

Research Article

Maize response to competition from Speargrass (*Imperata cylindrica* (L.) Raeuschel) regrowth from planted rhizomes II: Competitive Relationship-Relative Yield and Relative Yield Total.

ABSTRACT

Field study was conducted to evaluate the competitive effect of speargrass shoot regrowth from planted rhizomes on the growth and yield of subsequent maize crop. The competitive relationship study was laid out 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 maize-speargrass regrowth competition experiment was initiated in September 2005 and September 2006 respectively after the previous maize harvest. All plot 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 plot previously planted to speargrass either in monoculture or in mixture with maize were allow to regrow from the previously planted densities .

Relative yields total (RYT) from the competition study indicated that maize and speargrass were competing for the same resources especially at 8:8 plants of both species in mixture, and there was mutual antagonism from severe competition for light, especially at high densities of both species (10:10-32:32 plants) in mixture. RYT of speargrass regrowth competition with maize was neither significantly higher nor lower than 2.0 for shoot competition ($P=0.522$); and was not significantly different ($P=0.475$) for rhizome competition among the various speargrass densities and proportions in competition with maize. Speargrass regrowth and maize interaction captured three resource competition scenarios of their association as follows: avoidance of competition, whereby individual species exploited the limiting resources separately (where, $RYT > 2.0$); both species competed fully or partial possibly at all densities in mixture since RYT values were not significantly higher or lower than 2.0; and both species may also have antagonized each other during their growth association (where, $RYT < 2.0$).

Speargrass is quite expensive to manage, and slashing, often employed by farmers probably encourages higher speargrass rhizome activity, resulting in a more intense competition with associated crops. Farmers should integrate a maize seeding rate that will compete favorably with speargrass shoot regrowth from rhizome by manipulating densities; especially after land preparation.

11

12

Key words  **Competition, Maize, Speargrass regrowth, Rhizome, Relative Yield,**

13

Relative Yield Total

14

15 1. INTRODUCTION

16

17 Maize is an important food staple for than 1 billion people in Sub-Saharan Africa,
 18 and a preferred crop of 900 million of world poor. In most developing countries it is
 19 grown in mixture with other crops or as sole crop [1]. Aggregated production
 20 especially in West Africa has shown an increase of about 73% between the 1980s
 21 and 2000s [2]. However, this increase is due to expansion in the area under
 22 cultivation while productivity per unit area still very low (0.5-1.0 ton/ha) due to
 23 several agro ecological factors including weeds infestation. Maize is sensitive to
 24 weed competition especially in the first 3 weeks after emergence [3]. Although
 25 maize is a vigorous and tall growing plant, it is susceptible to competition from
 26 weeds, with losses greater than 30% commonly reported [4]. Maize is a high- risk
 27 crop, mainly due to the varying climatic conditions as well as inadequate
 28 management practices. Researchers indicate that maize plants are very susceptible
 29 to weed competition and yield losses and are estimated at 35% to complete crop
 30 failure [5]. To obtain high crop yields weed control is very important because weed
 31 compete with maize for nutrients soil moisture and light. Therefore, information on
 32 competitive interaction between speargrass and maize will be useful for developing
 33 and implementing effective management programs. Speargrass [*Imperata cylindrica*
 34 (L.) Rauesch] is a rhizomatous, perennial grass weed, widely distributed throughout
 35 the tropics and in some warm areas of the temperate region [6]. It has become a
 36 major problem in the production of arable crops such as maize, soybean, and root
 37 and tuber crops in forest transition zone of West Africa [7, 8]. Most of the methods
 38 of control (hoe weeding, hand pulling and slashing) employed by rural farmers are
 39 not effective, because of its ability to infest, spread and colonize native vegetation
 40 [9, 10, 11, 12]. Yield loses attributed to speargrass infestation in maize has been
 41 reported to be between 40 and 80% [13, 14, 8, 15]. The competitive ability, density
 42 of speargrass and the competitive ability of the crop influence the effect of
 43 speargrass competition on crop yield. Most experiments conducted on speargrass
 44 have been to explore the relative aggressiveness of speargrass and certain crops
 45 [15] and few have been accomplished through the experimental manipulation of
 46 population crop density, proportion, or spatial arrangement [16]. However, none
 47 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 maize densities

53

54 2. MATERIAL AND METHODS

55

56 2.1 Description of study site

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

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

66

67 2.2 Experimental procedure and design

68 The speargrass for this study was initially planted on the 25th of May 2005, and May
69 30th, 2006 in both addition and replacement series experiments [18] from sprouted
70 rhizomes using a grid of 2 m by 2m with 64 quadrilles of 25 cm by 25 cm; and its
71 competitive effect monitored on maize growth. This previous treatment consisted
72 of three replicates of 16 established densities as monoculture, which included eight
73 monocultures of maize and speargrass at the following densities (4, 8, 12, 16, 20,
74 32, 48, 64) and eight mixtures of maize: speargrass (2:2, 4:4, 6:6, 8:8, 10:10, 16:16,
75 24:24, 32:32) per plot of 2 m ×2 m. All the plots were slashed immediately after

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

99 2.3 Data Collection

100 In both years data were collected on total above ground biomass of both species by
 101 cutting at the soil surface, and below ground biomass of speargrass (rhizomes) on
 102 27 December 2005 and on 30 December 2006, to evaluate relative yield and
 103 relative yield total of both species in mixture. An area of 2m^2 of was harvested from
 104 each plot for the determination of total above biomass of maize and speargrass.
 105 Speargrass rhizomes—were excavated by digging to the depth of 30-40 cm and
 106 manually separated from the soil for dry weight determination. Both maize and
 107 speargrass plant samples were oven dried in a Gallenkamp oven (OVE-300 Plus
 108 Series) at 80°C until constant mass was recorded with a digital balance (XD-4K
 109 B042809, Denver Instrument Company, USA).

110 2.4 Data Analysis

111 All the data collected was analyzed by year. The complete relationship between
 112 maize and speargrass was calculated using the following indices of competition,
 113 relative yield (RY) and relative yield total (RYT). The relative yield total (RYT) is an
 114 index which measures the relative performance of mixtures compared with the
 115 corresponding monoculture [19, 20, 21, 22, 23]. The relative yield total (RYT)
 116 describes how the species in mixture share or utilize common limiting resources.
 117 Values of RYT approximating two (2.0) indicate that two species are in competition
 118 for the same limiting resources. Values of $\text{RYT} > 2.0$ means the species avoids
 119 competition and may somehow allow for over-yielding. Values of $\text{RYT} < 2.0$ imply
 120 mutual antagonism.—The relative yield total of (RYT) measured was based on the
 121 mean plant biomass yield of maize and speargrass. .The relative yield (RY) and
 122 relative yield total (RYT) were calculated as follows:

123 Relative yield of maize (RYm): $RYm = Yms/Ymm$ [1]

124 Relative yield of speargrass (RYs): $RYs = Ysm/Yss$ [2]

125 Relative yield total (RYT) $RYT = RYm + RYs$ [3]

126 Where RYm, RYs, Yms, Ysm, Ymm and Yss are the relative yield of maize,
127 speargrass, the mean yield/plant of maize and speargrass in mixture, the mean
128 yield/plant of maize and speargrass in monoculture. However, competition effect of
129 speargrass regrowth on maize was partitioned into the follow: (1) speargrass shoot
130 competition with maize, (2) speargrass rhizome competition with maize and (3) the
131 effect of whole plant of speargrass (shoot + rhizome). This was derived by mere
132 calculation of the relative yield and relative yield total.

133 ANOVA was performed using the MIXED MODEL and general linear model (GLM)
134 procedures in the Statistical Analysis Systems software (SAS) [24, 25]. In the mixed
135 model procedure, years and replication were considered random effects in the
136 model. Data were analyzed and presented by year. Least-square means of the
137 individual treatment effects were separated using the contrast at $P = 0.05$ and
138 standard error of the means in the LSMEANS output, and least significant difference
139 (LSD) for relative yield (RY) and relative yield total (RYT).

140

141

142

143

144 3. RESULTS

145

146 3.1 Relative yield (RY) and relative yield total (RYT) of maize and 147 speargrass regrowth in competition

148 In 2005, the relative yield of maize (RYm) in mixture with speargrass, except at 8:8
149 and 32:32 plant proportions in mixture with speargrass, was not significantly

150 ($P \geq 0.05$) higher than 1.0 (Table 1). However, RYm at 4:4 (0.96) plant proportions
 151 was not significantly different from 1.0. Similarly, in 2006, except at 24:24 (maize:
 152 speargrass) proportions, RYm of all proportions in mixtures was not significantly
 153 different from the pure stand expectation (1.0). RYm at 6:6 plant proportions (0.99),
 154 though lower than 1.0, and was not significant (Table 1).
 155 Similarly in 2005, except at 4:4 (0.84) and 2:2 (0.75) plant proportions; speargrass,
 156 relative yield of speargrass shoot (RYs) were significantly less than 1.0 for the plant
 157 proportions of 6:6 –32:32 in mixture (Table 1). The overall effect was a RYT that
 158 was lower than 2.0 at 6:6-32:32 plant proportions, but the values were not
 159 significantly different from 2.0 (Table 1). The RYT of all the different proportions of
 160 maize and speargrass in mixture did not differ significantly ($P > 0.05$). However,
 161 RYT at 2:2 (2.08) and 8:8 (2.56) plant proportions were higher than 2.0. RYT in
 162 2006 at all proportions were not significantly different from pure stand expectation
 163 (2.0) ($P > 0.05$), meaning that maize and speargrass are equal resource competitors.
 164 However, RYT was higher at plant or mixture proportions of 6:6 (3.24), 8:8 (2.53)
 165 and 24:24 (2.13), indicating that the competition effect was negligible (partial), or
 166 that at one time maize and speargrass were making different demands on the
 167 resources. The RYs at the 6:6 (1.32) plant proportion was significantly higher than
 168 RYs at plant proportions of 2:2 (0.63), 10:10 (0.55), 16:16 (0.36), 24:24 (0.42), and
 169 32:32 (0.26) plant proportion in mixture. However, RYs at 6:6 was significantly
 170 higher than 1.0 (pure stand yield expectation). RYs was lowest at 32:32 (0.25) plant
 171 proportions (Table 1). Thus, at high densities of the species proportions in mixture
 172 (10:10-32:32) speargrass did not develop to its potentials; hence it did not contribute
 173 its expected share to the mixture yield. Hence, the RYT average of the years for the

174 higher density proportion was lower than the expected total yield of 2.0. The RYT of
 175 all the mixtures when averaged over the years was neither significantly higher nor
 176 lower than 2.0 ($P=0.5224$). Thus, speargrass shoot competition with maize captures
 177 the three different interpretations of competition based on the RYT of the species in
 178 competition , which therefore means that speargrass shoot regrowth competition
 179 with maize can result as follows: (1) both maize and speargrass avoided
 180 competition, thus they exploited the resources differently, especially at 6:6 and 8:8
 181 plant proportions (RYT > 2.0); (2) they also may have competed fully or partially at
 182 certain times of growing together possibly at all proportions in mixture, since RYT
 183 values calculated were not significantly higher or lower than 2.0; (3) both species
 184 may have also antagonized each other at certain periods of the association,
 185 especially at 10:10, 16:16, and 32:32 proportions (RYT < 2.0).

186

187 **TABLE.1. Relative yield and the relative yield total (RYT) of maize and speargrass**
 188 **shoot in response to competition from the speargrass shoot regrowth.**

Mixture proportions		RY			RY		
Maize	Speargrass	Maize	Shoot	RYT	Maize	Shoot	RYT
No. per plot		2005	2005	2005	2006	2006	2006
2	2	1.33	0.75	2.08	1.30	0.52	1.82
4	4	0.96	0.84	1.80	1.39	0.50	1.89
6	6	1.12	0.40	1.52	0.99	2.24*	3.24
8	8	1.93	0.63	2.56	1.13	1.39	2.53
10	10	1.28	0.49	1.71	1.10	0.61	1.71
16	16	1.36	0.34	1.70	1.14	0.38	1.53

24	24	1.53	0.27	1.80	1.56*	0.56	2.13
32	32	1.69	0.22	1.91	1.33	0.29	1.62
LSD for proportion		0.81	0.56	1.11	0.695	1.78	1.82

*, Significantly different from 1.0, at $P < 0.05$

LSD (P=0.05) for comparing 2005 RYT with 2.0= 0.722

LSD (P=0.05) for comparing 2006 RYT with 2.0= 1.266

LSD (P=0.05) for comparing years average RYT with 2.0= 0.697

189

190

191

192 **3.2 Relative yield (RYr) and relative yield total (RYT) of speargrass**

193 **rhizome in competition with maize (belowground competition).**

194 RYT in 2005 relative to speargrass rhizome (RYr) competition was not
 195 significantly ($P=0.4752$) different among various speargrass densities and
 196 proportions in competition with maize (Table 2). In both years, RYT except at
 197 8:8 was lower than 2.0, as well as not significantly different from 2.0, indicating
 198 that there may have been an antagonistic effect between maize and speargrass
 199 rhizomes at these proportions, and may also have competed for the available
 200 growth resources at one stage (Table 2). RYT for rhizome in 2006 was also not
 201 significantly different with the various densities and proportions ($P>0.05$) due to
 202 rhizome competition. In 2006, at plant proportions of 10:10, 16:16, and 24:24,
 203 RYT was lower than 2.0, but was not significantly different from 2.0, while at
 204 2:2(2.09), 4:4 (2.07), 32:32 (2.03), and 8:8(2.01) RYT were approximately 2.0,
 205 indicating that maize and speargrass rhizomes at these proportions in mixture
 206 were fully competing for the same resources (Table 2). The RYT result in 2006
 207 seems to suggest that competition with maize was greater with rhizomes (cutting
 208 across four densities and proportions) than with shoots at the same density. The
 209 averaged RYT of the mixture proportions for the period of study was not different
 210 ($P>0.05$). The years' average RYT at 8:8 (2.27), 6:6 (2.16), and 2:2 (2.04) were
 211 slightly higher than 2.0, while at 4:4 (1.95), 32:32 (1.94) and 24:24 (1.83)
 212 proportions RYT values were less than or approximately 2.0, while at 16:16
 213 (1.68) and 10:10 (1.6) mixtures, values were not significantly lower than 2.0.

214

215 **TABLE 2. Relative yield and the relative yield total (RYT) of maize and speargrass rhizome in**
 216 **response to below ground competition from rhizome in replacement proportion.**

Mixture proportions		RY			RY		
Maize	Speargrass	Maize	Rhizome	RYT	Maize	Rhizome	RYT
No. per plot		2005	2005	2005	2006	2006	2006
2	2	1.33	0.66	1.99	1.30	0.78	2.08
4	4	0.96	0.85	1.81	1.39	0.67	2.07
6	6	1.12	0.33	1.46	0.99	1.87	2.86
8	8	1.93	0.59	2.52	1.13	0.88	2.01
10	10	1.28	0.41	1.63	1.10	0.48	1.58
16	16	1.36	0.37	1.73	1.14	0.48	1.63
24	24	1.53	0.26	1.79	1.56	0.31	1.87
32	32	1.69	0.16	1.84	1.33	0.70	2.03
LSD for plant proportion		0.81	0.50	1.01	0.695	1.56	1.76
LSD (P=0.05) for comparing 2005 RYT with 2.0= 0.658							
LSD (P=0.05) for comparing 2006 RYT with 2.0=1.16							
LSD (P=0.05) for comparing years average RYT with 2.0=0.623							

217

218

219

220

221

222

223

224 **3.3 Relative yield and relative yield total of speargrass plant (shoot + rhizome)**
 225 **in competition with maize in replacement proportion**

226 In 2005, RYT was ≥ 2.0 only at 2:2 and 8:8 plant proportions, meaning that it was
 227 only at these proportions that speargrass reached its growth potentials and hence
 228 contributed to the total yield (Table 3). However, the RYT value was not
 229 significantly different from 2.0, indicating that speargrass competed at these
 230 proportions or densities with maize. However, at 32:32, 4:4, 16:16, 10:10, RYT $\geq$
 231 $1.50 \leq 1.88$, and at 6:6, RYT was 1.49. These values were not significantly different
 232 from 2.0, and can be interpreted as follows: (1) since RYT was lower than 2.0, there
 233 may have been an antagonistic effect between maize and speargrass regrowth at a
 234 certain period of their growth association, (2) at another stage of their interaction in
 235 the mixture, both may have competed for the same resource, hence RYT was not
 236 significantly lower or different from 2.0. In 2006, the RY of speargrass at 6:6 (1.89)
 237 and 8:8 (1.23) plant proportions in mixture with speargrass grew to its potential and
 238 thus contributed significantly to the mixture yield (Table 3). The result indicated
 239 that maize and speargrass may have exploited the resources differently at 6:6
 240 mixtures, and may have competed at 8:8 mixtures, since RYT was not significantly
 241 different from 2.0. At the rest of the species proportion in mixture, RYT was not
 242 significantly lower than 2.0, meaning that they may have been an equal competitive
 243 effect between maize and speargrass, as well as the antagonistic effect between them,
 244 The RYT of the proportions over the years was not different from each other, and

245 hence was not different from 2.0 ($P>0.05$), indicating that speargrass competed with
246 maize equally.

247 . **TABLE 3. Relative yield and the relative yield total (RYT) of maize and**
248 **speargrass biomass (shoot + rhizome) in competition with maize in**
249 **replacement proportion**

Mixture proportions		RY		RY			
		Maize	Total	RYT	Maize	Total	RYT
Maize	Speargrass		biomass			biomass	
No. per plot		2005	2005	2005	2006	2006	2006
2	2	1.33	0.71	2.04	1.30	0.62	1.92
4	4	0.96	0.84	1.81	1.39	0.56	1.96
6	6	1.12	0.37	1.49	0.99	1.89*	2.89*
8	8	1.93	0.61	2.54	1.13	1.23	2.36
10	10	1.28	0.44	1.67	1.10	0.57	1.67
16	16	1.36	0.35	1.71	1.14	0.42	1.56
24	24	1.53	0.27	1.80	1.56	0.36	1.92
32	32	1.69	0.20	1.88	1.33	0.44	1.77
LSD		0.81	0.52	1.06	0.695	1.06	1.183

LSD ($P=0.05$) for comparing 2005 RYT with 2.0= 0.693

LSD ($P=0.05$) for comparing 2006 RYT with 2.0=0.813

LSD ($P=0.05$) for comparing years average RYT with 2.0=0.515

*, Significantly different from 1.0, $P < 0.05$

250

251

252

253 **3.4 Relative yield and relative yield total of maize and speargrass biomass**
 254 **(shoot + rhizome) in competition with maize in addition proportion**

255 At all densities in addition proportions with speargrass in both years, maize grew to
 256 its potential, hence RY was ≥ 1.0 at all proportions ($P > 0.05$), (Table 4). The relative
 257 yield (RY) of speargrass plant in competition with maize was less than 1.0 in both
 258 years (Table 4) hence speargrass did not grow to reach its potential, it therefore did
 259 not contribute its expected share to the mixture yield. Therefore, the relative yield
 260 total (RYT) of both plants in competition, except at 8:8 (RYT maize–speargrass
 261 $= 1.77 \pm 0.14$, in 2005 and 1.88 ± 0.17 , in 2006) was significantly ($P \leq 0.05$) less than
 262 the total pure stand yield expectation of both species (2.0) in both years (Table 4).
 263 Combined analysis of both years indicates that speargrass competed equally with
 264 maize only at 8:8 maize: speargrass proportion in mixture, hence RYT was not
 265 different from 2.0 at this proportion ($P > 0.05$), while at 4:4, 16:16, and 32:32 species
 266 proportions, RYT was significantly ($P < 0.05$) different from 2.0 (Table 4).

267

268

269

270

271

272

273

274

275

276

277 **Table 4. Relative yield and the relative yield total (RYT) of maize and speargrass**
 278 **biomass in competition in addition proportion**

279

Relative yield (RY) of maize and speargrass								
Mixture Proportion		2005		2006		Relative yield total (RYT)		Combined
Maize	Speargrass	Maize	Speargrass	Maize	Speargrass	2005	2006	
4 :	4	0.97	0.40*** ¹	0.92	0.39**	1.37**	1.32**	1.34**
8 :	8	1.20	0.57**	1.19	0.69a	1.77	1.88	1.82
16 :	16	1.27	0.23***	0.78	0.27**	1.50**	1.05**	1.27**
32 :	32	0.84	0.14***	0.72	0.26**	0.98b**	0.98**	0.98**
² LSD (P=0.05)		0.69	0.34	0.48	0.66	0.71	0.84	0.43
³ LSD (P=0.05)		0.44	0.22	0.30	0.39	0.42	0.53	0.30

280 ¹*, **, *** significantly different from 1.0 for RY or 2.0 for RYT $P \leq 0.05$, $P \leq$
 281 0.01 and $P \leq 0.001$ respectively

282 ²LSD for comparing densities and proportion of mixture

283 ³LSD for comparing densities in competition with expected mixture yield (2.0)

284

285

286

287

288 4. DISCUSSION

289

290 The effect of competition from speargrass regrowth affected the growth and
 291 development of both species in pure or mixed cultures. However, maize also
 292 responded to density effect. However, data on the RY of both maize and speargrass
 293 indicate that an increase in the relative yield of maize resulted in a decrease in the
 294 relative yield of speargrass. But this effect on speargrass was lower or not
 295 significant at previously lower density proportions of maize: speargrass. RYT values
 296 of speargrass when grown with maize at the various proportions were either lower
 297 or not significantly different from 2.0; meaning that both species antagonized each
 298 other at one stage of their growth, and also may have competed at another stage.
 299 This confirms the results of previous replacement series experiments where, maize
 300 and speargrass growing in mixture were crowding for the same resources
 301 (competing for the same resources) and are mutually exclusive [19]. RYT lower
 302 than 2.0 indicate an antagonistic effect between maize and speargrass. The
 303 observed antagonistic effect between maize and speargrass is attributable to severe
 304 competition for light, which is evident by the intensity of competition at high maize
 305 densities. These results are in agreement with similar studies that report on
 306 nutsedge competition with maize and tomato [26]. Since maize and speargrass
 307 have similar growth habits and life cycles, the two species may have been
 308 competing for the same resources and the success of speargrass in this case may
 309 be dependent on the extent of rhizome regrowth and interference. Species
 310 exhibiting similar growth forms and life cycles may compete more for specific
 311 resources at similar times of their growing seasons, thus intensifying interference

312 between them [20]. Previous studies on the nature of crop weed competition have
 313 shown that belowground (roots or rhizomes) competition has a greater effect on the
 314 relative performance of species than does above ground (shoot) competition [27,
 315 28, 29, 30,]. Though the RYT values were not statistically different from 2.0, they
 316 suggest that speargrass was incapable of realizing its potential yield due to the
 317 shading effect of maize on speargrass especially at the high maize densities.
 318 Although speargrass was established from presprouted rhizomes, maize grew taller
 319 and developed a closed canopy faster than speargrass. This may have induced
 320 shade over speargrass, and reduce PAR available to speargrass, which therefore
 321 reduced speargrass competitive ability against maize. However, rhizomes
 322 competitive ability with maize in this study was possible at all densities in mixed
 323 proportions, especially being higher at low density proportions. This result suggest
 324 that greater rhizome competition may be weighted by the fact that the ecological
 325 survival of speargrass is depended much on the activity and viability of the
 326 rhizomes.. The under ground rhizome reserves of speargrass have been reported
 327 to contribute significantly in its competitive ability in crops [31,32]. Speargrass
 328 would require more time to develop significant quantities of rhizome reserve under
 329 closed maize canopy to be able to out compete maize in a 1:1 mixed proportion. The
 330 following mechanisms probably account for the pattern of interference observed in
 331 this study (1) mutual antagonism might be occurring through competition for
 332 resources (especially light), (2) not all the resources were available to speargrass
 333 and (3) low and inconsistent light availability under the maize canopy. The result
 334 from this study does not completely agree with reports of previous studies
 335 conducted on speargrass infested field, which identified speargrass as being more

competitive than maize [33,34]. 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 so as the density of maize may have been fixed across all level of speargrass infestation, and also under varied management strategies. However, under varied densities the result is likely to differ, due to species canopy relationships and densities. Though, maize was more competitive than speargrass in 1:1 mixture in this study, there was also an indication that speargrass competed with maize, and this can be more intense depending on the density and proportion in competition, and duration of infestation. However, previous reports have shown that response of relative yield to mixed ratio depends on total density of the species in proportion [35,36].

348

349

5. CONCLUSION

350

351

352

353

354

355

356

357

358

359

360

361

The outcome of this study fits into the various interpretations of weed crop competition, based on the relative yield total (RYT). The competitive interaction between maize and speargrass indicate that both compete for the same resources, but there was also a mutual antagonism in which neither maize nor speargrass contributed its expected share to the yield of the mixture. The antagonistic effect observed was attributable to canopy relationship and perhaps competition for light resources. Their competitive interaction and ability depends on the proximity, the regrowth stage, and the canopy relationship during growth association. The greater competitiveness of speargrass regrowth, as we observed, may be apparent only under conditions of relatively high speargrass infestation and long duration of competition. 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 with maize had the greatest rhizome biomass due to vigorous regrowth. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Badu-Apraku B, Fakorede M. A.B.,and Ajala S.O. (2003) Promoting maize technology transfer in West and Central Africa: a networking approach. In: Maize revolution in West and Central Africa. Proceedings of a Regional Maize Workshop (eds B Badu- Apraku, MAB Fakorede, M Ouedraogo, RJ Carsky& A Menkir), 14–18 May, 2001, IITA–Cotonou, Benin Republic. 45–65., WECAMAN/IITA, Ibadan, Nigeria.
2. Fakorede MAB, Badu-Apraku B, Kamara AY, Menkir A and Ajala SO (2003) Maize revolution in West and Central Africa: an overview. In: Maize revolution in West and Central Africa. Proceedings of a Regional Maize Workshop (eds B Badu-Apraku, B, MAB Fakorede, M Ouedraogo, RJ Carsky & A Menkir), 14–18 May, 2001, IITA– Cotonou, Benin Republic. 3–15. WECAMAN/IITA, Ibadan, Nigeria.

- 398 3. Olorunmaiye PM, and Olorunmaiye KS (2009). Effect of integrated weed
399 management on weed control and yield components of maize and cassava
400 intercrop in a southern Guinea savanna ecology of Nigeria. *Aus J Crop Sci.*
401 3: 129-136.
402
- 403
- 404 4. Rahman, A. 1985. Weed control in maize in New Zealand. Pp 37-45 In:
405 Maize-Management to Market. (Eds.): H.A. Eagles and G.S. Wratt. *Agron.*
406 *Soc. N.Z.*, Special pub. No. 4, Palmerston North, New Zealand.
407
- 408 5. Sharma, V., D.R. Thakur and J.J. Sharma. 1998. Effect of metachlor and its
409 combination with atrazine on weed control in maize (*Zea mays*). *Indian J.*
410 *Argon.* 43: 677–80.
411
- 412
- 413 6. Holm, L.G., Plucknett, D.L., Pancho, J.N. and Hherberger, J.P. 1977.
414 *Imperata cylindrica* (L.) Beauv. In *The world's worst weeds* , pp 62–
415 71. University Press of Hawaii, Honolulu. Hawaii.
416
- 417 7. Chikoye D , Ekeleme F and Ambe JT (1999) Survey of distribution and
418 farmers' perceptions of speargrass [*Imperata cylindrica* (L.) Raeuschel] in
419 cassava-based systems in West Africa. *International Journal of Pest*
420 *Management* 45, 305–311.
421
- 422 8. Udensi, U. E., Akobundu, I. O., Ayeni, A. O. and Chikoye, D. (1999)
423 Management of speargrass (*Imperata cylindrica* (L.) Raeuschel) with velvet
424 bean (*Mucuna pruriens* var. utilis) and herbicides .*Weed Technology* 13:
425 201–208.
426
- 427 9. Dozier H, Gaffney JF, McDonald SK, Johnson RL and Shilling DG (1998)
428 Cogongrass in the United States: history, ecology, impacts and
429 management. *Weed Technology* 12, 737–743.
430
- 431 10. Akobundu, I. O. and Fagade S. O. 1978. Weed problems of African rice
432 lands. In: *Rice in Africa*, pp 181-192, Buddenhagen, I W. and Persley, G.
433 F.(eds) Academic Press, London..
434
- 435
- 436 11. Ogunyemi, S. (1977).The distribution of some weeds of arable crops in
437 Southwestern Nigeria. In: *Proceedings Seventh Conference of the Weed*
438 *Science Society of Nigerian* July 1977,pp 29–34, NRCRI, Umudike, Nigeria
439
- 440 12. Eussen, J. H. H., Slamet, S. and Soeroto, D (1976). Competition between
441 alang-alang [*Imperata cylindrica* (L.) Beauv.] and some crop plants. *Biotrop*
442 *Bulletin* 10: 24pp.
443

- 444 13. Lagoke, S.T.O, and A. A. Fayemi {1981}. Competition of speargras
 445 {Imperata cylindrica var. Africana {L.} Beauv} with maize. Indian Journal of
 446 Weed Science. 13 {2}: 83-94.

- 447
 448 14. Koch W, Grobmann F, Weber A, Lutzeyer HJ and Akobundu, IO (1990)
 449 Weeds as components of maize/cassava cropping systems. In:
 450 Standortgemaesselandwirtschaft in West Africa, 283–298.
 451 UniversitaetHohenheim. Stuttgart, Germany.

- 452
 453 15. Chikoye D, Ekeleme F and Udensi UE (2001) Imperata cylindrica
 454 suppression by intercropping cover crops in Zea mays /Manihot esculenta
 455 systems. Weed Science 49; 658–667

- 456
 457 16. Udensi Ekea Udensi and David Chikoye (2013). Effect of relative proportion
 458 and density on competition between Speargrass (*Imperata cylindrica*
 459 *ca* l (L.) Raeuschel) and Maize (*Zea mays* L.) in a moist savannah of
 460 South-western Nigeria

- 461
 462 17. Okigbo, B. N. (1995). Major farming systems of the lowland savanna of sub-
 463 Saharan Africa and the potential for improvement. In: *Moist savannas of*
 464 *Africa*: potentials and constrains for crop production. B.T. Kang, I.O.
 465 Akobundu, V.M. Manyong, R.J. Carsky, N. Sanginga and E.A. Kueneman,
 466 eds. Proceedings of the International Workshop held at Cotonou, Republic of
 467 Benin, 19-23 September 1994, pp 31-48. Produced by IITA, Ibadan, Nigeria.

- 468
 469 18. Radosevich SR (1987) Method to study interactions among crops and
 470 weeds. Weed Technology 1, 190–198.

- 471
 472 19. De Wit, C. T. (1960). On competition. Agricultural Research Reports
 473 (Verslagen Landbouwkundig Onderzoek) 66(8), 82 pp..

- 474
 475 20. Harper, J. (1977). The Population biology of plants .Academic Press,
 476 London..

- 477
 478 21. Snaydon R.W (1991) Replacement or additive designs for competition
 479 studies. Journal of Applied Ecology 28, 930–946.

- 480
 481 22. Radosevich S.R, Holt J.S and Ghera C. (1997) Weed ecology: Implication
 482 for Management 2nd ed. New York, John Wiley and Sons Inc.

- 483
 484 23. Tuor, F. A. and Froud-Williams, R. J. (2002). Interaction between purple
 485 nutsedge, maize and soybean. *International Journal of Pest Management*
 486 48: 65-71

- 487
 488

- 489 24. SAS Institute Inc. 1995. *SAS/STAT User's Guide, Version 6 Fourth Edition*.
490 Vol. 2. SAS Institute Inc. Cary, NC, USA.
491
- 492 25. Littell, R.C., Milliken, G.A., Stroup, W.W, and Wolfinger, R.D. (1996). SAS
493 system for mixed models. SAS Institute Inc., Cary, NC, USA. 656 pp.
494
- 495 26. Santos, B.M., T.A. Bewick and D. J. Shilling (1997b). Competitive interaction
496 of tomato (*Lycopersicon esculentum*) and nutsedge (*Cyperus spp.*). *Weed*
497 *Science* 45:229-233.
498
- 499 27. Martin, M. P. and R. W. Snaydon (1982). Intercropping barley and beans:
500 Effects of planting pattern. *Exp. Agric.* 18:139- 148.
501
- 502 28. Radosevich SR and Holt JS (1984) *Weed ecology: implication for vegetation*
503 *management* , 265 pp. John Wiley and Sons Inc. New York, USA.
504
- 505 29. Martin, M.P.L.D and Field RJ (1988). Influence of time of emergence of wild
506 oat on competition with wheat. *Weed Res.* 28:111–116.
507
- 508 30. Bozsa, R. C. and L. R. Oliver. 1990. Competitive mechanisms of common
509 cocklebur (*Xanthium strumarium*) and soybean (*Glycine max*) during
510 seedling growth. *Weed. Sci.* 38:344-350.
511
- 512 31. Akobundu I.O and Ekeleme F (2000) Effect of method of *Imperata cylindrica*
513 management on maize grain yield in the derived savannah of southwestern
514 Nigeria. *Weed Research* 40, 335–341
515
- 516 32. Eussen, J. H. H. 1981. The effect of light intensity on some growth
517 characteristics. In *Studies on growth characteristics of Alang-alang [Imperata*
518 *cylindrica* (L.) Beauv.] Biotrop Bulletin 8: 3–12.
519
- 520 33. Akobundu IO, Udensi UE and Chikoye D (2000) Velvetbean (*Mucuna* 318
521 *spp.*) suppresses *Imperata cylindrica* (L.) Raeuschel and increases maize
522 yield. *International Journal of Pest Management* 46,103–108.
523
- 524 34. Chikoye D, Manyong VM and Ekeleme F (2000) Characteristics of
525 speargrass (*Imperata cylindrica*) dominated fields in West Africa: crops, soil
526 properties, farmer perceptions and management strategies. *Crop Protection*
527 19, 481–487.
528
- 529 35. Connolly J (1986) On difficulties with replacement series methodology in
530 mixture experiments. *Journal of Applied Ecology* 23, 125–137.
531
- 532 36. Baumann DT, Bastiaans L and Kropff MJ (2002) Intercropping system
533 optimization for yield, quality, and weed suppression combining mechanistic
534 and descriptive models. *Agronomy Journal* 94, 734–742.