WATER TREATMENT OF *PARKIA BIGLOBOSA* PULP DRESSED MAIZE (*ZEA MAYS* L.) SEEDS FOR *STRIGA HERMONTHICA* CONTROL AT MINNA, NIGERIA

KOLO M.G.M., MAMUDU A.Y.

Abstract

Seeds of two maize (Zea mays L.) varieties (Striga resistant Jo-98 and susceptible Obatanpa) were dressed with Parkia biglobosa (Jacq.) R. Br. pulp at 164 g to 1.0 kg maize seed. Various volumes of tap water (0, 50, 75, 100, 125 and 150 ml) were each added, stirred with a stirring rod and left overnight for 18 hours before sowing to evaluate their efficacy in Striga hermonthica (Del.) Benth. control under field conditions. The control was maize seeds without Parkia pulp dressing. The experiment was laid out as a split-plot arrangement in a randomized complete block design with maize varieties in the main plots and Parkia pulp concentration constituting the sub-plot treatments. All the treatments were replicated three times in both 2004 and 2005. Results indicate that maize varieties did not significantly differ in delaying Striga shoot emergence, reducing Striga shoot density per m^2 and number flowering and maize syndrome reaction score in 2004, but the resistant maize variety Jo-98 effectively reduced these parameters than the susceptible Obatanpa in 2005. Also, the resistant maize was significantly taller and produced greater grains than the susceptible one in both years of the study. The addition of 50 ml water significantly delayed Striga shoot emergence by 14 and 4 days in 2004 and 2005, respectively and correspondingly reduced shoot density by 58 to 62% and 69 to 71% compared with the no-water treatment. It also reduced Striga development and enhanced maize growth. These resulted in significant increase in maize grain yield by over 80% compared with the treatment without addition of water and with greater grain yield in the resistant variety than the susceptible one at each pulp concentration. Maize grain yield obtained from both varieties showed a high negative correlation with number of Striga shoots/m^2 and positive relationship with maize plant height.

Keywords: *Parkia biglobosa* pulp, maize seed treatment,*Striga hermonthica* management

INTRODUCTION

The parasitic witchweed (*Striga hermonthica* (Del.) Benth.) is a major constraint to cereal (maize, sorghum, upland rice and millet) production in African sub-Sahara. It is the most economically important of all *Striga* spp. The weed did not pose severe agricultural problems until 20–30 years ago even though it existed in the African cropping systems (Parker and Riches, 1993). This was because farmers practiced crop rotation, mix cropping and shifting cultivation which allowed prolonged periods of fallow. However, this pattern of cropping system changed as a result of high human population growth which has led to little or no fallow periods for land rejuvenation.

Yield losses caused by the weed are often times significant and complete crop failure could occur. The weed is difficult to control because of the build-up of a large reserve of its seeds in the soil which remain viable for many years. The *Striga* problem continues to increase and as a result, farmers are forced to abandon *Striga* infested fields (Kanampiu et al., 2003). For now, no control measure has so far been developed that is effective in *S. hermonthica* control. Several methods of controlling the weed are recommended, but are either incompatible with the cropping system, expensive or unstable and have to be practiced over several cropping seasons. Therefore, cost effective alternative control methods that are acceptable to small-scale farmers are needed. Such alternative approach is to identify technological practices that either inhibit or cause suicidal germination of *S. hermonthica*.

Efforts have been made to identify chemicals that could either inhibit or stimulate *S. hermonthica* seeds germination. For example, Berner (1994) observed that cowpea seeds treated with imazaquin herbicide significantly reduced number of *S. hermonthica* shoots in a laboratory/screen house studies. The results of a similar study (Gworgwor et al., 2002) showed that soaking millet (*Pennisetum glaucum* (L.) R.Br. seeds in cow urine for about 6–7 hours supported less emergence of *S. hermonthica* shoots. Also, Kanampiu et al. (2003) indicated that maize seed coating with imazapyr and pyrithiobac provided *Striga* control throughout the season. It has also been demonstrated (Kolo and Nkonchoson, 2003; Kolo et al., 2005) that *P. biglobosa* parts (husk and seed extracts) reduced *S. hermonthica* shoots in maize. Recently, Ma et al. (2004) found several Chinese herb extracts to have either inhibited or induced *S. hermonthica* seed germination in laboratory studies.

As a follow-up to previous studies (Kolo and Nkochoson, 2003; Kolo et al., 2005) this study focuses on the use of *P. biglobosa* pulp for *S. hermonthica* control in maize. *P. biglobosa* is an important traditional economic tree legume of the African savanna zone. It has multipurpose potentials (fodder, human food, medicine) and contains high tannin and phenolic compounds (Sabiiti and Cobbina, 1992). Most Nigerian farmers dress their crop seeds with insecticide/fungicide chemicals prior to sowing, mainly against soil borne pests and diseases. It is therefore reasoned that this economically viable technology will be accepted by farmers, especially that the pulp material is readily and abundantly available. The objective of this study therefore, was to evaluate *P. biglobosa* pulp at various concentrations for *S. hermonthica* control under field conditions.

MATERIALS AND METHODS

A field trial was conducted on fields naturally infested by *S. hermonthica* in 2004 and repeated in a separate, but similar field condition during 2005 cropping season in Minna (9^0 37'N and 6^0 32'E), in the Southern Guinea Savanna agro-ecological zone of Nigeria. The ridges were manually constructed 75 cm apart with hand hoe on 6 July and 23 June 2004 and 2005, respectively after land clearing. The main plot size was 4 x 5 m and 4 x 2.5 m sub-plots each with five 2.5 m long ridges. Two maize varieties (Jo-98 (*Striga* resistant) and Obatanpa (*Striga* susceptible)) were separately dressed with *P. biglobosa* pulp at the rate of 164 g to 1.0 kg of maize seed. The pulp was obtained from *P. biglobosa* fruits harvested in each year of study by removing the husk, pounding the seed in a mortar with a pestle and then the mixture was sieved to obtain the pulp which was kept until required. The treatments were the undressed maize seeds (control) or the addition of graduated quantities of tap water (0 ml, 50 ml, 75 ml, 100 ml, 125 ml and 150 ml) to the dressed maize seeds. All the dressed maize seeds (with or without water) were thoroughly stirred with a stirring rod and left overnight for 18 hours before sowing without washing off the pulp.

Two maize seeds were sown per hill at 25 cm × 75 cm on 7 July and 24 June 2004 and 2005, respectively and thinned to one plant per stand at two weeks after sowing (WAS). The treatments were randomly laid out in a split-plot design such that maize varieties constituted the main plots and seed dressing formed the subplots. They were replicated three times in each year of the study. Compound fertilizer (NPK 20 : 10 : 10) was applied at 3 WAS at the rate of 60 kg N, 30 kg P and 30 kg K in a single dose since high rates would reduce *S. hermonthica* growth. Manual hoe weeding was carried out at three weeks after sowing and hand pulling of weeds other than *S. hermonthica* was adopted at 5 and 8 WAS in order to avoid damage to *Striga* shoots.

Data were taken on days to *Striga* shoot emergence, *Striga* shoot density per m^2, *Striga* shoot density/maize plant stand, number of *Striga* shoots flowering at 10 WAS, visual maize damage score (on a scale of 1–10, where 1 indicated no plant damage by *Striga*, 5 was average damage and 10 was severe maize damage), maize plant height at 10 WAS and maize grain yield per ha. Maize 100-grain weight was also recorded. The data were subjected to analysis of variance and the treatment means separated by Duncan New Multiple Range Test (DNMRT) at $P \leq 0.05$.

RESULTS

The effect of maize variety on days to *S. hermonthica* shoot emergence was not significantly different in 2004 cropping season (Table 1). However, in 2005 and the combined effects of the two seasons maize variety Jo-98 significantly delayed *Striga* shoot emergence than the susceptible Obatanpa by over two days.

The most concentrated dressed maize seeds (addition of 50 ml water) significantly delayed *S. hermonthica* shoot emergence most (Table 1). However, days to *Striga* shoot emergence in maize seeds diluted with 75 ml water was similar to that obtained in the control treatment (maize only) and addition of 125 ml water or more to dressed maize seeds allowed *S. hermonthica* shoot emergence earliest. The 2004 and 2005 cropping seasons combined effect showed that dilution of *P. biglobosa* pulp dressed maize seeds with 50 ml water significantly delayed *S. hermonthica* shoot emergence more than the undressed (control) and undiluted treatments only. There were no interaction effects between the maize varieties and *P. biglobosa* pulp concentrations in 2004, 2005 and their combined data (Table 1).

The effect of maize variety on *Striga* shoot density did not vary significantly throughout the sampling periods in 2004 cropping season (Table 2). *Striga hermonthica* shoot density per m^2 in 2004 was lowest in maize seeds dressed with addition of 50 ml water, although this was not significantly different from those with addition of 75 or 100 ml water throughout the sampling periods (Table 2). In addition, the differences between the undressed or undiluted maize and those diluted with 100 ml or more water were not significant throughout the season. The mean data indicate that addition of 50 ml water to *P. biglobosa* pulp dressed maize seeds significantly reduced *S. hermonthica* shoot density than all other treatments and it significantly increased with increase in dilution factor.

The *Striga* resistant maize variety (Jo-98) significantly supported fewer number of *Striga* shoots than the susceptible Obatanpa throughout the sampling periods in 2005 cropping season (Table 2). The *S. hermonthica* shoot density per m^2 was significantly lowest throughout the growth period when 50 ml water was added to the *P. biglobosa* pulp dressed maize seeds in 2005 (Table 2). It was observed that *Striga* shoot density was consistently highest in the undressed maize (control). As observed in 2004, the weed's density in 2005 was directly proportional to the amount of water added to the dressed maize seeds throughout the sampling methods. The mean effect in 2005 showed that 50 and 75 ml dilution treatments were significantly most effective in reducing *Striga* shoot density.

Tab. 1: Effect of maize variety and *Parkia biglobosa* pulp concentration on number of days to first *Striga hermonthica* shoot emergence in 2004 a cropping seasons

Treatments	Days to *Striga* shoot emergence		
	2004	2005	combined
Maize variety (V)			
Obatanpa	51.7[a]	57.2[a]	54.5[a]
Jo-98	58.5[a]	59.7[b]	59.1[b]
SE (±)	N.S.	0.1	0.1
Pulp concentration (P)			
Maize only (No pulp)	47.3[a]	58.8[cd]	53.1[a]
Maize + pulp (No water)	47.3[a]	57.7[bc]	52.5[a]
Maize + pulp + 50 ml water	61.3[a]	62.0[e]	61.7[b]
Maize + pulp + 75 ml water	58.5[a]	59.7[d]	59.1[ab]
Maize + pulp + 100 ml water	58.7[a]	58.0[c]	58.4[ab]
Maize + pulp + 125 ml water	55.8[a]	56.3[a]	56.1[ab]
Maize + pulp + 150 ml water	56.5[a]	56.7[ab]	56.6[ab]
SE (±)	N. S	0.6	0.5
Interaction (VxP)	N.S.	N.S.	N.S.

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant

Tab. 2: Effect of maize variety and *P. biglobosa* pulp concentration on *S. hermonthica* shoot density per m^2 in 2004 and 2005 cropping seasons

Treatments	*Striga* shoot density per m^2							
	2004 – weeks after sowing				2005 – weeks after sowing			
	8	10	12	mean	8	10	12	mean
Maize variety (V)								
Obatanpa	4.4[a]	5.1[a]	5.7[a]	5.1[a]	5.2[b]	5.8[b]	6.6[b]	5.9[b]
Jo-98	4.5[a]	5.4[a]	6.1[a]	5.3[a]	4.2[a]	5.3[a]	5.9[a]	5.1[a]
SE (±)	N.S..	N.S.	N.S.	N.S.	0.4	0.3	0.3	0.2
Pulp concentration (P)								
Maize only (No pulp)	5.4[bc]	7.1[b]	7.6[b]	6.7[e]	6.9[f]	8.5[g]	9.1[g]	8.2[e]
Maize + pulp (No water)	5.5[bc]	6.6[b]	7.3[b]	6.5[e]	6.7[f]	8.0[f]	8.5[f]	7.7[e]
Maize + pulp + 50 ml water	2.1[a]	2.5[a]	3.1[a]	2.6[a]	2.0[a]	2.3[a]	2.6a	2.3[a]
Maize + pulp + 75 ml water	2.4[a]	3.1[a]	4.0[a]	3.1[b]	2.5[b]	2.7[b]	3.3[b]	2.8[a]
Maize + pulp + 100 ml water	4.0[ab]	4.8[ab]	5.3[ab]	4.7[c]	3.9[c]	4.7[c]	5.6[c]	4.7[b]
Maize + pulp + 125 ml water	5.3[bc]	5.8[b]	6.6[b]	5.9[d]	4.8[d]	6.0[d]	6.6[d]	5.8[c]
Maize + pulp + 150 ml water[c]	6.5	6.7[b]	7.7[b]	7.0[e]	6.1[e]	6.9[e]	8.0[e]	7.0[d]
S.E (±)	6.1	7.4	9.1	1.6	1.1	0.9	0.6	2.0
Interaction (VxP)	N.S.	N.S..	N.S..	*	*	N.S..	*	*

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant, * = significant at $P \leq 0.05$

Significant differences were not found in *Striga* shoot density/maize plant stand among the two maize varieties tested throughout the sampling periods, however the mean value indicated that the resistant variety Jo-98 significantly suppressed *Striga* shoot density than the susceptible Obatanpa (Table 3). The *S. hermonthica* shoot density per maize plant stand in 2004 cropping season was significantly lowest in 50 ml water treated maize seeds dressed with *P. biglobosa* pulp, although it was similar with those with addition of 75 ml water throughout the sampling periods (Table 3). As observed earlier, the *Striga* shoot density/maize plant stand increased with water dilution throughout the growth period. The mean effect shows that *Striga* shoot density/maize plant stand also significantly increased with the amount of water added to the dressed maize seeds. The interaction effect of the mean *Striga* shoot density/maize plant stand in 2004 is shown in Table 9.

Tab. 3: Effect of maize variety and *P. biglobosa* pulp concentration on number of *S. hermonthica* shoots per maize plant stand at various times in 2004 cropping season

	Number of *Striga* shoots/maize stand – weeks after sowing			
Treatments	8	10	12	mean
Maize variety (V)				
Obatanpa	3.6[a]	4.1[a]	4.2[a]	4.0[a]
Jo-98	3.8[a]	4.3[a]	4.5[a]	4.2[b]
SE (±)	N.S.	N.S..	N.S.	0.1
Pulp concentration (P)				
Maize only (No pulp)	3.9[bc]	4.8[bc]	5.0[bc]	4.6d
Maize + pulp (No water)	4.1[bc]	4.8[bc]	5.0[bc]	4.6d
Maize + pulp + 50 ml water	1.6[a]	2.4[a]	2.2[a]	2.1[a]
Maize + pulp + 75 ml water	2.8[ab]	3.3[ab]	3.5[ab]	3.2[b]
Maize + pulp + 100 ml water	3.8[bc]	4.3[bc]	4.2[bc]	4.1[c]
Maize + pulp + 125 ml water	4.5[c]	5.0[bc]	4.7[bc]	4.7[d]
Maize + pulp + 150 ml water	5.1[c]	5.1[c]	5.5[c]	5.2[e]
S.E(±)	0.5	0.5	0.6	0.1
Interaction (VxP)	N.S.	N.S.	N.S.	*

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant, * = significant at $P \leq 0.05$

Tab. 4: Interaction between maize variety and *P. biglobosa* pulp concentration on number of *Striga* shoots per maize plant stand in 2005 cropping season

	Number of *Striga* shoots/maize stand – weeks after sowing			
Treatments	8	10	12	mean
Pulp concentration				
Jo-98				
Maize only	4.6[i]	5.5[j]	5.9[h]	5.3[h]
0 ml water	4.8[jk]	5.5[j]	5.9[h]	5.4[h]
50 ml water	1.4[a]	2.1[a]	2.2[a]	1.9[a]
75 ml water	2.5[c]	3.3[c]	3.7[c]	3.2[c]
100 ml water	3.5[e]	3.8[e]	3.9[d]	3.7[d]
125 ml water	3.8[f]	4.3[g]	4.4[e]	4.2[e]
150 ml water	4.1[h]	4.8[h]	5.5[g]	4.8[g]
Obatanpa				
Maize only	4.8[j]	5.7[k]	6.0[i]	5.5[i]
0 ml water	4.9[k]	5.9[l]	5.9[hi]	5.6[hi]
50 ml water	1.7[b]	2.5[b]	2.8[b]	2.3[b]
75 ml water	2.8[d]	3.5[d]	3.9[d]	3.4[d]
100 ml water	3.8[f]	4.0[f]	4.5[e]	4.1[e]
125 ml water	4.0[g]	4.8[h]	5.1[f]	4.6[f]
150 ml water	4.8[jk]	5.1[i]	5.9[h]	5.3[h]
S.E (±)	0.1	0.1	0.1	N.S

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$)

The effect of interaction between *Parkia* pulp concentration and maize variety on *S. hermonthica* shoot density/maize plant stand in 2005 cropping season shows that the maize variety Jo-98 consistently significantly had fewer *S. hermonthica* shoots/maize plant stand at each *Parkia* pulp concentration than the susceptible Obatanpa throughout the growth period and their mean observation (Table 4). The density of *Striga* shoots/maize plant stand also increased as the amount of water added to the *P. biglobosa* pulp dressed maize seeds increased (Table 4).

The effect of maize variety on the number of flowering *Striga* shoots were statistically similar in 2004, while the resistant maize variety Jo-98 significantly reduced the number than the susceptible Obatanpa in 2005 (Table 5). The number of *S. hermonthica* shoots flowering was such that it increased with increase in addition of water to *P. biglobosa* dressed maize seeds for both years of study (Table 5). While the addition of 50 ml water to dressed maize seeds significantly produced the fewest number of *Striga* shoots with flowers which was similar to those with 75–100 ml water addition in 2004, that with 50 ml water treatment significantly produced the least number in 2005 cropping season. The interaction effect of maize variety and *P. biglobosa* pulp concentration on *Striga* shoots flowering in 2005 is shown in Table 9. The two years combined effect indicates that the addition of 50 or 75 ml water to *P. biglobosa* dressed maize seeds significantly suppressed *Striga* shoots flowering than other treatments (Table 5).

The maize varieties did not significantly influence maize damage severity score in 2004, however Jo-98 was significantly less attacked by *Striga* than Obatanpa in 2005 cropping season (Table 5). However, the overall effect of the combined years data did not show any significance among the two varieties. The effect of *S. hermonthica* on maize damage severity score was about 100% more in non-diluted dressed maize seeds than

Tab. 5: Effect of maize variety and *P. biglobosa* pulp concentration on number of flowering *S. hermonthica* shoots per m^2 at 10 weeks after sowing and *Striga* severity score in 2004 and 2005 cropping seasons

	Flowering *Striga* shoots per m^2			*Striga* severity score		
Treatments	2004	2005	combined	2004	2005	combined
Maize variety (V)						
Obatanpa	4.7^a	5.2^b	5.0^a	6.7^a	7.8^b	7.3^a
Jo-98	4.9^a	4.7^a	4.8^a	6.9^a	6.8^a	6.9^a
SE (±)	N.S.	0.3	N.S.	N.S.	0.1	N.S.
Pulp concentration (P)						
Maize only (No pulp)	6.1^c	7.6^g	6.9^d	8.0^b	10.0^g	9.0^d
Maize + pulp (No water)	5.9^c	7.3^f	6.6^d	0^b	9.3^f	8.7^d
Maize + pulp + 50 ml water	2.4^a	1.9^a	2.1^a	4.0^a	3.8^a	3.9^a
Maize + pulp + 75 ml water	3.4^{ab}	2.4^b	2.9^a	4.2^a	4.3^b	4.3^a
Maize + pulp + 100 ml water	4.3^{abc}	4.1^c	4.2^c	7.2^b	7.2^c	7.2^b
Maize + pulp + 125 ml water	5.5^{bc}	5.3^d	5.4^c	7.7^b	7.7^d	7.7^{bc}
Maize + pulp + 150 ml water	6.1^c	6.0^e	6.1^{cd}	8.3^b	8.5^e	8.4^{bc}
S.E (±)	7.0	0.3	0.4	0.9	0.1	0.5
Interaction(VxP)	N.S.	*	N.S.	N.S.	N.S.	N.S.

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant, * = significant at $P \leq 0.05$

Tab. 6: Effect of maize variety and *P. biglobosa* pulp concentration on maize plant height (cm) in 2004 and 2005 cropping seasons

	Maize plant height (cm)					
	2004 weeks after sowing			2005 weeks after sowing		
Treatments	8	10	mean	8	10	mean
Maize variety (V)						
Obatanpa	28.0^a	41.0^a	34.5^a	31.2^a	42.7^a	37.0^a
Jo-98	33.1^b	47.8^b	40.5^a	34.3^b	45.2^b	39.8^a
SE (±)	0.8	1.0	N.S.	0.7	0.2	N.S.
Pulp concentration (P)						
Maize only (No pulp)	14.0^a	18.7^a	16.4^a	15.4^a	22.0^a	18.7^a
Maize + pulp + 0 ml water	15.1^a	17.5^a	16.3^a	15.6^a	21.1^a	18.4^a
Maize + pulp + 50 ml water	54.2^f	80.1^f	67.2^f	50.5^e	76.3^f	63.4^f
Maize + pulp + 75 ml water	40.9^e	68.0^e	54.5^e	42.1^d	61.4^e	51.8^e
Maize + pulp + 100 ml water	35.7^d	55.8^d	45.8^d	41.6^d	51.6^d	46.6^d
Maize + pulp + 125 ml water	29.6^c	41.4^c	35.5^c	36.9^e	44.3^c	40.6^c
Maize + pulp + 150 ml water	24.4^b	29.1^b	26.8^b	27.2^b	30.9^b	29.1^b
S.E (±)	1.6	2.2	1.8	1.3	0.4	0.8
Interaction (VxP)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant

Tab. 7: Interaction effect of maize variety and *P. biglobosa* concentration on maize grain yield (kg/ha^2) in 2004 and 2005 cropping seasons

Pulp concentration/maize variety	Grain yield (kg/ha)		
	2004	2005	combined
Jo-98			
Maize only (No pulp)	416^c	325^b	371^b
Maize + pulp + 0 ml water	440^c	448^d	444^c
Maize + pulp + 50 ml water	2 437^m	2 737^l	2 542^l
Maize + pulp + 75 ml water	1 796^k	1 892^j	1 844^j
Maize + pulp + 100 ml water	1 244^i	1 019^h	1 132^h
Maize + pulp + 125 ml water	985^g	987^g	986^g
Maize + pulp + 150 ml water	632^e	528^e	580^e
Obatanpa			
Maize only (No pulp)	207^a	230^a	219^a
Maize + pulp (No water)	273^b	411^c	342^b
Maize + pulp + 50 ml water	2 088^l	2 416^k	2 252^k
Maize + pulp + 75 ml water	1 448^j	1 566^i	1 507^i
Maize + pulp + 100 ml water	1 030^h	999g^h	1 015^h
Maize + pulp + 125 ml water	907^f	956^f	932^f
Maize + pulp + 150 ml water	589^d	424^{cd}	507^d
S.E. (±)	6	6	7

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$)

those with 50 ml water in both years of the study (Table 5). It was observed that the addition of either 50 or 75 ml water in 2004 produced significantly less attacked maize plants than those in other treatments Table 5 further shows that the effect of *Striga* damage on maize plants significantly increased as the volume of water added to *P. biglobosa* pulp increased in both 2004 and 2005 such that the least addition of 50 ml water significantly produced the least damaged maize plants. The 2004 and 2005 combined maize plant damage severity score was such that the least attack by *Striga* was in maize seeds dressed with 50 or 75 ml water addition (Table 5).

The *Striga* resistant maize variety (Jo-98) significantly produced taller plants than Obtatanpa in both 2004 and 2005 cropping seasons (Table 6). Treating the dressed maize seeds with 50 ml water significantly resulted in taller plants at 8 and 10 WAS in both years of the study. However, maize plant height was significantly reduced by the effect of *Striga* as the amount of water added to *P. biglobosa* pulp dressed maize seeds increased from 50 ml to 150 ml in both years of study. It was observed that maize seeds dressed without addition of water and those not dressed (control) produced the shortest plants which did not significantly differ from each other in the two cropping seasons.

The maize variety Jo-98 out-yielded Obatanpa at all water levels in the two cropping seasons (Table 7). Furthermore, maize grain yield in the two varieties reduced with increase in addition of water to *P. biglobosa* pulp dressed maize seeds in both seasons and their combined effect. The undressed and undiluted dressed seeds produced the lowest grain yield in both maize varieties (Table 7). The maize variety Jo-98 significantly produced heavier grains than Obatanpa in both 2004 and 2005 cropping seasons and following previous trends, maize seed weight significantly reduced as the amount of water added to the dressed maize seeds increased from 50 to 125 ml in the two seasons and the combined effect of the two seasons (Table 8). Maize grain weight of undressed or undiluted dressed seeds in one hand and those diluted with 125 or 150 ml water on the other were similar, respectively, whether in 2004, 2005 or their combined effect (Table 8). The interaction effect of maize variety and *P. biglobosa* pulp concentration on grain weight in 2005 is shown in Table 9.

Table 9 shows the interaction effects of maize variety and *P. biglobosa* concentration on mean *Striga* shoot density per m in 2004 and 2005, mean *Striga* shoot density/maize plant stand in 2004, *Striga* shoots flowering m^{-2} and maize 100-grain weight in 2005. The undressed and undiluted *Striga* resistant Jo-98 maize seed had the highest *Striga* shoot density per m^2 that were similar to those diluted with either 150 ml or susceptible Obatanpa diluted with 125–150 ml water in 2004 and 2005, respectively (Table 9). Dressed maize seeds diluted with 50 or 75 ml water had significantly reduced *Striga* shoot density per m^2 in both varieties than other treatments in the two years of the study (Table 9).

The *Striga* shoot density/maize plant stand in 2004 shows that non-dressed, non- diluted or those diluted with 100–150 ml water resistant Jo-98 maize seeds were at par with the susceptible Obatanpa maize seeds diluted with 100–150 ml water (Table 9). While only 50 ml diluted *P. biglobosa* dressed resistant Jo-98 maize seeds significantly reduced *Striga* shoot density/maize plant stand, the undressed, undiluted and 50 ml diluted susceptible Obatanpa significantly reduced *Striga* shoot density/maize plant stand (Table 9).

While the addition of 50–75 ml water to *P. biglobosa* dressed resistant Jo-98 significantly reduced the number of *Striga* shoots flowering, only 50 ml water addition significantly reduced it than other treatments in the susceptible Obatanpa (Table 9). It was observed that the effect of non-dilution of resistant Jo-98 maize was similar to that of the susceptible variety with addition of 150 ml water (Table 9). The resistant maize variety Jo-98 dressed seeds diluted with 50 ml water produced the heaviest grains and the addition of 75 ml water gave

Tab. 8: Effect of maize variety and *P. biglobosa* concentration on 100 grain weight (g) of maize in 2004 and 2005 cropping seasons

Treatments	100-grain weight (g)		
	2004	2005	combined
Maize variety (V)			
Obatanpa	3.1^{a}	14.6^{a}	13.9^{a}
Jo-98	15.9^{b}	16.3^{b}	16.1^{b}
SE (±)	0.5	0.2	0.2
Pulp concentration (P)			
Maize only (No pulp)	8.0^{ab}	9.6^{a}	8.8^{a}
Maize + pulp (No water)	7.8^{a}	9.6^{a}	8.7^{a}
Maize + pulp + 50 ml water	27.0^{e}	27.9^{e}	27.5^{e}
Maize + pulp + 75 ml water	22.1^{d}	23.1^{d}	22.6^{d}
Maize + pulp + 100 ml water	15.6^{c}	15.2^{c}	15.4^{c}
Maize + pulp + 125 ml water	10.7^{b}	11.7^{b}	11.2^{b}
Maize + pulp + 150 ml water	10.2^{ab}	11.0^{ab}	10.6^{b}
S.E (±)	1.0	0.6	0.6
Interaction(V × P)	N.S.	*	N.S.

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$); N.S. = Not Significant, * = significant at $P \leq 0.05$

Tab. 9: Interaction combined effects of maize varieties and *P. biglobosa* concentration on *S. hermonthica* shoot density per m^2 in 2004 and 2005, *Striga* shoot density/maize plant stand in 2004 and *Striga* shoots flowering per m^2 in 2005 and 100-grain weight (g) in 2005

Treatments	*Striga* density/m^2		*Striga* density/ maize plant	*Striga* shoots flowering/m^2	100-grain weight (g)
	2004	2005	2004	2005	2005
Pulp concentration					
Maize variety Jo-98					
Maize only	7.9^{e}	7.9^{g}	4.3^{def}	7.5^{i}	9.7^{ab}
0 ml water	7.6^{e}	7.4^{fg}	4.3^{def}	6.9^{h}	9.9^{ab}
50 ml water	2.5^{a}	1.8^{a}	1.9^{a}	1.8^{ab}	31.3^{g}
75 ml water	3.0^{a}	2.5^{ab}	3.0^{abc}	2.2^{ab}	23.9^{ef}
100 ml water	4.2^{ab}	4.3^{cd}	3.8^{cde}	3.6^{d}	16.2^{d}
125 ml water	5.6^{bcd}	5.4^{de}	4.5^{ef}	4.9^{f}	11.6^{b}
150 ml water	6.7^{cde}	6.6^{efg}	5.1^{ef}	5.7^{g}	11.1^{ab}
Maize variety Obatanpa					
Maize only	5.5^{bcd}	5.6^{de}	2.9^{abc}	7.8^{i}	9.5^{a}
0 ml water	5.3^{bc}	8.0^{g}	2.9^{abc}	7.6^{i}	9.4^{a}
50 ml water	2.8^{a}	2.7^{ab}	2.4^{ab}	1.9^{ab}	24.5^{f}
75 ml water	3.3^{a}	3.2^{bc}	3.4^{bcd}	2.5^{c}	22.2^{e}
100 ml water	5.2^{bc}	5.2^{de}	4.3^{def}	4.6^{e}	14.1^{c}
125 ml water	6.2^{cde}	6.1^{ef}	5.0^{ef}	5.8^{g}	11.7^{b}
150 ml water	7.2^{de}	7.3^{fg}	5.3^{f}	6.6^{h}	10.9^{ab}
SE(±)	5.7	4.4	0.4	0.7	0.6

Means followed by the same letter(s) in the same column are not significantly different from each other by DNMRT ($P \leq 0.05$)

similar grains as the susceptible Obatanpa diluted with 50 ml water (Table 9).

Significant negative correlation (r = –0.765) was observed between the number of *Striga* shoots per m^2 and days to first *Striga* shoot emergence in the resistant maize variety Jo 98, and not the susceptible variety Obatanpa (Table 10). However, number of *Striga* shoots per maize plant stand was highly and positively related (r = 0.925) to number of *Striga* shoots per m^2 in the susceptible variety only. It was observed that the number of *Striga* shoots flowering at 10 WAS was negatively correlated (r = –0.749) with days to first *Striga* shoot emergence in the resistant maize variety Jo-98. The number of *Striga* shoots flowering was highly significantly positively correlated (r = 0.992 and 0.993) with number of *Striga* shoots per m^2 in both maize varieties, respectively. The susceptible Obatanpa maize variety showed a positive relationship (r = 0.912) with number of *Striga* shoots found per maize plant and not the resistant variety Jo-98. The latter showed a significant negative correlation (r = –0.777) between maize plant damage severity score with days to *Striga* shoot emergence. The degree of maize plant attack by *Striga* was positively significantly related (r = 0.962 and 0.982) with *Striga* shoot density per m^2 in both varieties, respectively. While the level of attack by *Striga* in susceptible maize variety Obatanpa was positively significantly correlated with density of *Striga* shoots/maize plant stand, the resistant maize variety was not affected. It was noted that maize plant damage was positively and significantly correlated (r = 0.953 and 0.979) with the number of *Striga* shoots flowering, respectively (Table 10).

Tab. 10: Correlation coefficient of 2004 and 2005 combined data between *Striga* and maize parameters in Obatanpa (light phase) and Jo-98 (bold phase).

	1	2	3	4	5	6	7
2	0.104 –0.765**	–					
3	0.249 0.223	0.925** –0.090	–				
4	0.063 –0.749**	0.992** 0.993**	0.912** –0.079	–			
5	0.225 –0.777**	0.962** 0.982**	0.911** –0.122	0.953** 0.979**	–		
6	0.613** 0.756**	–0.699** –0.975**	–0.541* 0.011	–0.723** –0.980**	–0.561** –0.968**	–	
7	0.509* 0.857**	–0.769** –0.956**	–0.664** 0.164	–0.792** –0.948**	–0.664** 0.971**	0.971** 0.953**	–

Levels of significance are indicated by * and ** at 0.05% and 0.01% probability, respectively.
1 = Days to first *Striga* shoot emergence; 2 = Number of *Striga* shoots/m^2; 3 = Number of *Striga* shoots/maize plant stand; 4 = Number of *Striga* shoots flowering at 10 WAS; 5 = Maize damage severity score; 6 = Maize plant height; 7 = Maize grain yield

Furthermore, Table 10 shows that maize plant height was positively (r = 0.756) and negatively (r = –0.975) correlated with days to first *Striga* shoot emergence and number of *Striga* shoots/m^2 in the resistant maize variety Jo-98, respectively. While maize plant height was greatly reduced by the number of *Striga* shoots per maize plant stand in the susceptible variety, the resistant maize variety was not significantly affected. However, maize plant height was highly negatively correlated (r = –0.723 and –0.980) with number of *Striga* shoots flowering and maize plant damage (r = –0.561 and –0.968) in both maize varieties, respectively.

A highly significant positive correlation (r = 0.857) existed between maize grain yield and days to first *Striga* shoot emergence in the resistant variety, such that the more shoot emergence was delayed, the higher was the maize grain yield. However, maize grain yield was highly negatively correlated (r = –0.769 and –0.956) with number of *Striga* shoots/m^2 in both maize varieties, respectively. That notwithstanding, while maize grain yield was negatively correlated (r = –0.664) with the number of *Striga* shoots per maize plant stand in the susceptible maize variety Obatanpa, the resistant variety (Jo-98) was not significantly affected. Similarly, maize grain yield was highly significantly negatively (r = –0.792 and –0.948) affected by the number of *Striga* shoots flowering, negatively (r = –0.664) and positively (r = 0.971) affected by maize plant damage in both varieties, respectively. Interestingly, maize grain yield was positively correlated (r = 0.971 and 0.953) with maize plant height, respectively.

DISCUSSION

The ability of maize variety Jo-98 to consistently delay *S. hermonthica* shoot emergence than the susceptible Obatanpa in both years of study could be due to its natural tolerance, thereby making *Striga* haustorium attachment to the resistant host maize root difficult as observed by van Ast et al. (2000). It was observed in this study that the resistant maize variety Jo-98 greatly reduced *Striga* shoot density, but only in 2005 cropping season. This is in consonance with the findings of van Ast and Bastiaans (2006) who noted that sensitive sorghum cultivar was more severely affected by *Striga* than the susceptible one.

The results presented indicate that the use of *P. biglobosa* pulp to dress maize seeds with 50 ml water offered significant control of *S. hermonthica* in all the parameters measured in this study which was achieved by delaying *Striga* shoot emergence and reducing shoot density in agreement with the findings of Kanampiu et al. (2003). *S. hermonthica* shoot density was reduced by about 58–62% and 69–71% compared with those without addition of water in 2004 and 2005 cropping seasons, respectively. Dilution of *P. biglobosa* pulp with 50 ml water also reduced *S. hermonthica* shoot per maize plant stand by 50–61% in comparison with those without water in both years of the study. However, *S. hermonthica* shoot density increased with dilution factor in both maize varieties, which could be due to reduced binding effect of the pulp with maize seeds. Heavy rains could have washed the *P. biglobosa* pulp away from the crop's rhizosphere which probably reduced the efficacy of those with high dilution with time.

The greater the *Striga* shoot density, the higher the number flowering, which has implication on its seed production. The higher the number of *Striga* shoots flowering the greater the soil seed bank for future infestation. Since a single *S. hermonthica* plant can produce as many as 50 000 seeds in one growth cycle (Bebawi et al., 1984), control strategies should be directed towards prevention of seed forming shoots and hence, seed bank build-up depletion. Maize seeds dressed with addition of 50 ml water had fewer number of *S. hermonthica* shoots flowering because it was more concentrated than other treatments. As a result therefore, more pulp could have stuck to maize seeds thereby giving a better reaction. Similarly, number of *Striga* shoots flowering was reduced by 59% and 74% in maize seeds with 50 ml water treatment compared with that dressed without addition of water, and was even greater than that observed in the undressed maize seeds in 2004 and 2005, respectively. The role of water in dressing maize seeds with *P. biglobosa* pulp was to allow the latter to stick to the maize seeds and probably imbibed by the seeds as they germinated thereby affecting *Striga* seeds since Parkia is said to contain high concentration of tannin and phenolic compounds (Sabiiti and Cobbina, 1992).

Despite higher *Striga* infestation of the resistant maize variety Jo-98 in 2004 and not in 2005 (Tables 2 and 3), it produced taller plants and out-yielded the susceptible Obatanpa in the two years of the study. In addition to resistance, this could be explained by a delay in the onset of *Striga* haustorium attachment to the host maize root as demonstrated by shoot emergence (Table 1). Rodenburg et al. (2006) found that host crop resistance played an important role in *Striga* reproduction by reducing it by 70–93% compared with the susceptible one.

The effect of *S. hermonthica* attack on maize (syndrome reaction score) was least in maize seeds dressed with *P. biglobosa* pulp with 50 ml water because *Striga* shoots emerged late (Table 1) and density was fewer (Tables 2 and 3) in this treatment. It was possible that *Striga* seed germination and/or attachment to the host maize root in treatments with 50 ml water were more severely inhibited than those in other treatments. Consequent upon this therefore, maize plants from seeds dressed with addition of 50 ml water developed taller throughout the two seasons and maize grain yield was eventually greater. Kanampiu et al. (2003) obtained a 3-4-fold increase in maize yield when the seeds were coated with imazapyr and pyrithiobac before sowing. The heaviest maize grains were also obtained from this treatment in both years of the study.

The correlation analysis showed that both the growth and grain yield of the susceptible maize variety Obatanpa were more adversely affected by *Striga* than the resistant variety Jo-98 in agreement with the findings of van Ast et al. (2000).

CONCLUSION

We conclude that resistant/tolerant maize varieties are strongly recommended for sowing in *Striga* – infested fields for enhanced crop yield. Furthermore, *S. hermonthica* can be controlled by dressing 1.0 kg maize seeds with 164 g of *P. biglobasa* pulp in 50–75 ml water as a component of integrated *Striga* management package.

REFERENCES

Ast van A., Bastiaans L., Kropff M.J. (2000): A comparative study on Striga hermonthica interaction with a sensitive and a tolerant sorghum cultivar. Weed Research, 40: 479–493.

Ast van A., Bastiaans L. (2006): The role of infection time in the differential response of sorghum cultivars to Striga hermonthica infection. Weed Research, 46:264–274.

Bebawi F.E., Eplee R.E., Harris C.E., Norris R.S. (1984): Longevity of witchweed (Striga asiatica) seed. Weed Science, 32: 494–497.

Berner D.K., Awad A.E., Aigbokhan E.I. (1994): Potential of Imazaquine seed treatment for control of

Striga gesnerioides and Alectra vogelii in cowpea (Vigna unguiculata). Plant Disease, 78: 18–23.

GWORGWOR N.A., SHALL S.D., ABBA A. (2002): Preliminary evaluation of effectiveness of cow urine in controlling Striga hermonthica (Del.) Benth. in the semi-arid zone of Nigeria. Journal of Sustainable Tropical Agricultural Research, 4: 50–55.

KANAMPIU F.K., KABAMBE V., MASSAWE C., JASI L., FRIESEN D., RANSOM J.K., GRESSEL J. (2003): Multisite, multi-season field tests demonstrate that herbicide seed coating herbicide-resistance maize controls Striga spp. and increases yields in several African countries. Crop protection, 22: 697–706.

KOLO M.G.M., NKONCHOSON M.G. (2003): Maize (Zea mays L.) seed dressing with Parkia biglobosa (Jacq.) R.Br. for Striga hermonthica (Del.) Benth. control in Minna, Nigeria. Journal of Sustainable Tropical Agricultural Research, **7**: 83–87.

KOLO M.G.M., USMAN I., FADIPE A.L., ADESINA G.O., IBIKUNLE G.F. (2005): Dressing of maize (Zea mays L.) seed with Parkia biglobosa (Jacq.) R. Br. extracts to control Striga hermonthica (Del.) Benth. Journal of Sustainable Tropical Agricultural Research, 13: 81–85.

MA Y.Q., CHENG J.M, INANAGA S., SHUI J.F. (2004): Induction and Inhibition of Striga hermonthica (Del.) Benth. germination by extracts of traditional Chinese medicinal herbs. Agronomy Journal, 96: 1349–1356.

PARKER C., RICHES C.R. (1993): Parasitic weeds of the world: Biology and control. CAB International, Wallingford, U.K.

RODENBURG J., BASTIAAN L., KROPFF M.J., AST VAN A. (2006): Effects of host plant genotype and seedbank density on Striga reproduction. Weed Research, 46: 251–263.

SABIITI E.N., COBBINA J. (1992): Initial agronomic evaluation of Parkia biglobosa in the humid zone of Nigeria. Agroforestry Systems, 17: 271–279.

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Corresponding author:

M.G.M. Kolo
Department of Crop Production,
Federal University of Technology,
P.M.B. 65, Minna, Nigeria.
e-mail: mgmkolo@yahoo.com