



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

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Abstract

The entomocidal efficacy of six plant species including *Azadirachta indica*, *Cardamine hirsuta*, *Allium sativum*, *Curcuma longa*, *Citrus colocynthis* and *Calotropis gigantean* was studied against maize weevil cultured on maize grains (Cv. Azam white) in the laboratory of Entomology Department, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan. Six different doses *i.e.* 5000, 10000, 15000, 200000, 25000 and 30000ppm, respectively of each plant powder were applied to 20g sterilized maize grains at mean conditions of $27 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ R.H. Twenty (20) newly emerged adult maize weevils were introduced in 15cm diameter glass petri dishes on maize grains treated with the evaluated plant powders. Cumulative mortality of maize weevil was recorded after 24 hours to 21 days exposure periods. The maximum efficacy of all the tested plant powders was found at 21 days after exposure period. Among the treatments, at 21 days after the exposure period, *A. indica* plant powder showed the maximum mean cumulative adult mortality of 91% followed by *C. longa* registering 76.66% mortality of adult maize weevil, whereas minimum adult mortality of 2.66% was recorded in control where none of the plant powders were applied. However, among the tested plant powders, least mean cumulative adult mortality of 18.66% was observed in *C. gigantean* treated grains. It was obvious from the obtained results that mortality of adult maize weevils increased with increase in the doses of the tested plant powders. On the basis of present findings, it is concluded that the tested plant powders can be utilized for the management of maize weevil.

Keywords: botanical powders, mortality, maize weevil, doses, maize grains

Introduction

Maize (*Zea mays* L.) is a multipurpose crop which can be grown in a number of different environments; it is grown on every continent except Antarctica. Maize crop, together with wheat and rice, is one of the three most important crops in the world. In Pakistan, maize is the most abundant crop following wheat and rice. The global demand for maize imports continues to increase. There is considerable competition from other coarse grain such as wheat, which can be substituted as feed for livestock, depending on available supply. Maize is presently recognized as one of the most important food crops cultivated in tropical countries (Asawalam and Hassanali, 2006; Masood *et al.*, 2020) ^[7, 22]; as main source of nutrition for one-third of the world's poorest population in Sub-Saharan Africa and South-East Asia (Abdurahman, 2009) ^[1]. Maize provides 20% of the world's food calories and 15% protein obtained from all food crops (Meseret, 2011) ^[23]. The maize flour is consumed in bakeries and in the manufacturing of laundry starch (Ogungbite and Oyeniyi, 2014) ^[5]. Keeping in view the importance of maize crop in human food; it is imperative to pay attention to the problems of this crop *i.e.* attack of weevils, beetles and moths, in the field and during storage conditions (Akinneye and Ogungbites, 2013; Asif *et al.*, 2020) ^[11, 9]. Maize weevil (*S. zeamais*), is widespread throughout the world where maize is grown. The eggs, larval and pupal phases of the weevils are found inside the grains which give rise to adult emergence forming holes and leaving the hole leading to secondary infection (Sahaf *et al.*, 2008; Akob and Ewete, 2007) ^[6].

The fully developed weevils and larvae nourishes on intact

grains causing severe powdering, rendering the grains unfit for consumption being unhealthy for human utilization (Ofuya *et al.*, 2008). Adult and larval stages of maize weevil consume grains, causing weight losses of the infested grains (Adedire, 2001) ^[2].

The control of maize weevil has largely relied upon the use of synthetic chemical insecticides (Akinneye and Ogungbite, 2013) ^[5]. Synthetic insecticides are costly and their excessive use leads to different problems like; pest reappearance, accumulation of noxious deposit in foods and hazards to user's contagion. Their effects on human health and environmental degradation are still some more demerits of chemicals used as insecticide (Oppert *et al.*, 2010; Ogungbite and Oyeniyi, 2014; Yaqoob *et al.*, 2020) ^[4]. In order to get rid of these man-made chemical insecticides, researchers have been paying attention to the use of plant derivatives as a mean of controlling insect pests (Ogungbite and Oyeniyi, 2014; Hayat *et al.*, 2020a, b) ^[11, 17]. Emphasis is getting momentum as they are easily biodegradable and eco-friendly, have low mammalian toxicity and are safe to the environment if used in small amounts (Adedire *et al.*, 2011) ^[3]. The exploration of biodegradable, easily available; insect pest management options are attaining attention of global scientific community. Generally, plant-based products are successful and easy methods for controlling wide range of insect pests with broad spectrum of actions (Muhammad, 2009) ^[24]. This study was specifically aimed to evaluate the entomocidal effectiveness of plant powders of *A. indica*, *C. hirsuta*, *A. sativum*, *C. longa*, *C. colocynthis* and *C. gigantean* against maize weevil.

Materials and methods

The studies were carried out in the Laboratory of Entomology Department, Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK, Pakistan.

Insect cultures

The maize grains having 12-14% moisture content (MC) were sterilized, to inhibit the development of previous infestation, in deep freezer maintained at $-20 \pm 2^\circ\text{C}$ for two weeks (Isah *et al.*, 2012) [19]. All the materials used for the investigations were thoroughly cleaned. The sterilized maize grains (500g) were shifted to plastic jars. The weevils were cultured in the laboratory at $27 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ relative humidity under 12:12 hour day length (L:D). Two hundred pairs of maize weevils, one week old, were introduced in each jar. The jars were then shifted to an incubator after covering the top using muslin cloth and rubber band at controlled temperature for 10 days. The jars were left undisturbed in incubator for 20 days. New emerging adult weevils were shifted to new jars as per their age. Adult weevils emerging on the same day were considered of uniform age and were used for the studies.

Plant Powder preparation

The selected plant materials were obtained from local farmers and were washed using plenty of tap water. Plant materials were then dried under shade conditions till reaching constant weight. After drying plant materials were minced in an electric mill and were sieved for getting fine powder. The plant powders were stored at room temperature in nylon bags after due tagging (Sayonara *et al.*, 2009).

Entomotoxicity of various doses of plant powders

To investigate the toxicity of selected plant powders against maize weevil the experiment was laid out in CRD and replicated 5 times. Six doses i.e. 50000, 10000, 150000, 200000, 25000 and 30000ppm w/w and a control treatment were tested. Each treatment contained 20g of maize grains treated with different doses of plants powders. The maize grains treated with different doses of tested plant powders were shifted to Petri dishes (12cm diameter) and were well shaken to ensure complete coating of plant powders on maize grains before release of adult weevils. 20 newly emerged weevils (10 male and 10 female) were introduced in the middle of the tested arena. The weevils were starved for an hour before releasing in the arena. The data were recorded on the percent mortality of weevils after 24, 48, 72 hours, 7, 14 and 21 days, respectively, after exposure

period. The dead weevils were removed daily from the petri dishes.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) technique and means were separated with LSD test at 5% probability level. The two-way ANOVA were used to determine the effect of treatments, concentrations of plant powders and interaction between treatments and concentrations of plant materials against maize weevil. The recorded data was statistically analyzed using STATISTIX version 8.1.

Results

Mortality of maize weevil 24 hours after treatment

Effect of treatments

The mortality of maize weevil recorded after 24 hours subsequent to the use of the botanical powders was non-significantly different ($P>0.05$). However, numerically among the seven treatments *A. indica* plant powder depicted the highest adult mortality of 5.33% followed by *C. longa* (5.16 %) and minimum mortality was recorded in control (0%). The effectiveness of the treatments is in the array of *A. indica* and *C. longa* >*A. sativum*>*C. colocynthis*>*C. hirsuta*>*C. gigantean* compared with control.

Effect of concentrations

The effect of different concentrations of plant powders did not differ significantly ($P>0.05$) with respect to mortality of targeted insect. Among the concentrations, the maximum concentration of 30000ppm was found most effective causing 3.85 % mortality of the test insect followed by 25000, 200000, 150000, 10000 and 5000ppm causing 3.85, 2.85, 2.00, 1.85 and 1.42%, adult mortality, respectively.

Interactions between treatments and concentrations

The mortality of maize weevil on grains treated with different plant powders and concentrations were found non-significantly ($P>0.05$) different from cumulative weevil mortality in untreated grains (Table-1). However, numerically maximum mortality of 8% of maize weevil was recorded with (25000ppm) and (30000ppm) of *C. longa* followed by *A. indica* (7%) with concentration (25000ppm) and (30000ppm). Least (0%) cumulative adult mortality was recorded in control treatment having untreated grains. The interactions of different concentrations extending from 5000ppm to 30000ppm were found non-significant as compared with control after 24 hours of treatment.

Table 1: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder's varying concentrations and their interaction on maize grains after 24 hours exposure period

Treatments	Concentrations						Mean of treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	4.000 ^{N.S}	4.000	4.000	4.000	7.000	7.000	5.0 a
<i>Cardamine hirsute</i>	0.000	1.000	1.000	1.000	2.000	2.000	1.166 cd
<i>Allium sativum</i>	2.000	3.000	3.000	4.000	5.000	5.000	3.666 ab
<i>Curcuma longa</i>	2.000	3.000	4.000	6.000	8.000	8.000	5.166 a
<i>Citrullus colocynthis</i>	2.000	2.000	2.000	3.000	3.000	3.000	2.500bc
<i>Calotropis gigantean</i>	0.000	0.000	0.000	0.000	2.000	2.000	0.666 cd
Control	0.000	0.000	0.000	0.000	0.000	0.000	0.000 d
Mean of concentrations	1.428 c	1.857 bc	2.000 bc	2.857ab	3.857a	3.857a	

LSD for treatments = 1.938

LSD for concentrations = 1.055

LSD for interaction between treatments and concentrations = Non-significant

Mortality of maize weevil 48 hours after treatment

Effect of treatments

Cumulative mortality of maize weevil recorded after 48 hours of the application of botanical plant powders was significantly different (P<0.05) (Table 2). Among the tested plant powders, *A. indica* plant powder showed the highest adult mortality of 18.33% followed by *C. longa* (14.66 %). The lowest mortality of 0.33% was observed in control treatment. The effectiveness of the treatments is in the range of *A. indica* and *C. longa* > *A. sativum* > *C. colocynthis* > *C. hirsuta* > *C. gigantean* compared with control.

Effect of concentrations

All the tested concentrations of plant powders were found significantly different (P<0.05) with respect to cumulative mortality of maize weevil (Table-2). Among the concentrations, the highest concentration of 30000ppm exhibited 14% cumulative adult mortality after 48 hours followed by (25000ppm) registering 12.14% adult mortality and least (5000ppm) with 2.28% mortality. Thus, among the tested dosages of plant powders, the maximum dose of 30000ppm was found most effective against adult maize

weevil.

Interactions between treatments and concentrations

The cumulative mortality of maize weevil on grain treated with different plant powders at different concentrations were found significant (P>0.05) different (Table-2). Maximum cumulative mortality (27%) of maize weevil was recorded with (30000ppm) of *A. indica* followed by *A. indica* (26%) at (25000ppm) and least (0%) at (5000ppm) concentration, respectively of *C. gigantean* plant powder and control treatment having untreated grains.

The effectiveness of different treatments in interactions of different concentrations extending from 30000 ppm to 5000 ppm are in the array of *A. indica* > *A. indica* > *A. indica* > *C. longa* > *C. longa* > *C. longa* > *A. indica* > *A. sativum* > *A. sativum* > *A. indica* > *A. sativum* > *C. longa* > *C. longa* > *C. colocynthis* > *A. sativum* > *C. hirsuta* > *C. gigantean* > *C. colocynthis* > *C. colocynthis* > *C. hirsuta* > *C. colocynthis* > *C. gigantean* > *A. sativum* > *C. hirsuta* and *C. gigantean* > *A. indica* and *C. longa* > *A. sativum* and *C. hirsuta* > *C. hirsuta* > *C. colocynthis* > *C. colocynthis* > *C. colocynthis* and least *C. gigantean*.

Table 2: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder’s varying concentrations and their interaction on maize grains after 48 hours exposure period

Treatments	Concentrations						Means of mortality For treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	5.0k-n	13.0c-f	15.0cd	24.0ab	26.0a	27.0a	18.333 a
<i>Cardamine hirsute</i>	0.0 o	3.0l-o	4.0k-o	6.0i-m	8.0g-k	10.0e-i	5.167 de
<i>Allium sativum</i>	4.0k-o	7.0h-l	10.0e-i	13.0c-f	14.0c-e	15.0cd	10.500 c
<i>Curcuma longa</i>	5.0j-n	11.0d-h	12.0c-g	16.0c	21.0b	23.0b	14.667 b
<i>Citrullus colocynthis</i>	2.0m-o	3.0lm-o	8.0g-k	9.0f-j	8.0g-k	11.0d-h	6.833 d
<i>Calotropis gigantean</i>	0.0o	1.0no	2.0m-o	6.0i-m	8.0g-k	10.0e-i	4.500 e
Control	0.0o	0.0o	0.0o	0.0o	0.0o	2.0m-o	0.333 f
Mean of mortality for concentrations	2.286e	5.429d	7.286c	10.571b	12.143b	14.000a	8.619

LSD for Factor A (Treatments) = 2.2450

LSD for Factor B (Concentration) = 1.6060

LSD for Interaction A × B (treatments and concentrations) = 4.2491

Mortality of maize weevil 72 hours after treatment

Effect of treatments

Cumulative mortality of maize weevil recorded after 72 hours subsequent to the use of the botanical powders was significantly different (P<0.05) (Table 3). Among the seven treatments including control; *A. indica* plant powder showed the highest adult mortality of 28% followed by *C. longa* (21.66 %) and minimum mortality was observed in *C. gigantean* (4.50%) compared with control (2.00%). The effectiveness of the treatments is in the array of *A. indica* and *C. longa* > *A. sativum* > *C. colocynthis* > *C. hirsuta* > *C. gigantean* compared with control.

Effect of concentrations

The mortality of adult weevils increased by increasing the doses of tested plant powders. Concentrations were found significantly (P<0.05) different with respect to the

cumulative mortality of adult weevils (Table-3). Among the concentrations the (30000ppm) was found most effective causing (26.14 %) mortality of the test insect followed by (25000ppm) with (16.42%) mortality and least mortality of 6.71% was observed in (5000ppm) concentration. Among the evaluated dosages, the maximum dose (30000ppm) was found the most effective dose against the tested insects.

Interactions between treatments and concentrations

Cumulative mortality of maize weevil in grains treated with different plant powders and different concentrations were found significantly different at P<0.05 (Table-3). Maximum cumulative mortality (56 %) of maize weevil was recorded with (30000ppm) of *A. indica* followed by *C. longa* (42%) at 30000ppm and least mortality of 2% was registered with 5000ppm of *C. gigantean* plant powders and in the control having untreated grains.

Table 3: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder’s varying concentrations and their interaction on maize grains after 72 hours exposure period

Treatments	Concentrations						Means of mortality For treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	15.00h-k	18.00g-i	19.00f-h	26.00de	34.00c	56.00a	28.00a
<i>Cardamine hirsute</i>	2.00r	3.00qr	7.00n-q	10.00lm-o	11.00k-n	17.00hi	8.333e
<i>Allium sativum</i>	8.00m-p	10.00lm-o	12.00j-m	15.00h-k	16.00h-k	27.00d	14.667c

<i>Curcuma longa</i>	12.00j-m	11.00k-n	15.00h-k	23.00d-f	27.00d	42.00b	21.667b
<i>Citrullus colocynthis</i>	6.00o-r	6.00o-r	8.000m-p	11.00k-n	14.00i-l	22.00e-g	11.167d
<i>Calotropis gigantean</i>	2.00r	3.00qr	4.00p-r	8.00m-p	11.00k-n	17.00hi	7.5000e
Control	2.00r	2.00r	2.00r	2.00r	2.00r	2.00r	2.00f
Mean of mortality for concentrations	6.714e	7.571e	9.571d	13.571c	16.429b	26.143a	13.047

LSD for Factor A (treatments) = 1.8494

LSD for Factor B (concentration) = 1.8528

LSD for Interaction A × B (treatments and concentrations) = 4.9020

Mortality of maize weevil 7 days after treatment

Effect of treatments

Significant differences (P<0.05) were observed among the treatments regarding cumulative mortality of maize weevil after 7 days subsequent to the use of botanical powders (Table 4). Among the seven treatments including control; *A. indica* plant powder showed the highest adult mortality of 71% followed by *C. longa* (60.66 %) and minimum mortality of 2.33% was observed in control. The effectiveness of the treatments is in the array of *A. indica* and *C. longa* > *A. sativum* > *C. colocynthis* > *C. hirsuta* > *C. gigantean* compared with control.

Effect of concentrations

There were significant differences (P<0.05) among different concentrations of tested plant powders and control with respect to cumulative mortality of tested insect as shown in Table-4. The maximum mortality of 51.57 % was recorded when maize weevil was reared on maize grains treated with 30000ppm of plant powders, it was followed by 25000ppm of tested plant powders registering 45.85 % mortality of adult weevils, whereas the minimum dose of 5000ppm caused minimum mortality of 17%.

Interactions between treatments and concentrations

The interaction of powders and their concentration after 7 days of application showed significant variations (P<0.05) regarding cumulative mortality of maize weevil in maize grains as depicted in Table-4. The maximum cumulative mortality of (100 %) and (92%) of adult weevils was recorded in samples treated with (30000ppm and 25000ppm) of *A. indica* and the least (6%) mortality was recorded in samples treated with 5000ppm of *C. gigantean* plant powders and in the control having untreated grains. The effectiveness of different treatments in interactions of different concentrations extending from 30000ppm to 5000ppm are in the array of *A. indica* > *A. indica* > *C. longa* > *C. longa* > *A. indica* > *A. sativum* > *C. longa* > *A. sativum* > *C. longa* > *A. indica* > *A. sativum* > *C. colocynthis* > *C. longa* > *C. colocynthis* > *A. indica* > *A. sativum* > *C. longa* > *C. colocynthis* > *C. hirsuta* > *C. hirsuta* > *A. sativum* > *C. hirsuta* > *C. colocynthis* > *C. gigantean* > *C. hirsuta* > *A. sativum* > *C. colocynthis* > *C. gigantean* > *C. gigantean* > *C. hirsuta* > *C. gigantean* and least *C. gigantean*.

Table 4: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder’s varying concentrations and their interaction on maize grains after 7 days exposure period

Treatments	Concentrations						Means of mortality For treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	39.00j-l	52.00gh	66.00d	77.00c	92.00b	100.00a	71.000a
<i>Cardamine hirsute</i>	7.00t-v	13.00rs	21.00pq	27.00no	29.00n	33.00m	21.667e
<i>Allium sativum</i>	19.00q	28.00no	39.00j-l	50.00h	60.00ef	67.00d	43.833c
<i>Curcuma longa</i>	36.00k-m	41.00ij	56.00fg	63.00de	78.00c	90.00b	60.667b
<i>Citrullus colocynthis</i>	10.00s-u	19.00q	25.00nop	35.00lm	40.00jk	44.00i	28.833d
<i>Calotropis gigantean</i>	6.00u-w	6.00u-w	11.00st	17.00qr	19.00q	24.00op	13.833f
Control	2.00w	2.00w	2.00w	2.00w	3.00vw	3.00vw	2.333g
Mean of mortality for concentrations	17.00f	23.00e	31.43d	38.714c	45.86b	51.57a	34.595

LSD for Factor A (treatments) = 2.250

LSD for Factor B (Concentrations) = 1.3942

LSD for Interaction A × B (treatments and concentrations) = 3.688

Mortality of maize weevil 14 days after treatment

Effect of treatments

The mean cumulative percent adult mortality of maize weevil was significantly affected (P<0.05) by all the tested plant materials at 14 days after confinement compared to control. The maximum mean adult mortality of 79.50% was recorded on grains treated with *A. indica* plant powder followed by *C. longa* (69.83 %) and minimum mortality of 17.66% was observed in *C. gigantean* treated grains compared to control (2.33%). Among the evaluated plant powders, the *A. indica* and *C. longa* powders were found most effective whereas; *C. colocynthis* and *C. gigantean* powders were found least effective against maize weevil at 14 days after confinement (Table 5).

Effect of concentrations

Adult cumulative mortality increased significantly (P<0.05) with an increase in the concentration of the evaluated plant powders at 14 days post confinement period. Data depicted that among the tested concentrations the highest concentration of 30000ppm was found most effective whereas; lowest concentration of 5000ppm was found least effective. The mortality of maize weevil varied among the evaluated concentrations and decreased in the order of 30000>25000>20000>15000>10000>5000ppm, respectively.

Interactions between treatments and concentrations

Interaction of different plant powders and concentrations were found significantly different at (P<0.05) regarding mortality of *S. zeamais* in maize grains as shown in Table-5. Though adult mortality increased with increase in

concentration of different treatments, yet, maximum cumulative mortality (100 %) of maize weevil was recorded with two concentrations (30000ppm) and (25000ppm) of *A. indica* and least mortality (6%) was recorded in 5000ppm of *C. gigantean* plant powders and in the control having untreated grains.

The effectiveness of different treatments in interactions of different concentrations extending from 30000ppm to 5000ppm are in the array of *A. indica*>*A. indica*>*C.*

longa>*A. indica*> *C. longa*>*A. indica*>*C. longa*>*A. sativum*>*C. longa*> *A. sativum*>*A. sativum*>*A. indica*> *A. indica*> *C. colocynthis*>*C. longa*> *C. colocynthis*> *A. sativum*> *C. hirsuta*> *C. colocynthis*> *C. hirsuta*> *A. sativum*> *C. hirsuta*> *C. sativum*> *C. colocynthis*> *C. gigantean* > *C. hirsuta*> *C. colocynthis*> *C. gigantean* > *C. gigantean* > *C. longa* > *C. hirsuta*> *C. gigantean* > *C. colocynthis*>*C. gigantean*> *C. gigantean*> *C. colocynthis*> *C. gigantean*and least *C. gigantean*.

Table 5: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder’s varying concentrations and their interaction on maize grains after 14 days exposure period

Treatments	Concentrations						Means of mortality For treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	50.00h	56.00g	80.00c	91.00b	100.00a	100.00a	79.500a
<i>Cardamine hirsute</i>	9.00uv	17.00rs	25.00o-q	33.00m	42.00kl	44.00jk	28.33e
<i>Allium sativum</i>	38.00l	32.00mn	45.00ijk	59.00fg	63.00f	72.00de	48.67c
<i>Curcuma longa</i>	21.00qr	49.00hi	68.00e	74.00d	90.00b	100.00a	69.83b
<i>Citrullus colocynthis</i>	14.00st	24.00pq	28.00no	43.00jk	47.00h-j	50.00h	34.33d
<i>Calotropis gigantean</i>	6.00vw	12.00tu	17.00rs	22.00pq	23.00pq	26.00op	17.67f
Control	2.00w	2.00w	2.00w	2.00w	3.00vw	3.00vw	2.33g
Mean of mortality for concentrations	20.00f	27.429e	37.857d	46.286c	52.571b	56.429a	34.595

LSD for Factor A (treatments) = 2.447

LSD for Factor B (concentrations) =1.514

LSD for Interaction A × B (treatments and concentrations) = 4.007

Mortality of maize weevil 21 days after treatment

Effect of treatments

The results of plant powders toxicity against maize weevil showed that all the tested plant products caused significant mortality (P<0.05) of the targeted insect at 21 days after post exposure period compared to control. Among the seven treatments, including control, *A. indica* plant powder was found most effective causing 91% cumulative adult mortality followed by *C. longa* (76.66 %) and minimum mortality of 2.66% was observed in control. The efficacy of the evaluated plant products increased with the increase in the post-exposure time, the effectiveness of the treatments was found in the range of *A. indica* and *C. longa* >*A. sativum*>*C. colocynthis*>*C. hirsuta*>*C. gigantean* compared with control.

Effect of concentrations

The mortality of the maize weevil increased significantly (P<0.05) with the increase in the concentration of the evaluated plant products (Table 6). Among the evaluated concentrations, the highest concentration of 30000ppm was found most effective causing 57.42 adult cumulative mortality of the test insects, whereas; the lowest concentration of 5000ppm was found least effective showing 24.28 % cumulative adult mortality. The mortality of the maize weevil decreased in the range of

30000>25000>20000>15000>10000>50000.

Interactions between treatments and concentrations

Interaction of different plant powders and different concentrations were found significantly different (P<0.05) for cumulative mortality of maize weevil. The data depicted in Table-6 showed that adult mortality and bio-cidal effect increased with increase in the concentration of different plant powders. However, maximum cumulative mortality of 100 % was recorded with 25000 and 30000 ppm of *A. indica* and *C. longa* plant powders and least mortality of 7 % was recorded in 5000ppm concentration of *C. gigantean* plant powder and control having untreated grains. Moreover, the effectiveness of different treatments in interactions of different concentrations extending from 5000 to 30000ppm were found in the sequence of *A. indica* and *C. longa* >*A. indica* and *C. longa* >*A. indica*>*A. indica*> *C. longa*>*A. indica*>*C. longa*>*A. sativum*>*A. indica*>*A. sativum*>*A. sativum*> *C. longa* > *A. sativum*> *C. colocynthis*> *A. hirsuta*>*A.colocynthis*> *C. hirsuta*> *C. longa* >*A. sativum*>*C. hirsuta*> *C. colocynthis*> *A. gigantean* > *C. gigantean* > *C. hirsuta*> *C. colocynthis*> *A. sativum*>*C. gigantean* > *C. hirsuta*> *C. gigantean* > *C. colocynthis*> *C. gigantean* > *C. hirsuta*and least *C. gigantean*.

Table 6: Mean cumulative mortality (%) of maize weevil due to different plant powders, plant powder’s varying concentrations and their interaction on maize grains after 21 days exposure period

Treatments	Concentrations						Means of mortality For treatments
	5000ppm	10000ppm	15000ppm	20000ppm	25000ppm	30000ppm	
<i>Azadirachta indica</i>	72.00d	84.00c	93.00b	98.00a	100.00a	100.00a	91.167a
<i>Cardamine hirsute</i>	9.00pq	17.00n	25.00k-m	33.00j	42.00i	44.00i	28.333e
<i>Allium sativum</i>	23.00lm	33.00j	52.00g	63.00f	67.00e	75.00d	52.167c
<i>Curcuma longa</i>	41.00i	52.00g	75.00d	92.00b	100.00a	100.00a	76.667b
<i>Citrullus colocynthis</i>	14.00no	24.00lm	28.00k	43.00i	48.00h	52.00g	34.833d
<i>Calotropis gigantean</i>	7.00qr	12.00op	17.00n	22.00m	26.00kl	28.00k	18.667f
Control	4.00rs	2.00s	2.00s	2.00s	3.00s	3.00s	2.667g

Mean of mortality for concentrations	24.286f	32.00e	41.714d	50.42c	55.143b	57.429a	43.5000
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LSD for Factor A (treatments) = 2.447

LSD for Factor B (concentrations) = 1.514

LSD for Interaction A×B (treatments and concentrations) = 4.0079

Discussion

The cumulative results of treatments (plant powders), their concentrations and period of exposure are in line with the findings of Ogban *et al.*, (2015) they reported that *A. loeracea* leaves and *L. camara* showed significant mortality of maize weevil at higher doses of 3 to 5% concentrations whereas, minimum efficacy was recorded at 1% concentration. They further revealed that efficacy of plant powders on the weevils was dose dependent, higher doses provided high protection of grains. These findings support our results in which all the tested plants' powders showed strong efficacy at higher doses of 25000 and 30000ppm whereas least cumulative mean mortality was found at lowest dose of 5000ppm. Sarangthem *et al.*, (2010) also reported comparable results but with different plant powders, however, efficacy trend was similar. However, the effectiveness of plant powders increased with increase in application time. The *A. indica* and *C. longa* plant powders showed considerable cumulative mortality of maize weevil after 48 hours exposure period. Nwachukwu *et al.*, (2014) conducted contact toxicity tests and reported that the *Allium Sativum* juice (having the allicin chemical compound) registered maximum mortality of maize weevil while in our study it stand at third position out of six plant powders showing moderate efficacy. This may be due to low allicin in crude plant powders as compared to garlic juice. Nukenine *et al.*, (2011)^[26] studied the efficacy of NeemAzal powder, two local neem products [neem seed powder (NSP) and neem seed oil (NSO)], as well as a local Lamiaceae, *Plectranthus glandulosus* leaf powder, applied at four different rates for the control of maize weevil. They reported that NeemAzal was superior compared to local neem products in grain protection against germination loss, with *P. glandulosus* being the least effective and recommended that NeemAzal and NSO had sufficient efficacy to be a component of an integrated management package for the control of maize weevil.

Nzulu & Okonkwo (2016)^[28] reported that *C. colocynthis* seeds extract showed 50% mortality of *Callosobruchus maculatus* while in our study 18.66% mortality was registered with *C. colocynthis* powders. These contrast results may be due to low concentration of toxic substance in fruit while higher in seeds. Secondly, in their study the efficacy of *C. colocynthis* seeds against *C. maculatus* which is a fragile insect compared to maize weevil which is a hard-bodied insect. Oni *et al.*, (2007) also reported that higher doses of plant powders carry significant mortality of maize weevil which agrees with our findings having maximum mortality of adult weevils when *A. indica* and *C. longa* plant powders were used at higher doses of 25000 and 30000ppm.

Conclusion

Among the tested plant powders, the powders of *A. indica* and *C. longa* caused significant mortality of adult weevils and could be used for the effective and safer management of maize weevil.

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