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Research Article

Infusion Extraction of Toxin from Chili Pepper (*Capsicum baccatum*) for Bedbug Protection

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Abstract

Background and Objective: The developing trend of resistance in bed bugs toward synthetic insecticidal agents makes their management extremely difficult. So, there is an urgent need to develop new approach in the protection of bedbugs consist of using native plants with insecticidal value. The present experiment was conducted to protect bed bugs through the use of *Capsicum baccatum* (chilli pepper) extract. **Materials and Methods:** The experiment was conducted to extract toxin from *Capsicum baccatum* for bedbug protection. The extract was prepared in 3 different concentrations in liquid form viz. 14.2, 16 and 18.8% as a direct admixture of salt. Adult bedbugs were collected from student's dormitory The collected insects were allowed to mate for 3 days and eggs from ovipositor site were collected. The extract was sprayed on adult bedbugs designed in experimental block with 3 treatment groups. The efficiency of acute toxicity of the extract was checked on the percentage of adults mortality in control with percentage control and inhibition of adult emergence was checked by percentage of adult emergence inhibition in control [IE %]. Bonferroni correction test was used to adjust for multiple comparisons of the blocks at 95% confidence interval [CI]. The experimental design for mortality and emergence test was randomized block design. **Results:** The result revealed that the extract was 100% effective at killing bedbugs and inhibiting adult emergence in all levels of concentration [CL] compared to treatments under control with significant mean difference ($p<0.05$). **Conclusion:** Generally, the study confirmed that the extract pose talented potential in protecting bedbugs and adult emergence inhibition only in small scale applications based on the demonstrated efficacy and reduced risk potential on non-target organisms and ecology.

Key words: Bioassay, home remedies, insecticides, mortality, native plants, pepper-extract

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pepper(*Capsicum* spp.)is a plant of the family Solanaceae. It originated from South and Central America[1]. Many archaeological evidences showed that peppers are the first used spice by human beings as early as 6000 years ago[2]. The genus *Capsicum* consists of all the chili pepper plants with 3-5 wild species and over 2000 cultivated species[3]. The term 'chili' is used interchangeably with other names including 'Chile', 'aji' and 'paprika'[1]. The genus name *Capsicum* came from a Latin word 'kapto', meaning to the heat or pungency[1]. There are about 5 domesticated species of Capsicum in the world; these are *C. annuum*, *C. baccatum*, *C. frutescens*, *C. chinense* and *C. pubescens*[4-5]. The species has been cultivated in its native South America and later around the world for use as a highly popular spice and commodities[1]. The representative species in Ethiopia is *C. baccatum*. It is commonly known as Aji Ethiopian Fire (Ethiopian local language'Amharic' called 'Mitmita')[6]. In Ethiopia it is growing in the home gardens and convenient sites are near the settlements but now it is growing as a monocrop on a large scale by commercial farmers. The countries like China and Mexico including Turkey produce chili pepper as a commercial crop, covering about 70% of the total worldwide production[7]. It is an important constituent of many foods, adding flavor, color, vitamins A and C and pungency or spiciness. It can also be used medically for the treatment of fevers, colds, indigestion, constipation and other degenerative diseases[8-9]. They are effective at killing microorganisms due to significant source of bioactive compounds[10]. It is also used by the security agencies in the preparation of tear gas for crowd control[1].

Many conventional insecticides were being used in Ethiopia to control insects on domestic goods and agricultural products. Home pests such as bedbugs are becoming increasingly apparent as a major threat to the country's people. Especially, the Ethiopian University including Wolaita Sodo University and College students are more vulnerable groups to this insect bite and seriously suffering from the impact. Most of the chemicals used to control the infestation of the bedbug are synthetics of inorganic compounds of 90%. Several studies agreed that, using such kinds of synthetic products to control pests has serious problematic drawbacks[11,12]. According to Lear[11], these pesticides are not easily degradable, persist in soil, leach to groundwater and contaminate with surface water in wide environment. Besides, they can enter to the organism bio-accumulate in food chains and consequently influence other non-target organisms. Overall intensive application has serious problems including accumulation of toxic residues, pollution of environment, biodiversity loss and hazard from handling and genetic resistance by the pest species[11,13-14].

However, in all of these, chemical control was not feasible to demolish the infestation of the bedbug and faced difficulties during implementation due to the cost and fear of poisoning. Using hot steams, heating, manual removal and other non-chemical treatments were not effective at complete eradication of the infestation. To overcome these problems, in the past many years researchers have working with alternative readily biodegradable, eco-friendly, safer for non-target organisms, technically not sophisticated, specific in their action and research based indigenous way of insect pest management[15]. For the last few years, the effect of different plant extracts on the cereal and home pests were widely recognized as alternatives to synthetic chemical insecticides[16]. Several other findings claim the use of extracts of plant origin in insect pest control[10,17-20]. However, most of these experiments are not highlighted the indigenous way of protecting bedbug, but offer a good opportunity to open up a new area to protect bedbug from natural products. Therefore, there is a need to look for alternative organic sources that are readily available, cheap and affordable, relatively a lesser amount of poisonous and fewer detrimental to the environment.

In many of the developing countries like Ethiopia, insecticides are extracted from plants, such as pepper for various purposes. For instance, it may decrease import costs of the synthetic chemicals and provides effective means for managing insects by maintaining the green economy. With this motive, such experimental research work was done by extracting toxin from *C. baccatum* plant for the protection of bedbug. Therefore, this study will serves as alleviating the existing serious problem of the students' dormitories, which are learning in many of the Ethiopian higher institutions and may also provide a useful and baseline information for any of interested scholars from botanical, agricultural, entomological and ethno botanical and other related scientific researches for the extraction of further toxins from other plant materials.

MATERIALS AND METHODS

Study area: Wolaita Sodo University (WSU) is one of the Higher Education Institutes in Ethiopia. It was established on October, 2007 by the government of Ethiopia under the Ministry of Education. It is found in Southern Nation Nationalities and People's Regional State (SNNPRS) in Wolaita Zone capital town of Sodo. Sodo town is located between 54°N Latitude and 380°S longitude. It is 396 km far away from

Addis Ababa, the capital city of the country and 130 km away from the regional city Hawassa. According to the 2018 Population Projection by the Central Statistics Agency, this town has a total population of 254,294 of whom 125,855 are men and 128,439 are women. The least amount of rainfall occurs in December. The average in this month is 23 mm. In July, the precipitation reaches its peak with an average of 223 mm. The temperatures are highest on average in February at around 21.2°C. At 16.8°C on average July is the coldest month of the year.

The vegetation and very comfortable climate of the large part of the region are conditioned by an overall elevation of between 1,500 and 1,800 masl. There are, however, 5 mountains higher than 2,000 m, with Mount Damota at 3,000 m at the center. Forests in Wolaita are vegetated with Fabaceae, Combretaceae and Oleaceae as the most species rich families and some of the families like Vitaceae, Ulmaceae, Thymelaeaceae, Ebenaceae, Olacaceae and Myrsinaceae whereas the least species rich families. *Calpurnia aurea* from Fabaceae, *Schreberaalata* from Oleaceae and *Combretum molle* from Combretaceae are the most abundant species.

Data sources: The experimental study was conducted by using both primary and secondary data sources. Primary data was collected in the course of doing experiment while secondary data was collected from published journals, exploring existing literatures related to the title from internet and published books. From primary source of data the number of living and dead replicates after treatments, amount of extract, concentration of extract/treatment, time of exposure and efficiency of the extract data was collected. From secondary sources of data literatures written by other authors, background information, formulas, sample calculations and results were obtained to make analysis and discussion.

Infusion extraction of the plant: Dried chili fruit was purchased from a commercial supplier in Merab Abaya local market and ground by grinder mill. Then by using electro balance the plant powder was prepared in 3 different masses. The powders then together with different masses of salt were dissolved by water in Florence flasks and put under electronic oven until the solutions were mixed well (Table 1). Then, the solutions were allowed to cool. After that, solutions were subjected to chromatographic way of filtration. Elute (prepared extract solution flowing out) were collected according to their concentrations in separate Florence flask. The concentration of the solutions were determined by w/w (%) Eq:

$$\text{Weight (\%)} = \frac{\text{Weight of solute}}{\text{Weight of solution}} \times 100$$

Application of extract on adult bedbugs and mortality assessment: Adult bedbugs were collected from Wolaita Sodo University Students Dormitory, from Wolaita Sodo Agricultural Technique and Vocational Training College (ATVET) dormitory and from private living houses in Wolaita Sodo, Ethiopia. One hundred eighty adult bedbugs were designed for experiment in 2 independent blocks. Block 1 was for experimental and block 2 was for controlled groups. Two of the blocks were hold 3 treatment groups. Within each of the treatment groups, there were 3 treatment replicates (experiments). In to each of the treatment replicates, 10 adult bedbugs were introduced randomly. After that, the treatment replicates within the experimental block was treated with different concentration levels of the extract accordingly (Table 2). Treatment group 1 (experiment 1) was treated with the 1st concentration level of extract 14.2% (w/w %), treatment group 2 (experiment 2) was treated with the 2nd concentration level of extract 16% (w/w %) and treatment group 3 (experiment 3) was treated with the 3rd concentration level of extract 18.8% (w/w %) via topical spraying. Then after, the treatment groups within controlled block were treated with water via topical spraying in the same way as done in the experimental group. The dead and living individuals in 2 of the groups were counted and recorded within 1 min. All adults in the petri-dishes were removed after finishing the experiment.

Table 1: Prepared extract in 3 different concentrations

Mass of *C. baccatum* powder (solute) (g)	Mass of salt (solute) (g)	Mass of water (solvent) (g)	Mass of the solution (g)	Concentration of solution (w/w %)
20	10	181	211	14.2
30	15	238	283	16.0
50	25	325	400	18.8

Amount of chili powder, salt and solvent (water) used during preparation of extract in three different concentrations

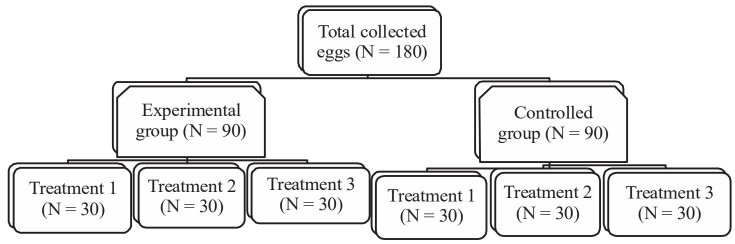

Fig. 1: Eggs (N =180) collected from the ovipositor site

Table 2: Adult bedbugs (N = 180) that were designed for experiment

Block 1 experimental (90)			Block 2 controlled (90)		
Treatment 1	Treatment 2	Treatment 3	Control 1	Control 2	Control 3
10	10	10	10	10	10
10	10	10	10	10	10
10	10	10	10	10	10

Application of extract on eggs and assessment of adult emergence inhibition: For the assessment of adult emergence, the collected insects were allowed to mate and ovipositor for 3 days. Totally about 180 eggs were collected from the ovipositor site and 30 eggs were introduced into each of petri-dishes designed for experiment in 2 independent blocks. Block 1 was for experimental and blocks 2 was for controlled group (Fig. 1). Each of the blocks was hold 3 treatment groups.

The treatment groups within experimental block were treated with different concentration levels of the extract accordingly. Treatment group 1 (experiment 1) was treated with the 1st concentration level of extract 14.2% (w/w %), treatment group 2 (experiment 2) was treated with the 2nd concentration level of extract 16% (w/w %) and treatment group 3 (experiment 3) was treated with the 3rd concentration level of extract 18.8% (w/w %) via spraying. Then after, the treatment replicates within controlled group was treated with nothing. Then, petri-dishes were securely kept in room temperature and number of adult emergence was counted and recorded for consecutive 10 days in 1 day interval.

Data analysis and interpretation: The lion share of analysis was qualitative method but also quantitative analysis was also used. Simple analytical tools such as percentage, table and descriptive analysis were used to describe toxicity of the plant extract on bedbug. Data from mortality assessment was corrected in the control by using Abbott's[21] Eq:

$$\text{Controlled (\%)} = \frac{(1-\text{n in T after treatment})}{(\text{n in Co after treatment})}\times 100$$

where, n is the insect population, T is the treated and Co is the control.

The data was checked for mortalities in the control by using Henderson-Tilton’s[22] Eq:

$$\text{Controlled (\%)} = \frac{1-\text{n in Co befor treatment}\times \text{n in T after treatment}}{1-\text{n in Co after tretment}\times \text{n in T befor treatment}}\times 100$$

where, n is the insect population, T is the treated and Co is the control.

The percentage of reduction in progeny was determined using the following Eq:

$$\text{IE (\%)} = 100-\left(\frac{\text{T}\times 100}{\text{C}}\right)$$

where, C is the number of emerged adult in control and T is the number of emerged adult in treatment.

The data was checked for reduction in progeny by using Aldryhim[23] Eq:

$$\text{Reduction (\%)} = \frac{\text{Co}-\text{Tr}}{\text{Co}}\times 100$$

where, Co is the number of progeny in control and Tr is the number of progeny in treatment.

Statistical analysis: The experimental design for mortality and adult emergence inhibition tests was randomized block design. The data obtained from mortality and emergence inhibition assessment was analyzed statistically using randomized block design with replicates, two-way ANOVA using MS-Excel 2010.

RESULTS

For effective bedbug protection and adult emergence inhibition, the *Capsicum baccatum* extract poses significant insecticidal property. The bioassay of the extract's toxic effect

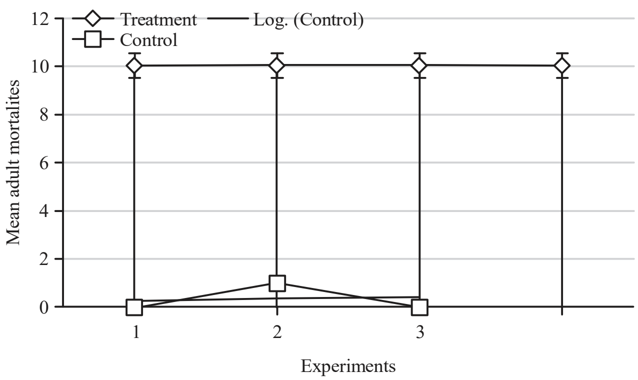

Fig. 2: Mean mortality response of adults under treatment

Table 3: Mortality response of adults

Conditions	Experiments 1	2	3
Treatment 1	10	10	10
Treatment 2	10	10	10
Treatment 3	10	10	10
Control 1	0	1	0
Control 2	0	2	0
Control 3	0	0	0

Table 4: Summary calculation of the mean mortality test

Summary	Experiments 1	2	3	Total
Treatment				
Count	3	3	3	9.0
Sum	30	30	30	90.0
Mean	10	10	10	10.0
Variance	0	0	0	0.0
Control				
Count	3	3	3	9.0
Sum	0	3	0	3.0
Mean	0	1	0	0.3
Variance	0	1	0	0.5

on the bedbug was evaluated by observing the number of bedbugs died soon after the extract was applied and inhibited adult emergence (Table 3). The extract was acute and non-time and concentration dependent at causing complete mortality within 3 min of time in all experimental groups. As shown in Table 3, the numbers of adults killed within the experimental group in all treatment plates were significant when compared to the mortalities in control. Hundred percent of the mortality was achieved in the experimental group and no significant changes were observed in the controlled group. The count of the treatment plates, sum of the mortalities, the mean number of mortalities and variance of the treatments in both the experimental and controlled group was also described in the Table 4.

Table 5: Analysis of variance on the mortality of adults in both controlled and treatment

Source of variation	SS	df	MS	F	p-value	F-critical
Sample	420.5	1	420.5	2523**	2.543E-15	4.7
Columns	1.0	2	0.5	3	0.0877915	3.9
Interaction	1.0	2	0.5	3	0.0877915	3.9
Within	2.0	12	0.2			
Total	424.5	17				

**Significant difference at p<0.05

Table 6: Post-test calculation for mean adult mortality

Comparison	Mean experimental-Mean controlled	95% CI of difference	Significant (p<0.05)	t-value
1	+10.0	+5.6 to +14.4	Yes	20.000
2	+9.0	+4.6 to +13.4	Yes	18.000
3	+10.0	+5.6 to +14.4	Yes	20.000
4	+9.7	+5.3 to +14.1	Yes	19.400

On the basis of F-value, the significance of the experiment was judged. The F statistic value is less than that of calculated F-value at the rejection point $\alpha = 0.05$ with $p<0.05$ (Table 5).

The post test calculation by using the Bonferroni correction to adjust for multiple comparisons result at 95% confidence in the whole family of comparisons were significant and there is no chance that any one or more of these comparisons would be significant by chance (Table 6).

The mean number of adults killed in all tested concentration of the extract in treatment group was significant when compared to mean adult mortality observed in control. In experimental group, 100% mortality was achieved and no significant change observed in controlled group (Fig. 2).

Data from mortality assessment was corrected in the control by using Abbott's[21] Eq:

Given: T = 0 and Co = 9:

$$\text{Controlled (\%)} = \frac{(1-0)}{(9)} \times 100$$

$$\text{Controlled (\%)} = 100$$

$$100\%$$

According to Abbott's[21] formula the extract was 100% effective at controlling the bedbugs.

The Data were checked for mortalities in the control by using Henderson-Tilton's[22] Eq.

Given:

- Mean population in treated plot before treatment = 10
- Mean population in treated plot after treatment = 0
- Mean population in control plot before treatment = 10
- Mean population in control plot after treatment = 9

Table 7: Adult emergence test

	Exposure time (days)			
Conditions	3	5	7	10
Treatment 1	0	0	0	0
Treatment 2	0	0	0	0
Treatment 3	0	0	0	0
Control 1	6	5	6	3
Control 2	10	8	7	5
Control 3	7	9	10	3

Table 8: Summary calculation of adult emergence test

	Days				
Summary	3	5	7	10	Total
Treatment					
Count	3.0	3.0	3.0	3.0	12.0
Sum	0.0	0.0	0.0	0.0	0.0
Mean	0.0	0.0	0.0	0.0	0.0
Variance	0.0	0.0	0.0	0.0	0.0
Control					
Count	3.0	3.0	3.0	3.0	12.0
Sum	23.0	22.0	23.0	11.0	79.0
Mean	7.7	7.3	7.7	3.7	6.6
Variance	4.3	4.3	4.3	1.3	5.7

Table 9: Analysis of variance on progeny production inhibition in both controlled and experimental plates

Source of variation	SS	df	MS	F	p-value	F-critical
Sample	260	1	260	145.1**	1.94E-09	4.5
Columns	17.1	3	5.7	3.2	0.05	3.2
Interaction	17.1	3	5.7	3.2	0.05	3.2
Within	28.7	16	1.8			
Total	322.9583	23				

**Significant difference at p<0.05

Table 10: Post-test calculation for mean adult emergence

Comparison	Mean experimental-Mean controlled	95% CI of difference	Significant (p<0.05)	t-value
1	-7.7	-12.7 to -2.7	Yes	15.400
2	-7.3	-12.3 to -2.3	Yes	14.600
3	-7.7	-12.7 to -2.7	Yes	15.400
4	-3.7	-8.7 to +1.3	No	7.400
5	-6.6	-1.6 to -1.6	Yes	13.200

$$\text{Controlled (\%)} = 1-\left(\frac{10\times 0}{9\times 10}\right)\times 100$$

$$\text{Controlled} = 100$$

$$100\%$$

Data check for mortality with Henderson-Tilton's[22] formula was again certified the 100% efficiency of the extract at controlling the bedbugs. The number of adult emergence inhibition in all treatment plates within the experimental group was significant compared to the controlled adult emergence. Hundred percent emergence inhibitions were achieved in the experimental group and no significant emergence inhibition was observed in the controlled group (Table 7).

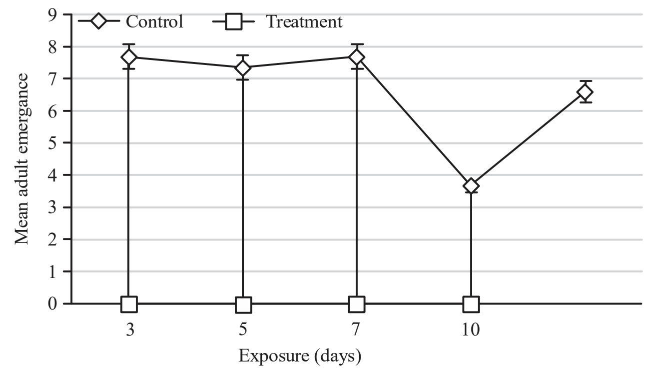

Fig. 3: Mean adult emergence inhibition

The count of the treatment plates, sum of adult emergence, means number of the adult emergence and variance of the treatments both in experimental and controlled group is described in the Table 8. The overall effects of 3 different extract concentration levels were significant with calculated F value (p<0.05) (Table 9).

The post-test calculations by using the Bonferroni correction to adjust for multiple comparisons result at 95% confidence in whole family of comparisons were significant and there is only a 5% chance that anyone of these comparisons would be significant by chance (Table 10). The mean numbers of adults produced in treatments were reduced significantly when compared with the progeny production observed in control after 10 days of exposure. In experimental group, 100% inhibition was achieved and no significant change observed in controlled group (Fig. 3).

The overall percentage mean adult emergence inhibition IE (%) was calculated on the basis of the number of eggs exposed to the extract and adults emerged by using the following Eq:

$$\text{IE (\%)} = 100-\left(\frac{T\times 100}{C}\right)$$

where, T is the percentage emergence in treated batches, C is the percentage emergence in the control.

Given: C = 6.6 and T = 0:

$$\text{IE (\%)} = 100-\left(\frac{0\times 100}{6.6}\right)$$

$$\text{IE} = 100$$

$$100\%$$

According to the Eq. the extract was 100% effective at emergence inhibition.

Data checked for mortality with Aldryhim[23] Eq. was again certified the 100% efficiency of the extract at emergence inhibition:

$$\text{Reduction (\%)} = \frac{\text{Co} - \text{Tr}}{\text{Co}} \times 100$$

where, Co is the number of progeny in control, Tr is the number of progeny in treatment.

Given: Co = 6.6 and Tr = 0:

$$\text{Reduction (\%)} = \frac{6.6 - 0}{6.6} \times 100$$
$$\text{Reduction} = 100$$
$$100\%$$

The range of mortality in adult bedbugs (Fig. 2) and emergence inhibition (Fig. 3) in relation to 3 different extract concentrations was considerably demonstrated the 100% efficacy of extracts in protecting bedbugs and inhibiting adult emergencies significantly $p<0.05$.

DISCUSSION

As shown in this result, the *Capsicum baccatum* extract has excellent insecticidal activity for effective bedbug protection. The extract has low environmental effect and not harms non target species such as humans, birds, amphibians, or fishes based on the acceptance as a food grade spice, generally recognized as safe and well tolerated by humans[24,25]. The extract on bedbug toxicity was occurred mainly through oral consumption but not mechanical. The smell is acceptable to human. It is water base, so it can penetrate deep into cracks and crevices if used in field environment. The killing ability is due to a naturally occurring compound called capsaicin and other chemicals collectively known as capsaicinoids in their fruit[26]. The capsaicin is primarily interested in insect control[27,28]. It is neurotoxin known for its ability to cause deterioration of small unmyelinated primary sensory neuron in both spinal and cranial nerves[29,30]. Salt absorbs fluid from the body and lead to physical, psychological and environmental stress by dehydrating the cell[26]. No matter how bedbugs are strong, stubborn and smart pest they resist most kinds of pesticides, they have no chance to escape from this treatment since the extract is rich with these chemicals.

Unfortunately, there are not any accessible literatures regarding the toxic effects of chili pepper (*C. baccatum*) fruit extract to be compared with the present study. No matter how, this finding is similar with what Ashouri and Shayesteh[31] found the insecticidal activities of 2 powdered spices, black pepper concentration level tested (0.5%) and red pepper at highest dosage (5%) on adults of *Rhyzopertha dominica* (F.) and *Sitophilus granaries* after 14 days. Also this finding is in line with what Asawalam *et al.*[32] showed that, the *P. guineense* and *C. frutescens* powders toxicity at the highest percentage concentration on *S. zeamais* (Mots) with significantly reduced adult emergence.

This finding is additionally supported by others such as Javaid and Poswal[33], who investigated the insecticidal effects of *Piper nigrum* on *Callosobruchus maculatus*, Scott *et al.*[24], who investigated the efficacy of *Piper nigrum* extract for control of forest and ornamental trees defoliator insects viz. *Duplicarias imilis*, *Malacosoma disstria*, *Lymantria dispar* and *Choristoneura fumiferan*. Mahdi and Rahman[27] and Gudeva-Koleva *et al.*[28] investigated the capsaicin extracted from *Capsicum annuum* on *Myzus persicae* and *Leptinotarsa decemlineata*. The insecticidal ability of *Capsicum frutescens* against *Trogoderma granarium* was investigated by Al-Moajel[34]. Echezona[35] has shown the dried and ground fruits of 4 pepper cultivars (*Capsicum* spp.) toxic ability on adult mortality of *Callosobruchus maculatus*. Mahdi and Rahman[27] investigated the toxicity of spices such as black pepper (*P. nigrum*), Ceylon cinnamon (*Cinnamomum zeylanicum*), turmeric (*Curcuma longa*) and red pepper (*C. frutescens*) against the pulse beetle (*Callosobruchus chinensis*) and *Callosobruchus maculates* on stored black gram (*Phaseolus bengalensis*).

In their article, Hikal *et al.*[36], reviewed the use of plant compounds (essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids) with anti-insect effects and their significance as an alternative to chemical compounds used in the elimination of insects in various ways, namely repellents, feeding deterrents/anti-feedants, toxicants, growth retardants, chemosterilants and a plants can be used as a great alternative to synthetic products to control insects by secondary, natural products and their extracts.

Botanical pesticides are recognized by the United States Food and Drug Administration (FDA) as safe and safe for insect control, instead of synthetic pesticides, which cause an increased risk in ozone depletion, neurotoxic, carcinogenic, teratogenic and mutagenic effects in non-targets[37]. They have repulsive, insecticidal, anti-feedants, growth inhibitors, oviposition inhibitors, ovicides and growth-reducing effects on a variety of insects[37]. Essential oils form botanical sources have evaluable larvicidal effects against ants, cockroach, bedbugs, flat head lices, moth and termites. *Mentha piperita* oil repels *Callosobruchus maculates*, triboliums, lice, moth, etc.[38].

Field strains of bedbugs are, in fact, resistant to most pesticides currently available. They resist neonicotinoid and pyrethroid combinations[39] and IGRs like methoprene and hydroprene[40]. Resistance to DDT has resulted in similar problems with other pesticides such as pyrethroids[41]. Although some bedbugs can be killed by residual chlorfenapyr, their actions are very slow[42]. There was no effective residual pesticide in the bedbug so that they are notoriously difficult to control[43,44]. However, *C. baccatum* extract investigated in this experiment killed adults earlier than they could lay eggs and provided full protection against bedbug infestation along with the significantly suppressed adult development. Therefore, it can be used as a great alternative to synthetic products to substantially control insect pest with no side way effect on non-target organisms and ecology.

CONCLUSION

It could be concluded on the basis of the finding that *Capsicum baccatum* extract is 100% effective in killing bedbugs and inhibiting adult's emergence. In view of the side way effects of synthetic products, the present study showed that these plant extracts could have no side effect while protecting the infestation of the bedbug in substantial level. The extract is cheap, safe to environment and non-target organisms and can be easily prepared at home. A number of experiments have been conducted to protect pests from the field environment and home, but most of them are dominated by laboratory sets whose results cannot be extrapolated to field conditions. For more fascinating results, it is good to expand the scope of the experiment to the field environment. Beside this, the *C. baccatum* extract targeted only on bedbug leaving other non-target useful organisms and safe for environment. Therefore, we recommend using botanical insecticides as an integrated insect management program which can greatly reduce the harmful effect of synthetic insecticides.

SIGNIFICANCE STATEMENT

In developing countries such as Ethiopia, insecticide extracted from plants such as pepper is very important in a number of ways. First, the extract may decrease synthetic chemicals import costs. Secondly, by maintaining their green economy, they provide effective means for managing insects. This study can therefore serve as a useful and informative baseline for any interested botanical, agricultural, entomological and other ethno-scientific researcher(s) for further toxin extraction from plant materials. Generally, the study confirmed that the extract pose talented potential in protecting bedbugs and adult emergence inhibition only in small scale applications based on the demonstrated efficacy and reduced risk potential on non-target organisms and ecology.

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