Vol. 11(3), pp. 20-26, July 2019
DOI: 10.5897/JABSD2019.0342
Article Number: 00F8C3B61440
ISSN: 2141-2340

http://www.academicjournals.org/JABSD

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Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research

Integrated weed management systems in sorghum based cropping system in Nigeria

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Received 23 January, 2019; Accepted 7 May, 2019

Sorghum (*Sorghum bicolor* (L) Moench) is the fifth most important staple food crop after wheat, rice, maize and barley. Sorghum is consumed by more than 70% of the population. *Striga hermonthica* is a serious biotic constraint to cereal production in the dry savannas of sub-Saharan Africa. *Striga* infestation in sorghum is reported to be higher in Nigeria than in other West African countries with about 80% (8.7 million ha) of land cropped to sorghum infested by this weed. Field trials were conducted in 2012 and 2013 to evaluate the effect of seed treatment, sowing date and trap crop in the management of *S. hermonthica*. During the investigation in two sorghum (resistance and susceptible) which involved intercropping with soyabean, seedtreatment with *parkia biglobosa* pulp and sowing at different dates (June and July), these were found to reduce the infestation of sorghum by *S. hermonthica*. The results showed that the effect of shading by soyabean, putative allelopathic mechanism effect of *parkia* material and high relative humidity due to established rainfall in July showed some benefits against *S. hermonthica* infestation. Growth of *S. hermonthica* was almost completely suppressed and yield increased with the resistant sorghum intercropped with soyabean, primed at 66 g/L *parkia* and planted in July.

Key words: Shading, soyabean, allelopathy, *Parkia* pulp, sorghum, *Striga*.

INTRODUCTION

Producing enough food for an ever-growing population is the biggest problem facing the human race, worldwide. A large proportion of crops are lost to insects, diseases, weeds, and parasitic plants. In the developing world where farmers and governments struggle to feed hungry mouths, the cost of the damage caused by these pests on agriculture is of utmost concern. Sorghum is a very economic important cereal crop and represents major staple food crop for many developing countries (FAO, 2012). Sorghum was severely affected by weeds infestation during the 4-5 weeks after seeds emergence and seedling growth. As a consequence, severe uncontrolled weed infestations often cause poor crop establishment or complete crop failure (Pannacci et al., 2010). The origin of *Striga hermonthica* is unclear. It may have originated in Northeast Asia (Scholes and Press, 2008). It is the largest and most destructive of the *Striga* species and considered as one of the most serious

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weeds in Africa (Oswald, 2005). The *Striga* problem in *Africa* is intimately associated with human population growth. Traditional African cropping systems included prolonged fallow, rotations and intercropping, which were common practices that kept *Striga* species infestations at tolerable levels (IITA, 2004; Kanampiu et al., 2002). The use of *Parkia* pulp has been found to improve the soil's physicochemical properties and inhibits the germination of S. gesnerioides seeds in cowpea at Burkina Faso (Itta et al., 2014). Similarly, Magani et al. (2010) reported 29.1 and 38.8% less *S. hermonthica* emergence in field and greenhouse respectively, when Parkia based products were used in maize. Incidence and severity of *S*. *hermonthica* are exceptionally high on sorghum, pearl millet and maize, the main staple foods for over 300 million people in Sub-Saharan Africa (Scholes and Press, 2008). The impact of *Striga* damages depends on ecological conditions, cropping systems, local cultural practices and farmers' skills on the ecology (IITA, 2002). Intercropping of cereals with legumes, application of organic fertilizers and genetic resistance of host plants are three control methods with a high potential for adoption by farmers (Oswald, 2005). Allelopathy plays an important role in agricultural ecosystems and in a large scale, in the plant covers among the crop-crop, crop-weed and tree-crop covers. These interactions are detrimental and occasionally, are useful and gave attention to allelopathy in natural and agricultural ecosystems. Today, allelopathy is recognized as appropriate potential technology to control weeds using chemicals released from decomposed plant parts of various species (Naseem et al., 2009). Bioherbicides represent solution to heavy use of synthetic herbicides which cause serious threats to the environment, consumers and increase costs of crop production (Asghari and Tewari, 2007). Moreover, continuous use of herbicides for weeds control causes herbicide resistant (Naseem et al., 2009). Many authors reported employing plants extracts for controlling weeds with variable success (Hussain et al., 2007; Iqbal et al., 2009; Naseem et al., 2009).

MATERIALS AND METHODS

Field experiment was conducted in 2012 and 2013 rainy season, at the Federal University of Technology Minna, (09° 39' N and 06° 28' E) in the Southern Guinea Savannah ecological zone of Nigeria with mean annual rainfall of 1300 mm. The experiment was carried out on sandy clay loamy in a field with a history of high *S. hermonthica* infestation. Three concentrations of *Parkia biglobosa* pulp at 0, 66 and 100 g/L was used to prime two sorghum cultivars (resistance ICSV 1002 and susceptible local variety), and two sowing dates (15 June and 21 July). The trap crop (soyabean variety TGX 1448-2E) was planted three days before the sorghum while planting distance was 75 cm between rows and 30 cm between plants. Seed were socked for 16 h and sown two to three seeds of sorghum per hill on the chosen dates and plant stands with excess seedling were thinned to two plants per hill at two weeks after sowing. The treatment design was a randomized complete block (RCBD) with three replicates. Hand pulling of weeds other than *S. hermonthca* seedling was done at week 4 and second weeding was carried out at week 8 after sowing. Sorghum panicles was harvested at weeks 22 and 23 after sowing for June and July dates respectively, panicles were dried threshed and grain yield determined. Data collected include days to first *Striga* emergence, *Striga* count per stand and per plot, severity score of maize using a scale of 1-5, where 1 indicate no *Striga* damage and 5 indicating a very high severely level, plant height from tagged stand using tape rule and measuring from the soil surface to neck of last leaf, grain yield per plot using weighing balance. The data were subjected to analysis of variance (ANOVA) using the computer software Genstat (2010), and differences between variables means were compared using least significant difference ($P < 0.05$). The 2013 experiment was repeated on the same land where the 2012 experiment was conducted.

RESULTS AND DISCUSSION

There were significant ($P < 0.05$) differences in the combined effect of sorghum varieties, *Parkia* concentration at 66 g/L and sowing date on days to first *Striga* shoot emergence. Sowing ICSV1002 sorghum in July delayed the *Striga* emergence of all *Parkia* combinations in 2012 as shown in Table 1. The delayed *Striga* emergence in priming of sorghum with 66 g/L *Parkia* concentration compared to 100 and 0 g/L in 2012 and 2013 might be due to allelochemical in the *Parkia* pulp which inhibited *Striga* development at that concentration or level. A similar observation was made by Kolo and Mamudu (2008) that dressing of maize seed with *P*. *biglobosa* pulp gave better maize development both vegetative and in grain yield especially with the resistant varieties as described in Table 1. Irrespective of the year of planting, the combined effects of sorghum varieties with *Parkia* treatments and sowing date on *Striga* count per stand of sorghum were not significantly ($P < 0.05$) different in all the sampling periods except at 10 WAS in 2013 as shown in Table 1. Generally, sorghum variety ICSV 1002, priming at 66 g/L *Parkia* concentration and planting in July had fewer *Striga* shoot count compared to other treatment combinations. There were no significant ($P < 0.05$) differences in interaction effect of sorghum varieties, *Parkia* concentration and sowing date on *Striga* count per plot at 10 and 18 WAS in 2012. The ICSV1002 variety primed at 100 g/L *Parkia* concentration and sown in July supported fewer *Striga* compared to other treatments at 14 WAS. In the local variety, priming at 66 g/L *Parkia* concentration and sowing in July supported fewer *Striga* count compared to other treatment combination in 2012. In 2013, ICSV1002 variety primed at 66 g/L *Parkia* concentration and sown in July supported fewer *Striga* count per plot compared to other treatment combinations at 10 and 14 WAS, but in the local sorghum variety, fewer *Striga* count was recorded at 66 g/L *Parkia* treatment and sowing in July for 10 WAS; and at 100 g/L *Parkia* concentration and sown in July for 14 WAS compared to other treatment combinations. Fewer *Striga* count in 66 g/L *Parkia* concentration in 2012 and 2013 compared to 100 and 0 g/l confirms the ability of *Parkia* concentration in

Table 1. Interaction effect of sorghum, *Parkia*concentration and sowing date on days to first *Striga* shoot emergence, *Striga* shoot count per stand and per plot.

Sorghum variety	*Parkia* concentration (g/l)	Sowing date	2012							2013						
			DFE	SCS			SCP			DFE	SCS			SCP		
				10	14	18	10	14	18		10	14	18	10	14	18
ICSV 1002	0	June	58.50	3.67	5.00	6.17	5.00	8.50	17.50	59.50	2.83	4.33	7.33	4.67	6.67	8.17
ICSV 1002	0	July	62.00	1.83	3.67	4.67	3.83	7.67	16.83	60.00	1.51	2.83	4.17	2.50	5.33	6.00
ICSV 1002	66	June	60.83	2.33	3.88	4.67	3.00	6.50	11.33	60.67	2.40	2.56	4.50	2.50	4.00	5.50
ICSV 1002	66	July	66.33	1.33	2.50	3.00	2.67	4.83	11.17	61.83	0.93	1.39	2.50	0.12	2.67	3.33
ICSV 1002	100	June	59.50	3.00	4.50	4.67	3.50	6.00	11.50	60.33	4.00	5.50	6.67	5.83	7.17	8.83
ICSV 1002	100	July	66.17	2.00	3.67	4.00	3.33	4.67	13.00	61.83	1.09	2.00	3.17	1.94	3.33	6.33
Local variety	0	June	56.83	9.17	13.67	14.67	12.33	18.33	9.00	59.50	7.17	8.33	10.50	10.33	12.33	14.33
Local variety	0	July	56.00	6.00	10.33	11.67	11.17	17.67	11.00	62.33	3.83	5.00	7.33	6.50	8.50	9.67
Local variety	66	June	58.33	4.67	6.67	8.33	7.17	10.67	7.50	61.00	4.00	6.33	8.17	5.50	7.33	9.50
Local variety	66	July	59.33	3.00	5.83	6.17	6.33	10.33	7.00	64.67	2.33	3.67	6.00	4.67	7.00	8.50
Local variety	100	June	58.00	5.50	9.83	9.83	9.00	11.33	9.17	61.00	4.67	6.83	8.67	7.00	9.17	11.33
Local variety	100	July	58.17	4.67	8.00	8.67	9.00	13.50	10.17	64.17	2.67	4.67	6.33	4.67	6.33	8.17
Mean	-	-	60.00	3.93	6.46	7.21	6.36	10.00	11.26	61.40	3.12	4.45	6.28	4.69	6.65	8.31
LSD(0.05)	-	-	0.82	NS	NS	NS	NS	2.26	NS	NS	1.10	NS	NS	1.23	1.30	NS

DFE: Day to first *Striga* emergence, SCS: *Striga* shoot count per stand, SCP: *Striga* shoot count per plot, NS: Non-significant, LSD: Probability level at 0.05.

controlling *Striga;* although the mobility of *Parkia* pulp phytochemical in sorghum has not been documented, it is likely that the *Parkia* pulp concentration has an indirect mechanism by which it reduced *Striga* level. This is similar to the findings of Marley et al. (2004) that all plant material like neem and *Parkia* extract significantly reduced *Striga* emergence as described in Table 1. Fewer *Striga* count observed in July sowing date compared to June might be due to the lower weed pressure in July because of cooler soil temperature, high relative humidity and regular rainfall which cause the *Striga* seeds to undergo wet dormancy and fail to germinate. Dugje et al. (2008) had also reported that sowing maize in mid-July reduced *Striga* infestation compared to sowing earlier in mid-May or mid-June in parts of the Northern and Southern Guinea Savanna of Nigeria (Gressel et al., 2004).

The interaction effects of sorghum varieties, *Parkia* concentration and sowing date did not significantly affect severity score in 2012. However in 2013, ICSV1002 variety primed at 66 g/L *Parkia* concentration in both June and July suffered less *Striga* damage compared to 0 g/l *Parkia* concentration in July. In the local sorghum variety, priming at 66 g/L *Parkia* treatment and sowing in July suffered less *Striga* damage compared to other treatment combination. The significance of the lower *Striga* damage in 66 g/L compared to 100 and 0 g/L *Parkia* concentration could be due to lower *Striga* population in the former which decreased severity of attack on host. This is in agreement with the work of Ndungu (2009) that coating sorghum seed with herbicides reduced *Striga* infestation. Reduction in *Striga* infestation accounted for fewer *Striga* damages. The reduced *Striga* damage in planting in July compared to June could be attributed to less weed pressure and unfavorable environmental condition of low temperature and high humidity which inhibited *Striga* emergence and population and reduced attack on host. This is similar to observation by Odhiambo and Ariga (2011) that when planting is delayed, *Striga* seeds are unable to germinate and seedlings fail to attach to host root systems due to unfavorable low soil temperature during the middle of the rainy season. This translated into less *Striga* damages as shown in Table 2**.** Sorghum varieties with *Parkia* concentration and sowing date were not

Table 2. Interaction effect of sorghum, *Parkia* concentration and sowing date on severity score, plant height and grain yield (g/plot).

Sorghum	*Parkia* concentration (g/l)	sowing date	2012 SC	2012 PH weeks after sowing 10	2012 PH weeks after sowing 14	2012 GY	2013 SC	2013 Weeks after sowing 10	2013 Weeks after sowing 14	2013 GY
ICSV 1002	0	June	3.33	41.50	51.33	1387.60	2.67	46.67	57.00	1587.20
ICSV 1002	0	July	2.83	45.33	54.33	1505.50	2.83	46.67	55.17	1616.40
ICSV 1002	66	June	2.83	31.00	59.33	1495.90	2.00	50.17	62.00	1712.60
ICSV 1002	66	July	2.17	52.00	60.67	1741.80	2.00	52.50	58.00	1744.70
ICSV 1002	100	June	2.67	48.50	56.83	1457.90	2.33	50.33	61.00	1539.00
ICSV 1002	100	July	2.00	49.33	58.33	1670.00	2.50	47.83	52.67	1675.60
Local variety	0	June	5.00	23.33	31.50	975.30	5.00	38.83	43.67	1036.30
Local variety	0	July	5.00	29.17	38.33	1143.20	5.00	39.50	42.83	1272.00
Local variety	66	June	5.00	33.67	43.00	1173.20	5.00	43.33	46.67	1175.70
Local variety	66	July	3.50	41.83	49.50	1339.80	4.67	42.17	46.83	1344.80
Local variety	100	June	4.83	33.00	43.00	1242.80	5.00	40.67	46.17	1090.50
Local variety	100	July	3.67	38.17	48.33	1388.70	5.00	40.17	48.00	1358.90
Mean	-	-	3.82	38.90	49.54	1376.81	4.00	45.32	51.67	1429.48
LSD(0.05)	-	-	NS	NS	NS	NS	0.70	NS	2.51	NS

SC: Severity Score, PH: Plant height (cm), GY: Grain yield (g/plot): Non-significant, LSD: Probability level at 0.05.

significantly (P < 0.05) different in their combined effect on plant height in all the sampling periods in both years, except at 14 WAS in 2013. ICSV 1002 variety primed at 66 g/L *Parkia* concentration and sown in July produced tallest plant height compared to other treatment combinations, while in local sorghum variety, priming at 100 g/L *Parkia* concentration and sowing in July produced taller plant compared to other treatments. The taller plant height in July compared to planting in June may however be attributed to delayed attack in relation to phenological development and reduced competition for the host nutrient and food with consequent luxuriant growth. This supports the findings of Van Delf (1997), that early attachments and final growth reduction on the plant are a strong indication that control practices based on a reduction in the *S. hermonthica* problem**.** There were no significant difference in interaction effect of sorghum variety, *Parkia* concentration and sowing date on grain yield in 2012 and 2013 as shown Table 2.

The interaction effect of cropping system, *Parkia* concentration and sowing date did not significantly influence *Striga* emergence in 2012 and 2013 planting years as depicted in Table 3. In all the sampling periods (10, 14 and 18 WAS), *Striga* count per stand of sorghum was not significantly affected by cropping system, *Parkia* concentration and sowing date in both 2012 and 2013. The interaction effect of cropping system *Parkia* concentration and sowing date on *Striga* count per plot showed similar trend with *Striga* count per stand. There were no significant (P < 0.05) difference in all the sampling periods and the planting years 2012 and 2013 as described in Table 3.

The combined effects of intercropping system with 66 g/L *Parkia* concentration and sowing in July significantly suffered less *Striga* damage compared to other treatment combinations in 2012. The less *Striga* damage in sorghum intercropped with soyabean compared to sole sorghum confirms the effectiveness of soyabean as trap crop to induce suicidal germination of *Striga* seed. As cover crop, soyabean interfered with the sun radiation and chemical environment of *Striga* seed, lowering the light and daily temperature and inhibiting emergence of *Striga* seed, as well as increasing soil fertility through nitrogen fixation. All these caused unfavorable

Table 3. Interaction effect of soyabean, *Parkia*concentration and sowing date on days to first *Striga* emergence, *Striga* shoot count per stand and per plot.

Sorghum Soyabean	Soyabean *Parkia* concentration (g/l)	Sowing date	2012							2013						
			DFE	SCS			SCP			DFE	SCS			SCP		
				10	14	18	10	14	18		10	14	18	10	14	18
Sole sorghum	0	June	57.17	8.50	12.17	12.83	11.33	17.00	17.50	59.50	6.17	8.33	11.33	9.50	11.50	12.83
Sole sorghum	0	July	58.00	5.00	8.67	9.83	9.17	15.17	16.83	60.00	3.50	5.00	7.00	6.00	9.00	10.17
Sole sorghum	66	June	59.00	4.17	6.17	8.17	6.50	11.00	11.33	60.67	3.58	5.33	7.67	5.00	7.00	9.00
Sole sorghum	66	July	61.50	2.67	5.00	5.50	5.17	9.33	11.17	61.83	2.16	3.00	5.00	3.83	6.00	7.33
Sole sorghum	100	June	58.33	5.00	7.83	8.17	7.00	9.83	11.50	60.33	4.33	6.83	8.00	6.50	8.50	10.50
Sole sorghum	100	July	61.17	3.67	6.50	7.50	7.17	12.00	13.00	61.83	2.00	3.83	5.17	4.00	5.67	7.33
Soyabean	0	June	58.17	4.33	6.50	8.00	6.00	9.83	9.00	59.50	3.84	3.83	6.50	5.50	7.50	9.67
Soyabean	0	July	60.00	2.83	5.33	6.50	5.83	10.17	11.00	62.33	1.85	2.83	4.50	3.00	4.83	5.50
Soyabean	66	June	60.17	2.83	4.33	4.83	3.67	6.17	7.50	61.00	2.82	3.56	5.00	3.00	4.33	6.00
Soyabean	66	July	63.83	1.67	3.33	3.67	3.83	5.83	7.00	64.67	1.11	2.06	3.50	0.95	3.69	4.50
Soyabean	100	June	59.17	3.50	6.50	6.33	5.50	7.50	9.17	61.00	4.33	5.50	7.33	6.33	7.83	9.67
Soyabean	100	July	63.17	3.00	5.17	5.17	5.17	8.17	10.17	64.17	1.75	2.83	4.33	2.61	4.00	7.17
Mean	-	-	63.17	3.93	6.46	7.21	6.36	10.17	11.26	64.17	3.12	4.41	6.28	4.69	6.65	8.31
LSD(0.05)	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DFE: Day to first Striga emergence, SCS: Striga shoot count per stand, SCP: Striga shoot count per plot, NS: Non significant, LSD: Probability level at 0.05.

condition for *Striga* seed germination and resulted in less attack and damages. This is similar to observation by Carsky et al. (2000) and Schulz et al. (2003) that varieties of cowpea, groundnut and soyabean have potential to cause suicidal germination of S. *hermonthica* and improve soil fertility.

The significance of the lower *Striga* damage in 66 g/L compared to 100 and 0 g/L *Parkia* concentration could be due to lower *Striga* population in the former which decreased severity of attack on host. This is in agreement with the work of Ndungu (2009) that coating sorghum seed with herbicides reduced *Striga* infestation. Reduction in *Striga* infestation accounted for fewer *Striga* damages. There were no significant differences in 2013 among the treatments; also, there were no significant (P < 0.05) difference in interaction effects of cropping system, *Parkia* concentration and sowing date on plant height in the two planting years of 2012 and 2013 in all the sampling periods as shown in Table 4. Intercropping with priming at 66 g/L *Parkia* concentration and sowing in July produced highest sorghum grain yield compared to other treatment combinations in 2012. The less *Striga* damage in sorghum intercropped with soyabean compared to sole sorghum confirms the effectiveness of soyabean as trap crop to induce suicidal germination of *Striga* seed. As cover crop, soyabean interfered with the sun radiation and chemical environment of *Striga* seed, lowering the light and daily temperature and inhibiting emergence of *Striga* seed, as well as increasing soil fertility through nitrogen fixation. All these caused unfavorable condition for *Striga* seed germination and resulted in less attack and damages. This is similar to observation by Carsky et al. (2000) and Schulz et al. (2003) that varieties of cowpea, groundnut and soyabean have potentials to cause suicidal germination of S. *hermonthica* and improve soil fertility.

The significance of the lower *Striga* damage in 66 g/L compared to 100 and 0 g/L *Parkia* concentration could be due to lower *Striga* population in the former which decreased severity of attack on host. This is in agreement with the work of Ndungu (2009) that coating sorghum seed with herbicides reduced *Striga* infestation. Reduction in *Striga* infestation accounted for fewer *Striga* damages as presented in Table 4.

Table 4. Interaction effect of soyabean, *Parkia* concentration and sowing date on severity score, plant height, and grain yield.

Soyabean	*Parkia* concentration (g/l)	Sowing date	2012				2013			
			SC	PH weeks after sowing		GY	SC	PH weeks after owing		GY
				10	14			10	14	
Sole sorghum	0	June	6.17	27.83	36.67	1084.00	5.00	38.67	47.33	1253.30
Sole sorghum	0	July	5.17	33.17	42.50	1267.10	5.00	42.33	45.17	1407.70
Sole sorghum	66	June	4.67	37.83	47.00	1272.10	3.83	45.17	51.00	1327.50
Sole sorghum	66	July	3.17	43.83	51.50	1446.30	3.50	46.00	48.67	1465.30
Sole sorghum	100	June	4.33	34.83	44.17	1325.30	4.33	43.17	50.50	1261.30
Sole sorghum	100	July	3.00	39.17	50.00	1483.40	3.50	42.67	50.17	1499.20
Soyabean	0	June	4.50	37.00	46.17	1279.00	4.00	46.83	53.33	1370.20
Soyabean	0	July	3.33	41.33	50.17	1381.60	3.50	43.83	52.83	1480.80
Soyabean	66	June	3.17	46.83	55.33	1397.00	3.50	53.33	57.67	1560.80
Soyabean	66	July	2.50	50.00	58.67	1635.30	3.17	48.67	56.17	1624.20
Soyabean	100	June	3.17	46.67	55.67	1375.30	4.17	47.83	56.17	1368.20
Soyabean	100	July	2.67	48.33	56.67	1575.30	4.00	45.33	50.50	1535.40
Mean	-	-	3.82	40.57	49.54	1376.81	3.96	45.32	51.63	1429.49
LSD(0.05)	-	-	0.42	NS	NS	63.56	NS	NS	NS	NS

SC: Severity Score, PH: Plant height (cm), GY: Grain yield (g/plot), NS: Non significant; LSD: Probability level at 0.05.

CONCLUSION AND RECOMMENDATION

The results demonstrate resistant sorghum varieties to reduce the impact of *Striga,* the high potentiality of using *Parkia* based products for *S. hermonthica* control by seed soaking at high concentration and the intensifying cropping by integrating soyabean varieties and sorghum; this could provide a sustainable system than the sole sorghum cultivation. The relatively low of *Striga* count and high yield in ICSV1002 resistant sorghum variety at 66 g/l *Parkia* concentration and under intercropping system indicates a reduced potential for flowering and capsule production and consequently, a reduced capacity of increasing the *Striga* seed bank in the soil. *Parkia* pulp powder might be used in *S. hermonthica* control to reduce dependence on herbicides. However, further studies are needed to determine if the efficacy of *Parkia* could be enhanced, as well as to analyze the active allelochemicals in *Parkia* pulp powder. This would be a promising start in producing bio-herbicide for *S. hermonthica* control.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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