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Bio-Efficacy of Medicinal Plants on Management of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on Chickpea in Ethiopia

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ABSTRACT

Chickpea (*Cicer arietinum* L.) is one of the most momentous pulse crops that play an important role in the diet of humans. One of the main insect pests attacking the chickpea crops is the African bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in Ethiopia. The Laboratory study was done to investigate the efficacy of five botanicals at Guder Mamo Mezemir Campus, Ambo University. The experiment was replicated three times and prepared in CRD Randomized Design. All the botanicals were filtered and strained through cheesecloth and made stock solution mixed with water at 50, 75, and 100 ml/L of water. Botanical crude extracts were sprayed on *H. armigera* larvae (10 larvae/Petri dish). Post-spray counts were done at 1, 3, 5, and 7th days after spraying of botanicals under laboratory conditions. The result has shown that the botanical efficacy of *Carica papaya, Lantana camara, Moringa olifera, Eucalyptus glubulus,* and *Capsicum sp*. caused percent mortality of *H.armigera larvae* 70.0, 86.67, 90.0, and 93.33%, respectively. Further research must be given attention to the efficiency of botanical products in farmers' fields in the diverse agroecology of the country for further consideration as a part of integrated pest management tools against the targeted insect pests.

Keywords: Botanicals, Chickpea, Efficacy, *Helicoverpa armigera*, Insecticide, Mortality.

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INTRODUCTION

Chickpea, *Cicer arietinum* L. (Family: Fabaceae) is one of the most momentous pulse crops grown in many parts of Asia and Africa. It is the second greatest pulse crop in global production terms, after dry beans (*Phaseolus vulgaris* L.), with over 13.7 million metric tons made annually [1].

Chickpeas, contribute a lot to the food security and nutrition of smallholders in the world [2, 3]. It provides different profits to smallholder households as a protein source, soil improvement tools, and cash income [4]. It is an important source of high-quality protein [5].

Ethiopia is one of the major producers of chickpeas in Africa and shares 4.5% of the total chickpea market and more than 60% of the total chickpea market of Africa [6]. Among the numerous crops, grain legumes subsidize smallholder crop making, diet as a cost-effective basis of protein accounting for around 15% of consumption of protein, and revenue as a high-value crop, the third-largest export crop following sesame and coffee [7].

In Ethiopia, in the production season of 2015/2016, about 282,216.28 ha of land was covered by chickpeas, and 496,302.78 tons were produced [8]. Its fecundity in Ethiopia during 2015 was about 1.8 t ha^{-1}, however, the average on-station fecundity potential was 2 t ha^{-1} [4, 9]. This indicates that the present fecundity of chickpeas in Ethiopia is lower than the average on-station yield perspective.

In farming methods, grain legumes are potential resources of plant nutrients that can supplement or complement inorganic fertilizers for cereal crops. This is because of their capacity to fix natural nitrogen and indirect quantity of manure-based nitrogen inputs when contained in farming methods such as crop rotation intercropping and with cereals like tef and wheat which are extensively grown in comparatively well-drained black soils [10, 11]. Though it is cultivated in utmost regions of the state; Amhara, Oromia, SNNPR (Southern Nations, Nationalities and People's Region), and Tigray, in declining order, are the key producer's regions. Oromia and Amhara regions together generate 93% of total chickpea production in Ethiopia, while Tigray and SNNPR produce 3 and 3.5 %, respectively [12].

However, the productivity and production of *C. arientinum* in Ethiopia are very low because of adverse biotic and abiotic factors. There are many factors to decline in the productivity and production of this crop viz, abiotic and biotic factors including insect pests, and diseases, which cause major yield losses on-farm, and storage. *C. arientinum* is visible to an extensive range of insect pests, of which *H. armigera* is the most common and serious challenge for chickpea production in the world [13, 14].

In Ethiopia, crop growers are facing severe challenges in managing this resistant insect as the main synthetic insecticides in chickpeas have lost their efficiency in field situations. Therefore, to decrease the side impacts of synthetic chemicals, the utilization of locally accessible botanical extracts and bio-pesticides as an IPM part would be an alternate method for the favored management of *H. armigera*. The utilization of essential oils, botanical extracts, and isolated compounds [15-18] as promising insect pest management implements.

Insect pest damage is among the most important, often causing considerable chickpea yield loss in Ethiopia. Among the African bollworms, *H. armigera* is the most damaging insect pest of chickpeas. In Ethiopia, nearly 21-36 percent of annual chickpea yield losses were recorded due to *H. armigera*, however, most of the crop growers continue a "do nothing" strategy [18, 19]. The yield loss in chickpeas has been estimated to be 10 to 60 percent under normal weather conditions and can accelerate to 50 to 100 percent in favorable climatic conditions worldwide [20].

Pesticides are often applied without meticulousness, which clues to some adverse impacts on human health, from chronic diseases to acute intoxication that includes different types of cancer (colon cancer, bladder cancer, prostate cancer, breast cancer, and brain cancer) [21, 22]. Although, Pesticides have many benefits for agricultural fecundity. They assist in raising crop yields by minimizing losses caused by insect pests, weeds, and diseases [23, 24]. Increasing concern about environmental awareness of the hazards of pesticides has aroused worldwide interest in searching for control mechanisms alternatives. Thus, the objectives of these experiments were to determine the effective rate of medicinal plants against *H. armigera* under laboratory conditions and field evaluation.

MATERIALS AND METHODS

Description of the study area

The Laboratory experiments were conducted at Ambo University's main campus where the field experiment was conducted on a farmer's field during the main cropping seasons (August to February) in 2020/21. The geographically lies at 37^0 32′ 0''to 38^0 3'0'' E longitude and 8^0 47'0'' to $9^0$21'0''N latitude with an average elevation of 1380-3030 m.a.s.l [25]. The total cultivable area of the district is 44,565 km^2. The ecology of the district covers 35.3% highland, 50% mid-altitude, and 14.7% lowland and the dominant soil types of the district are red (36.25%), grey (24.36%), clay loam (5%), and black (34.37%) [26]. The trial site received 15-29°C temperature, and 800-1000mm and annual rainfall during the study period, respectively.

Collection and preparation of botanicals

Fresh fruit of green pepper, *Carica papaya* for its aqueous seed, and *Moringa oleifera* leaf powder extracts were brought from Ambo town, and leaves of *Eucalyptus* tree and Leaves of *Lantana camara* were collected from Ambo University main campus and brought to the Plant Science Department's laboratory of Guder Mamo Mezemir Campus in October 2020. Botanical Crude extracts of botanicals were sprayed on *H. armigera* larvae per Petri-dish using micropipettes and as control treatments, the larvae were treated with distilled water. The treatments were checked after 1, 3, 5, and 7 days of exposure and the dead larvae observed were removed as soon as possible from the Petri dishes to prohibit decomposition which may cause quick death of the remaining larvae. After the laboratory experiment, botanicals that had good performance were selected for the field experiment.

Field experiment

Treatments and experimental design

The study was done in field conditions from September 2020 to January 2021. The field was plowed by harrows and oxen manually to bring the soil to fine tilth. The size of each plot was 2m wide and 3m long ($6m^2$ area) with 0.50m space between plots and 1m between blocks. Chickpea seed (Natoli variety) used as planting material was sown 6cm deep on prepared beds in rows per plot at a spacing of 10 cm between plants and 30 cm between rows. There were seven rows per plot 30 plants per row and a total of 210 plants per plot from each plot five plants were randomly chosen and tagged for data collection. Fertilizer NPS at the rate of 100 kg/ha was utilized during the sowing date. The field was monitored regularly when reached the economic threshold level.

Table 1. Lists of botanicals used in the experiment during 2020, under laboratory condition

Treatments	Rate (ml/L)	Family	Tested parts
Capsicum sp(L)	25	Solanaceae	Green fruit extract
	50		
	75		
Lantana camara	50	Verbanaceae	Fresh leaf extract
	75		
	100		
Eculaptus globulus	50	Myrataceae	Fresh leaf extract
	75		
	100		
Carica papaya	25	Caricaceae	Aqeous seed extract
	50		
	75		
Moringa olifera	25	Moringaeae	Leaf powder extract
	50		
	75		
Belt SC480 (Standard check)			
Control (untreated check)			

Data collection and measurement

The bollworm larvae number was determined by visual observation on the chickpea plant/plot and the date of *H. armigera* damage symptoms observed was recorded. Several pod borer larva/plant, total pods per plant, and damaged pods were provided from the whole above-ground parts of five randomly chosen and tagged plants in each treatment. Data were collected on the larvae number of *H. armigera* a day before the first spray. Based on laboratory tests, the effective concentration level of botanicals was used under field conditions to verify their effectiveness. The control plots were not sprayed and/ or sprayed with distilled water and as a standard check Belt, SC 480 (0.12L/ha) was used. Pre-spray counts were performed at 1, 3, 5, and 7 days after spray in all three round applications from five randomly selected plants. As suggested by Hossain *et al*. [27] each plot received three sprays of each insecticide therapy to get the insecticide's maximum protection potential. Periodic examination of the chickpea fields was done to notice the crop phenology and target insect populations. The second and third sprays were used at a ten-day interval to get maximum protection from the pest. Mean number of infestation and mortality of larvae at each observation was recorded and calculated using the following formula:

$$\text{Infestation percentage} = \frac{\text{Total number of damaged pods per plant}}{\text{Total number of pods of the plant}} \times 100 \quad (1)$$

$$\text{Pod borer larva reduction percentage} = \frac{\text{Mean of treated}}{\text{Mean of untreated}} \times 100 \quad (2)$$

Growth and phenological parameters

Days to emergence were recorded several days from the date of sowing to the date 50% of the plants in a plot emerged above the ground. From four central rows of each study plot, the height of five randomly chosen plants was calculated at physiological maturity from the ground to the top of the plant and the means were determined as plant height. The Basal primary branch numbers and secondary branch numbers were recorded.

Yield and yield components

Yield and yield component parameters were taken from the number of total pods per plant, Hundred seed weight (g), and Seed yield (kg ha^{-1}). Yield per plot was changed to per hectare basis and the average yield was determined in kg ha^{-1}. At the experiment end, after harvesting, the yield from each study plot was weighted by digital balance. Hundred seed weights were taken from each plot after threshing using randomly counting 100 undamaged seeds.

Yield loss assessments

The yield loss assessment per hectare was measured based on the following formula [25, 28].

$$Yield\ loss\ (\%) = \frac{Potential\ yield - Actual\ yield}{Potential\ yield} \times 100 \quad (3)$$

The potential yield was the yield obtained from the protected plots which were considered as the standard check for comparison with the other yields obtained from unprotected plots *(*Actual yield). Several pod-infested, non-marketable, and marketable seeds, bored/tunneled pod, and fruit were determined during harvesting, and finally, yield data were weighed and calculated.

Data analysis

All collected data were analyzed by SAS version 9.2 software [28]. Mortality data was corrected for control mortality and subjected to the ANOVA procedure of SAS software. The mean number of pod/plant, pod damage, infestation percent, plant height, primary branch, secondary branches, pod without seed, branches with pondless, hundred seed weight, marketable and non-marketable, and mean of yield loss by *H. armigera* larvae obtained from field trials were subjected to analyzed.

RESULTS AND DISCUSSION

Results

Laboratory evaluation

The impact of botanicals on mortality of *H. armigera* larvae among the treatments on 1st day of application (F = 57.62; df = 16; P< 0.01), after three days (F = 123.05; df = 16; P< 0.01), after five days (F = 68.15; df = 16; P< 0.01(F = 68.15; df = 16; P< 0.01), and after seventh days (F = 68.15; df = 16; P< 0.01), presented in **(Table 2)**. The application of *Lantana camara* at 50ml, 75ml & 100ml/L of stock solution caused mortality of *H. armigera* after 1st, 3rd, 5th, and 7th days of treatment exposure recorded a mean percent mortality of 10.0, 10.0, and 10.0%; 30,40, and 50%); 53.33, 60.00, & 70% and 66.67, 76.67, & 86.67%, respectively.

Similarly, application of *Capsicum sp.* at 25ml, 50ml, 75ml/L of stock solution was caused mortality of *H. armigera* after 1st, 3rd, 5th, and 7th days post-treatment exposure of mean percent mortalities were recorded 10.0, 10.0, & 20.0%; 36.67, 43.33, & 60.0%; 66.67, 63.33, & 80.0% and 80.0, 86.67 & 93.33%, respectively **(Table 2)**.

Treatment of *Eucalyptus globulus* at 50ml, 75ml & 100ml/L of stock solution caused percent mortality of *H. armigera* larvae were 10.0% in each concentration after 1st day of application and 36.67, 50.0, & 56.67%; (50.0, 63.33, & 76.67% and 76.67,80.0, & 86.67% after treatment exposure of 3rd, 5th, and 7th days, respectively.

The fourth treatment using *Carica papaya* at 25ml, 50ml, and 75ml/L caused mortality of *H. armigera* after 1st, 3rd, 5th, and 7th days, the mean mortality of the larvae recorded was 10.0% from each concentration, and 26.67, 30.0 & 40.0%, 40.0, 46.67, & 60.0% and 50.0, 63.33, & 70.0%, respectively. The other fifth treatment *Moringa olifera* at 25ml, 50ml, and 75ml/L of stock solution caused mortality of *H. armigera* after 1st, 3rd, 5th & 7th days showed the mean percent mortality of 10.0% in each concentration of 1st-day treatment exposure; while in the 3rd, 5th & 7th days 30.0,40.0&50.0%; 50.0,53.33&66.67% and 60.0,80.0&90.0%, respectively **(Table 2)**.

Table 2. Efficacy of bioassays testing on *H. armigera* larvae under laboratory conditions during 2020/21

Treatments	Percent mortality (%)				
	te (ml/L)	1st day	3rd day	5th day	7th day
Lantana camara	50	1.00 (10)±0.10d	3.00(30)±0.17fg	5.33(53.33)±0.23efg	6.67(66.67)±0.28ef
Lantana camara	75	1.00(10)±0.10d	4.00(40)±0.20e	6.00(60)±0.25cdef	7.67(76.67)±0.28cde
Lantana camara	100	1.00(10)±0.10d	5.00(50)±0.22cd	7.00(70)±0.26abc	8.67(86.67)±0.29abc
Capsicum sp.	25	1.00(10)±0.10d	3.67(36.67)±0.19ef	5.67(56.67)±0.24defg	8.00(80)±0.28bcd
Capsicum sp.	50	1.00(10)±0.10d	4.33(43.33)±0.21ed	6.33(63.33)±0.25cde	8.67(86.67)±0.29abc
Capsicum sp.	75	2.00(20)±0.14b	6.00(60)±0.25b	8.00(80.0).28a	9.33(93.33)±0.31a
E. globulus	50	1.00(10)±0.10d	3.67(36.67)±0.19ef	5.00(50.0)±0.22fgh	7.67(76.67)±0.28cde
E. globulus	75	1.00(10)±0.10d	5.00(50.0)±0.22cd	6.33(63.33)±0.25cde	8.00(80)±0.28bcd
E. globulus	100	1.67(16.70)±0.13c	5.67(56.70)±0.24bc	7.67(76.70)±0.28ab	8.67(86.70)±0.29abc
Carica papaya	25	1.00(10)±0.10d	2.67(26.70)±0.16g	4.00(40)±0.20h	5.00(50)±0.22g
Carica papaya	50	1.00(10)±0.10d	3.00(30)±0.17fg	4.67(46.70)±0.22gh	6.33(63.30)±0.25f
Carica papaya	75	1.00(10)±0.10d	4.00(40)±0.20e	6.00(60)±0.25cdef	7.00(70)±0.26def
Moringa olifera	25	1.00(10)±0.10d	3.00(30)±0.17fg	5.00(50)±0.22fgh	6.00(60)±0.25fg
Moringa olifera	50	1.00(10)±0.10d	4.00(40)±0.20e	5.33(53.30)±0.23efg	8.00(80)±0.28bcd
Moringa olifera	75	1.00(10)±0.10d	5.00(50)±0.22cd	6.67(66.70)±0.28bcd	9.00(90.0)±0.30ab
Belt SC480	0.12	3.00(30)±0.17a	10.00(100)±0.10a	……	……
Control		0.00±0f	0.00±0h	0.00±0i	0.33 (0.33)±0.11h
MSE±		0.14	0.31	0.47	0.55
LSD at 0.01		0.31	0.71	1.01	1.23
CV%		12.1	7.48	8.92	8.05

Note: All treatment impacts were significant at p<0.01 (LSD). Means with the same letter(s) in rows are not significantly different from each other.

The standard check insecticide belt SC 480 caused the highest mortality which was observed (100%) and *Carica papaya* (25ml/L) had the lowest mortality (26.67%)after three days of application but higher than the control treatment. However, after the seventh-day application *Capsicum sp., Moringa olifera,* and *Eucalyptuss globulus* caused mean percent mortality of 93.33, 90.0 & 86.67%, respectively, and in control treatment recorded the lowest mortality of 3.3%. Generally, as the concentration of botanicals increased, the mortality of larvae of *H. armigera* also increased through time.

Field evaluation of botanical extracts

Among the treatments in the first round spray of 1st day post spray treatment exposure ($F = 48$; $df = 6$; $p < 0.01$), 3rddays ($F = 173.14$; $df = 6$; $p < 0.01$), after 5th days ($F = 89.64$; $df = 6$; $p < 0.01$) and after 7th day ($F = 64$; $df = 6$; $p < 0.01$).

In the 2nd and 3rd round spray, there was no significant difference during the 1st round post spray treatment after 1st day of application ($F = 76.45$; $df = 6$; $p < 0.01$); 3rd day ($F = 25.55$; $df = 6$; $p < 0.01$); 5th day ($F = 51.10$, $df = 6$, $p < 0.01$) and 7th day ($F = 22.95$; $df = 6$; $p < 0.01$) showed significantly differences.

At the 3rd round application: ANOVA showed that ($F = 4.05$; $df = 6$; $p < 0.02$) on the 3rd day ($F = 6.6$; $df = 6$; $P<0.03$), 5th day ($F = 1.43$; $df = 6$; $p<0.01$) and 7th days ($F = 25.71$; $df = 6$; $p < 0.01$) highly significantly different **(Table 3, Figures 2 and 3)**. The application of *Lantana camara* at 100ml/L affected percent mortality of *H. armigera* after 1st, 3rd, 5th & 7th days gave 20.0, 40.0, 60.0 & 80.0%; 23.10, 46.19, 76.91 & 84.75

and 33.33, 55.67, 66.67 & 89.00% after 1st, 2nd and 3rd round application of the treatments, respectively.

Application of *Capsicum sp.* at 75ml/L affected percent mortality of *H. armigera* after 1st, 3rd, 5th & 7th days were 22.17, 44.50, 66.60 & 77.83%; 33.40, 53.40, 80.0, & 86.67% and 23.09, 38.57,69.30 & 92.37 in 1st, 2nd and 3rd round spray of the treatments exposure, respectively.

Eucalyptus globulus at 100ml/L also caused mortality percentage of *H. armigera*after1st, 3rd, 5th & 7th days recorded for about 20.0, 46.67, 66.67 & 86.67%; 21.41, 49.89, 71.31 & 85.65% and 16.21, 50.15, 60.0, 90.09 % for 1st, 2nd & 3rd round spray, respectively.

Application of *Carica papaya* at 75ml/L was caused mortality of *H. armigera* after 1st, 3rd, 5th day & 7th days also showed 20.0, 40.0, 53.40 &73.40%; 30.03,50.15,80.18 & 80.18 % and 23.33, 44.33, 55.67 & 74.90% for 1st,2nd and 3rd round spray, respectively.

Botanical treatment of *Moringa olifera* at 75ml/L was affected percent mortality of *H. armigera* after 1st, 3rd, 5th & 7th days resulted in 25.00, 41.75, 75.0% & 91.75%; 16.17, 38.57, 69.28 & 84.75 % and 23.33, 44.33, 55.67&74.90% for 1st, 2nd & 3rdround spray, respectively.

The standard check (Belt SC 480) at 0.12ml/ha affected significantly different from all botanicals and gave 93.40 & 100% for 1st and & 3rddays after treatment exposure, respectively. Generally, the concentration of botanicals increased, also the percent mortality of larvae increased over time. However, no mortality of larvae was observed in control treatment during the first day up to the seventh day of application of treatments **(Figure 1)**.

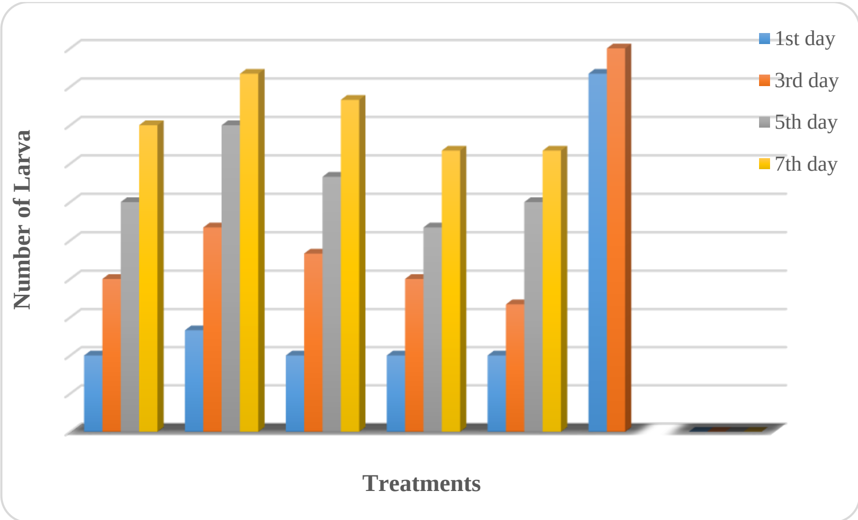

Figure 1. Efficacy of botanical extracts of 1st round spray under field conditions on larval the population of *H. armigera* in chickpeas during cropping season of 2020/21

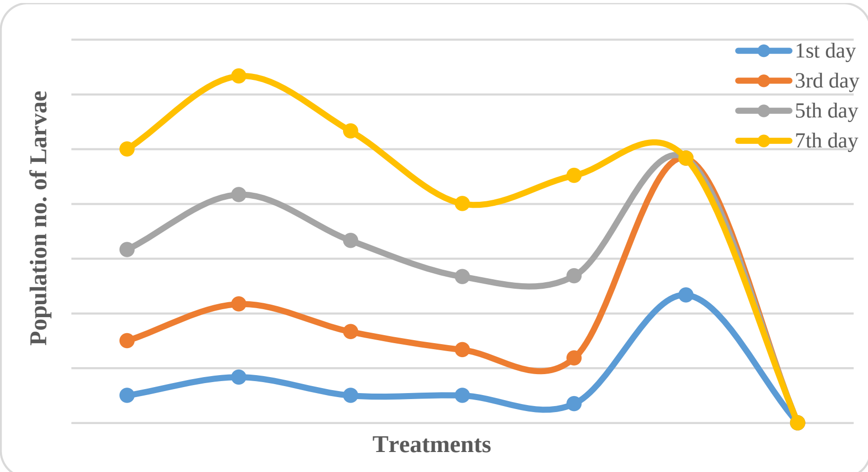

Figure 2. Efficacy of botanical extracts of 2nd round spray under field conditions on larval the population of *H. armigera* in chickpeas during cropping season of 2020/21

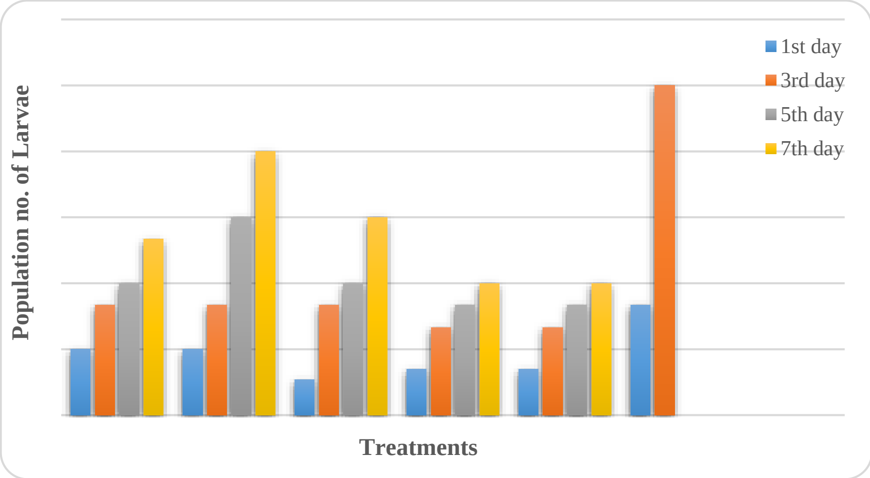

Figure 3. Efficacy of botanical extracts of 3rd round spray under field conditions on larval the population of *H. armigera* in chickpeas during the cropping season of 2020/21

Effect of botanical extracts on pod production of chickpea

The comparative effectiveness of various treatments on the number of pod borers per plant has been shown in **Table 3.** The data showed that the highest number of pod per plant (52.48/plant) was observed in Belt SC 480treated plot followed by *Carica papaya* (41.93/plant), *Moringa olifera* (41.13/plant), *Capsicum sp* (39.39/plant), *Lantana camara* (40.13/plant) and *Eucalyptus glubulus* (40.13/pant) treated plots showed significant difference among them, respectively. The lowest number of pods per plant was observed in untreated plots (27.13/plant) during the cropping season.

Chickpea pod damaged by the H. armigera larvae

The mean number of pods damaged and the pods damaged percentage by *H. armigera are* presented in **(Table 3)**. The data of pods mean a number that was damaged by the *H. armigera* larvae was significantly reduced in all treatments compared to control ($p < 0.05$). The lowest percentage of pod damage (0.43%) was reported in the Belt SC480 treated plot followed by Benezer Plus 38.5% EC (0.6%), Voyage SC 200 treated (1.41%), Shark 2.5%EC (1.43%), and Focus 5% EC (1.46%). There were statistically significant differences in pod damage between all botanical and chemical insecticide treatments. The highest percentage of pod damage was reported in untreated plot (9.00%) followed by *Carica papaya* (4.50%), *Lantana camara* (4.43%), *Eucalyptus glubulus* (3.30%), *Capsicum sp.* (2.65%), and *Moringa olifera* (2.26%) treated plots. Among the five botanical treatments, *Capsicum sp.* and *Moringa olifera* were proven to be more effective in decreasing pod damage in the field.

Effect of botanicals and synthetics insecticides on chickpea yield

The yield of chickpeas at the end of the cropping season from each study was determined as shown in **Table 3.** The highest mean yield was reported from Belt SC 480 treated plots (2.89 ton/ha) followed by Voyage SC200 treated plots (2.83 ton/ha), Benezer plus 38.5%EC (2.78 ton/ha), and Focus5%EC (2.78 ton/ha) and Shark 2.5%EC treated plots (2.72 ton/ha). Whereas, the lowest mean chickpea yield was reported from the control plots (1.81 ton/ha). The plots treated with *Moringa olifeara* gave 2.67 ton/ha and followed by *capsicum sp.* (2.55 ton/ha), *Lantana camara* (2.50 ton/h), *Carica papaya* (2.28 ton/ha) and *Eucalyptus glubulus* (2.22 ton/ha). The overall yields were revealed significantly higher in treated plots compared to untreated plots. The results indicated that the highest yield was reported from the plots treated with standard control Belt SC 480. The yields obtained from both botanicals and chemical insecticide-treated plots were found statistically significant differences ($p<0.05$; LSD value 0.12). The total percentages of yield losses ranged from 1.92 to 38.50% if the plots were not sprayed.

Effect of botanical insecticides on yield components & hundred seed weight

The results showed that there was a non-significantly (p >0.05) difference in the mean number of pods without seed in all treatments **(Table 4)**. A maximum hundred seed weight was reported on positive treatment with belt SC 480 (33.67gm), followed by *Moringa olifera*, *Capsicum sp. Lantana camara, Eucalyptus glubolus*, and *Carica papaya* 33.33, 32.33, 32.33, 32.33, 32.33 & 31.33gm, there were significant differences between belt SC 480 & control treatment, and no significant difference among treatments respectively. The lowest hundred seed weight was reported on the untreated control treatment (30.33g). Significant differences were observed in the mean of plant height, mean number of primary branches, mean number of secondary branches, and except the mean number of pods without seeds per plant among the treatments **(Tables 3 and 4)**. However regarding pod bored or tunneled and the number of plants without pods (pod less).

The highest pod bored/tunneled seed (5.33gm) was found in check control plots, which differed significantly from other treatments. Lower seeds of bored/tunneled (1.00gm infested pod) were obtained in a plot treated with Belt SC 480 (standard check). From botanical treatments, plots that were treated with *Capsicum sp.* and *Moringa olifera* gave the lowest bored seeds 2.00gm & 2.33gm, respectively **(Table 4)**.

Table 3. Effect of botanical insecticides on pod yields per hectare in chickpeas, during 2021.

Treatments	Mean no. of Pods/plants	Mean No. of Pod Damage/ plant	Infestation % over Control	Mean Yield Ton/ha	%yield loss/ha	100swt (gram)
Lantana camara	40.13[abcd]	1.66[b]	4.14[c]	2.50[d]	13.49	32.33[ab]
Capsicum sp.	39.93 [abcd]	1.06[cd]	2.65[e]	2.55[cd]	11.76	32.67[ab]
E. globulus	31.47[cd]	1.04[c]	3.30[d]	2.22[e]	23.18	32.00[ab]
Carica papaya	41.93 [abc]	1.88[b]	4.50[b]	2.28[e]	21.11	31.33[ab]
Moringa olifera	40.13[abcd]	0.93[c]	2.32[f]	2.67[bcd]	7.61	32.33[ab]
Belt SC480	52.95[a]	0.23[d]	0.43[h]	2.89[a]	_	33.67[a]
Untreated control	27.13[d]	2.44[a]	9.00[a]	1.778[f]	38.46	30.33[b]
SEM(±)	4.52	0.17	0.08	99.66		1.63
LSDat 0.01	6.39	2.08	0.12	169.75		2.78
CV (%)	19.24	30.05	5.05	3.92		5.78

Note: All treatment impacts were significant at p<0.01(LSD). Means with the same letter(s) in rows are not significantly different from each other.

Table 4. Effect of botanical insecticides on the chickpea stands/performances per plant, during 2021

Treatments	Mean height(cm)	Mean no.of primary branch	Mean no. of secondary branch	Mean no.of pod without seed	Mean no. of podless/plant	Bored/ Tunneled pod (g)
Lantana camara	42.20[ab]	2.06[b]	10.47[abc]	1.20[a]	1.33[abc]	2.66[cd]
Capsicum sp.	46.93[ab]	2.33[b]	11.13[abc]	1.07[a]	1.40[abcd]	2.00[def]
E. globulus	45.40[ab]	2.06[b]	10.87[abc]	1.07[a]	1.60[abc]	3.33[bc]
Carica papaya	42.27[b]	2.13[b]	10.20[bc]	1.20[a]	1.67[ab]	4.33[ab]
Moringa olifera	46.67[ab]	2.60[b]	11.73[abc]	1.07[a]	1.60[abc]	2.33[cde]
Belt SC480	48.00[a]	3.13[a]	12.73[a]	1.00[a]	0.80*d*	1.00[f]
Untreated control	36.67[c]	2.00[b]	9.73[c]	1.13[a]	1.80[a]	5.33[a]
SEM(±)	3.2	0.47	1.47	0.30	0.37	0.31
LSDat 0.01	5.45	0.79	2.50	0.51	0.63	1.02
CV%	7.06	19.22	12.88	27.07	28.77	13.67

Note: All treatment impacts were significant at p<0.01(LSD). Means with the same letter(s) in rows are not significantly different from each other.

Results of the analysis revealed that both botanical and synthetic insecticides were found to be effective against pod borer (*H. armigera)* even though their efficacy level varied in the mortality of the larval population. The study conducted under field situations in 1st to 3rd round spray every ten days intervals the field treated with botanical insecticides revealed significant differences in mortality of *H. armigera*. *Lantana camara* at the dose of 100ml/L caused the highest percent mortality (80%) of *H. armigera* on *the* 7th day of post-spray*.* The present findings are supported by Kumar *et al*. [29] who reported that *Lantana* leaf was effective in reducing the population of *H. armigera* in chickpea crops. Saxena *et al.* [30] studied the insecticidal action of aerial parts of *L. camara* against *Calloso bruchus chinensis* (Coleoptera: Bruchidae) and found 10-43% mortality while this study was better percent mortality in *H. armigera* larvae.

In the present study, *Capsicum sp.* at the rate of 75ml/L caused mortality of *H. armigera* on the 7th day of post-spray by 86.67%. These findings are similar to studies that were conducted by Aslam *et al.* [31] who tested six species of botanical powders against *C. chinensis*and in which Clove and Black pepper were found as good protectants of stored chickpea versus the beetle. Nadra [32] also studied that *Capsicum frutescens* caused significant and high mortality (85%) of *Trogoderma granarium* adults at all concentrations (1, 2, 4, and 6%) within 7 days. Antonious *et al.* [33] also supported this study which indicated the insecticidal activity of preparations according to chili peppers. In trials of field application, chili pepper aqueous extracts have been utilized to control lepidopteran pests [34-36], and Thysanopteran pests, yet the results obtained were consistent with this study. In addition, research by Belmain *et al.* [37] has revealed that chili peppers were effective in repelling and killing different species of weevil attacking stored grains.

Eucalyptus globulus at a rate of 100ml/L stock solution gave 86.67 percent mortality of *H. armigera* larvae. Lucia *et al.* [38], in their studies, proved that as *Eucalyptus* include many terpenoids like terpineol, 1, 8-cineole (CIN), α and β pinene, and globulol which are found to have insecticidal, antimicrobial, and antifungal activities against many pests [39].

Moringa olifera at the rate of 75ml/L caused promising percent mortality (91.75%) of H. *armigera* larvae on the 7th day of post sprays. Baidoo and Adam [40] supported these results and reported *Moringa oleifera* root and leaf extracts are effective plant growth regulators and bio-pesticides against various sucking and chewing insect pests.

Carica papaya at the rate of 75ml/L caused mortality (73.40%) of *H. armigera* larvae on the 7th day after spray. In previous research with powdered *C. papaya* seeds, Figueroa-Brito [41] stated 100% larval mortality of *S. frugiperda* at concentrations of 10%, 15%, and 20% with powder of the cultivar Mammee. Franco *et al*. [42] investigated mortality associated with time, noting that the powder of the four cultivars at 10% and 15% caused corrected mortality rates in the pest of over 90% after 72 and 96 h, respectively.

The findings showed that control of the *H. armigera* larvae can be obtained, by significantly decreasing the population number of *H. armigera* larvae. This result was in agreement with the work of Hidalgo *et al*. and Megha *et al*. [43, 44], who stated that the mixture with natural ACGs (Squamocin and Rolliniastatin-2) at 100 μg/mL concentration (very low concentrations) triplicate the toxic impact, causing 100% lethality *in S. frugiperda* larvae. These findings allow us to infer that the natural ACGs addition synergizes the insecticidal activity of the commercial product.

CONCLUSION

The present findings indicated that *Capsicum sp., Eucalyptus globulus, Lantana camara, Moringa olifera,* and *Carica papaya* gave high percent mortality in the management of *H. armigera*. Therefore, to increase production and productivity of chickpea, reduce infestation of *H. armigera,* by using botanical extract insecticides as part of IPM tools at recommended rates.

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