RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
56 (4) 1643-1653, 2024
http://doi.org/10.54910/sabrao2024.56.4.29
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

INSECTICIDAL POTENTIAL OF HEXANE PLANT EXTRACTS AGAINST PULSE BEETLE (*CALLOSOBRUCHUS ANALIS*) ON STORED MUNG BEAN (*VIGNA RADIATA* L.)

M. NAEEM and M. MAMOON-UR-RASHID*

Department of Entomology, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan
*Corresponding author's email: mamoon@gu.edu.pk
Email address of co-author: aown4488@gu.edu.pk

SUMMARY

The pulse beetle is a primary pest of mung bean (*Vigna radiata* L.), causing heavy losses during storage. Conventional control of pulse beetle with insecticides has led to various challenges. This study sought safer alternatives by exploring the efficacy of hexane extracts derived from seeds of *Azadirachta indica* and *Trachyspermum ammi*, *Curcuma longa* rhizomes, *Allium sativum* bulbs, *Citrullus colocynthis* fruits, and *Caralluma tuberculata* stems against pulse beetle. Each plant extract was tested at six concentrations of 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% w/v, under the constant laboratory conditions of the Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. The hexane extracts prepared from *A. sativum* and *C. longa* at 3% concentration exhibited significant efficacy, resulting in mortality rates of 99.20% and 94.40% of adult beetles, respectively. Furthermore, mung bean grains treated with the *A. sativum* extracts at the maximum concentration (3%) demonstrated minimum egg deposition (2.20 per grains^{-20}), prolonged time to adult emergence (25.10 days), minimum progeny emergence (33.40), lowest infestation (5.47%), minimum weight loss (4.39%), and shortest adult life span (8.70 days). The hexane plant extracts prepared from *A. sativum* and *C. longa* powders at higher concentrations (2.5% and 3.0%) can benefit the safer management of pulse beetles.

Keywords: Mung bean (*Vigna radiata* L.)**,** hexane plant extract, *Callosobruchus analis*, mortality, sub-lethal effects

Key findings: The hexane plant extract demonstrated insecticidal properties and caused significant mortality of beetle adults in mung bean (*Vigna radiata* L.). The hexane plant extracts also affected significantly the biology and survival of beetles. Among the six-tested plant extracts, the hexane extracts of *A. sativum* and *C. longa* proved the most effective, whereas *C. tuberculata* extracts were found least effective.

Communicating Editor: Dr. Qasim Hussein Ahmed

Manuscript received: November 03, 2023; Accepted: March 26, 2024.

Citation: Naeem M, Mamoon-Ur-Rashid M (2024). Insecticidal potential of hexane plant extract against pulse beetle (*Callosobruchus analis*) on stored mung bean (*Vigna radiata* L.). *SABRAO J. Breed. Genet.* 56(4): 1643-1653. http://doi.org/10.54910/sabrao2024.56.4.29.

INTRODUCTION

The mung bean (*Vigna radiata* L.) is one of the valuable pulse crops in rainfed and partially irrigated areas, with semi-annual cultivation in autumn and spring. Mung bean increases soil fertility by fixing biological nitrogen and preventing soil erosion (Ali *et al*., 2010; Ranawake *et al*., 2011). Among the numerous insect pest species infesting stored grain legumes, the pulse beetles, *Callosobruchus spp*., are serious pests (Ahad, 2003). The pulse beetle, *C. analis,* is the economically most critical pest of all grain legumes, inflicting 40%–50% losses in storage (Gosh and Durbey, 2003; Papan *et al*., 2021). Infestation of pulse beetle starts in the field on maturing pods before crop harvest. This infestation is carried to storage which results in further pest multiplication and deterioration of the stored grains (Kawuki *et al*., 2005). The damage arose from the larval stage of the pulse beetle, reaching 64% from April to October. The larvae make holes in stored grains and consume the innermost portion, leaving empty seeds and making them unfit for human consumption and cultivation. (Weaver *et al.,* 1995). The *C. analis* is a chief and primary pest of mung bean and other pulses. In severe infestation, this pest causes heavy losses and total grain damage (Deeba *et al*., 2006).

Generally, using synthetic chemicals to manage stored grain insect pests has been the prime method of grain protection due to their efficacy and quick knockdown effects (Atwal and Dhaliwal, 2015); however, this approach has many serious drawbacks. Synthetic chemicals can adversely affect non-target organisms, including humans, and pollute the atmosphere, soil, and groundwater (Jovanović *et al*., 2007; Lu and Wu, 2010; Rani *et al*., 2021). Specific synthetic insecticides have also provided a direct link to cancer (Akbar *et al*., 2022). Moreover, the misuse of synthetic chemicals for insect control poses threats to animals and human beings (Rani *et al*., 2021). Avoiding the toxic effects of synthetic pesticides necessitates finding other effective options to manage insect pest populations with minimum environmental impacts (Furlan and Kreutzweiser, 2015). Extensive use of synthetic pesticides and fumigants against stored grain pests produces resistance against all pesticide groups (Mahanta *et al*., 2021). Moreover, toxic residues in food due to these pesticides have resulted in the search for biopesticides as an alternative for stored grain pest control.

Alternative approaches to pest management utilizing botanical extracts and powders began adoption in many countries. Botanical products are eco-friendly, relatively specific in their mode of action, easy to use, environmentally safe, less hazardous, cheaper, and readily available. Applying plant powders and extracts against insect pests of stored products dates back to early ages in some parts of the world (Kedia *et al*., 2015). Growers and small-scale industries can easily prepare plant products as rough or partially purified extracts. Insecticidal plants are better substitutes for chemical pesticides to minimize their large-scale utilization and adverse environmental effects (Radha and Susheela, 2014). Aslam *et al*., 2002 reported the bioefficacy of 10 plant extracts against *C. chinensis* in stored pulses. Botanical insecticides are best applicable in organic pest management, contributing more to crop production and protection of storage commodities in developing countries (Isman, 2006).

Considering the problems of fumigants and synthetic insecticides and the advantages of botanical insecticides, the presented research assessed six indigenous plant extracts in solvent hexane. All six plants are well available in Pakistan, and their leaves and fruits exhibit insecticidal and repellent properties against stored grain insect pests. The selected indigenous plant extracts assessment against *C. analis* studied their direct toxicity and biological effects against various developmental stages of pulse beetle.

MATERIALS AND METHODS

Insect culture

The pulse beetle culturing commenced on mung bean (*Vigna radiata* L.) cultivar 'Dera

mung.' For this purpose, placing fresh grains in a plastic jar of 3-liter capacity weighed 500 grams. Grain sterilization ensured insect elimination and avoided mite infestation. Adults of *C. analis* came from infested mung bean seeds from the grain market local store sieved out for further multiplication. Releasing 10 pairs of adult *C. analis* continued in each jar for feeding and oviposition. Covering the jars with muslin cloth fastened with rubber bands prevented adult beetles from escaping and facilitated aeration. The jars placed in an incubator (Sanyo Japan, Model-MLR-350 H) had a controlled temperature of 27 °C ± 3 °C, 65% ± 5% R.H., and a photoperiod of 12:12 hours (Light: Dark) till the emergence of adult beetles. After seven days, sieving adult beetles shifted them into other jars to multiply the insect culture. The newly emerged adult beetles were specimens for the experiments.

Collection of plant material

The collected plant materials included seeds of neem (*A. indica*) and ajwain (*T. ammi*), turmeric (*C. longa*) rhizomes, bulbs of garlic (*A. sativum*), fruits of *C. colocynthis,* and stems of *C. tuberculata,* coming from the field, local market, and local growers. The plant materials received shade drying to prepare extracts in hexane under constant environmental conditions until used for experiments.

Extraction of plant materials

The six plant materials sustained grinding in a mechanical grinder to make fine powders. Hexane extracts of plant materials preparation used the standard method by Okoye and Osadede (2009). The dried plant powders' mixture and maceration with hexane had a 1:4 ratio for seven days. Mix the solutions thoroughly utilizing an electric stirring machine for 30 minutes after every 12 hours. The extract filtration ran through Whatman No.1 filter paper. Then, obtaining the concentrated extracts employed a rotary evaporator to remove the organic solvent. The crude extracts in sterile universal bottles remained in a refrigerator for further experimentation.

Experimental procedure

The experiment transpired to know the efficacy of selected plant extracts in hexane against *C. analis* under controlled laboratory conditions. The experimental arrangement had a completely randomized design with five replications each, consisting of seven treatments, including the control. The mung bean grains in the control treatment received hexane only. Sterilized mung bean grains (50 grams per treatment) acquired hexane plant extracts by spraying with the extracts using a hand automizer and vigorously shaking the contents previously stored in transparent plastic jars. The prepared crude hexane extracts had accurate weights by measuring concentrations using a digital balance and then mixed with 3 mL hexane before spraying to mung bean grains. Each plant extract treatment had six different concentrations of 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 percent weight per volume (w/v). An hour after the treatment of grains, the release of five pairs of newly emerged adult beetles continued in each jar, followed by shutting the jars with a muslin cloth and tightening them with rubber bands. Recording the data on the mortality occurred after 24, 48, 72, and 168 hours from the release of beetles. Dead beetles' removal ensued after each observation. The corrected mortality calculation used the formula:

$$\text{Mortality (\%)} = \frac{\text{Number of dead weevils}}{\text{Total number of weevils released}} \times 100$$

Removing the remaining beetles from the jars after seven days, the bio-efficacy of hexane plant extracts further appraisal proceeded by recording the data on the number of eggs grain^{-20}, days to F_1 adult emergence, total emergence of adult progenies, infestation (%), percentage weight loss, and life span of adult beetles.

Statistical analysis

The collected data's statistical analysis followed standard statistical procedures, with means

separated by applying the least significant difference (LSD) Test at the 5% probability level using a computer program, Statistix Version 8.1.

RESULTS

Mortality after 24 hours

At 24 hours after the application of hexane extracts, none of the extracts could cause satisfactory mortality of adult beetles at all the evaluated concentrations (Table 1). The minimum adult mortality (1.6%) of beetles surfaced in grains treated with the lowest concentration (0.5%) of *T. ammi* hexane extracts, showing nonsignificant variation from untreated grains. Conversely, the maximum adult mortality (21.20%) of pulse beetle was visible in mung bean grains treated with the maximum concentration of *A. sativum* hexane extracts, which was statistically similar to the 19.20% adult mortality recorded in grains treated with *C. longa* extracts.

Cumulative mortality after 48 hours

A slight increase in the mortality of adult beetles was prominent at 48 hours after applying hexane extracts compared to 24 hours. At the minimum concentration of 0.5%, the maximum adult mortality (26.40%) was apparent in grains treated with hexane extracts prepared from *A. sativum* powder. Regarding concentrations, the maximum concentration of 3% emerged as highly effective, and hexane extracts prepared from *A. sativum* powder proved the most effective, resulting in a maximum mortality (37.40%) of adult beetles being statistically different from all the other hexane extracts. At the same concentration, the *C. tuberculata* extracts gave the least effective result, with only 10.00% mortality of adult beetles (Table 2).

Cumulative mortality after 72 hours

At 72 hours after the treatment of hexane extracts, only the *A. sativum* extracts caused more than 50% mortality of adult beetles. The *C. tuberculata* extracts were notably least effective and caused minimum mortality (16.00%) of pulse beetles at the lowest concentration of 0.5%, with a significant variation only from untreated grains. The maximum adult mortality (66.60%) of pulse beetle resulted in mung bean grains treated with the maximum concentration (3%) of *A. sativum* extracts, followed by 62.40% mortality of adult beetles recorded in mung bean grains treated with the *A. sativum* extract at 2.5% concentration. Generally, a minimum mortality of 7.80% occurred in untreated grains (Table 3).

Cumulative mortality after 168 hours

At 168 hours after the treatment, all the tested plant extracts at varied concentrations caused more than 60% mortality of the pulse beetle adults. Among the treatments, the *A. sativum* extracts revealed superior effectivity, whereas the least effective were *C. tuberculata* extracts. The effectiveness of the extracts increased by increasing the concentrations of the plant extracts, reaching a peak at the maximum concentration of 3%. Among the plant extracts, the *C. tuberculata* extracts used at the lowest concentration of 0.5% proved least effective, causing 64.80% mortality of beetles. The *A. sativum* extracts used at a maximum concentration of 3% caused 99.20% adult beetle mortality. Largely, minimum adult mortality emerged in untreated grains (Table 4.).

Number of eggs per grains^{-20}

The number of eggs decreased by increasing the concentration of the tested hexane extracts (Table 5). The *A. sativum* extracts were the most effective, with few beetle eggs recorded on grains treated with these extracts. Among the plant extracts treated grains, 8.80 eggs appeared on treated grains with the lowest (0.5%) concentration of *C. tuberculata* extracts. At higher concentrations of 2.5% and 3%, the *A. sativum* extracts were highly effective, and only 2.20 eggs were evident on grains treated with *A. sativum* extracts, which showed statistically similar to the number of

Table 1. Percent mortality of pulse beetle in grains treated with hexane plant extracts after 24 hours.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	7.80±0.84 b	8.20±0.84 b	8.40±0.55 c	9.60±1.52 b	11.00±0.71 c	13.40±1.14 b
Curcuma longa	8.60±1.14 ab	10.00±1.58 b	11.20±1.64 b	13.20±1.30 a	15.20±1.48 b	19.20±1.48 a
Allium sativum	10.60±1.52 a	13.00±1.00 a	14.20±1.79 a	15.00±1.58 a	18.60±1.14 a	21.20±1.30 a
Trachyspermum ammi	1.60±0.89 d	2.80±0.84 cd	3.80±1.30 d	5.80±0.84 cd	7.40±1.14 d	8.20±1.48 c
Citrullus colocynthis	4.40±0.89 c	5.00±1.87 c	6.60±1.14 c	6.80±1.48 c	9.40±1.82 cd	12.20±1.79 b
Caralluma tuberculata	2.00±1.00 d	2.60±0.55 de	3.20±0.84 de	3.60±1.14 d	4.20±1.30 e	5.00±1.00 d
Control	0.40±0.89 d	0.40±0.54 e	0.80±0.83 e	0.40±0.54 e	0.80±0.84 f	0.40±0.54 e
$LSD_{0.05}$	2.10	2.27	2.46	2.51	2.52	2.62

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 2. Percent mortality of pulse beetle in grains treated with hexane plant extracts after 48 hours.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	13.20±0.84 c	15.00±1.58 c	15.80±0.84 c	16.80±0.84 d	21.00±1.58 c	22.00±1.58 c
Curcuma longa	19.40±1.52 b	19.40±1.79 b	23.60±1.52 b	25.80±1.48 b	26.80±1.30 b	33.40±2.61 b
Allium sativum	26.40±1.67 a	26.80±1.79 a	32.20±1.92 a	33.40±1.67 a	34.00±2.54 a	37.40±2.07 a
Trachyspermum ammi	12.40±1.14 c	13.60±1.14 cd	15.40±1.14 c	20.40±1.14 c	21.00±1.22 c	22.20±1.30 c
Citrullus colocynthis	8.80±1.30 d	11.60±1.34 d	15.20±0.84 c	20.00±1.00 c	22.60±1.52 c	24.60±1.52 c
Caralluma tuberculata	3.80±0.84 e	4.20±0.84 e	8.00±0.71 d	8.40±0.89 e	9.40±0.54 d	10.00±1.00 d
Control	2.20±1.22 e	2.20±0.84 e	4.20±0.84 e	2.80±0.84 f	2.60±0.89 e	2.00±0.71 e
$LSD_{0.05}$	2.54	2.78	2.38	2.33	2.99	3.31

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 3. Percent mortality of pulse beetle in grains treated with hexane plant extracts after 72 hours.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	25.60±1.14 c	27.80±1.30 c	29.40±1.52 c	33.20±1.30 c	33.40±1.14 c	36.60±1.52 c
Curcuma longa	29.60±1.34 b	32.00±1.87 b	36.60±1.82 b	40.00±2.12 b	41.00±2.55 b	45.40±2.30 b
Allium sativum	33.80±1.92 a	42.00±2.24 a	51.00±2.54 a	56.00±2.74 a	62.40±2.70 a	66.60±2.86 a
Trachyspermum ammi	22.00±1.58 d	23.00±1.58 d	23.80±1.64 d	25.00±1.58 d	25.60±1.67 d	26.80±1.30 d
Citrullus colocynthis	25.00±1.58 cd	30.80±1.30 bc	35.20±1.92 b	36.00±1.58 c	39.00±1.58 b	40.20±1.58 c
Caralluma tuberculata	16.00±1.58 e	15.40±1.14 e	17.20±1.30 e	20.80±1.30 e	22.00±1.58 d	23.80±1.79 d
Control	7.80±1.30 f	8.60±1.52 f	7.80±1.30 f	6.00±1.58 f	8.00±1.58 e	7.00±1.58 e
$LSD_{0.05}$	3.03	3.21	3.55	3.62	3.82	3.94

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 4. Percent mortality of pulse beetle in grains treated with hexane plant extracts after 168 hours.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	86.00±1.58 a	88.60±2.07 a	88.00±1.58 a	90.20±1.64 b	90.00±2.24 b	90.80±2.78 bc
Curcuma longa	88.60±1.67 a	88.60±2.07 a	88.40±2.07 a	91.20±2.68 ab	93.00±2.00 b	94.40±2.07 b
Allium sativum	89.00±1.58 a	90.40±2.07 a	91.40±2.07 a	94.40±1.52 a	98.80±1.30 a	99.20±1.09 a
Trachyspermum ammi	72.00±2.12 b	72.20±1.92 c	73.00±1.87 c	75.20±1.64 d	80.40±2.70 c	77.80±1.92 d
Citrullus colocynthis	73.80±1.48 b	78.00±2.55 b	81.60±2.41 b	83.00±2.00 c	83.60±2.30 c	88.40±2.70 c
Caralluma tuberculata	64.80±1.92 c	66.40±2.41 d	69.80±2.28 c	74.40±2.70 d	75.00±1.87 d	75.00±2.00 d
Control	18.00±1.58 d	17.20±1.48 e	17.00±1.58 d	18.00±1.58 e	18.00±1.58 e	18.00±1.58 e
$LSD_{0.05}$	3.45	4.22	4.01	4.06	4.10	4.20

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 5. Number of eggs per 20 grains of pulse beetle in grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	6.60±1.14 cd	5.40±1.67 cd	5.20±1.30 cd	4.80±1.30 cd	4.20±1.30 cde	4.00±1.00 cd
Curcuma longa	4.80±0.83 de	5.20±1.30 cd	3.80±0.83 de	4.20±1.64 cd	3.20±0.83 de	3.40±1.14 cd
Allium sativum	4.00±0.71 e	3.60±0.89 d	2.80±0.84 e	2.80±0.84 d	2.20±0.84 e	2.20±0.84 d
Trachyspermum ammi	8.40±1.14 bc	8.20±1.30 b	7.60±1.52 b	6.40±1.14 bc	6.00±1.22 bc	5.60±1.14 bc
Citrullus colocynthis	6.60±1.34 cd	6.20±0.84 bcd	6.60±1.14 bc	6.00±1.22 bc	5.00±1.22 bcd	4.20±0.84 cd
Caralluma tuberculata	8.80±0.84 b	7.60±1.34 bc	8.00±0.71 b	8.20±0.83 b	7.00±1.00 b	6.60±1.14 b
Control	14.40±1.34 a	14.60±1.52 a	14.40±1.14 a	15.20±1.64 a	15.40±1.14 a	15.00±1.58 a
$LSD_{0.05}$	2.16	2.60	2.21	2.54	2.19	2.25

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 6. Number of days to F_1 adult emergence in grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	24.35±1.20 a	24.90±1.08 ab	25.20±1.48 ab	25.70±1.04 ab	25.90±1.19 ab	26.60±0.96 a
Curcuma longa	22.80±1.20 ab	23.70±1.44 abc	23.40±1.43 abc	24.90±1.56 ab	25.40±1.52 ab	25.80±1.48 ab
Allium sativum	24.40±1.52 a	25.10±0.96 a	25.30±1.68 a	26.10±1.19 a	27.10±0.96 a	27.10±1.19 a
Trachyspermum ammi	22.00±0.79 bc	22.90±0.96 bcd	22.70±1.03 bc	22.50±0.79 cd	23.00±0.79 c	23.50±0.79 c
Citrullus colocynthis	22.00±0.79 bc	23.00±0.79 abc	22.50±0.79 cd	23.50±0.79 bc	24.00±0.79 bc	25.00±0.79 ab
Caralluma tuberculata	21.70±0.57 bc	22.30±1.04 cd	23.50±0.79 abc	23.50±0.79 bc	24.30±0.75 bc	24.00±0.79 bc
Control	20.60±0.96 c	20.90±0.96 d	20.60±1.29 d	20.30±1.35 d	20.50±1.27 d	20.50±1.27 d
$LSD_{0.05}$	2.12	2.11	2.52	2.23	2.16	2.15

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

eggs noted on grains treated with *C. longa* and *A. indica* extracts. The *C. colocynthis* and *T. ammi* extracts emerged as least effective, with a maximum number of beetle eggs (8.80 and 8.40) observed in these treatments. In general, a maximum number of 15.40 beetle eggs were prevalent on untreated grains.

Days to adult emergence

At lower concentrations of 0.5% and 1%, the hexane extracts prepared from *C. tuberculata*, *C. colocynthis,* and *T. ammi* powders had no significant effect on the days to adult emergence of pulse beetle compared with the control (Table 6). The maximum (24.40 and 25.10) days to adult emergence were evident on grains treated with *A. sativum* extracts at lower concentrations of 0.5% and 1%, with nonsignificant variations from grains treated with *C. longa* and *A. indica* extracts. At higher concentrations, the *A. sativum* extracts prolonged the developmental duration of the pulse beetle, and the maximum duration to adult emergence appeared when culturing beetles on mung bean grains treated with hexane extracts prepared from *A. sativum* powder. It was statistically similar to the number of days to adult emergence on grains treated with *C. longa* and *A. indica* extracts. Generally, the minimum developmental duration (20.30 days) of pulse beetle was prominent when reared on untreated mung bean grains.

Total adult emergence

All the tested hexane extracts had significant effects on the progeny emergence of the pulse beetle, with the *A. sativum* extracts as the most effective, resulting in the minimum emergence of beetle adults. At a minimum concentration, the least (46.20) progeny emergence resulted from grains treated with *A. sativum* extracts, which gradually decreased by increasing the concentration. The least (33.40) progeny emergence prevailed in grains treated with the maximum concentration of the same extracts. Contrastingly, at the lowest concentration, the maximum progeny emergence was notable in grains treated with *C. tuberculata* extracts, which was almost three times the progeny emergence compared to *A. sativum* extracts. Generally, the maximum progeny emergence (150.20) arose from untreated mung bean grains (Table 7).

Percent infestation

The hexane extracts substantially affected the infestation of mung bean grains compared with the control. The least (5.47%) infestation of pulse beetle was distinct when culturing the beetle adults on mung bean grains treated with the maximum (3%) concentration of *A. sativum* extracts. At the same concentration, the maximum infestation (12.44%) of pulse beetle resulted from grains treated with *C. tuberculata* extracts with a nonsignificant difference from 10.01% progeny emergence from mung bean grains treated with *C. colocynthis* extracts (Table 8).

Grain weight loss

The weight loss of mung bean grains proved less in grains treated with hexane extracts at all the tested concentrations than in untreated grains (Table 9). The lowest concentration of 0.5% appeared as the least effective, whereas the maximum concentration revealed the most effective in preventing weight loss of mung bean grains caused by pulse beetles. The weight loss of mung bean grains gradually decreased by increasing hexane extract concentration, and the minimum weight loss of 4.39% manifested in mung bean grains treated with the *A. sativum* extracts at a maximum concentration of 3%. The maximum weight loss of 25.45% prevailed in untreated grains (Table 9).

Adult life span

The hexane extracts prepared from *A. sativum* powder exhibited maximum effectiveness, and the least adult life span of pulse beetles occurred on grains treated with these extracts. At the maximum concentration (3%), the minimum adult life span of 8.70 days appeared on grains treated with *A. sativum* extracts, having a nonsignificant variation from grains

Table 7. F_1 adult pulse beetle emergence in grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	83.20±2.86 e	82.40±2.79 e	78.00±1.58 e	72.40±2.41 d	64.80±2.39 d	61.00±2.74 e
Curcuma longa	60.60±2.30 f	59.60±2.41 f	58.20±2.86 f	54.60±1.95 e	50.20±1.92 e	45.40±2.30 f
Allium sativum	46.20±2.86 g	45.00±2.91 g	43.20±2.77 g	41.40±2.30 f	38.80±2.38 f	33.40±2.30 g
Trachyspermum ammi	114.80±2.38 c	110.40±2.30 c	108.80±2.59 c	102.80±2.83 c	96.00±2.74 c	88.20±2.77 c
Citrullus colocynthis	97.60±2.41 d	95.80±2.77 d	85.00±2.92 d	72.00±1.58 d	69.20±2.42 d	67.80±2.77 d
Caralluma tuberculata	131.80±1.92 b	120.60±2.30 b	118.60±2.30 b	115.60±2.30 b	114.60±1.82 b	105.40±2.70 b
Control	148.40±2.87 a	145.00±2.70 a	137.80±2.56 a	132.20±2.66 a	135.80±2.54 a	150.20±2.91 a
$LSD_{0.05}$	5.51	6.47	6.19	5.90	5.48	6.11

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 8. Percent infestation of pulse beetle in grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	21.93±0.90 cd	21.14±0.59 c	19.15±1.28 c	18.10±1.16 c	14.88±1.13 c	9.87±1.07 d
Curcuma longa	20.26±1.09 de	17.73±0.94 d	13.49±0.91 d	12.61±0.80 d	10.89±0.93 d	8.09±0.90 d
Allium sativum	18.07± 0.98 e	14.40±0.87 e	10.68±1.04 e	8.91± 1.01 e	7.47±0.85 e	5.47±1.00 e
Trachyspermum ammi	25.19±1.30 b	24.26±1.45 b	23.11±1.19 b	21.46±1.36 b	19.83±1.34 b	18.67±1.08 b
Citrullus colocynthis	21.96±0.92 cd	20.57± 1.39 c	18.45±1.49 c	12.61±1.28 d	15.47±1.45 c	10.01±1.14 cd
Caralluma tuberculata	24.20±1.01 bc	22.76±1.06 bc	20.91±0.93 bc	18.68±1.31 c	15.55±1.57 c	12.44±1.67 c
Control	39.04±1.86 a	39.67±1.76 a	40.27±1.99 a	40.52±1.64 a	39.40±1.87 a	39.82±1.45 a
$LSD_{0.05}$	2.39	2.43	2.63	2.50	2.70	2.44

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 9. Percent weight loss of mung bean grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	11.07±1.12 cd	11.67±0.98 c	9.88±0.90 cd	10.03±0.90 c	9.42±1.13 c	7.97±1.25 cd
Curcuma longa	10.05 1.20±d	9.79±1.11 c	9.16±1.09 de	8.84±0.88 c	7.10±0.98 de	5.09±0.95 de
Allium sativum	9.00±0.86 d	7.31±1.60 d	7.44±1.29 e	6.24±0.88 d	5.81± 1.17 e	4.39±1.03 e
Trachyspermum ammi	16.41±1.08 b	16.31±0.72 b	15.46±0.89 b	14.10±1.17 b	14.01±1.16 b	12.61±1.34 b
Citrullus colocynthis	12.33±1.11 c	11.63±1.15 c	11.59±1.28 c	10.13±1.02 c	9.30±0.99 cd	8.43±1.13 c
Caralluma tuberculata	16.86±1.15 b	16.83±0.99 b	14.81±1.15 b	13.98±1.07 b	12.80±0.96 b	11.08±0.83 b
Control	24.89±1.57 a	25.45±1.37 a	25.39±1.06 a	25.43±1.24 a	24.93±1.53 a	25.15±1.13 a
$LSD_{0.05}$	2.35	2.18	2.21	2.07	2.24	2.22

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

Table 10. Life span of adult pulse beetles after emergence in grains treated with hexane plant extracts.

Treatments	Concentrations (%)					
	0.5	1.0	1.5	2.0	2.5	3.0
Azadirachta indica	10.50±0.79 bc	10.20±0.57 c	9.90±0.74 bc	9.60±0.96 bcd	9.10±0.65 bc	9.40±0.65 bc
Curcuma longa	10.00±0.79 bc	9.60±0.65 c	9.80±1.20 bc	9.40±0.74 cd	8.60±0.96 c	9.20±0.84 bc
Allium sativum	9.60±0.65 c	9.60±0.96 c	9.40±0.96 c	9.00±0.79 d	9.00±0.79 c	8.70±0.84 c
Trachyspermum ammi	11.40±0.65 ab	11.00±0.79 abc	11.00±0.79 abc	11.10±0.96 abc	10.80±1.03 ab	10.40±0.42 b
Citrullus colocynthis	10.70±0.57 abc	10.30±0.57 bc	10.20±0.84 abc	10.20±1.04 ab	10.20±0.84 bc	10.00±0.79 bc
Caralluma tuberculata	12.10 ±0.96 a	11.80±1.04 ab	11.50±1.12 ab	11.40±1.04 ab	10.80±1.04 ab	10.70±0.57 ab
Control	12.20±0.76 a	12.40±0.74 a	12.00±0.79 a	12.10±1.20 a	12.40±0.96 a	12.00±1.12 a
$LSD_{0.05}$	1.50	1.56	1.87	1.98	1.73	1.55

Mean values in corresponding column having dissimilar letter(s) are significant using the LSD test.

treated with *C. longa* and *A. indica* extracts at the same concentration. The *C. tuberculata* extracts proved the least effective. Generally, the maximum adult life span of 12.40 days was gainful in untreated mung bean grains (Table 10).

DISCUSSION

Different compounds, including alkaloids, tannins, terpenoids, saponins, and phenols, present in plant extracts are better sources of biopesticides that affect the biology of insects by inhibiting their fecundity, feeding, and damage (Adesina, 2022; Akbar *et al*., 2022). The plant extracts are considerably cheaper alternatives to synthetic pesticides, especially for small-scale farmers. These studies showed that plant extracts significantly affect the behavior and survival of pulse beetles, inhibiting fecundity. The lowest number of beetle eggs was visible in the mung bean grains treated with *A. sativum*, *C. longa,* and *A. indica* extracts, particularly at higher concentrations. Study findings revealed that the hexane plant extracts are a potential source of biological pesticides. The crude hexane extracts showed better insecticidal properties against *C. analis*. The toxicity of plant extracts occurred in the dose and duration of exposure dependent (Lestari *et al*., 2015).

The presented results confirm the findings of previous researchers in which documented insecticidal effects of various plant materials against stored grain insect pests were valid. Akbar *et al*. (2022) tested the insecticidal effects of six indigenous plant extracts in hexane and methanol against *C. maculatus.* They observed the highest mortality of *C. maculatus* with *Nicotiana tabacum,* followed by *N. rustica* and *A. indica* extracts. Ahad *et al*. (2012) tested hexane extracts of 13 various local plants against *C. chinensis.* All the tested plant extracts showed insecticidal activity by showing mortality, inhibition of F_1 adult emergence, reduced seed infestation, and fecundity. Murugesan *et al*. (2021) used leaf extracts of *Solanum torvum* against *C. maculatus* on green gram. They reported 98% mortality of adult beetles using ethyl acetate extracts after 72 hours, followed by methanol extracts at 70% and hexane extracts at 48%. Similar findings also came from Ahad *et al*. (2015). They tested different weed extracts in hexane and found shial mutra weed, *Blumea lacera* Dc. extracts at 4% concentration are most effective in causing mortality of adult beetles. Ogunsina *et al*. (2011) evaluated the insecticidal potential of three local plant extracts in hexane against *C. maculatus* and *S. zeamais*. The results showed that African nutmeg extracts in hexane appeared most effective against pulse beetles, causing 100% mortality within 24 hours. Similarly, Ahad *et al*. (2016) evaluated n-hexane extracts of five different local weeds against *C. chinensis* on stored mung bean. High mortality of adult beetles occurred at higher concentrations.

The tested hexane plant extracts at higher doses significantly affected the adult emergence of *C. analis.* The lowest beetle emergence materialized in mung bean grains treated with *A. sativum*, *C. longa*, *A. indica,* and *C. colocynthis* extracts. Similar to the presented findings, Ahad *et al*. (2015) also reported 33% to 63% inhibition of adult beetle emergence by applying five diverse weed extracts in hexane. Our results proved that the efficacy of extracts increased at higher concentrations. Roy *et al*. (2012) also reported the dose-dependent inhibitory effect of *X. strumerium* fruit extract on the oviposition and F_1 adult emergence of *C. chinensis*.

In addition to the poisonous effects, all the tested plant extracts substantially reduced the percent infestation of mung bean grains, the percent weight loss, and the number of eggs laid compared with control treatments. The results of this experiment are similar to the findings of Kosini and Nukenine (2017). They stated that *Gnidia kaussiana* extracts in hexane at 5 g/kg dose completely protected the Bambara groundnut from cowpea weevil infestation for up to four months during storage versus untreated nuts, where the infestation was 100%. Similarly, no weight loss was distinct at 1 and 5 g/kg doses of Gnidia extracts. Ahad *et al*. (2015) reported that some local weed extracts in hexane significantly reduced grain damage by *C. chinensis*. Among the treatments, grain damage inhibition varied from 13% to 49%. Ahad *et al*. (2016) tested five dissimilar weed plant extracts in n-hexane, stating that at higher concentrations, weed extracts exhibited inhibition of egg laying and adult emergence, significantly decreasing the percent infestation of stored mung bean grains.

The minimum adult life span of 8.70 days of pulse beetle emerged on grains treated with *A. sativum* extracts, with a nonsignificant variation from the adult life span recorded from grains treated with *C. longa* and *A. indica* extracts. The findings of Adeleye and Soyelu (2020) are in complete conformity with these results. They documented that the minimum fecundity and life span of beetle adults were noticeable when culturing beetles on cowpea seeds with n-hexane extracts of *A. indica* leaves at a 3% concentration. The recorded minimum life span and fecundity of beetle adults in the treated mung bean grains will likely have the chance of progeny development and new progeny emergence.

CONCLUSIONS

The hexane plant extracts of *A. sativum* and *C. longa* carried insecticidal and biological properties against *C. analis* on stored mung bean. The maximum mortality of the beetle adults, minimum infestation, weight losses of mung bean grains and least progeny emergence was observed in grains treated with *A. sativum* and *C. longa* hexane extracts. Based on the results, the study recommends that the hexane plant extracts prepared from *A. sativum* and *C. longa* powders at higher concentrations of 2.5% and 3.0% could benefit the safer management of pulse beetles.

REFERENCES

Adeleye A, Soyelu O (2020). Bioactivity of aqueous and n-hexane neem leaf extracts against the cowpea weevil, *Callosobruchus maculatus* (F.). *FUDMA JAAT* 5: 160–169.

Adesina JM (2022). Bioactive constituents and fumigant toxicity of *Datura* metal extracts as grain protectant and progeny emergence inhibition of *Callosobruchus maculatus* (Coleoptera: Bruchidae). *J. Plant Dis. Prot.* 129: 819–829.

Ahad A, Haque F, Akter M, Islam MN, Rahman SA (2012). Screening and biological activity of indigenous plant extracts against pulse beetle, *Callosobruchus chinensis* (Bruchidae: Coleoptera). *Int. J. Bio-resource Stress Manag.* 3(2): 196–205.

Ahad MA (2003). Trinojatiyo Fashaler Balai Bebosthapana (Pest Management in Gramicious Crops). Textbook Division, Bangla Academy, Dhaka, Bangladesh, 184.

Ahad MA, Nahar MK, Amin MR, Suh SJ, Kwon YJ (2015). Biological activities of five weed extracts against *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Korean J. Appl. Entomol*. 54(2): 83–89.

Ahad MA, Nahar MK, Amin MR, Suh SJ, Kwon YJ (2016). Effect of weed extracts against pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) of mung bean. *Bangladesh J. Agric. Res.* 41(1): 75–84.

Akbar R, Khan IA, Alajmi RA, Ali A, Faheem B, Usman A, Aboul-Soud MA (2022). Evaluation of insecticidal potentials of five plant extracts against the stored grain pest, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Insects*, 13(11): 1047.

Ali MA, Abbas G, Mohy-ud-Din Q, Ullah K, Abbas G, Aslam M (2010). Response of mungbean (*Vigna radiata*) to phosphatic fertilizer under arid climate. *J. Anim. Plant Sci*. 20(2): 83–86.

Aslam M, Khan KA, Bajwa MZH (2002). Potency of some spices against *Callosobruchus chinensis* Linnaeus. *J. Biol. Sci.* 2(7): 449–452.

Atwal AS, Dhaliwal GS (2015). Agricultural Pests of South Asia and Their Management. Kalyani Publishers, New Delhi, India. 300 p.

Deeba F, Sarwar M, Khuhro RD (2006). Varietal susceptibility of mungbean genotypes to pulse beetle, *Callosobruchus analis* F (Coleoptera: Bruchidae). *Pak. J. Zool.* 38(4): 265–268.

Furlan L, Kreutzweiser D (2015). Alternatives to neonicotinoid insecticides for pest control: Case studies in agriculture and forestry. *Environ. Sci. Pollution Res.* 22(1): 135–147.

Gosh SK, Durbey SL (2003). Integrated Management of Stored Grain Pests. International Book Distribution Company, 263 p.

Jovanović Z, Kostić M, Popović Z (2007). Grain-protective properties of herbal extracts against the bean weevil *Acanthoscelides obtectus* Say. *Indus. Crops Prod*. 26(1): 100–104.

Kawuki RS, Agona A, Nampala P, Adipala E (2005). A comparison of effectiveness of plant-based and synthetic insecticides in the field management of pod and storage pests of cowpea. *Crop Protec.* 24(5): 473–478.

Kedia A, Prakash B, Mishra PK, Singh P, Dubey NK (2015). Botanicals as ecofriendly biorational alternatives of synthetic pesticides against *Callosobruchus* spp. (Coleoptera: Bruchidae) A review. *J. Food Sci. Technol.* 52: 1239–1257.

Kosini D, Nukenine EN (2017). Bioactivity of novel botanical insecticide from *Gnidia kaussiana* (Thymeleaceae) against *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in stored *Vigna subterranea* (Fabaceae) grains. *J. Insect Sci.* 17(1): 31.

Lestari P, Khumaida N, Sartiami D, Mardiningsih TL (2015). Selection criteria of *Graptophyllum pictum* resistance to *Doleschallia bisaltide* Cramer (Lep: nymphalidae) attack based on insect feeding reference. *SABRAO J. Breed. Genet*.47(2): 172-184.

Lu J, Wu S (2010). Bioactivity of essential oil from *Ailanthus altissima* bark against 4 major stored-grain insects. *Afric. J. Microbiol. Res.* 4(3): 154–157.

Mahanta K, Rajkhowa D, Kumar M, Verma H (2021). Impact of herbicides used in Agriculture: Benefits and hazards. *Biotechnol. Res. Today*. 3: 999–1001.

Murugesan R, Vasuki K, Kaleeswaran B, Santhanam P, Ravikumar S, Alwahibi MS, Alkahtani J (2021). Insecticidal and repellent activities of *Solanum torvum* (Sw.) leaf extract against stored grain pest, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *J. King Saud Uni. Sci.* 33(3): 101390.

Ogunsina OO, Oladimeji MO, Lajide L (2011). Insecticidal action of hexane extracts of three plants against bean weevil, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus zeamais* Motsch. *J. Ecol. Nat. Environ.* 3(1): 23–28.

Okoye FBC, Osadebe PO (2009). Studies on the mechanisms of anti-inflammatory activity of the extracts and fractions of *Alchornea floribunda* leaves. *Asian Pacific J. Trop. Medic.* 2(3): 7–14.

Papan P, Chueakhunthod W, Poolsawat O, Arsakit K, Tharapreuksapong A, Tantasawat PA (2021). Validation of molecular markers linked to cercospora leaf spot disease resistance in mungbean (*Vigna radiata* [L.] Wilczek). *SABRAO J. Breed. Genet.* 53(4): 749-757. https://doi.org/10.54910/sabrao2021.53.4.16

Radha R, Susheela P (2014). Efficacy of plant extracts on the toxicity, ovipositional deterrence and damage assessment of the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *J. Entomol. Zool. Stud.* 2(3): 16–20.

Ranawake AL, Dahanayaka N, Amarasingha UGS, Rodrigo WDRJ, Rodrigo UTD (2011). Effect of water stress on growth and yield of mung bean (*Vigna radiata* L). *Tropical Agric. Res. Exten.* 14(4): 76–79.

Rani L, Thapa K, Kanojia N, Sharma N, Singh S, Grewal AS, Kaushal J (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *J. Cleaner Prod.* 283, 124657.

Roy B, Jalal S, Sarker BC, Amin MR, Jeon YH, Chun IJ (2012). Evaluation of insecticidal activities of common cocklebur fruit extract against pulse beetle *Callosobruchus chinensis* (Coleoptera: Bruchidae). *Korean J. Appl. Entomol.* 51(4): 325–329.

Weaver DK, Phillips TW, Dunkel FV, Weaver T, Grubb RT, Nance EL (1995). Dried leaves from Rocky Mountain plants decrease infestation by stored-product beetles. *J. Chemic. Ecol.* 21(2): 127–142.