduce PAR
 303 available to speargrass. Therefore, maize limited the light received by speargrass .
 304 Previous study reported that little in height differences of two plants in time of
 305 competition can cause a lot differences in competition [25]. Change in height
 306 difference between crop and weeds has been considered as one of the most
 307 important effects of weed competition that can be favorable for crop or weeds based
 308 on species and purposed conditions [26]. Maize height irrespective of culture or
 309 proportion with speargrass averaged 172cm and 142 cm at 7 WAP in 2005 and
 310 2006 respectively; while speargrass height averaged 58.5 cm and 80.5 cm at 7
 311 WAP in 2005 and 2006 respectively. Plant leaf area at 7 WAP averaged 2131.4 cm
 312 and 1519.1cm in 2005 and 2006 respectively for maize whether or not in mixture.
 313 Similarly speargrass leaf area at 7 WAP averaged 245.3 cm and 262.9 cm in 2005
 314 and 2006 respectively. Plant height and leaf area have been reported as important
 315 attributes of plants that defines growth and competitive ability in mixtures [27, 28,
 316 29, 30, 31]. The observed differences in the competitive ability of maize and
 317 speargrass from previous reports may be attributed to differential densities and
 318 proportion of the species in competition, as well as canopy relationship of the
 319 species. This is more so as the density of maize may have been fixed across all level
 320 of speargrass infestation, and also under varied management strategies. Though
 321 maize was more competitive than speargrass in 1:1 mixture in this study; the fact
 322 that speargrass shoot density was negatively correlated with maize grain yield per
 323 plant ($r=-0.73$, $P<.0001$) and maize biomass per plant ($r=-0.49$, $P=0.0004$) is also an

324 indication of speargrass competition with maize, and this can be more intense
325 depending on the density and proportion in competition, and duration of infestation.

326 This result conforms to earlier studies that have reported on the competitive
327 relationships between maize and speargrass [8, 15].

328

329

330 5. CONCLUSION

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332 The competitive interaction between maize and speargrass indicate that both
333 compete for the same resources. Their competitive interaction and ability depends
334 on the proximity, the regrowth stage, and the canopy relationship during growth
335 association. Maize due to taller canopies had advantage for light competition over
336 speargrass, and was more competitive than speargrass at low densities of
337 speargrass. The greater competitiveness of speargrass, as we observed, may be
338 apparent only under conditions of relatively high speargrass infestation and long
339 duration of competition. Speargrass can compete strongly with maize for light
340 especially at high densities, and competition for light must therefore be managed to
341 its disadvantage. Speargrass competition can be intensified if disturbance due to
342 slashing encouraged shoot regrowth from rhizomes, because rhizome competition
343 was found to have a greater effect on the relative performance of speargrass. Thus,
344 speargrass densities of 8-16 plant m⁻² in mixture with maize had the greatest
345 rhizome biomass and hence caused a grain yield reduction of up to 43%, due to
346 vigorous regrowth. Slashing, often employed by farmers probably encourages
347 higher speargrass rhizome activity, resulting in a more intense competition with
348 associated crops. Speargrass is quite expensive to manage if effective control is
349 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.

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COMPETING INTERESTS

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Authors have declared that no competing interests exist.

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