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Field bioefficacy of mahogany seed extract (*Khaya senegalensis*: meliaceae, (desv.) a. juss) for management of bollworm infestation on cotton in Zaria, Nigeria

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Abstract

Field trials were conducted at two locations in Samaru (11° 11' N, 07° 38' E and 686m above sea level) and Maigana (11° 10' N, 07° 37' E and 675m above sea level) both 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 damage on cotton (SAMCOT 9) by bollworms. The experimental design was strip plot fitted into randomized complete block design. A total of four sprays at two weeks interval beginning from 9WAS (which corresponded to the period of formation of first square to the detection of first flower) were applied. Data were recorded on the number of terminal shoot damage, number of damaged shed squares, number of damaged shed cotton bolls and number of matured green bolls damaged by bollworms. There was no significant difference in the number of terminal shoot damaged by spiny bollworm (*Earias spp.*) from spray application of Lambda cyhalothrin, KSE and the untreated control. Significant reduction in the number of shed cotton squares, shed cotton bolls and matured green bolls damaged by bollworms were observed on Lambda cyhalothrin and 40%w/v KSE sprayed plots than the other treatments and the untreated control.

Keywords: *Khaya* seed extract, Lambda cyhalothrin, bollworms, infestation, cotton bolls.

Introduction

Cotton is an important cash crop of considerable social and economic importance in Nigeria, cultivated for its fibre and oil. It is mainly grown in the Savanna region of the Northern States in the areas extending from latitude 7°N to 13°N under rain-fed (Poswal, 1988) [19]. In cotton production, there are many factors that can reduce yield. One important cause is arthropod pests with those that cause loss to the fruit more destructive than those that damage leaves, stems, and roots (Mapuranga *et al.*, 2015) [15]. Total annual losses in the world are estimated at about U.S. \$300 billion, and average yield loss range from 30 to 40% and are generally much higher in many tropical and subtropical countries (Greenberg *et al.*, 2012) [9]. The pest pressure particularly from bollworms becomes very high and drives growers to adopt all tactics which may not be really suited to the given situation and would ensure failure of such efforts (Jothi, 2007) [10]. 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 (Matthews, 1989; Ahmad, 2007; Mapuranga *et al.*, 2015) [16, 4, 15]. Cotton receives more pesticide protection per season than any other crop (Matthews, 1989) [16] and accounts for more than 25 percent of all agricultural insecticides used worldwide (Pimentel *et al.*, 1993; Greenberg *et al.*, 2012) [18, 9]. This has prompted the necessity for the development of non-insecticidal alternatives that could be viable and effective for insect pest management, while also being compatible with the environment (Kranthi, 2016) [13]. Hence a current shift in the desire for biopesticides from botanical sources rather than synthetic chemicals using the extract of plants having pesticidal properties. Botanical insecticides have more advantages than synthetic mainly upon their quick degradation and lack of persistence and bioaccumulation in the ecosystem, which have been key problems in chemical pesticide use

(Senthil-Nathan, 2013) [22]. 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 (Thacker, 2002) [23]. These plant extracts have a wide range of anti-insect properties including insecticidal, repellent, antifeedant, and insect growth inhibitory activities (Ahmad, 2007; Dhaliwal and Koul 2011; Senthil-Nathan, 2013) [4, 7, 22]. One of such plant is African mahogany (*Khaya senegalensis*) a member of the timber tree species of the family Meliaceae with rich source for limonoids (Paritala *et al.*, 2015) [17], with no real exploitation recognized regarding its rich phytochemical constituents (Satti and Elamin 2012) [21]. The limonoids have been found to give effective control against cotton bollworms (Abdelgaleil *et al.*, 2001; Abdelgaleil and Nakatani 2003; Abdelgaleil *et al.*, 2004) [3, 1, 2]. Hence, this study was conducted to determine the effect of different concentrations of *Khaya* seed extract (KSE) on damage by bollworms on cotton 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 (I.A.R) farm Samaru, (11° 11' N, 07° 38' E and 686m above sea level) and Kaduna State Agricultural Development Agency (K.A.D.A) research farm in Maigana (11° 10' N, 07° 37' E and 675m above sea level) both in Northern Guinea Savannah ecological zone of Nigeria. The study areas has 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 at 0.90m inter-row spacing. 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 a 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. Maturity period is between 130-150 days with a potential yield of 1500-2000Kg/ha⁻¹. It was obtained from the Cotton Research Programme of the Institute for Agricultural Research (IAR), and the seeds were treated with Dress Force 42WS (Imidacloprid 20% + Metalaxyl-M 20% + Tebuconazole 2%) 8g/Kg before sowing. Seeds were sown at 4 seeds per hole at a depth of 3cm, 90cm inter-row spacing and 45cm intra-row spacing into the prepared ridges. Emerged seedlings were 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. Supplementary hoe weeding was done throughout especially at the critical periods of weeds interference. Fertilizer was applied at the recommended rate of 60: 13: 25 Kg/ha using NPK 15:15:15 and MOP at 3WAS, and Urea was used for top dressing at 8WAS.

Preparation and Application of *Khaya* seed extract:

Matured seeds of *K. senegalensis* were collected around IAR and Savanna Forestry Research Station in Samaru, Zaria. The seeds were air-dried 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 stirred vigorously and allowed to stand for 48hrs but were continuously stirred at 24hrs interval. The contents of each bucket were filtered with 500ml of water with the aid of a double-layer cheese cloth, after which 300ml of 5% w/v starch and flaked soap (50g each/1000ml of water) were added to each filtrate crude 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) per plot with knapsack sprayer to all the experimental plots except the untreated control. Application commenced from 9WAS which corresponded to the 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 collections and Analysis: Five plants were randomly selected from the net plot (9.45m²) and observations were recorded on number of plants with bored/damaged terminal growing points from *Earias sp.* attack, number of shed flowers/cotton squares damaged by bollworms, number of shed cotton bolls damaged by bollworms and number of matured cotton bolls damaged by bollworms. Data on fruiting bodies damaged by bollworms were transformed using square root transformation. All transformed data were subjected to analysis of variance (ANOVA) using SAS software package (version 9.0). Mean differences among treatments were separated using Students Newman's Keul test (SNK) at $P=0.05$.

Results and Discussion

Effect of aqueous *Khaya* seed extract on terminal shoot damage on Cotton caused by *Earias spp.* at Samaru and Maigana in 2016 wet season.

There were no significant difference ($P>0.05$) in the number of terminal shoot damaged by *Earias spp.* both in Samaru and Maigana with the application of different rates of KSE at 24hrs and 10days post spray application (PSA) (Table 1). The results of the two locations combined also follow similar trends at 24hrs and 10days PSA. The result indicated that similar number of terminal shoot were damaged by *Earias spp.* among different rates of KSE in both locations, even though the untreated control recorded higher terminal shoot damage. This finding could be attributed to low pest pressure of spiny bollworms at the early stage of the crop development. Spiny bollworm has been reported to appear late, usually in September and reaching peak pest population by the end of October especially in Northern Nigeria (Lyon, 1971) [14]. Klein *et al.* (1982) [12] reported that *E. insulana* is a serious pest of cotton in late summer in USA, when most of the plants have already started producing bolls. Matthews (1989) [16] reported absence of diapause, presence of alternative host plants, length of growing season, time of sowing and presence of ratoon cotton are among the factors that can influence the prevalence of *Earias* on cotton. Infestation by *Earias spp.* are principally in areas where alternative hosts

(*Abutilon spp.*, *Hibiscus spp.* and *Waltheria indica*) are common. Similarly, Vennila *et al.* (2007) [24] reported that *Earias* population build up is more during the boll development phase of the crop causing damage to all fruiting forms.

Table 1: Effect of *Khaya* seed extract on terminal shoot damage 9WAS in Samaru and Maigana

Mean number of damaged terminal shoot 24hrs and 10days post spray application						
Treatment	Samaru		Maigana		Combined	
	24hrs	10days	24hrs	10days	24hrs	10days
KSE (%w/v)						
20	0.71	0.71	0.71	0.71	0.71	0.71
30	0.71	0.71	0.71	0.71	0.71	0.71
40	0.71	0.75	0.71	0.71	0.71	0.73
Lambda cyhalothrin	0.71	0.71	0.71	0.71	0.71	0.71
Untreated control	0.71	0.75	0.71	0.71	0.71	0.73
SE±	0.000	0.024	0.000	0.000	0.000	0.013
Significance	NS	NS	NS	NS	NS	NS

NS=Not significant at $P=0.05$ using SNK.

Effect of aqueous *Khaya* seed extract on shed cotton squares damage by bollworms at Samaru and Maigana in 2016 wet season.

There were significant difference on the number of shed cotton squares damaged by bollworms with KSE in Maigana at 24hrs and 10days post spray applications but not in Samaru (Table 2). At 24hrs PSA in Samaru, all the KSE and Lambda cyhalothrin treatments resulted in less shed cotton squares damaged by bollworms which were similar ($P>0.05$), but were found to be significantly ($P<0.05$) lower than the untreated control which had higher number of shed cotton squares. However at 10days PSA, all the treatments resulted in similar ($P>0.05$) number of damaged shed squares. At 24hrs PSA in Maigana, Lambda cyhalothrin resulted in significantly ($P<0.05$) lower number of damaged shed squares than all the three KSE and the untreated control. All the KSE (30%w/v, 40%w/v, and 20%w/v) were found to have similar ($P>0.05$) numbers of damaged shed cotton squares which were significantly ($P<0.01$) lower than the untreated control. At 10days PSA, Lambda cyhalothrin resulted in similar ($P>0.05$) number of damaged shed squares with 40%w/v KSE, but significantly ($P<0.05$) lower than 30%w/v, 20%w/v and untreated control. Although, the number of damaged shed cotton squares from 30%w/v was similar ($P>0.05$) to 20%w/v but significantly ($P<0.05$) lower than untreated control which was found to be similar ($P>0.05$) to 20%w/v, and gave the highest number of damaged shed cotton squares. The result of the combined analysis from the two locations 24hrs PSA, Lambda cyhalothrin had the lowest number of damaged shed cotton squares which was significantly ($P<0.05$) lower than all the KSE and the untreated control. However, all the KSE treatments resulted in similar ($P>0.05$) number of damaged shed cotton squares which were significantly ($P<0.05$) lower than the untreated control. At 10days PSA, both Lambda cyhalothrin and 40%w/v resulted in similar ($P>0.05$) number of damaged shed cotton squares that were significantly ($P<0.05$) lower than all the other KSE and the untreated control. Although 30%w/v was similar ($P>0.05$) to 20%w/v but significantly ($P<0.05$) lower than the untreated control which was found to be similar ($P>0.05$) to 20%w/v on the number of damaged shed cotton squares.

The result indicated that the number of shed cotton squares damaged by bollworms was affected by different rates of KSE and intra-row spacings and this vary with location. In Samaru, all KSE rates and Lambda cyhalothrin treated plots were observed to have similar effect in reducing the number of shed squares damaged by bollworms and their effects were found to be better than the untreated plots. At Maigana, similar trend was observed among all the KSE which were effective in reducing the number of shed squares damaged by bollworms when compared with untreated plot. However, it was only Lambda cyhalothrin that was more effective in reducing the number of damaged shed cotton squares. Similarly, the damaged shed squares recorded for the two locations indicated an increasing effect of KSE from 20%w/v to 40%w/v in reducing the number of shed squares damaged by bollworms, although only 40%w/v KSE was comparable to Lambda cyhalothrin. Hence this result could suggests that the use of KSE at rate as high as 40%w/v could compete with Lambda cyhalothrin in reducing the number of shed squares damaged by bollworms. The significant reduction on the number of damaged shed squares could be as a result of differential concentration of the active ingredients present in KSE called liminoids which is known to possess potent anti-insect properties (Paritala *et al.*, 2015) [17] as well as antimicrobial properties (Govindachari and Krishna Kumari 1998; Roy and Saraf, 2006) [8, 20]. It could be that KSE at the highest rate of 40% w/v has more of the concentration of the limonoids and hence the better efficacy. Similarly, Wondafrash *et al.* (2012) [25] reported that significantly lower number of cotton squares were damaged by the larvae of African bollworm when high concentration of NSKE was used as compared to the control.

Table 2: Effect of *Khaya* seed extract on shed cotton squares damage 9WAS in Samaru and Maigana

Mean number of damaged terminal shoot 24hrs and 10days post spray application						
Treatment	Samaru		Maigana		Combined	
	24hrs	10days	24hrs	10days	24hrs	10days
KSE (%w/v)						
20	0.71b	0.83	1.63b	1.71ab	1.17b	1.27ab
30	0.78b	0.71	1.41b	1.46b	1.10b	1.08b
40	0.71b	0.71	1.41b	1.04c	1.06b	0.88c
Lambda cyhalothrin	0.71b	0.71	1.13c	0.94c	0.92c	0.83c
Untreated control	1.12a	0.83	1.97a	1.95a	1.54a	1.39a
SE±	0.038	0.047	0.172	0.155	0.085	0.078
Significance	*	NS	*	*	*	*

NS=Not significant *= ($P<0.05$). 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 shed cotton bolls damaged by bollworms at Samaru and Maigana in 2016 wet season.

The results shows that the effect of different rates of KSE in Samaru and Maigana resulted in a significant difference on the number of damaged shed cotton bolls at 24hrs and 10days post spray application (Table 3). At 24hrs PSA in Samaru, all KSE and Lambda cyhalothrin had similar ($P>0.05$) number of damaged shed cotton bolls which were significantly ($P<0.05$) than the untreated control. At 10days PSA, similar trend was observed with Lambda cyhalothrin, 40%w/v and 20%w/v having similar ($P>0.05$) number of damaged shed cotton bolls which were significantly

($P < 0.05$) lower than 30%w/v and the untreated control. The 30%w/v was also significantly ($P < 0.05$) lower than the untreated control. At 24hrs PSA in Maigana, Lambda cyhalothrin recorded significantly ($P < 0.05$) lower number of damaged shed cotton bolls than all the KSE treatments and the untreated control. Also, 40%w/v was found to be similar ($P > 0.05$) to 30%w/v but significantly ($P < 0.05$) lower than 20%w/v and untreated control. However, both 30%w/v and 20%w/v had similar ($P > 0.05$) number of damaged shed cotton bolls which were significantly ($P < 0.05$) lower than the untreated control. At 10days PSA, Lambda cyhalothrin and 40%w/v had similar ($P > 0.05$) number of damaged shed cotton bolls which were significantly ($P < 0.05$) lower than the other KSE and the untreated control. Both 30%w/v and 20%w/v also recorded similar ($P > 0.05$) number of damaged shed cotton bolls that were significantly ($P < 0.05$) lower than the untreated control during the period. The result of the 24hrs PSA for the two locations combined shows a significant difference among treatments with Lambda cyhalothrin having significantly ($P < 0.05$) lower number of damaged shed cotton bolls than all the KSE and the untreated control. More so, 40%w/v also recorded significantly ($P < 0.05$) lower numbers of damaged shed cotton bolls than the other KSE and the untreated control. Likewise, both 30%w/v and 200%w/v had similar ($P > 0.05$) numbers of damaged shed cotton bolls which were significantly ($P < 0.05$) lower than the untreated control. At 10days PSA, similar observation was made on

the result of the two location combined with Lambda cyhalothrin and 40%w/v having similar ($P > 0.05$) number of damaged shed cotton bolls which were significantly ($P < 0.05$) lower than the other KSE and the untreated control. More so, both 20%w/v and the 30%w/v were also significantly ($P < 0.05$) lower than the untreated control. Application of different rates of KSE spray in Samaru were found to have similar effects with Lambda cyhalothrin which are better than the untreated plots in reducing the number of damaged shed cotton bolls. However, at Maigana, it was observed that only 40%w/v KSE had similar effect with Lambda cyhalothrin in reducing the number of shed cotton bolls damaged by bollworms, although the other KSE rates were better than the untreated plots. The combined result for both locations also shows similar effects of 40%w/v KSE and Lambda cyhalothrin which were better than the other rates of KSE and untreated plots. The observed reduction in the number of damaged shed cotton bolls by the KSE indicates the potential of the extract to have effect on the insect. This finding is in line with the findings of Ahmad (2007) [4]; Dhaliwal and Koul (2011) [7]; Senthil-Nathan, (2013) [22] that Khaya seed contains various types of secondary metabolites such as limonoid that have wide range of anti-insect properties. Application of Neem kernel seed extracts with this source of limonoids has also been found to suppress bollworms and whiteflies without affecting the natural balance of cotton ecosystem (Jothi, 2007) [10].

Table 3: Effect of aqueous *Khaya* seed extract on shed cotton bolls damage 11WAS in Samaru and Maigana

Mean number of damaged shed cotton bolls 24 hours and 10 days post spray application						
Treatment	Samaru		Maigana		Combined	
	24hrs	10days	24hrs	10days	24hrs	10days
KSE (%w/v)						
20	0.80b	1.08c	1.62b	2.02b	1.21b	1.55b
30	0.84b	1.39b	1.48bc	1.78b	1.16b	1.59b
40	0.75b	1.00c	1.29c	1.31c	1.02c	1.15c
Lambda cyhalothrin	0.71b	0.84c	0.97d	1.27c	0.84d	1.05c
Untreated control	1.44a	2.18a	2.56a	2.58a	2.00a	2.38a
SE±	0.066	0.222	0.198	0.163	0.105	0.132
Significance	*	*	*	*	*	*

*= ($P < 0.05$). 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 bollworm damage to Matured cotton bolls on plants at Samaru and Maigana in 2016 wet season.

Spray application of different rates of KSE in Samaru and Maigana resulted in a highly significant difference on the number of damaged matured cotton bolls at 13weeks and 15weeks post spraying (Table 4). At 13weeks PSA in Samaru, both Lambda cyhalothrin and all the KSE treatments recorded similar ($P > 0.05$) numbers of damaged matured cotton bolls which were significantly ($P < 0.05$) lower than the untreated control which recorded the highest damage. At 15weeks PSA, Lambda cyhalothrin recorded significantly ($P < 0.05$) lower number of damaged matured cotton bolls than all the KSE and the untreated control. Likewise, the 40%w/v was similar ($P > 0.05$) to 20%w/v but significantly ($P < 0.05$) lower than 30%w/v and the untreated control. However, the 20%w/v and 30%w/v recoded similar ($P > 0.05$) number of damaged matured cotton bolls which were significantly ($P < 0.05$) lower than the untreated control. At 13weeks PSA in Maigana, Lambda cyhalothrin (1.40) recorded significantly ($P < 0.05$) lower number of

damaged matured cotton bolls than all the KSE and the untreated control. Similarly, 40%w/v KSE also recorded significantly ($P < 0.05$) lower number of damaged matured cotton bolls than the other KSE and the untreated control. Likewise, 30%w/v also had significantly ($P < 0.05$) lower number of damaged matured cotton bolls than 20%w/v and the untreated control. And the 20%w/v was also significantly ($P < 0.05$) lower than the untreated control which recorded highest number of damaged matured cotton bolls during the period. At 15weeks PSA, similar trend was observed with Lambda cyhalothrin having significantly ($P < 0.05$) lower number of damaged matured cotton bolls than all the KSE and the untreated control. The 40%w/v also recorded significantly ($P < 0.05$) lower number of damaged matured cotton bolls than the other two KSE and the untreated control. However, both 30%w/v and 20%w/v were similar ($P > 0.05$) but significantly ($P < 0.05$) lower than the untreated control which recorded higher number of damaged matured cotton bolls. The combined result of the two locations at 13weeks PSA showed that Lambda cyhalothrin had significantly ($P < 0.05$) lower number of damaged

matured cotton bolls than all the KSE and the untreated control. The 40%w/v also recorded significantly ($P<0.05$) lower number of damaged matured cotton bolls than the other two KSE and the untreated control. The 30%w/v also recorded significantly lower ($P<0.05$) number of damaged matured cotton bolls than 20%w/v and the untreated control. Likewise, the 20%w/v had significantly ($P<0.05$) lower number of damaged matured cotton bolls than the untreated control. At 15 weeks PSA, Lambda cyhalothrin recorded significantly ($P<0.05$) lower number of damaged matured cotton bolls than all the KSE and the untreated control. The 40%w/v also recorded significantly ($P<0.05$) lower number of damaged matured cotton bolls than the other KSE and the untreated control. Similar numbers of damaged matured cotton bolls ($P>0.05$) were recorded on 30%w/v and 20%w/v which were significantly ($P<0.05$) lower than the untreated control. The result indicated that the number of matured green bolls damaged by bollworms was affected by different concentrations of KSE and this vary with locations. The results of the two locations combined also indicated an increasing effect of the KSE from 20%w/v to 40%w/v in reducing the number of damaged matured green bolls by bollworms with only 40%w/v KSE found to be similar with Lambda cyhalothrin. This finding suggests a comparable effect of KSE at 40%w/v concentration with Lambda cyhalothrin in reducing the number of matured green bolls damaged by bollworms. The efficacy of the KSE in reducing the level of damage to matured green bolls on cotton plants in this study could be attributed to the insecticidal action of the secondary metabolites (limonoids) that is found in KSE which could interfere with the feeding and repelling large number of the bollworms that could have caused substantial damage to the developing bolls. This is corroborated by the findings of Satti and Elamin (2012) [21] that mahogany seed is rich in phytochemical constituent (limonoids) which have been found to give effective control against cotton bollworms (Abdelgaleil *et al.*, 2001; Abdelgaleil and Nakatani 2003; Abdelgaleil *et al.*, 2004) [3, 1, 2] as well as some storage pests of cowpea and sorghum (Bamaiyi and Bolanta 2006; Bamaiyi *et al.*, 2006) [5, 6]. Khattak *et al.* (2012) [11] reported that aqueous NKSE which is also a rich source of limonoids at higher concentrations adversely affect the attack of pink bollworms up to 12 days after spray.

Table 4: Effect of aqueous *Khaya* seed extract on matured bolls damaged in Samaru and Maigana.

Mean number of damaged matured bolls 13 weeks and 15 weeks post spray application						
Treatment	Samaru		Maigana		Combined	
	13wks	15wks	13wks	15wks	13wks	15wks
KSE (%w/v)						
20	1.13b	1.44bc	3.23b	1.91b	2.18 ^b	1.68b
30	1.15b	1.55b	2.79c	1.70b	1.97c	1.62b
40	0.88b	1.26c	1.77d	1.10c	1.33d	1.18c
Lambda cyhalothrin	0.88b	0.96d	1.40e	0.84d	1.14e	0.90d
Untreated control	2.02a	2.40a	3.80a	2.63a	2.91a	2.52a
SE±	0.075	0.113	0.117	0.072	0.076	0.063
Significance	*	*	*	*	*	*

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

Conclusion

Application of aqueous KSE at (40%w/v) can significantly reduce bollworms damage on cotton plants 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% than no treatment at all. The efficacies demonstrated by aqueous KSE in this study points to the potential of the material as being a good alternative for managing bollworms infestation on cotton.

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