Full Length Research

Integrated weed management systems in sorghum based cropping system in Nigeria

A. Y. Mamudu\(^1\)*, K. P. Baiyeri\(^2\) and B. C. Echezona\(^2\)

\(^1\)Department of Crop Production, School of Agriculture and Agricultural Technology, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.
\(^2\)Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria.

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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. \textit{Striga hermonthica} is a serious biotic constraint to cereal production in the dry savannas of sub-Saharan Africa. \textit{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 \textit{S. hermonthica}. During the investigation in two sorghum (resistance and susceptible) which involved intercropping with soyabean, seedtreatment with \textit{parkia biglobosa} pulp and sowing at different dates (June and July), these were found to reduce the infestation of sorghum by \textit{S. hermonthica}. The results showed that the effect of shading by soyabean, putative allelopathic mechanism effect of \textit{parkia} material and high relative humidity due to established rainfall in July showed some benefits against \textit{S. hermonthica} infestation. Growth of \textit{S. hermonthica} was almost completely suppressed and yield increased with the resistant sorghum intercropped with soyabean, primed at 66 g/L \textit{parkia} and planted in July.

**Key words:** Shading, soyabean, allelopathy, \textit{Parkia} pulp, sorghum, \textit{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 \textit{Striga hermonthica} is unclear. It may have originated in Northeast Asia (Scholes and Press, 2008). It is the largest and most destructive of the \textit{Striga} species and considered as one of the most serious...
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 (IITA 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 Savanna 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 (soybean 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 soaked 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. hermonthica 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 ruler 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 compared to other treatments at 14 WAS. In the local sorghum variety, fewer Striga shoot 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
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

| Sorghum variety | *Parkia* concentration (g/l) | Sowing date | 2012 DFE | 2012 SCS | 2012 SCP | 2013 DFE | 2013 SCS | 2013 SCP |
|----------------|-------------------------------|------------|--------|--------|--------|--------|--------|--------|
| ICSV 1002      | 0                             | June       | 58.50  | 6.17   | 5.00   | 17.50  | 95.00  | 2.83   | 7.33   | 4.67   | 8.17   |
| ICSV 1002      | 0                             | July       | 62.00  | 4.67   | 3.83   | 16.83  | 60.00  | 1.51   | 4.17   | 2.50   | 6.00   |
| ICSV 1002      | 66                            | June       | 60.83  | 2.67   | 3.00   | 11.17  | 61.83  | 0.93   | 2.50   | 0.12   | 3.33   |
| ICSV 1002      | 66                            | July       | 66.33  | 6.00   | 2.67   | 8.43   | 61.83  | 0.93   | 2.50   | 0.12   | 3.33   |
| ICSV 1002      | 100                           | June       | 59.50  | 4.67   | 3.50   | 11.50  | 60.33  | 4.00   | 5.50   | 6.67   | 8.83   |
| ICSV 1002      | 100                           | July       | 66.17  | 4.00   | 3.33   | 13.00  | 61.83  | 1.09   | 3.17   | 1.94   | 3.33   |
| Local variety  | 0                             | June       | 56.83  | 14.67  | 12.33  | 18.33  | 9.00   | 59.50  | 7.17   | 10.50  | 10.33  | 14.33  |
| Local variety  | 0                             | July       | 56.00  | 11.67  | 11.17  | 17.67  | 11.00  | 62.33  | 3.83   | 7.33   | 6.50   | 8.50   |
| Local variety  | 66                            | June       | 58.33  | 8.33   | 7.17   | 10.67  | 7.50   | 61.00  | 4.00   | 8.17   | 5.50   | 9.50   |
| Local variety  | 66                            | July       | 59.33  | 7.00   | 6.33   | 10.33  | 7.00   | 64.67  | 2.33   | 6.00   | 4.67   | 7.00   |
| Local variety  | 100                           | June       | 58.00  | 9.83   | 9.00   | 11.33  | 9.17   | 61.00  | 4.67   | 8.67   | 7.00   | 9.17   |
| Local variety  | 100                           | July       | 58.17  | 8.67   | 9.00   | 13.50  | 10.17  | 64.17  | 2.67   | 6.33   | 4.67   | 6.33   |
| Mean           | -                             | -          | 60.00  | 7.21   | 6.36   | 10.26  | 11.26  | 61.40  | 3.12   | 6.28   | 4.69   | 6.65   |
| LSD(0.05)      | -                             | -          | 0.82   | NS     | NS     | NS     | 2.26   | NS     | NS     | 1.10   | NS     | 1.23   |

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.
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

| Sorghum   | Parkia concentration (g/L) | sowing date | SC | PH weeks after sowing | GY | SC | Weeks after sowing | 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    | 0.70    | NS  | 2.51  | NS    | NS    |

SC: Severity Score, PH: Plant height (cm), GY: Grain yield (g/plot); 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.

| Sorghum Soyabean | Soyabean *Parkia* concentration (g/L) | Sowing date | DFE  | SCS  | SCP  | 2012 |  |  |  | 2013 |  |  |  |
|------------------|--------------------------------------|-------------|------|------|------|------|------|------|------|------|------|------|------|
| 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|
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| Mean             | -                                    | -           | 63.17| 3.93 | 6.46 | 7.21 | 6.36 | 10.17| 11.26| 64.17| 3.12 | 4.41 | 6.28 |
| LSD(0.05)        | -                                    | -           | 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.
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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