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Research Article

Entomocidal effectiveness of some indigenous botanicals' aqueous extracts against maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae)

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Abstract

As part of efforts to explore environmental friendly alternatives to synthetic chemicals, aqueous extracts of *Azadirachta indica, Caralluma tuberculata, Allium sativum, Curcuma longa, Citrulus colocynthis* and *Calotropis procera* were used to investigate the entomotoxicity of selected plant materials against maize weevil, *Sitophilus zeamais* in stored maize. In order to investigate the effect of selected plant materials on the mortality of maize weevil, maize seeds (20g) were treated with 0.5, 1, 1.5, 2, 2.5 and 3% v/w of aqueous extracts in the laboratory of Entomology Department, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan under controlled environmental conditions of 27 ± 1^{0}C and 65 ± 2% R.H and 12: 12 hour dark: light regimes. Experiment was laid out in Completely Randomized Design with five replications. The adult mortality of *S. zeamais* was recorded after 1 day, 2 days, 3 days, 7 days, 14 days and 21days, post exposure time period. The *A. indica* and *C. longa* plant aqueous extracts were found more toxic to adult maize weevil compared to other plant extracts recording (95%) and (91%) mortality at 3% concentration whereas; minimum adult mortality was recorded in *C. procera* (26%) at 3% concentration after 21 days' time span compared with control (2%). The toxicity of the selected plant materials increased with increase in the concentration and exposure period. It is concluded from the present findings that the aqueous extracts of *A. indica* and *C. longa* can be used as safe alternative to chemical insecticides for the management of maize weevil under storage conditions.

Keywords: Maize weevil; Entomotoxicity; Exposure period; Plant materials; Stored maize

Introduction

Maize (*Zea mays*. L) is the highest yielding and the most versatile emerging cereal crop having wide adaptation under various agro- climatic conditions of tropical and sub-tropical regions across the globe **[1]**. Maize crop is a rich source

of nutrients such as fats, proteins, carbohydrates, minerals and vitamins [2]. Among cereal crops, maize stands at 3rd position after wheat and rice cultivation in Pakistan [3]. Maize crop was cultivated on an area of 1144 thousand hectares with a total production of 2920 thousand tones during 2015-2016 growing season [4].

Among the insect pests of stored grains, maize weevil (*Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) is the most devastating pest of maize. It is polyphagous in nature and found in tropical and sub-tropical regions of the world. Maize weevil infests maize grains both in field as well as during storage conditions. Maize weevil causes grain losses ranging from 20 to 90% during storage and it may infest 80 percent stored maize [2, 5]. The maize weevil caused 37.51% grain damage and 33.23% weight losses in Dera Ismail Khan and its adjacent Punjab province areas [6].

Many methods have been developed to control maize weevil but its control is mainly achieved by the successive use of synthetic chemicals in the form of fumigants having quick knock-down effect. The use of synthetic chemicals causes many problems like resurgence of pests, residual effects on stored grains, lead to accumulation of residues on maize grains causing environmental and health hazards to human beings [7, 8]. Furthermore, methyl bromide has been banned internationally by "Montreal International Agreement" due to its depletion effect on ozone layer [6]. To address the problems caused by synthetic insecticides scientists are trying to develop alternate control methods which are eco-friendly, economic, less health hazardous and readily available [9].

In present investigation, studies were conducted to investigate the entomotoxicity of six plant aqueous extracts including *Azadirachta indica* (Neem-seed), *Caralluma tuberculata* (bitter cress-succulent leaf), *Allium sativum* (Garlic-rhizome), *Citrulus colocynthis* (Bitter Apple fruit), *Curcuma longa* (Turmeric-Rhizome), *Calotropis procera* (Ak-leaves) against maize weevil.

Materials and methods

Insect cultures

The maize weevil were cultured on maize grains in the laboratory of Entomology department, Gomal University, Dera Ismail Khan, Pakistan. The maize grains (CV Azam White) used for culturing maize weevil were sterilized in a deep freezer maintained at -20 ± 2°C for two weeks, to remove chances of previous infestation following standard method [10]. Maize grains were thoroughly cleaned before using in the trials. Two hundred pairs of newly emerged adult weevils were introduced in each jar and were maintained at 27 ± 2°C and 65 ± 5% relative humidity under 12:12 hour day length (L:D). The plastic jars were covered with muslin cloth tightened with rubber band in order to prevent the insects from escaping and to facilitate the exchange of gases and were later placed in an incubator for 10 days. Afterwards, these insects were removed by sieving and were introduced to other jars for multiplication. The jars having infested maize grains were kept in incubator for 20 days. Newly emerged adult weevils were collected and kept in separate jars according to their age. Adults that emerged on same day were used for experimental purpose.

Plant Aqueous Extracts preparation

The plant materials (*A. indica, C. tuberculata, A. sativum, C. longa, C. colocynthis* and *C. procera*) used in this experiment were obtained from local market and brought to the laboratory of Entomology Department, Faculty of Agriculture Gomal University Dera Ismail Khan Pakistan. Plant materials were thoroughly washed with distilled water and were dried under shade in ventilated area till reaching constant weight. The outcome products were crushed/milled in an electric grinder and sieved with mesh having 2mm size to get fine powders. The aqueous extracts for each treatment were prepared by using 0.5, 1, 1.5, 2, 2.5 and 3grams of each plant powder in 100 ml of distilled water for 24hours in 250 ml conical flask for 30 minutes and peculated via Whateman No. 1(9cm) filter paper. The filtered products were stored in plastic containers after

due tagging and refrigerated till required for experimentation [11].

Entomotoxicity of various plant aqueous extracts against maize weevil

Aqueous extracts were used at six different concentrations of 0.5, 1, 1.5, 2, 2.5 and 3%, respectively and applied to 20grams of maize grains in plastic jars (200ml capacity) for each treatment. The aqueous extracts were stirred gently with glass rod for 4 to 5 minutes in order to ensure uniform distribution of extracts on the grains. The treated maize grains were removed from the plastic jars containing the aqueous extracts and were kept for 1hour on blotting paper in order to dry the seeds before the start of trials. For control, 20grams seeds were treated with distilled water only and were kept in separate jars.

Ten pairs of newly emerged adult weevils were introduced in each plastic jar. The muslin cloth was used to cover the plastic jars and tightened up with rubber bands in order to provide aeration and halt the passage of weevils from the jars. Experiment was arranged in Completely Randomized Design (CRD), with five replications for each treatment.

To record the data on the mortality of adult weevils, the number of dead insects were counted after 1, 2, 3, 7, 14 and 21days, respectively, after treatment. The cumulative mortality of the weevils was assessed by using Abott's (1925) formula:

Where: $PT = (P_o - P_c) / (100 - P_c)$, PT= percentage of corrected mortality, P_0 = percentage of observed mortality, P_c = Percentage of control mortality

Statistical analysis

Recorded data were subjected to analysis of variance (ANOVA) and means were separated by applying least significant difference (LSD) test at ($P<0.05$). One way (ANOVA) was applied to investigate the effectiveness of treatment and varied concentrations of plant aqueous extracts against maize weevil. All statistical analyses were conducted by using STATISTIX version 8.1.

Results

Mortality of maize weevil after 1 day

The effect of different treatments at all the evaluated concentrations except the highest (3%) on the adult mortality of maize weevil after 1day exposure period was non-significantly different ($P>0.05$) (Table 1). Among the treatments, the *A. indica* and *C. longa* aqueous extracts indicated the highest adult mortality of 7.00% followed by *A. sativum* (5.00%) at the highest concentration whereas no mortality was recorded on untreated maize grains. The efficacy of the treatments was in the sequence of *A. indica* and *C. longa* > *A. sativum* > *C. colocynthis* > *C. tuberculata* > *C. procera* compared with control. The efficacy of the treatments increased linearly with increasing the concentration of the evaluated extracts. Maximum concentration (3%) of *A. indica* was found most effective causing 7.00% mortality of the targeted insect followed by 2.5, 2, 1.5, 1 and 0.5% causing 6.00, 5.00, 3.00, 3.00 and 2.00 % adult mortality, respectively. No mortality was registered in control treatment having untreated maize grains.

Mortality of maize weevil after 2 days

After an exposure period of 2 days, the maximum adult mortality of maize weevil (23%) was observed in *A. indica* treated maize grains which differed significantly from all other treatments followed by *C. longa* (18%) at 3% concentration. Among the treatments, the minimum adult mortality of 6.00% was recorded on maize grains treated with *C. procera* aqueous extracts which differed non-significantly from 8.00% mortality in *C. colocynthis* treated maize grains. No mortality was observed when maize weevil was reared on untreated maize grains. The efficacy of the treatments decreased with decreasing the concentration of the selected botanical extracts. Among the tested concentrations, the highest concentration (3%) was found most effective, whereas; the lowest concentration (0.5%) was found least effective against the weevils (Table 2). The efficacy of the treatments was found in the array of *A. indica* and *C. longa*> *A. sativum* > *C. colocynthis* > *C. tuberculata* > *C. procera*

compared with control.

Mortality of maize weevil after 3 days

Table 3 presents the mortality of maize weevil after 3 days exposure period on maize grains treated with different concentrations of botanical extracts. From the results shown, it was observed that the mortality of maize weevil increased with increase in the concentration and exposure period to treated grains. The highest adult mortality (43.00%) of weevil was recorded on maize grains treated with 3% concentration of *A. indica* extracts which was followed by (27.00%) mortality at the highest concentration of *C. longa* extracts and 2.5% *A. indica* and *C. longa* extracts (26.00 and 22.00%). Among the treatments the least mortality was observed in *C. procera* and *C. colocynthis* extracts at all the evaluated concentrations. No. mortality of the weevils was observed in untreated maize grains.

Mortality of maize weevil after 7days

At 7days after treatment, significant increase in the efficacy of botanical extracts against weevils was recorded (Table 4). Among the treatments, *A. indica and C. longa* extracts were found the most effective at all the evaluated concentrations ranging from 0.5 to 3%, whereas the *C. tuberculata* and *C. procera* extracts were found the least effective. The highest adult mortality of 78% was recorded on maize grains treated with *A. indica* extracts followed by *C. longa* (70%) and *A. sativum* (50.00%) extracts whereas minimum adult mortality of 21% was observed in *C. procera* treated grains at 3% compared with control (2%).

Mortality of maize weevil after 14 days

Table 5 shows that all the evaluated plant aqueous extracts significantly affected ($P<0.05$) the mortality of adult weevils at 14 days after exposure compared with control. The maximum adult mortality of 88% was observed in *A. indica* treated maize grains followed by *C. longa* (78%) and the least (23%) was observed in *C. procera* treated grains at maximum concentration of 3% compared with control (2 %). Among the evaluated plant aqueous extracts *A. indica* and *C. longa* extracts caused maximum mortality whereas *C. tuberculata* and *C. procera* extracts caused minimum mortality of maize weevil. The *A. indica* extracts registered more than 50% mortality of weevils at all the evaluated concentrations except the lowest concentration of 0.5%, whereas *C. longa* extracts caused more than 50% mortality at concentrations ranging from 1.5 to 3%. The *A. sativum* extracts resulted into 53.00% mortality of weevils at highest concentration of 3%. All other treatments at the evaluated concentrations could not register ≥ 50% mortality of weevils.

Mortality of maize weevil after 21 days

It is clear from the results that the mean percent mortality is directly proportional to the exposure period and concentration of evaluated extracts. Although none of the tested plant extracts caused 100% adult mortality, the *A. indica* extracts caused 95.00% adult mortality which differed non-significantly from 91.00% adult mortality in *C. longa* extracts followed by 60.00% mortality on *A. sativum* treated grains at maximum concentration of 3%. Among the evaluated treatments, the *A. indica* and *C. longa* extracts caused ≥ 50% adult mortality at concentrations ranging from 1 to 3%. All other evaluated plant extracts caused < 50% mortality of weevils at all the evaluated concentrations except *A. sativum* extracts at 2.5% causing 54.00% weevil mortality. Among the treatments, *C. tuberculata* and *C. procera* were found the least effective treatments against the tested insect. Overall, at 21 days after exposure, the lowest adult mortality of 0.23% was recorded when maize weevil was reared on untreated maize grains (Table 6).

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Table 1. Mean mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 1 day exposure period

Treatments	Concentrations (%)					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**
Azadirachta indica	2.00 ± 2.73^{NS}	3.00 ± 2.73 ^{NS}	3.00 ± 2.73 ^{NS}	5.00 ± 0.00 ^{NS}	5.00 ± 2.23 ^{NS}	7.00 ± 2.73 a
Caralluma tuberculata	0.00± 0.00	0.00 ± 0.00	1.00 ± 2.23	1.00 ± 2.23	2.00 ± 2.73	2.00 ± 2.73 cd
Allium sativum	1.00± 2.23	2.00 ± 2.73	2.00 ± 2.73	3.00 ± 2.73	4.00 ± 4.18	5.00 ± 0.00 ab
Curcuma longa	2.00± 2.73	3.00 ± 2.73	3.00 ± 2.73	4.00 ± 2.23	4.00 ± 0.00	7.00 ± 2.73 a
Citrullus colocynthis	1.00 ± 2.23	1.00 ± 2.23	2.00 ± 2.73	2.00 ± 2.73	2.00 ± 2.73	4.00 ± 2.23 bc
Calotropis procera	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.00 ± 2.23	2.00 ± 2.73 cd
Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00 d
LSD Value	2.04	3.56	3.89	5.44	5.19	2.89

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

Table 2. Mean cumulative mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 2 days exposure period

Treatments	Concentrations (%)					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**
Azadirachta indica	4.00 ± 2.23 a	10.00 ± 3.53 a	12.00 ± 2.73 a	19.00 ± 4.18 a	20.00 ± 3.53 a	23.00 ± 2.73 a
Caralluma tuberculata	0.00 ± 0.00 b	2.00 ± 2.73 d	3.00 ± 2.73 de	4.00 ± 2.23 de	5.00 ± 0.00 d	7.00 ± 2.73 d
Allium sativum	2.00 ± 2.73 ab	6.00 ± 2.23 bc	6.00 ± 2.23 cd	8.00 ± 2.73 c	11.00 ± 4.18 c	13.00 ± 12.73 c
Curcuma longa	3.00 ± 2.73 a	8.00 ± 2.73 ab	10.00 ± 3.53 ab	12.00 ± 2.73 b	16.00 ± 4.18 b	18.00 ± 2.73 b
Citrullus colocynthis	2.00 ± 2.73 ab	3.00 ± 2.73 cd	7.00 ± 2.73 bc	7.00 ± 2.73 cd	6.00 ± 2.23 d	8.00 ± 2.73 d
Calotropis procera	0.00 ± 0.00 b	1.00 ± 2.23 d	2.00 ± 2.73 e	2.00 ± 2.73 ef	4.00 ± 2.23 d	6.00 ± 2.23 d
Control	0.00 ± 0.00 b	0.00 ± 0.00 d	0.00 ± 0.00 e	0.00 ± 0.00 f	0.00 ± 0.00 e	0.00 ± 0.00 e
LSD Value	2.56	3.28	3.37	3.54	3.71	3.19

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

Table 3. Mean cumulative mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 3 days exposure period

Treatments	Concentrations (%)					
	0.5	1	1.5	2	2.5	3
Azadirachta indica	12.00 ± 2.73 a	13.00 ± 2.73 a	15.00 ± 3.53 a	22.00 ± 2.73 a	26.00 ± 4.18 a	43.00 ± 4.47 a
Caralluma tuberculata	2.00 ± 2.73 cd	3.00 ± 2.73 cd	5.00 ± 3.53 cd	8.00 ± 2.73 c	8.00 ± 2.73 c	12.00 ± 2.73 d
Allium sativum	6.00 ± 2.23 b	7.00 ± 2.73 b	9.00 ± 2.23 bc	10.00 ± 3.53 c	14.00 ± 4.18 b	19.00 ± 2.23 c
Curcuma longa	8.00 ± 2.73 b	12.00 ± 2.73 a	13.00 ± 2.73 ab	16.00 ± 4.18 b	22.00 ± 2.73 a	27.00 ± 2.73 b
Citrullus colocynthis	5.00 ± 3.53 bc	6.00 ± 2.23 bc	7.00 ± 2.73 cd	8.00 ± 2.73 c	10.00 ± 3.53 bc	18.00 ± 2.73 c
Calotropis procera	2.00 ± 2.73 cd	2.00 ± 2.73 d	4.00 ± 5.47 de	7.00 ± 2.73 c	7.00 ± 2.73 c	10.00 ± 3.53 d
Control	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 e	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 e
LSD Value	3.37	3.19	4.24	3.79	4.09	3.79

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

Table 4. Mean cumulative mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 7 days exposure period

Treatments	Concentrations (%)					
	0.5	1	1.5	2	2.5	3
Azadirachta indica	27.00 ± 2.73 a	40.00 ± 3.53 a	52.00 ± 2.73 a	65.00 ± 3.53 a	69.00 ± 2.23 a	78.00 ± 2.73 a
Caralluma tuberculata	8.00 ± 2.73 c	12.00 ± 2.73 e	18.00 ± 2.73 e	22.00 ± 2.73 d	23.00 ± 2.73 e	27.00 ± 2.73 e
Allium sativum	14.00 ± 2.23 b	24.00 ± 2.23 c	30.00 ± 3.53 c	35.00 ± 3.53 c	45.00 ± 3.53 c	50.00 ± 3.53 c
Curcuma longa	24.00 ± 4.18 a	36.00 ± 4.18 b	46.00 ± 4.18 b	45.00 ± 3.53 b	62.00 ± 2.73 b	70.00 ± 3.53 b
Citrullus colocynthis	12.00 ± 2.73 b	17.00 ± 2.73 d	24.00 ± 2.23 d	25.00 ± 3.53 d	35.00 ± 6.12 a	39.00 ± 4.18 d
Calotropis procera	6.00 ± 2.23 c	7.00 ± 2.73 f	9.00 ± 2.23 f	13.00 ± 2.73 e	15.00 ± 3.15 f	21.00 ± 2.23 d
Control	0.00 ± 0.00 d	2.00 ± 2.73 g	2.00 ± 2.73 g	1.00 ± 2.23 f	2.00 ± 2.73 g	2.00 ± 2.73 g
LSD Value	3.46	3.94	3.87	4.09	4.64	4.09

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

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Table 5. Mean cumulative mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 14 days exposure period

Treatments	Concentrations (%)					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**
Azadirachta indica	37.00 ± 4.47 a	52.00 ± 2.73 a	69.00 ± 4.18 a	75.00 ± 3.53 a	82.00 ± 2.73 a	88.00 ± 2.73 a
Caralluma tuberculata	8.00 ± 2.73 e	14.00 ± 2.23 e	23.00 ± 2.73 e	26.00 ± 2.23 e	29.00 ± 4.18 e	30.00 ± 3.53 e
Allium sativum	19.00 ± 4.18 c	29.00 ± 4.18 c	42.00 ± 2.73 c	41.00 ± 4.18 c	45.00 ± 3.53 c	53.00 ± 2.73 c
Curcuma longa	30.00 ± 5.00 b	46.00 ± 2.23 b	53.00 ± 2.73 b	63.00 ± 2.73 b	70.00 ± 3.53 b	78.00 ± 2.73 b
Citrullus colocynthis	13.00 ± 2.73 d	22.00 ± 2.73 d	28.00 ± 4.47 d	31.00 ± 4.18 d	38.00 ± 2.73 d	40.00 ± 3.53 d
Calotropis procera	7.00 ± 2.73 e	10.00 ± 3.53 f	14.00 ± 2.23 f	18.00 ± 2.73 f	20.00 ± 3.53 f	23.00 ± 2.73 f
Control	1.00 ± 2.23 f	2.00 ± 2.73 g	2.00 ± 2.73 g	1.00 ± 2.23 g	2.00 ± 2.73 g	2.00 ± 2.73 g
LSD Value	4.64	3.87	4.16	4.16	4.31	3.87

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

Table 6. Mean cumulative mortality (%) of maize weevil due to different plant aqueous extracts and its varying concentrations on maize grains after 21 days exposure period

Treatments	Concentrations (%)					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**
Azadirachta indica	42.00 ± 4.47 a	56.00 ± 4.18 a	73.00 ± 2.73 a	78.00 ± 2.73 a	87.00 ± 2.73 a	95.00 ± 3.53 a
Caralluma tuberculata	11.00 ± 4.18 e	20.00 ± 3.53 e	28.00 ± 2.73 d	30.00 ± 3.53 e	33.00 ± 4.47 e	35.00 ± 3.53 d
Allium sativum	24.00 ± 4.18 c	33.00 ± 2.73 c	47.00 ± 2.73 c	46.00 ± 4.18 c	54.00 ± 4.18 c	60.00 ± 3.53 b
Curcuma longa	35.00 ± 5.00 b	48.00 ± 2.73 b	56.00 ± 4.18 b	67.00 ± 2.73 b	70.00 ± 3.53 b	91.00 ± 4.18 a
Citrullus colocynthis	18.00 ± 2.73 d	26.00 ± 4.18 d	29.00 ± 4.18 d	36.00 ± 4.18 d	43.00 ± 4.47 d	48.00 ± 2.73 c
Calotropis procera	10.00 ± 3.53 e	12.00 ± 2.73 f	16.00 ± 4.18 e	21.00 ± 2.23 f	20.00 ± 3.53 f	26.00 ± 2.23 e
Control	1.00 ± 2.23 f	2.00 ± 2.73 g	2.00 ± 2.73 f	1.00 ± 2.23 g	2.00 ± 2.73 g	2.00 ± 2.73 f
LSD Value	5.01	4.31	4.44	4.16	4.83	4.24

Each value is a mean ± standard error of five replications. Means followed by the same letters along the column are not significantly different at (P>0.05) using LSD Test

Discussion

A superior entomocidal effectiveness of *A. indica* and *C. longa* plant aqueous extracts against maize weevil was observed in present study. These results are in conformity with the previous studies in which *A. indica* extracts were found most effective against maize weevil [12]. These results also confirm the findings of previous workers who reported that neem extracts carry insecticidal properties against *Cylas puncticollis* in Potato tuber. Neem oil caused 100% mortality whereas neem leaves extract produced moderate mortality of the tested insects [13]. Similarly, *C. longa* has been reported to carry insecticidal and repellent properties against, *Spodoptera frugiperda* and *S. zeamais*. The *C. longa* extracts caused complete mortality of maize weevil after 6 days of contact with Ar-turmerone at 1% (mm^{-1}) while 58% mortality of *S. frugiperda*. The *S. frugiperda* caterpillars exposed to ar-turmerone were 60.0% and 93.8% lower than control caterpillars, respectively. The direct contact of ar-turmerone on target insect achieved 100 percent mortality [5]. Whereas, in our study turmeric extracts caused significant mortality of adult weevils. Similarly, previous studies showed that seed extract of black pepper, *Piper guineese*, prepared in different solvents and found that acetone extract had highest toxicity (100%) while aqueous extract had low toxic effect [11]. The extracts prepared from ar-turmerone (*C. longa*) have been reported to cause 60.0 and 93.8% control of maize weevil. All the other evaluated extracts resulted into less than 50% mortality of weevils except *A. indica* extracts at 15000, 20000 and 25000ppm [7].

According to our findings *A. indica* extracts caused 95% mortality followed by *C. longa* (91%) extracts at highest concentration of 3%. The array of toxicity was found as *A. indica* (98.00%) >*Polygonum hydropiper* (94.43%) >*Nerium oleander* (56.63%)>*C. procera* >*Annonareticulate*. Mortality percentage was found directly proportional to exposure time after treatment. The *A. sativum* plant extracts were found effective against larvae of *Scyphophorus acupuntatus* along with other plant extracts. Maximum mortality of maize weevil was found by using *A. mexicana* (53%), *A. sativum* (43%) and *T. erecta* plant extracts [14].

In entomocidal effect study chemical constituents are involved which affect the biology and survival of insect pests. Similar results have been reported by different scientists in which neem extracts were found effective against different stored grain insect pests which have been attributed to the presence of many phyto-chemicals such as Azadirachtin, triterpenoids, meliantriol, salanin etc. [15]. Similarly, *C. longa* extracts have been reported to carry many phytochemicals such as Curcuminoids, monoterpinoids, terpenoids, odoriferous oils and oleoresins, turmerone and *ar*-turmeronephyto-chemicals constituents which strongly affect as repellant and antifeedent against stored grain insect pests [16-18]. The *C. longa* extracts having ar-turmerone caused maximum mortality of maize weevil [19]. The mortality of maize weevil increased by increasing the concentration of essential oils of *C. longa*. These findings agree to the present study in which the highest concentration (3%) exhibited the maximum mortality (91%) of tested insect. The *A. sativum* extracts possess flavonoids (Rutins) and sulfur compounds including allicine which affect the feeding behavior of noctuid larvae [12].

Conclusion and recommendations

Hence, it is concluded that *A. indica* and *C. longa* aqueous extracts are most effective against maize weevil and could be utilized as phyto-chemicals against maize weevil.

Authors' contributions

Conceived and designed the experiments: MM Rashid, Performed the experiments: Riazuddin, Analyzed the data and reviewed

the paper. M Tariq, AA Khan & MQ Kakar.

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