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FIELD EVALUATION OF MAHOGANY SEED EXTRACT (*Khaya senegalensis*: MELIACEAE, (DESV.) A. JUSS) ON BOLL INFESTATION AND YIELD LOSS OF COTTON CAUSED BY BOLLWORM IN ZARIA, NIGERIA

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SUMMARY

Two field trials were conducted at Samaru (11^0 11$'$ N, 07^0 38$'$ E and 686m above sea level) and Maigana (11^0 10$'$ N, 07^0 37$'$ E and 675m above sea level) in Northern Guinea Savannah ecological zone of Nigeria during the 2016 wet season to determine the effects of three concentration of aqueous *Khaya* seed extract (KSE) (20%w/v, 30%w/v and 40%w/v) on boll infestation, yield and yield loss of cotton (SAMCOT 9) caused by bollworms. Randomized complete block design was used with four spray application at two weeks interval beginning from 9weeks after sowing. The results showed that lower percentage boll infestation was recorded in Lambda cyhalothrin (27.8%) and 40%w/v (33.3%) than 30%w/v (52.3%), 20%w/v (58.4%) and untreated control (62.2%). Similarly, significantly high seed cotton yield was obtained from Lambda cyhalothrin (1638.9Kg) and 40%w/v (1396.8Kg) treated plots than 30%w/v (832.5Kg), 20%w/v (784.6Kg) and untreated control (779.6Kg). Percentage yield losses recorded from Lambda cyhalothrin (17.8%) and 40%w/v (21.9%) treated plots were found to be significantly lower than 30%w/v (43.8%), 20%w/v (44.3%) and untreated control (45.6%) which recorded the highest yield loss. The result of the boll stripping analysis showed that 50.6% of boll infestation was due to Pink bollworm (*Pectinophora gossypiella*) while American bollworm (*Helicoverpa armigera*), Red bollworm (*Diparopsis watersi*), and Spiny bollworm (*Earias spp.*) accounted for 25.0%, 13.7% and 10.9% of boll infestations respectively. Therefore, application of KSE in this study at

different rates especially at 40%w/v was found to be effective in reducing yield loss and percentage boll infestation of caused by bollworms on Samcot 9.

Keywords: Cotton, *Khaya senegalensis*, Bollworms, Infestation, Zaria

COTTON production in Nigeria dates back to 1903. At its peak in the 1990's the Nigeria textile industry was the second largest in Africa with over 200 vibrant textile factories operating at more than 50% installed capacity (7). In Nigeria, cotton is adapted to most ecological zones and is been cultivated in the northern, eastern and southern cotton growing zones with a total production of 58,990 metric tonnes (17). Unfortunately, total production remains far below the national requirements of the textile and the oil mills (7). This is due to low average yield recorded on farmers field (400-500Kg/ha and 600-900Kg/ha) (30, 21) which is below the genetic yield potential (4.1-4.4 tons/ha) of the commercial varieties (16). This is constrained by the prevalence of pests particularly the bollworm complex (33, 28, 10, 24) which causes 25-30% yield loss (6) annually, and affects the yield and fibre quality (15, 27) leading to a down turn of the fortunes of the textile industry.

The pest pressure particularly from bollworms, due to which crop loss becomes very high, drives growers to adopt all tactics which may not be really suited to the given situation and would ensure failure of such efforts (18). In intensive agriculture, insecticides have been looked upon as omnipotent weapons for modern pest management, but excessive and indiscriminate use has led to problems of pest resistance, pest resurgence, accumulation of harmful residues in the environment and toxicity to non-target organisms and man (25, 4, 24). Cotton receives more pesticide protection per season than any other crop (25) and accounts for more than 25 percent of all agricultural insecticides used worldwide (32, 14). This has prompted the necessity for the development of non-synthetic alternative that could be visible and effective for insect pest management, while also being compatible with the environment (20). Hence a current shift in the desire for biopesticides from botanical sources rather than synthetic chemicals using extract of plants having pesticidal properties. Botanical insecticides have more advantages than synthetic one mainly upon their quick degradation and lack of persistence and bioaccumulation in the ecosystem, which have been key problems in chemical pesticide usage (35).

Plant extracts also have the advantage that they contain a mixture of compounds which may significantly reduce the chances of tolerance or resistance build-up by insect pests (38). These plant extracts have a wide range of anti-insect properties including insecticidal, repellent, antifeedant, and insect growth inhibitory activities (4, 11, 35). One such plant is African mahogany (*Khaya senegalensis*) a member of the timber tree species of the family Meliaceae with rich source of limonoids (31), with no real exploitation recognized regarding its rich phytochemical constituents (34). The limonoids have been found to give effective control against cotton bollworms (3, 1, 2). Hence, this study was conducted to determine the effect of different concentrations of KSE on boll infestation and percentage yield loss of cotton by bollworms on the yield of SAMCOT 9 variety.

MATERIALS AND METHODS

Experimental sites, land preparation and experimental lay-out

The study took place during the 2016 wet season at two different locations situated in Institute for Agricultural Research (IAR) farm Samaru, (11^0 11' N, 07^0 38' E and 686m above sea level) and Kaduna State Agricultural Development Agency (KADA) research farm in Maigana (11^0 10' N, 07^0 37' E and 675m above sea level) both in the Northern Guinea Savannah ecological zone of Nigeria. The study area has a mean annual rainfall of 1016mm and mean maximum and minimum temperatures of 32.2°C and 23.5°C respectively. The fields for the experiments were ploughed, harrowed and ridged apart at 0.90 m inter-row spacing using tractor-mounted disc plough. The treatments consisted of 3 concentrations of *Khaya* seed extracts (KSE) of 20% w/v, 30% w/v and 40% w/v (200g, 300g and 400g/L of water), an insecticidal check (Lambda-cyhalothrin 25g ai/litre EC) and untreated control replicated 4 times in a strip plot fitted into randomized complete block design (RCBD) with plot size of 4.5m x 4.5m (Gross plot of 6 rows and 4.5m long) and 3.5m x 2.7m (Net plot of 4 rows and 3.5m long). Plots within replication were separated by a 1.5m alley while replications were separated by a 2.0m alley.

Seed material and sowing

The cotton variety used for the study was SAMCOT 9 an erect, hairy and medium staple cultivated commercial variety adapted to the North-West cotton growing zone of Nigeria under rain-fed conditions which attain maturity between 130-150 days with a potential yield of 1500-2000Kg/ha. The seeds were treated with Dress Force 42WS (Imidacloprid 20% + Metalaxyl M 20% + Tebuconazole 2%) 8g/Kg before sowing. Seed was sown at 4 seeds per hole at a depth of 3cm, 90cm inter-row spacing and 45cm intra-row spacing on the ridges. Emerged seedlings were later thinned to two plants per stand 3WAS.

A mixture of Paraquat and Butachlor as Pre-emergence at the rate of 1 litre/ha was applied to the experimental plots. Supplementary hoe weeding was done throughout especially at critical growing periods of weeds interference.

Fertilizer was applied at the recommended rate of 60: 13: 25: Kg/ha using NPK 15:15:15 at 3WAS and Urea was used for top dressing at 8WAS.

Preparation of Khaya seed extract

Matured seeds of *K. senegalensis* collected around IAR and Savanna Forestry Research Station in Samaru, Zaria were air-dried under shade. The seeds were decorticated and pounded with a wooden pestle and mortar and pulverized. The pounded seeds were weighed into lots of 200g, 300g and 400g separately and soaked in 1000ml of tap water inside a plastic bucket each and allowed to stand for 48hrs, and continuously stirred at 24hrs interval. The content of each bucket was filtered with 500ml of water with the aid of a double-layer muslin/cheese cloth, and 300ml of 5% w/v starch and flaked soap (50g each/1000ml of water) was added to each crude extract.

Application of Khaya seed extract

The crude seed extracts were applied at the rate of 100ml/L of water (10% v/v) per plot while the insecticidal check (Lambda cyhalothrin 2.5EC) was applied at the rate of 10ml/L of water (1%v/v) with Knapsack sprayer. Application commenced 9 WAS which corresponded to period of formation of First Square to the detection of first flower. Four applications were carried out at 2weeks interval at the different phenological stages of the crop.

Data collection and analysis

Five plants were randomly selected from the net plot and observations were recorded on infestation of bollworms in fruiting bodies (flowers, squares, matured green bolls, mummified bolls and split bolls) through boll stripping analysis and this was carried out in the laboratory 2weeks after the final spray application, and percent boll infestation/damage was calculated. Seed cotton yield was obtained through pickings at an interval of 15-20 days and seed cotton from each treatment was weighed separately and yield in Kg/ha and percent yield loss in Kg/ha were worked out. Percent's boll infestation and yield loss were arcsine transformed, and the data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) software (version 9.0). Mean differences among treatments were separated using Students Newman's Keul test (SNK) at *P=0.05*.

RESULTS

Effect of *Khaya* seed extract on fruiting body infestation by bollworms at Samaru and Maigana in 2016 wet season.

Application of different rates of KSE in Samaru and Maigana resulted in significant difference in percentage infestation of fruiting bodies at 17WAS (Table 1). In Samaru, there was a significant difference ($P \leq 0.05$) in percentage infestation of the fruiting bodies by bollworms from KSE treatments, Lambda cyhalothrin and the untreated control. Lambda cyhalothrin and 40%w/v had similar ($P \geq 0.05$) percentage infestation of fruiting bodies which were significantly ($P \leq 0.05$) lower than the other KSE and the untreated control. However, 30%w/v was also significantly ($P \leq 0.05$) lower than 20%w/v and the untreated control. Similarly, the 20%w/v recorded significantly ($P \leq 0.05$) lower percentage fruiting bodies infestation than untreated control which recorded higher percentage infestation of the fruiting bodies. In Maigana, Lambda cyhalothrin recorded significantly ($P \leq 0.05$) lower percentage infestation of fruiting bodies than all the KSE and the untreated control respectively. The percentage infestation of fruiting bodies recorded on 40%w/v was also significantly ($P \leq 0.05$) lower than the other KSE and the untreated control. Likewise, plants treated with 30%w/v also recorded significantly ($P \leq 0.05$) lower percentage fruiting bodies infestation than those treated with 20%w/v and the untreated control, both of which that were similar ($P \geq 0.05$) in percentage fruiting bodies infestation. The combined results of the two locations showed that Lambda cyhalothrin had significantly ($P \leq 0.05$) lower infestation of the fruiting bodies than all the KSE and the untreated control. Also, the 40%w/v resulted in a significantly ($P \leq 0.05$) lower percentage fruiting bodies infestation than the other KSE and the untreated control. Likewise, percentage fruiting bodies infestation from 30%w/v was significantly ($P \leq 0.05$) lower than those from 20%w/v and the untreated control. The 20%w/v was also found to be significantly ($P \leq 0.05$) lower in percentage fruiting bodies infestation than the untreated control which had the highest infestation.

Table 1: Effect of aqueous *Khaya* seed extract on percentage infestation of fruiting bodies in Samaru and Maigana.

Mean percentage infestation of Bollworms in fruiting bodies at 17 WAS			
Treatment	Samaru	Maigana	Combined
KSE (% w/v)			
20	62.8b	54.1a	58.4b
30	54.2c	50.4b	52.3c
40	35.2d	31.3c	33.3d
Lambda cyhalothrin	32.9d	22.6d	27.8e
Untreated control	67.3a	57.1a	62.2a
SE±	1.404	1.549	1.036
Significance	*	*	*

*= ($P \leq 0.05$). Means followed by same letter(s) within the same column are not different statistically at $P=0.05$ using SNK. KSE = Khaya seed extract; WAS = Weeks after sowing

Incidence of different types of bollworm in fruiting bodies at Samaru and Maigana in 2016 wet season.

The incidence of different types of bollworm in fruiting bodies (squares, flower, matured green bolls and split bolls) at 17WAS is presented in Table 2. In Samaru, there was a high to mild preponderance of different types of bollworm with Pink bollworm (*Pectinophora gossypiella*) being the most highly (64.0%) encountered of the bollworms and was followed by Red bollworm (*Diparopsis watersi*) (14.4%), American bollworm (*Helicoverpa armigera*) (12.8%) with the least encountered being the Spiny bollworm (*Earias spp.*) (8.8%). However, in Maigana, the most encountered bollworms were the American bollworm (*H. armigera*) (37.1%) and the Pink bollworm (*P. gossypiella*) (37.1%) while the Red bollworm (*D. watersi*) (12.9%) and the Spiny bollworm (*Earias spp.*) (12.9%) were mildly encountered. When the two locations were combined, the incidence and percentage showed that the Pink bollworm (*P. gossypiella*) (50.6%) was the most frequently encountered bollworm and was followed by American bollworm (*H. armigera*) (25.0%) while the Red bollworm (*D. watersi*) (13.7%) and the Spiny bollworm (*Earias spp.*) (10.9%) were mildly encountered.

Table 2: Preponderance of different types of bollworm 17WAS in Samaru and Maigana

Incidence and Percentage of Different types of Bollworm in Fruiting bodies (%)			
	Samaru	Maigana	Combined
Red bollworm (*D. watersi*)	14.4	12.9	13.7
Spiny bollworm (*Earias spp.*)	8.8	12.9	10.9
American bollworm (*H. armigera*)	12.8	37.1	25.0
Pink bollworm (*P. gossypiella*)	64.0	37.1	50.6
Total	100.0	100.0	100.0

Effect of *Khaya* seed extract on yield of seed cotton at Samaru and Maigana in 2016 wet season.

Spray application of different rates of KSE in Samaru and Maigana resulted in a significant difference on the yield of seed cotton (Table 3). In Samaru, Lambda cyhalothrin (2460.3Kg) gave the highest yield of seed cotton and this was significantly ($P \leq 0.05$) higher than 40%w/v (1918.9Kg), 30%w/v (1181.7Kg), 20%w/v (1175.5Kg) and the untreated control (1171.1Kg). Similarly, the seed cotton yield of 40%w/v was also significantly ($P \leq 0.05$) higher than the other KSE and the untreated control. However, the seed cotton yield obtained from the other KSE rates and the untreated control were found to be similar ($P \geq 0.05$). In Maigana, both the 40%w/v (874.8Kg) and Lambda cyhalothrin (817.5Kg) recorded similar ($P \geq 0.05$) higher seed cotton yield that were significantly ($P \leq 0.05$) higher than the 30%w/v (483.2Kg), 20%w/v (394.2Kg) and the untreated control (388.0Kg) respectively. However, 30%w/v, 20%w/v and the untreated control were found to be similar ($P \geq 0.05$) in their seed cotton yield. The result for the two location combined showed that Lambda cyhalothrin (1638.9Kg) had significantly ($P \leq 0.05$) higher yield than the 40%w/v (1396.8Kg), 30%w/v (832.5Kg), 20%w/v (784.6Kg) and untreated control (779.6Kg). Similarly, 40%w/v also recorded significantly ($P \leq 0.05$) higher seed cotton yield than the other KSE and the untreated control, which were similar ($P \geq 0.05$) in their seed cotton yield.

Table 3: Effect of aqueous *Khaya* seed extract on the yield of seed cotton 21WAS in Samaru and Maigana.

	Mean yield of seed cotton in Kgha^{-1}		
Treatments	Samaru	Maigana	Combined
KSE (%w/v)			
20	1175.5c	394.2b	784.6c
30	1181.7c	483.2b	832.5c
40	1918.9b	874.8a	1396.8b
Lambda cyhalothrin	2460.3a	817.5a	1638.9a
Untreated control	1171.1c	388.2b	779.6c
SE$\pm$	168.91	33.21	92.81
Significance	*	*	*

*= ($P \leq 0.05$). Means followed by same letter(s) within the same column are not different statistically at *P=0.05* using SNK.

Effect of *Khaya* seed extract on percentage yield loss of seed cotton at Samaru and Maigana in 2016 wet season.

Application of different rates of KSE in Samaru and Maigana significantly affected the percentage yield loss of seed cotton (Table 4). In Samaru, Lambda cyhalothrin (21.9%) and 40%w/v (23.5%) KSE had similar ($P \geq 0.05$) percentage yield loss which were significantly ($P \leq 0.05$) lower than 30%w/v (45.8%), the 20%w/v (46.5%) and the untreated control (46.8%) treatments respectively. However, 30%w/v, 20%w/v and the untreated control had similar ($P \geq 0.05$) yield loss of seed cotton. In Maigana, Lambda cyhalothrin (13.7%) recorded significantly ($P \leq 0.05$) lower percentage yield loss than 40%w/v (20.2%), 30%w/v (41.8%), 20%w/v (42.0%) and the untreated control (44.4%). Likewise, the 40%w/v also had significantly ($P \leq 0.05$) lower percentage yield loss of seed cotton than the other KSE and the untreated control. However, the 30%w/v, the 20%w/v and the untreated control were similar ($P \geq 0.05$) in their percentage yield losses in the same period. The combined result for the two locations showed significant difference in percentage yield loss of seed cotton with Lambda cyhalothrin (17.8%) having significantly ($P \leq 0.05$) lower percentage yield loss than the

40%w/v (21.9%), 30%w/v (43.8%), 20%w/v (44.3%) and the untreated control (45.6%) during the period.

Table 4: Effect of aqueous *Khaya* seed extract on percentage yield loss of seed cotton 21WAS in Samaru and Maigana.

	Mean percentage yield loss of seed cotton ha^{-1} (%)		
Treatments	Samaru	Maigana	Combined
KSE (%w/v)			
20	46.5a	42.0a	44.3a
30	45.8a	41.8a	43.8a
40	23.5b	20.2b	21.9b
Lambda cyhalothrin	21.9b	13.7c	17.8c
Untreated control	46.8a	44.4a	45.6a
SE±	1.082	2.679	1.647
Significance	*	*	*

*= ($P \leq 0.05$). Means followed by the same letter(s) within the same column are not different statistically at *P=0.05* using SNK.

DISCUSSION

Applications of different rates of KSE significantly reduced the percentage of fruiting bodies infested by bollworms and this varies with locations. When the two locations were combined, it indicated similar trends of increasing effects of KSE from 20%w/v to 40%w/v in reducing the percentage of the fruiting bodies infested by bollworms which were better than the untreated plots. Among the different rates of KSE, none was comparable to Lambda cyhalothrin but 40%w/v KSE exert better effect than the other two rates of KSE in reducing the percentage of fruiting infested by bollworms. The effectiveness of various rates of KSE applied in reducing the percentage boll infestation from this study is an indication of efficacy of the plant material particularly 40%w/v which has shown to be effective as the synthetic insecticide used. This observation is in line with the finding of (19) who reported that application of water extract of Neem seed on cotton resulted in significant reduction in percent fruiting bodies infestation by spotted bollworm and pink bollworm which was dose dependent, and (12) reported that application of some botanical preparations on tomato significantly reduced percent fruit damage by

African bollworm. Also (22) reported that high concentration of plant extract such as NSKE as high as (10%) resulted in lowering the percentage of pod damaged by *Helicoverpa armigera* by (3.9%) on chick pea. According to (36) who investigated the effect of extracts of different botanicals (Neem seed, Turmeric, Henge and Garlic) on tomato fruit worm (*H. armigera*) observed lower percentage fruit infestation on tomato treated with NSKE which performed significantly better than the other botanicals.

The results of the boll stripping analysis revealed that large number of the fruiting bodies were infested by the Pink bollworm (*P. gossypiella*) which may be the species responsible for high percentage of the infested bolls than the other bollworms in both Samaru and Maigana. The incidence and infestation of the fruiting bodies for the two locations showed that of all the bollworm types, Pink bollworm (*P. gossypiella*) has higher occurrence, while the other bollworms had lower occurrence. This observation is supported by (33) who identified the bollworms as the most important group of insects attacking cotton in Nigeria, and the species of five genera that attack cotton in Nigeria in order of importance are *D. watersi* (Red bollworm), *H. armigera* (American bollworm), *P. gossypiella* (Pink bollworm), *Earias spp.* (Spiny bollworms) and *C. leucotreta* (False codling moth). According to (24) who reported that African bollworm (*H. armigera*), red bollworm (*D. castanea*), spiny bollworms (*E. insulana* and *E. biplaga*) and pink bollworm (*P. gossypiella*) causes the greatest yield loss on cotton annually. Among the different pests attacking cotton, they account for 25-30% yield loss (Ahuja *et al.*, 2008). It has also been reported that the most critical period of cotton development takes place during a period of about 10 weeks after the first flower buds have formed which is period of rapid growth when there is an increasing number of buds and bolls which attract several different insect pests, particularly the bollworms (25). It has also been observed that bollworm complex numbers were high at 14 and 15 weeks after planting which is the period of cotton boll - setting when more bolls are still young, and low at 20 and 21 weeks after planting when most of the cotton bolls have burst (23).

The result on seed cotton yield indicated significant increase with applications of different rates of KSE and this varies with locations. In Samaru, KSE at 40%w/v significantly produced more seed cotton than the other two KSE with their yield found to be similar with the untreated plot, although highest seed cotton was obtained from Lambda cyhalothrin which was significantly different from the three KSE and the untreated plots. However, at Maigana, seed cotton yield obtained from the plot treated with 40%w/v KSE and Lambda cyhalothrin were similar and better than the other KSE rates and the untreated plots which were similar in yield. The results of the two locations combined indicated that among the different rates of KSE, 40%w/v KSE produced higher seed cotton yield than the other two KSE which were found to be similar with the untreated plots, although the highest yield of seed cotton was obtained from Lambda cyhalothrin which was significantly different from the three KSE and the untreated plots. This observation could be attributed to the efficacy of the bioactive compounds present in KSE particularly at the high rate of 40%w/v which could have high concentration of the active compounds that deter the bollworms from causing serious damage on the bolls. It has been reported that yields of seed cotton have been increased significantly since application of modern chemical techniques (26). However, simplistic approaches to the use of insecticides have led to their over-use and selection of resistant pest populations with subsequent crop failures in certain areas (23). This study indicates that both Lambda cyhalothrin and 40%w/v KSE treated plots produced similar cotton seed yield that amount to more than one tonne/ha which suggests that the yield obtained from this study is more than the average yield of 621Kg/ha for the country (Nigeria) ten years back (17), although the genetic potential yield of the seed cotton in the commercial varieties is estimated to be 2.5-3 tonnes/ha (30). It has been reported that seed cotton yield of above 2 tonnes/ha was obtained with the attack of cotton plant by leafhoppers and bollworm complex (23). These levels of yield are common under small-scale cotton production systems (13). Application of Decis and Mospilan (two synthetic insecticides) has also been reported to give similar seed cotton yields when compare with tobacco and garlic extracts for the control of leafhoppers and bollworm complex on cotton (23). The mean yield of seed cotton obtained from this study corroborate these findings and that of several other workers who proved the efficacy of several pesticidal plants including Khaya in controlling several insect pests and improving crop yield. For instance, (19) investigated the effect of water extract of NSKE on insect pests of cotton and observed that higher concentration of the extract significantly increased the yield of the treated plots compared with the control. The efficacy of NSKE for the control of African bollworm on chickpea was tested, and (22) reported a highest mean yield from the plots treated with NSKE than the control plots. Significantly higher tomato yield was also recorded from biopesticides treated plots than those obtained from the control plots (12). The observed difference in seed cotton yield from the two locations suggests variation in weather conditions especially rainfall, which commences late and ceases early through September at Maigana. This finding is in agreement with the finding of (23) who observed that sudden changes in the environmental conditions such as cool and cloudy weather could result to drop in seed cotton yield in a season. Report also showed that there was a difference in seed cotton yield when grown under the same agronomic practices in different locations which was attributed to early ending of rainy season in September (21). It is important to note that cotton requires a minimum temperature of 16^{o}C to grow and sunlight is necessary for the plant's photosynthesis (9), and the yield is also directly proportional to the amount of water consumed by the cotton (8).

In Samaru, the effect of spray application of 40%w/v KSE was found to be similar with Lambda cyhalothrin in reducing the percentage yield loss of seed cotton which were better than the other two KSE and the untreated plots. The effects of the other two KSE were also similar with the untreated plots. However, at Maigana, the effect of 40%w/v KSE significantly reduced percentage yield loss of the seed cotton which was better than the other two KSE and the untreated plots which were the same. Similarly, the results of the two locations combined indicated that 40%w/v KSE significantly reduced percentage yield loss (21.9%) of seed cotton which was found to be better than the other two KSE and the untreated plots which were similar, but different from Lambda cyhalothrin (17.8%) which recorded lowest percentage yield loss. This observation indicated that the higher the concentration of the bioactive compounds the more the efficacy, which suggests that KSE at high rate possess more of the active compounds than those at the lower rate. These results aligned with the finding of (19) who reported significantly lower percentage yield loss from high concentration of NSKE treated plots due to infestation by spotted bollworm and pink bollworm on cotton. Reduction in yield of seed cotton below 500Kg/ha has been attributed to infestations by red bollworm and American bollworm together with cotton stainer (26). Report from Pakistan as shown that bollworm and sucking pest complex causes about 20-40% yield losses (5). Yield loss of 15-30% by *H. armigera* has also been reported on sorghum in Botswana (29). When evaluating the efficacy of botanical extract and synthetic pesticide against tomato fruit worm (*H. armigera*), (36) reported about 10.1% yield loss as a result of using NSKE. Significant reduction of about 3.9% in yield loss of chickpea from NSKE treated plot *against H. armigera* and about 22.2% yield loss when NSKE was not applied has been reported (22). Similar observation was reported for NSKE against insect pests (*Earias insulana, Amrasca devastans* and *Oxycaremus loetus*) of Okra which resulted in lower percentage yield loss when 2.5% NSKE concentration was applied (37).

CONCLUSION

Application of aqueous KSE (40%w/v) significantly reduce boll infestation and percentage yield loss by bollworms, leading to yield increase, and was as good as the synthetic insecticidal check. This further suggests that farmers that could not use higher concentration of 40% can opt for lower rates of between 20-30% which proved to have a better yield than no treatment at all. The effectiveness exhibited by the material indicates its potential as being a good alternative for managing bollworms infestation on cotton. And incorporating this technology into the farming systems of resource-poor cotton farmers may help in reducing the cost of pest control, thereby maximizing yields and profit.

REFERENCES

1. **Abdelgaleil, S. A. M. and Nakatani, M. 2003.** Antifeeding activity of limonoids from *Khaya senegalensis*. *Journal of Applied Entomology*, 127 (4): 236–239.
2. **Abdelgaleil, S. A. M., Iwagawa, T., Doe, M. and Nakatani, M. 2004.** Antifungal limonoids from the fruits of *Khaya senegalensis*. *Fi-toterapia*, 75 (6): 566–572.
3. **Abdelgaleil, S. A. M., Okamura, H., Iwagawa, T., Sato, A., Miyihara, I., Doe, M. and Nakatani, M. 2001.** Khayanolides rearranged phragmalin limonoid antifeedants from *Khaya senegalensis*. *Tetrahedron*, 57 (1): 119–126.
4. **Ahmad, M. 2007.** Insecticide resistance mechanisms and their management in *Helicoverpa armigera* (Hübner) - A review. *Journal of Agricultural Research*, 45(4): 319–335.
5. **Ahmad, Z. 1999.** Pest problems of cotton: A regional perspective. *Proceedings of ICAC-CCRI, Regional Consultation: Insecticide Resistance Management in Cotton*, June 28-July 1st, Multan, Pakistan, pp. 5-20.
6. **Ahuja, S. L., Jeyakumar, P. and Dhayal, L. S. 2008.** Stability analysis for bollworm complex in *Gossypium hirsutum L. Euphytica* 161(3): 313-318.
7. **All Africa 2012.** In Nigeria, Boosting Cotton, Sorghum Production through Biotechnology. Distributed by AllAfrica Global Media (allAfrica.com). Soya tech. Growing Opportunities. http://www.soyatech.com/news_story.php?id=29295
8. **ARC-Tobacco and Cotton Research Institute. 1996.** Management Guide for the Cotton Producer. *Revised edition*. Cotton SA publication. 20pp.
9. **Boyd, M. L., Phipps, B. J. and Wrather, J. A. 2004.** Integrated Pest Management, Cotton Pests: Scouting and Management. M. U. Extension, University of Missouri at Colombia, 13 pp.
10. **Bre´vault, T., Oumarou, Y., Achaleke, J., Vaissayre, M. and Nibouche, S. 2009.** Initial activity and persistence of insecticides for the control of bollworms (Lepidoptera: Noctuidae) in cotton crops. *Crop Protection*, 28:401-406.
11. **Dhaliwal, G. S. and Koul, O. 2011.** Biopesticides and pest management:

Conventional and Biotechnological approaches. Ludhiana Kalyani publishers

12. **El Shafie, H. A. F. and Abdelraheem, B. A. 2012.** Field evaluation of three biopesticides for integrated management of major pests of tomato, *Solanum lycopersicum* L. in Sudan. A*griculture and Biology Journal of North Am*erica, 3(9): 340-344.
13. **Gouse, M., Kirsten, J. F. and Jenkin, L. 2002.** Bt cotton in South Africa: Adoption and the impact on farm incomes amongst small-scale and large-scale farmers. *Working paper* 18022, University of Pretoria, Department of Agricultural Economics, Extension and Rural Development.
14. **Greenberg, S. M., Adamczyk, J. J. and Armstrong, J. S. 2012.** Principles and Practices of integrated pest management on cotton in the Lower Rio Grande Valley of Texas, Integrated Pest Management and Pest Control-current and future tactics, Dr. Sonia Soloneski (Ed.), ISBN: 978-953-51-0050-8, In Tech, Available from: www.intechopen.com
15. **Husain, T. and M. Tahir. 1993.** Chemical Control of Bacterial Blight of Cotton. *Pakistan Journal of Phytopathology* 5: 119-121.
16. **Institute for Agricultural Research (IAR). 2018.** Our GMO cotton is targeting textile revival. Accessed online from Daily Trust Newspaper. https://www.dailytrust.com.ng/our-gmo-cotton-is-targeting-textile-revival-iar-266437.html
17. **International Cotton Advisory Committee (ICAC). 2017.** Cotton World Statistics. Bulletin of the International Cotton Advisory Committee.
18. **Jothi, B. D. 2007.** Bollworm Management in Cotton Production to meet the Quality Cotton Requirements of the industry. Model training course on "cultivation of long staple cotton (ELS)". December 15-22. Central Institute for Cotton Research, Regional station Combatore.
19. **Khattak, M. K., Mamoon-ur-Rashid, M. and Abdullah, K. 2012.** Evaluation of Botanical and Synthetic Insecticides for the Management of Cotton Pest Insects. *Pakistan J. Zool.*, 44(5), pp. 1317-1324.

20. **Kranthi, K. R. 2016.** Insecticide Resistance Management Strategies for Cotton Pests. Central Institute for Cotton Research (ICAR), Nagpur. Retrieved from https://www.indiaagronet.com/indiaagronet/pest_management/CONTENTS/insecticide_resistance_managemen.htm#top

21. **Kutama, A. S., Sherif, U., Dangora I. I., Umma, M., Salisu, A. and Rabiu, M. K. (2015).** Yield of Cotton and the Opinion of Small-Scale Farmers on Cotton Production in Kano and Katsina States, Nigeria. *Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 4(8): 434-438.* http://garj.org/garjas/home.

22. **Lulie, N. and Raja, N. 2012.** Evaluation of Certain Botanical Preparations against African Bollworm, *Helicoverpa armigera* Hubner (Lepidoptera: noctuidae) and Non-Target Organisms in Chickpea, *Cicer arietinum* L. *J. Biofertil Biopestici* 3(5):130. doi:10.4172/2155-6202.1000130.

23. **Malinga, L. K. 2012.** Efficacy of organic and synthetic insecticides on the control of cotton pests: The bollworm complex, *Helicoverpa armigera*, *Diparopsis castanea*, *Earias insulana* (Noctuidae) and the leafhopper, *Jacobiella fascialis* (Cicadellidae), for small-scale farmers. M.Sc. thesis submitted to the Department of Zoology and Entomology, Faculty of Science and Agriculture, University of Fort Hare, Alice. Pp 74.

24. **Mapuranga, R., Chapepa, B. and Mudada, N. 2015.** Strategies for integrated management of cotton bollworm complex in Zimbabwe: A review. *International Journal of Agronomy and Agricultural Research (IJAAR)* ISSN: 2223-7054 (Print) 2225-3610 (Online) http://www.innspub.net Vol. 7(1): 23-35.

25. **Matthews, G. A. 1989.** Cotton Insect Pests and their Management. Longman Scientific and Technical, Longman Group UK Limited, Longman House, Burnt Mill, Harlow, Essex CM202JE, England. 199pp.

26. **Matthews, G. A. 1999.** Cotton insect pest control in Zimbabwe. Pesticide Outlook,

Journal of the Royal Society of Chemistry, 198.

27. **Nahunnaro, H., Gwary, D. M. and Okunsanya, B. O. 2007.** An assessment of the reaction of ten cotton genotypes to angular leaf spot disease under field and controlled conditions in northern guinea savanna of northeast Nigeria. *Journal of Arid Agriculture*, 11:37-44.
28. **Obeng-Ofori, D. 2007.** Arthropod pests of cotton, *Gossypuim* spp (Malvaceae). In: *Obeng-Ofori D. (Ed.), Major pests of food and selected fruit and industrial crops in West Africa*. The City Publishers Limited, Accra, Ghana. pp. 179-192.
29. **Obopile, M. 2007.** Integrated pest management for African bollworm *(Helicoverpa armigera Hübner)* in Botswana: review of past research and future perspectives. *Journal of Agricultural, Food and Environmental Sciences*, 1(2): 1-9.
30. **Ogunlela, V. B. 2004.** Improved technologies for increased production in Nigeria. *Proceedings* of the Train the Trainer Workshop on Presidential Initiative on Vegetable Oils, Cotton and Groundnut Production, Lake Chad Research Institute May 10-12, Maiduguri.
31. **Paritala, V., Chiruvella, K. K., Thammineni, C., Ghanta, R. G. and Mohammed, A. 2015.** Phytochemicals and antimicrobial potentials of Mahogany family. *Revista Brasiliera de Farmacognosia*, 25(1): 61-83. doi: 10 1016/j.bjp.2014.11.009.
32. **Pimentel. D., McLaughlin, L., Zepp, A., Lakitan, B., Kraus, T., Kleinman, F., Vancini, P., Roach, W. J., Graap, E., Keeton, W. S. and Selig, G. 1993.** Environmental and economic effects of reducing pesticide use in agriculture. *Agriculture, Ecosystems & Environment* 46: 273–288.
33. **Raheja, A. K., Emechebe, A. M. and Oyedokun, A. O. 1982.** The Significance of and Problems associated with Cotton Pest control in Nigeria. Towards increased Cotton production in Nigeria. *Proceedings of the first National Symposium on Cotton Production*. Samaru, Zaria. 5^{th}-7^{th} May, 1982. Pp.80-88.
34. **Satti, A. A. and Elamin, M. M. 2012.** Insecticidal activities of two Meliaceous plants against *Trogoderma granarium* Everts (Coleoptera:

Dermestidae). *International Journal of Science and Nature*, 3(3): 696-701. ISSN 2229 – 6441.

35. **Senthil-Nathan, S. 2013.** Physiological and biochemical effect of neem and other Meliaceae plants secondary metabolites against Lepidopteran insects. *Frontier of Physiol*ogy, 4: 359. PMC3868951. doi: 10.3389/fphys.2013.00359

36. **Shah, J. A., Inayatullah, M., Sohail, K., Shah, S. F., Shah, S., Iqbal, T. and Usman, M. 2013.** Efficacy of botanical extracts and a chemical pesticide against tomato fruit worm, *Helicoverpa Armigera (*Lepidoptera: Noctuidae). *Sarhad J. Agric*. 29(1): 93-96.

37. **Sohail, K., Jan, S., Usman, A., Shah, S. F., Usman, M., Shah, M., Mashwani, M. A. and Mehmood, A. 2015.** Evaluation of some botanical and chemical insecticides against the insect pests of okra. *Journal of Entomology and Zoology Studies*, 3 (2): 20-24.

38. **Thacker, J. R. M. 2002.** An introduction to arthropod pest control Cambridge University Press, Cambridge, 343 pp.