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Effect of *Artemisia annua* L. leaf extract on the incidence and severity of *Aphis fabae* Scop. in intercropped and pure stand common bean (*Phaseolus vulgaris* L.)

Kennedy Odhiambo Ogonda*, **Millicent F. O. Ndonga**, **Francis N. Muyekho**, **Dennis Omaiyo**

Department of Biological Sciences, Faculty of Science, Masinde Muliro University of Science and Technology, Kenya

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Abstract

This field study was conducted in Kaimosi Agricultural Training Centre (KATC) farm in Kenya during the short rains of 2015 and long rains of 2016. The objective of the study was to evaluate the effect of *A. annua* leaf extracts on incidence and severity of *A. fabae* in bean pure stand, bean/maize and bean/*Solanum scabrum* Mill. intercrops. This was in attempt to find a cost-effective and environmentally friendlier alternative to synthetic insecticides. The experiment was laid out in a Randomized Block Design with twelve treatments each replicated thrice. Analysis of variance was used to compare means of number of *A. fabae* plant^{-1}, plant height, leaf width, number of pods plant^{-1}, number of crinkled leaves plant^{-1}, fresh and dry weights of bean plant and dry weight of bean seeds plant^{-1} at $p \leq 0.05$. From the results, *A. fabae* incidence was highest under bean/*S. scabrum* intercrop + distilled water combination at 80.76 and 44.32 during the short and long rains respectively. This was higher compared to 16.75 and 12.16 during the short and long rains respectively under bean/*S. scabrum* intercrop + 5% *A. annua* combination. Bean/*S. scabrum* + distilled water combination recorded the lowest grain weight plant^{-1} at 7.98g and 7.44g during the short and long rains respectively. This was lower compared to 12.10g and 12.19g under bean/*S. scabrum* + 5% *A. annua* during the short and long rains respectively. It can be concluded that *A. annua* extracts are effective in controlling incidence and severity of *A. fabae* under the three cropping systems.

* **Corresponding Author:** Kennedy Odhiambo Ogonda ✉ kennogonda@gmail.com

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most popular food crops grown in Kenya. Its popularity is mainly as a result of its short duration to maturity, excellent taste and high nutritional value (Mwang'ombe *et al.*, 2007). In Kenya, the average yield of common bean per unit area is 0.59 tons/ha under farmer managed conditions (FAOSTAT, 2015). This is way below the yield potential of improved bean varieties which is put at 1.4-2.0 tons/ha (KARI, 2008). One of the major factors affecting the productivity of common bean in Kenya is infestation by insect pests, key among them being *Aphis fabae* Scop. The high incidence of *A. fabae* calls for frequent application of synthetic insecticides in order to control the pest hence posing a big challenge to the subsistence farmers, majority of whom are resource poor with little means or skills of handling insecticides efficiently (Ogendo *et al.*, 2003). Additionally, the use of systemic insecticides has harmful effects on the environment, non-target organisms and human health (Rahaman and Prodhan, 2007).

In recent years, a lot of research has been done on the possibility of using botanical insecticides in the control of insect pests because of their safety to the environment, human life and non-target beneficial organisms as well as their cost effectiveness to the small scale subsistent farmers since they are usually available locally (Ogendo *et al.*, 2003; Rathi and Gopalakrishnan, 2006; Yallapa *et al.*, 2012; Amoabeng *et al.,* 2013). Extracts of *Artemisia annua* L. have been reported to exhibit certain insecticidal bioactivities through growth retardation, antifeedant and larvicidal effects on insect pests (Chiasson *et al.*, 2001; Kordali *et al.*, 2006; Haghighian *et al.*, 2008; Shekari *et al.* 2008; Hasheminia *et al.* 2011).

This field study was aimed at investigating the effectiveness of *A. annua* leaf extracts as a bioinsecticide against *A. fabae* under the commonly practised cropping systems (bean pure stand, bean/maize and bean/*Solanum scabrum* Mill. intercrops).

Since *A. annua* is commonly found naturally growing in the locality, the success of the study would open windows for several gains from its adoption as a botanical insecticide, such as cost effectiveness as well as safety to the environment and non-target beneficial organisms (Isman, 2006; Rathi and Gopalakrishnan, 2006; Yallapa *et al.*, 2012; Amoabeng *et al.,* 2013).

Materials and methods

Experimental site and design

This field study was carried out at KATC farm located in Nandi County, Kenya, between September 2015 and July 2016. The experiment was laid out in a randomized block design with 12 treatments each replicated thrice. These treatments were as follow; Bean pure stand treated with 5% *A. annua* leaf extracts (BPA_5), Bean pure stand treated with 1% *A. annua* leaf extract (BPA_1), Bean pure stand treated with lambda-cyhalothrin insecticide (Duduthrin) at recommended rate (BPL) as a positive control, Bean pure stand treated with distilled water (BPW) as a negative control, Bean/*S. scabrum* intercrop treated with 5% *A. annua* leaf extract (BSA_5), Bean/*S. scabrum* intercrop treated with 1% *A. annua* leaf extract (BSA_1), Bean/*S. scabrum* intercrop treated with lambda-cyhalothrin at recommended rate (BSL) as a positive control, Bean/*S. scabrum* intercrop treated with distilled water (BSW) as a negative control, Bean/maize intercrop treated with 5% *A. annua* leaf extract (BMA_5), Bean/maize intercrop treated with 1% *A. annua* leaf extract (BMA_1), Bean/maize intercrop treated with lambda-cyhalothrin at recommended rate (BML) as a positive control and Bean/maize intercrop treated with distilled water (BMW) as a negative control. Each plot measured 3m by 3m and was separated from one another by 0.5m wide path whereas the blocks were separated by 1m wide path.

Preparation of A. annua extracts

Fresh leaves of *A. annua* were harvested at flowering stage from KATC farm and placed in brown paper bags. They were taken to Masinde Muliro University of Science and Technology (MMUST) botany laboratory where they were left to dry under laboratory conditions for two weeks.

The dry leaves were crushed using a mortar and a pestle then screened through an 80-mesh screen. The dried powder was soaked in methanol at a ratio of 1g dried powder to 5ml methanol. The mixture was shaken on an electric shaker at 125 rpm for 72 hours. After 72 hours, the extracts were filtered through Whatman filter paper. The filtrate was evaporated to dryness in a rotary evaporator under vacuum. The crude material obtained was weighed and dissolved in distilled water (1g/10ml) to give a stock solution which was diluted further to obtain 5% and 1% concentrations of artemisia extracts. The filtrate was mixed with 3ml of teepol detergent per litre to assist in dispersion of the spray on the plant and pest surface since it acts as a sticking agent (Vigliaco *et al.,* 2008).

Land preparation, planting, weeding and spraying.

Seed bean (KK8 variety) and seed maize (WH505 variety) were obtained from Western Seed Company stores at Kapsabet, Kenya. *S. scabrum* seeds were bought from Simlaw Seeds stores at Kapsabet. Planting was done in September 2015.

Land was prepared to fine tilth by two ploughings and two harrowings. In the bean pure stand plots, bean seeds were sown at 5cm depth using a spacing of 30cm by 15cm. In the bean/*S. Scabrum* intercrop plots, bean rows were alternated with *S. scabrum* rows at a spacing of 30cm between the rows and 15cm within the rows. In bean/maize intercrop plots, maize seeds were planted in rows spaced 75cm apart and 30cm within the rows. In between rows of maize, there were 2 rows of beans spaced 30cm apart and 15cm within the rows. D.A.P fertiliser was applied in the planting holes at recommended rates. The plots were kept weed-free by mechanical weeding using a hoe. The experiment was carried out under rainfed conditions supplemented with drip irrigation during dry periods. The crops were sprayed twice on the 26th and 40th days after sowing using a trigger pump.

Observation and data analysis

Data was collected through random sampling of 15 bean plants per plot. The data was taken on nine separate days between the two sprayings, that is, a day before spraying, a day after spraying, 5th, 9th and 13th day after spraying. The parameters observed included number of *A. fabae* plant^{-1}, plant height, leaf width, number of damaged leaves plant^{-1}, number of pods plant^{-1}, fresh and dry weights of plants minus pods, dry weight of bean seeds plant^{-1} and number of shriveled seeds plant^{-1}.

The data collected were subjected to two-way analysis of variance (2-way ANOVA) using SPSS statistical software at $p \leq 0.05$ .Descriptive statistics such as means and standard deviations were generated using proc means while frequencies (percentages) were generated using proc frequency. Studentized test was applied to separate the means where necessary.

Result

Number of A. fabae

There was significant difference in the number of *A. fabae* between the twelve treatments ($p<0.05$) (Table 1.).

In both seasons, across the three cropping systems, the highest number of *A. fabae* was recorded on plants treated with distilled water, followed by 1% *A. annua* then 5% *A. annua* and finally lambda-cyhalothrin. The highest numbers during the short and long rains were (80.76) and 44.32 respectively and were both observed on BSW. The lowest numbers during the short and long rains were (10.72) and (10.16) respectively and were both observed on BML. In both seasons, across the three cropping systems, the number of *A. fabae* in plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin were all significantly lower than that in plants treated with distilled water ($p<0.05$).

Plant Height

The results showed significant differences in plant height among the different treatments during the short and long rains ($p<0.05$) (Tables 2 and 3). During the short rains (Table 2), the tallest plant (44.35cm) was recorded on BPL and the shortest plant (39.11cm) was recorded on BSW. A similar situation occurred during the long rains (Table 3) whereby the tallest plant (51.04cm) was recorded on BPL and the shortest plant (45.49cm) was recorded on BSW.

In both seasons, under bean pure stand and bean/*S. scabrum* intercrop the height of plants treated with 1% *A. annua* 5% *A. annua* and lambda-cyhalothrin were all significantly taller than those treated with distilled water ($p<0.05$). However, the situation was different under bean/maize intercrop.

Table 1. Mean (±SE) number of *A. fabae* per bean plant under bean pure-stand, bean/*S. scabrum* and bean/maize intercrop systems during the short and long rains.

Source of variation		Short rains	Long rains
		Mean no. of *A. fabae*	Mean no. of *A. fabae*
Bean pure stand	5% *A. annua*	15.33 ± 1.25 def	12.12 ± 1.02 def
	1 % *A. annua*	20.24 ± 1.58 c	13.99 ± 1.26 cde
	Lambda-cyhalothrin	11.57 ± 0.87 gh	10.67 ± 0.77 f
	Distilled water	75.51 ± 2.42 a	42.48 ± 2.90 a
Bean/*S. scabrum* Intercrop	5% *A. annua*	16.75 ± 1.37 cde	12.16 ± 1.02 def
	1 % *A. annua*	19.49 ± 1.56 cd	14.04 ± 1.24 cde
	Lambda-cyhalothrin	12.34 ± 0.97 fgh	10.69 ± 0.76 f
	Distilled water	80.76 ± 2.49 a	44.32 ± 2.91 a
Bean/maize Intercrop	5% *A. annua*	12.74 ± 1.01 fgh	10.87 ± 0.80 f
	1 % *A. annua*	16.97 ± 1.40 c	12.49 ± 1.08 def
	Lambda-cyhalothrin	10.72 ± 0.75 h	10.16 ± 0.63 f
	Distilled water	40.87 ± 2.33 b	21.24 ± 2.04 b

Means with the same letter(s) within the same column are not significantly different at p≤0.05; those with more than one letter are intermediate.

Leaf Width

In both seasons, there was significant difference in leaf width between the different treatments ($p<0.05$) (Tables 2 and 3). During the short rains (Table 2), the widest leaf (6.15cm) was recorded on BPL whereas the narrowest leaf (5.77cm) was recorded on BSW. During the long rains (Table 3), the widest leaf (6.17cm) was recorded on BPL while the narrowest leaf (5.62cm) was recorded on BPW. Under bean pure stand and bean/*S. scabrum* intercrop systems, the leaf width of plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin were all significantly wider than those treated with distilled water ($p<0.05$). However, under bean/maize intercrop, there was no significant difference in the leaf width of plants among the different treatments.

Table 2. Mean (±SE) Plant Growth Parameters under bean pure stand, bean/*S. scabrum* and bean/maize intercrops during the short rains.

Source of variation		Plant height	Leaf width	No. of crinkled leaves per plant
		Means		
		cm	cm	no.
Bean pure	5% *A. annua*	43.78 ± 0.06 abc	6.13 ± 3.37 abc	13.41 ± 0.75 bc
	1% *A. annua*	42.22 ± 0.07 cd	6.07 ± 3.38 abcde	13.96 ± 0.75 bc
	Lambda-cyhalothrin	44.35 ± 0.06 abc	6.15 ± 3.37 a	13.21 ± 0.73 bc
	Distilled water	39.91 ± 0.06 e	5.83 ± 3.34 fg	15.72 ± 0.84 a
Bean/*S. scabrum* Intercrop	5% *A. annua*	43.20 ± 0.06 bc	6.07 ± 3.39 abcd	13.71 ± 0.76 bc
	1% *A. annua*	42.84 ± 0.06 cd	6.02 ± 3.37 abcde	14.20 ± 0.76 b
	Lambda-cyhalothrin	43.63 ± 0.06 abc	6.11 ± 3.38 abc	13.09 ± 0.74 bc
	Distilled water	39.11 ± 0.07 e	5.77 ± 3.36 gh	16.26 ± 0.85 a
Bean/maize Intercrop	5% *A. annua*	44.07 ± 0.06 abc	6.07 ± 3.38 abcd	12.87 ± 0.73 cd
	1% *A. annua*	42.79 ± 0.06 cd	6.00 ± 3.38 abcdef	13.66 ± 0.74 bc
	Lambda-cyhalothrin	43.99 ± 0.06 abc	6.09 ± 3.39 abcd	12.78 ± 0.73 cd
	Distilled water	40.93 ± 0.06 de	5.91 ± 3.37 defg	14.16 ± 0.8 b

Means with the same letter(s) within the same column are not significantly different at p≤0.05; those with more than one letter are intermediate.

Number of damaged leaves plant^{-1}

In both seasons, significant differences were observed in the number of damaged leaves between the different treatments ($p<0.05$) (Tables 2 and 3). The highest number of damaged leaves was observed on BSW (16.26) and BPW (13.74) during the short and long rains respectively whereas the lowest number was observed on BML (12.78) and BML (10.47) during the short and long rains respectively. In all the three cropping systems, the number of damaged leaves on plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin were all significantly lower than that on plants treated with distilled water except under bean/maize intercrop during the short rains when there was no significant difference between BMA_1 and BMW ($p<0.05$).

Table 3. Mean (±SE) Plant Growth Parameters under bean pure stand, bean/*S. scabrum* and bean/maize intercrops during the long rains.

Source of variation		Plant height	Leaf width	No. of crinkled leaves per plant
		Means	Means	Means
		cm	cm	no.
Bean pure	5% *A. annua*	49.68 ± 0.07 a	6.07 ± 3.29 abcd	10.74 ± 0.65 d
Stand	1% *A. annua*	48.46 ± 0.07 a	5.96 ± 3.16 bcdefg	10.90 ± 0.66 d
	Lambda-cyhalothrin	51.04 ± 0.06 a	6.17 ± 3.30 a	10.51 ± 0.63 d
	Distilled water	45.80 ± 0.07 b	5.62 ± 3.21 h	13.74 ± 0.83 ab
Bean/*S. scabrum*	5% *A. annua*	49.27 ± 0.07 a	6.03 ± 3.29 abcde	10.80 ± 0.65 d
Intercrop	1% *A. annua*	49.24 ± 0.07 a	5.99 ± 3.24 abcdef	10.85 ± 0.65 d
	Lambda-cyhalothrin	50.30 ± 0.06 a	6.15 ± 3.13 ab	10.61 ± 0.64 d
	Distilled water	45.49 ± 0.07 bc	5.65 ± 3.11 h	13.58 ± 0.82 ab
Bean/maize	5% *A. annua*	49.06 ± 0.06 a	5.95 ± 3.29 bcdefg	10.51 ± 0.63 d
Intercrop	1% *A. annua*	48.73 ± 0.06 a	5.94 ± 3.29 cdefg	10.77 ± 0.65 d
	Lambda-cyhalothrin	49.72 ± 0.06 a	6.03 ± 3.29 abcde	10.47 ± 0.62 d
	Distilled water	48.51 ± 0.06 a	5.88 ± 3.29 efg	11.90 ± 0.74 c

Means with the same letter(s) within the same column are not significantly different at $p\leq0.05$; those with more than one letter are intermediate.

Number of pods plant^{-1}

There was significant difference in the number of pods plant^{-1} between the different treatments during the short and long rains ($p<0.05$) (Tables 4 and 5). During the short rains (Table 4), the highest number of pods was recorded on BSL (16.07) whereas the lowest number was recorded on BSW (8.12). During the long rains (Table 5), the highest number was recorded on BPL (15.36) whereas the lowest number was recorded on BPW (8.24). In both seasons, under bean pure stand and bean/*S. scabrum* cropping systems, the number of pods on plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin were all significantly higher than on plants treated with distilled water ($p<0.05$). However, under bean maize intercrop, there was no significant difference between the number of pods on plants treated with 1% *A. annua,* 5% *A. annua* and distilled water (Tables 4 and 5).

Number of shriveled seeds plant^{-1}

In both seasons, there was significant difference in the number of shriveled seeds per plant between the different treatments ($p<0.05$) (Tables 4 and 5). The highest number was obtained from BSW (8.91) and BPW (7.33) during the short and long rains respectively. The lowest number was recorded on BML (1.42) and BML (1.04) during the short and long rains respectively. Under the cropping systems, the number of shriveled seeds from plants treated with 1% *A. annua,* 5% *A. annua* and lambda-cyhalothrin were all significantly lower than that from plants treated with distilled water.

Fresh weight of bean plant

There was significant difference between the fresh weight of bean plant in the different treatments during the short and long rains ($p<0.05$) (Tables 4 and 5). During the short rains the highest weight (17.53g) was recorded from BPL whereas the lowest weight (10.91g) was recorded from BPW. During the long rains, the highest weight (17.76g) was obtained from BPL whereas the lowest weight (11.26g) was obtained from BSW.

Table 4. Plant yield in bean pure stand, bean/*S. scabrum* and bean/maize intercrops during the short rainy season

Source of variation	No. of pods	No. of shriveled seeds	Fresh weight of plant	Dry weight of plant	Dry weight of grains
	Means	Means	Means	Means	Means
Bean pure stand 5% *A. annua*	15.07 ± 0.22 abc	2.47 ± 0.09 efgh	17.35 ± 0.08 ab	8.74 ± 0.06 abc	12.84 ± 0.07 abc
1 % *A. annua*	12.40 ± 0.16 bcdef	3.13 ± 0.11 cdef	15.06 ± 0.11 cdef	7.60 ± 0.06 defgh	11.47± 0.09 bcde
Lambda-cyhalothrin	16.04 ± 0.20 a	1.73 ± 0.07 fgh	17.53 ± 0.09 ab	9.47 ± 0.05 a	13.33 ± 0.06 a
Distilled water	8.34 ± 0.22 gh	8.11± 0.22 ab	10.91 ± 0.13 l	6.22 ± 0.06 ijk	8.12 ± 0.16 hi
Bean/*S. scabrum* 5% *A. annua*	15.33 ± 0.22 abc	3.53 ± 0.12 cde	15.80 ± 0.09 bcde	7.87 ± 0.06 cdef	12.10 ± 0.08 abc
Intercrop 1 % *A. annua*	12.20 ± 0.23 bcdef	4.27 ± 0.13 cd	13.37 ± 0.11 fghi	6.92 ± 0.06 fghij	11.38± 0.06 cdef
Lambda-cyhalothrin	16.07 ± 0.22 a	2.09 ± 0.09 efgh	16.83 ± 0.09 abc	8.89 ± 0.06 ab	12.95 ± 0.07ab
Distilled water	8.12 ± 0.19 gh	8.91± 0.21 a	11.60 ± 0.13 ijkl	5.92 ± 0.06 k	7.98 ± 0.17 hi
Bean/maize 5% *A. annua*	11.44 ± 0.17 defg	2.07 ± 0.08 efgh	13.31 ± 0.10 fghij	6.92 ± 0.06 fghij	10.54± 0.05 defg
intercrop 1 % *A. annua*	11.27 ± 0.14 defg	2.18 ± 0.09 efgh	13.00 ± 0.10 hijk	6.69 ± 0.05 hijk	9.75 ± 0.06 gh
Lambda-cyhalothrin	12.56 ± 0.16 bcdef	1.42 ± 0.06 fgh	13.19 ± 0.10 ghij	7.15 ± 0.05 efghi	10.50 ± 0.06 defg
Distilled water	10.42 ± 0.18 efg	4.20± 0.12 cd	12.83 ± 0.11 hijk	6.55 ± 0.06 ijk	9.30 ± 0.07 gh

Means with the same letter(s) within the same column are not significantly different at $p \le 0.05$; those with more than one letter are intermediate.

In both seasons, under bean pure stand and bean/*S. scabrum* intercrop, the fresh weight of plant treated with 1% *A. annua,* 5% *A. annua* and lambda-cyhalothrin was generally higher than that treated with distilled water ($p<0.05$) (Tables 4 and 5). However, under bean/maize intercrop, there was no significant difference in the fresh weight of plants between the different treatments.

Dry weight of bean plant

A significant difference was realized in the dry weight of bean plant between the different treatments during the short and long rains ($p<0.05$) (Table 4 and 5). The highest weight was recorded from BPL (9.47g) and BPL (9.33g) during the short and long rains respectively. The lowest weight was recorded from BSW (5.92g) and BSW (6.07g) during the short and long rains respectively. During the long rains, under the three cropping systems (Table 4.), plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin all had significantly higher weights than those treated with distilled water. This was the same during the short rains except under bean/maize intercrop where there was no significant difference between the different treatments (Table 5.).

Dry weight of bean seeds plant^{-1}

In both seasons, there was significant difference in the dry weight of bean seeds plant^{-1} between the different treatments ($p<0.05$) (Table 4 and 5). During the short rains (Table 4), the highest weight (13.33g) was recorded from BPL while the lowest weight (7.98g) was recorded on BSW. During the long rains (Table 5.), the highest weight (13.16g) was recorded from BPL whereas the lowest weight (7.44g) was recorded from BSW. During the long rains, the dry weight of bean seeds from plants treated with 1% *A. annua*, 5% *A. annua* and lambda-cyhalothrin were all significantly higher than that from plants treated with distilled water under the three cropping systems ($p<0.05$) (Table 5). A similar situation was observed during the short rains under bean pure stand and bean/*S. scabrum* intercrop ($p<0.05$) (Table 4).

However, there was no significant difference among the different treatments during the short rains under bean/maize intercrop.

Discussion

Bean production in Kenya is threatened by the high incidence of *A. fabae* which leads to high use of synthetic insecticides hence posing several challenges such as high costs, toxicity risks (Mihale *et al.*, 2009), persistence of pesticide residues in the environment and destruction of beneficial organisms (Georghiou, 1986; Ruchika and Kumar, 2012). This necessitated the study on effectiveness of *A. annua* leaf extracts in the control of incidence and severity of *A. fabae* in common bean under the three cropping systems.

Table 5. Plant yield in bean pure stand, bean/*S. scabrum* and bean/maize intercrops during the long rainy season.

Source of variation		No. of pods	No. of shriveled seeds	Fresh weight of plant	Dry weight of plant	Dry weight of grains
		Means	Means	Means	Means	Means
Bean pure stand	5% *A. annua*	14.42 ± 0.25 abcd	2.20 ± 0.08 efgh	17.28 ± 0.13 ab	8.97 ± 0.08 ab	12.99 ± 0.07 ab
	1 % *A. annua*	13.42 ± 0.26 abcdef	2.76 ± 0.09 defgh	16.41 ± 0.12 abcd	8.53 ± 0.06 abcd	12.38 ± 0.07 abc
	Lambda-cyhalothrin	15.36 ± 0.24 ab	1.38 ± 0.06 gh	17.76 ± 0.12 a	9.33 ± 0.07 a	13.16 ± 0.07 a
	Distilled water	8.24 ± 0.30 gh	7.33 ±0.19 ab	11.47 ± 0.22 jkl	6.42 ± 0.10 ijk	7.55 ± 0.21 hi
Bean/*S. scabrum* Intercrop	5% *A. annua*	14.13 ± 0.23 abcd	2.40 ± 0.08 efgh	16.92 ± 0.13 ab	8.24 ± 0.07 bcd	12.19 ± 0.07 abc
	1 % *A. annua*	13.56 ± 0.24 abcde	3.00 ± 0.11 cdefg	16.37 ± 0.13 abcd	7.76 ± 0.07 defg	11.95± 0.09 abcd
	Lambda-cyhalothrin	14.33 ± 0.22 abcd	1.60 ± 0.08 fgh	17.32 ± 0.11 ab	8.19 ± 0.07 bcd	12.42 ± 0.08 abc
	Distilled water	8.36 ± 0.30 gh	6.78 ± 0.18 b	11.26 ± 0.21 kl	6.07 ± 0.11jk	7.44 ± 0.20 hi
Bean/maize intercrop	5% *A. annua*	12.11 ± 0.18 cdef	1.62 ± 0.07 fgh	15.02 ± 0.12 cdefg	8.02 ± 0.07 bcde	10.31 ± 0.11 efg
	1 % *A. annua*	12.31 ± 0.20 bcdef	2.29 ± 0.08 efgh	14.35 ± 0.13 defgh	7.86 ± 0.07 cdef	9.91 ± 0.10 fgh
	Lambda-cyhalothrin	13.53 ± 0.21 abcde	1.04 ± 0.05 h	14.62 ± 0.11 defgh	7.88 ± 0.07 cdef	10.14 ± 0.10 efg
	Distilled water	10.20 ± 0.24 f	4.64 ±0.14 c	13.04 ± 0.15 hijk	6.88 ± 0.08 ghijk	8.59 ± 0.12 h

Means with the same letter(s) within the same column are not significantly different at p≤0.05; those with more than one letter are intermediate.

In both seasons, the number of *A. fabae* on plants treated with *A. annua* leaf extracts was significantly lower than that on plants treated with distilled water under the three cropping systems. These results seem to imply that the leaf extracts of *A. annua* are effective in the control of incidence of *A. fabae* on common beans. This is due to the strong aromas and bitter tastes from terpenoids and sesquiterpene lactones, found in the essential oils of *A. annua*, which discourage herbivory (Nallammai, 2005).

The results appear to be in agreement with related studies involving the use of extracts of *A. annua* and other species of Artemisia on various insect pests. For example, Abdel-Shafy *et al.* (2007) found that diethyl ether, ethyl acetate and ethanol extracts of *Artemisia* manifested the highest toxicity against larvae of *Hylomma dromedarii* L. Shekari *et al.* (2008) found that the methanolic leaf extracts of *A. annua* was effective against 3rd instars larvae and adult of elm leaf beetle *Xanthogaleruca luteola* Mull., with LC50 48% and 43.77% for adult at 24 and 48 hours, respectively. Tripathi *et al.* (2000) showed that adults of *Tribolium castaneum* Herbst were more susceptible to cineole which had been extracted from *A. annua*. Hassanein *et al.* (2004) also recorded that hexane, chloroform, ethyl acetate and ethanol extracts of *Artemisia* were toxic to the fourth instar larvae of *Spodoptera littoralis* Boisduval. Soliman *et al.* (2005) found that successive extracts of *Artemisia* with petroleum ether, chloroform, ethyl acetate and ethanol were toxic to the two-spotted spider mite *Tetranychus urticae* Koch. The number of *A. fabae* also seemed to be affected by the concentration of

A. annua as well as the cropping system. A higher concentration of *A. annua*, that is, 5% *A. annua* seemed to result in lower number of *A. fabae* than 1% *A. annua* especially under bean/maize intercrop. This implies that *A. annua* is more effective when used in higher concentrations. Including maize as an intercrop with beans also seemed to be effective in controlling the populations of *A. fabae*. However, bean/*S. scabrum* intercrop had no significant effect in the number of *A. fabae*.

The leaf extracts of *A. annua* also had a positive effect on the growth of bean plants. Plants treated with *A. annua* extracts recorded greater heights, wider leaves and lower number of damaged leaves than those treated with distilled water. This was more evident under bean pure stand and bean/*S. scabrum* intercrop. These results could be attributed to the lower number of *A. fabae* infestations on plants treated with *A. annua* extracts compared to those treated with distilled water, especially under bean pure stand and bean/*S. scabrum* intercrop. The lower number of *A. fabae* infestations on plants treated with *A. annua* extracts possibly translated to lesser effect on the growth of the plants compared to those treated with distilled water (Wilkinson and Douglas, 2003). The effects of *A. annua* extracts were also observed in yield parameters such as number of pods, weight of plant and weight of bean seeds. Plants treated with *A. annua* extracts registered higher number of pods, higher fresh and dry weight of plant, higher weight of bean seeds and lower number of shriveled seeds than those treated with distilled water. This was more evident under bean pure stand and bean/*S. scabrum* intercrop. These results point a direct reflection of the effects of *A. fabae* on bean plants. *A. fabae* ingests large amounts of soluble nutrients from the phloem and xylem tissues of the plant using their stylets and this causes stunted growth and leaf curling thus resulting in fewer and smaller pods per plant as well as fewer and damaged seeds per pod (Wilkinson and Douglas, 2003). Since there was higher number of *A. fabae* infestations on plants treated with distilled water than on those treated with *A. annua*, it followed that the effects of *A. fabae* infestation were more pronounced on these plants than those treated with *A. annua*.

Under bean/maize intercrop, there appeared to be a less pronounced difference in growth and yield parameters between the different treatments, than under the other cropping systems. This was probably as a result of the unique micro-climatic conditions existing under bean/maize intercrop (shading, higher relative humidity and interference with aphid host-finding mechanism) resulting in lower *A. fabae* infestation levels and consequently less pronounced effects on the growth and yield of beans (Finch 1996; Finch and Kienegger 1999).

Conclusion

Based on the results, it can be concluded that *A. annua* leaf extracts have a significant negative effect on the incidence and severity of *A. fabae* in common bean.

The effect seems to be more pronounced on higher concentrations of *A. annua* and under bean pure stand where there is no influence from intercropping effect.

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