

Impact of Phytopesticides on *Trogodermagranarium* Everts (Coleoptera: Dermestidae) in Stored Wheat

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Abstract: Khapra beetle is considered as an economically important pest of stores grains. Although chemical treatment of stored grains against pests is cheaper and time saving but it has adverse effects on human health and eco-system. Therefore, efforts to manage these pests through plant extracts is required to implemented to prevent any contamination of synthetics in stored grains. Present study was designed to evaluate the effectiveness of some plants having insecticidal properties against Khapra beetle infesting the wheat grains. The mortality, repellency, growth inhibition effect and anti-feedant activities of botanicals were examined under laboratory condition. All of the botanicals provided significantly more mortality of Khapra beetle (Larval stage). Neem leaves and Kortuma peel extracts @ 15% provided 32.10%-30.86% mortality respectively after 9-days of treatment. Dirakh and Datura with 27% beetle mortality were followed by Shahtara, Kinow and Grape-fruit extract with ~20% mortality. All the products showed good repellent effects against Khapra beetle. In another experiment Neem, Dirakh, Kortuma and Datura inhibited the insect (Pupa, Adult) ranging from 37.34% to 50%. The final storage losses of wheat grains treated with these botanicals were also decrease significantly as compared to control. Findings suggested that most these botanicals are effective to control the pest infestation in stored grains.

Key words: Khapra Beetle • Grains Insect Pests • *Triticumasetivum* • Botanicals

INTRODUCTION

Khapra beetle *Trogodermagranarium* Everts (Coleoptera: Dermestidae) manifest their population in stored grains causing qualitative as well as quantitative losses. The grains sometimes left unusable by human being due to presence of huge amounts of fuss and damaged grains. The population of khapra beetle is affected by several factors biotic and abiotic in nature. But it is always necessary to control and eliminate this beetle from grains to get quality products.

The control and management of stored grain insect pests by the use of insecticides and fumigation technique has caused a number of difficulties in managing these insect pests. These problems include change in behaviour and development of resistance against the insecticides in different regions of the world [1, 2], often leading to control failure. Among various problems faced by using

chemical and synthetic insecticide, most serious are resistance in insect pest species, pest resurgence, widespread environmental hazards, residual toxicity and increase cost of application of presently used synthetic pesticides have directed the need for; effective bio gradable pesticides [3-5].

Stored grain pests have become resistant against chemical pesticides therefore it is needed to develop some alternate strategy to control these pests. Recently researchers' attention is diverted to essential oils from various medicinal plants those can serve as toxic for the pests but are safe for humans and animals. These oils of plant origin can be used to control insect pests of stored grain [6-9].

Plant origin products are getting better consideration as prophylactic measures for the control of pests in storage, due to security to other than target pests [10]. Capsicum had also confirmed its potent action against the pests in rice storage, Angomious grain moth [11].

The extracts obtained from *Piper guineense* and the extracts derived from *Piper nigrum* have been tested for their toxic and repellent affect some stored products insect pests [12].

Insecticidal effect of many plants against pests of stored grain has been demonstrated [13-18]. Many plant derived substances showed high physiological and behavioral activities against pests of stored grain, which includes repellent, toxic, antifeedant effects [19]. Turmeric oil and turmeric powder had repellent effects against a large number of stored grain pests [20-22]. Essential oils of aromatic plants which have rich insecticidal properties could be used as alternative insecticides [23, 24]. Several products of floral species have been evaluated to act as repellents, toxicants and antifeedants against a number of Coleopteran species that attack stored grain and their products [25, 26].

The extracts of plants having medicinal value are thought to be non-pollutant, less toxic and easily bio-degradable. A number of plants have already been reported to possess repellent action against stored grain pests [27, 28]. Among all these plants, Neem tree proved to be a good source for the control of these insect pests in the form of neem oil extracts and even seed water extracts. Its safe nature makes neem a better choice to the other synthetic chemicals. The compounds of prime importance in neem are Azadirachtin, Salanin, Nimbin and Malentrol which have different effects such as feeding deterrence, repellence, ovipositional inhibition and growth regulating against a great variety of insects [29].

Due to increasing environmental concerns and health consciousness efforts have been being made for plant derived and ecological safe repellent. The repellent that are derived from plants are superior to synthetically derived compounds; on the other hand, oils that are derived from plants for their repellent action is short lived due to their volatility. Moreover, plant material that is grinded into powder form [30], extracts obtained from plants [31] and the oils derived from plant material [32-34] has been prove to be lethal for their deterrent action against pests in storage.

Food-grain protection from pest insects through synthetic insecticides and fumigants has, since long, been a usual practice and an indiscriminate use of various insecticides has, from time to time, created a number of risks, like, genetic resistance in pest insects, contamination of food products with toxic residues, increased cost of application, handling hazards, ecological disorders etc. Such alarming issues have signified the need for some biodegradable and nature-friendly

pesticides, in order to replace the undesirable ones. Botanicals are one of the groups of safe insecticides, which have a broad spectrum of anti-pest activity, relatively specific mode of action, low mammalian toxicity and more tendency to disintegrate, in nature or to metabolize in a biological system. Moreover, their preparation and application, at farm level are more convenient for the farmers. Accordingly, the botanical pesticides are quite incorporable in the integrated-pest-management programs. Furthermore, the developed nations of the globe are emphasizing upon the adoption of organic farming for the conservation of the world health as well as for the development of sustainable agriculture. Therefore, it was imperative for us to utilize botanicals for the organic control of stored-food pest insects.

Present study was aimed to assess the dose rates of the indigenous plant extracts against the khapra beetle that lead to eco-friendly management of stored grains.

MATERIALS AND METHODS

Preparation of the Plant Extracts: *Azadirachta indica* (Neem) seeds and leaves, *Millia azadiraik* (Dharaik) seeds and leaves, *Colosynthus citrullus* (kourtumma) fruit, *Dhatura alba* (Datura) leaves, *Fumaria indica* (Shahtara plant) leaves and peel of *Citrus reticulata* (Kinnow) and *Citrus paradesi* (Grapefruit) extract were made in an organic solvent (acetone). For this purpose 50g powder of each plant parts was taken in labeled flasks. Then 100 ml of acetone was added to each flask. The samples were then loaded on the rotary shaker. The rotary shaker was run for 24 hours at 120 rpm. After shaking the samples were removed from the rotary shaker and filtered. Suction was turned on by inserting the screen in a conical flask until all filtrate was separated from residue. The filtrate was concentrated with a rotary evaporator under reduced pressure at 50°C to afford crude acetone extract. These crude acetone extracts (10ml) served as stock solution. The solution was then collected in Teflon bottle and tightly closed to check quality loss and kept at low temperature in refrigerator. Stock solution was then fractionated into 100 ml ethanol to get a 10 % (w/v) concentrated extract at time of application. Thus the extract were obtained and kept at low temperature in refrigerator.

For each botanical three concentrations 5%, 10% and 15% concentrations were prepared. Acetone was added to the stock solution to get 100ml solution of each concentration.

Culture of *Trogodermagranarium* (Everts): The mixed age culture of *T. granarium* (Everts) was reared by providing healthy wheat grains apparently free from insect infestation in controlled laboratory condition. The sample size of wheat grain was one kg which were fumigated and put in glass jars (20 × 15 cm). The jars were covered with muslin cloth with the help of rubber band and placed in the laboratory at 30±2°C and 65±5% RH for ten days for conditioning of grain. On the 10th day, the moisture level of grains ranged from 10-11%, which was favorable for insect growth and development. These grains were used as rearing medium. Out of the mixed age cultures collected from various destinations *T. granarium* (E) were separated at the pupal stage and then pupae were reared in an incubator at 32±2°C and 65±5% R.H. The newly emerged adults (24-48 hrs after emergence) were used for mass rearing. This mass culture was used for the further experimentation.

Mortality Test: The wheat grains samples (40 grams) were treated with the extract of each plant species at 0, 5, 10 and 15 percent concentrations. The treated grains in each sample were kept in jars. Then the larvae of khapra beetle having equal age were allowed to feed on the treated grains and the jars were covered with muslin cloth. The jars were kept at 32±2°C and 70±5% relative humidity. Data of the insect mortality were recorded at 3rd, 6th and 9th day of infestation. Percent corrected mortality was calculated using formula;

$$\text{Corrected Mortality} = 100 \times (Mt - Mc) / (100 - Mc)$$

Repellency Test: The experiment was performed in glass petri dishes measuring 80 mm. The Whatman filter paper was cut into half and used for bioassay. The experimental concentrations were applied on half of the filter uniformly by using micropipette leaving the other half as a control. Both the treated and untreated filter paper were attached with cellophane tape and placed in the petri dish. Thirty larvae were introduced at the centre of petri dish and placed them in walk growth chamber at 32±2°C and 70±5% relative humidity. The experiment was carried out in five replications. The data were recorded by observing the number of larvae present on both the treated and untreated halves after 24, 48 and 72 hours. The mean percent repellency was collected.

Growth Inhibitory Test: This experiment was performed in small plastic vials. Experimental concentrations were applied on semi crushed wheat grains and these grains were allowed to dry. Thirty larvae third larval instars of

uniform sizes at the third larvak were introduced in each ventilated vials and placed them in walk growth chamber at 32±2°C and 70±5% relative humidity. The experiment was carried out in five replications. Data %pupal emergence and adult formation in F₁ were recorded after two days interval, till the emergence of F₁ adults. The percent inhibition for pupal emergence and adult emergence was calculated by using the following formula.

$$\begin{aligned} \% \text{ Inhibition} &= 100 \times (1 - t/c) \\ t &= \text{Insect population treated group} \\ c &= \text{Insect population control group} \end{aligned}$$

Anti-Feedant Test: The wheat grains treated with different concentration were placed in jars having 200 grams treated with the experimental concentrations for each plant extracts and thirty larvae of uniform size were inserted in each jar and placed them in walk growth chamber at 32±2°C and 70±5% relative humidity. The experiment was carried out in five replications. The weight loss percentage for each plant extract and each experimental concentrations of the treated wheat grains was recorded on 30th, 60th and 90th days of experimentation. Grain weight loss %age was calculated by the following formula

$$\text{Percent Weight loss} = \frac{(W_u - N_d) - (W_d \times N_u)}{W_u \times (N_d + N_u)} \times 100$$

where;

W_u = weight of undamaged grains

N_u = number of undamaged grains

W_d = weight of damaged grains

N_d = number of damaged grains

Statistical Analysis: The data thus generated from these experiments were analyzed statistically using was subjected to ANOVA, Tukey's at 95 % level of confidence using SPSS® (IBM® Version-20, 2011).

RESULTS AND DISCUSSION

Percent Mortality of *Trogodermagranarium*: The results showed that insect exposure time, treatments and their concentrations have significant effect on *T. granarium* mortality. But the interactions between these factors were found insignificant. (df= 2, F=147.73, P<0.01 for exposure time), (df= 6, F=192.88, P<0.01 for treatments) and (df=2, F=174.67, P<0.01 for treatment concentrations), means in table 1.

Table 1: Percent corrected mortality of *Trogoderma granarium* (Mean±SE) treated with different plant extracts and their different concentrations.

Plant	Day			Mean
	3-days	6-days	9-days	
<i>Azadirachta indica</i>	22.62±1.19	25.79±0.99	27.99±1.25	25.47±0.77A
<i>Millia azadirak</i>	15.47±1.19	19.04±1.19	23.46±1.24	19.32±0.93C
<i>Kolosynthus citrullus</i>	19.04±1.19	22.61±1.19	27.57±1.25	23.08±0.96B
<i>Dhaturainoxia</i>	15.47±1.19	18.25±1.51	22.64±1.57	18.79±0.98C
<i>Fumaria indica</i>	11.90±1.19	13.09±1.19	17.28±1.23	14.09±0.81D
<i>Citrus reticulata</i>	8.33±1.19	9.52±1.19	13.58±1.23	10.48±0.80E
<i>Citrus paradesi</i>	9.12±1.05	10.71±1.03	14.81±1.07	11.55±0.75E
Mean	14.56±0.74C	17.00±0.84B	21.05±0.83A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 2: Percent corrected mortality of *Trogoderma granarium* (Mean±SE) after exposure time, treated with different plant concentrations.

Concentrations	Exposure Time			Means
	3 Days	6 Days	9 Days	
5%	11.05±1.13	13.43±1.30	17.28±1.24	13.92±0.77C
10%	14.62±1.13	17.17±1.36	21.17±1.31	17.65±0.80B
15%	18.02±1.17	20.40±1.33	24.69±1.34	21.04±0.81A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 3: Days x plant x treatment interaction mean±SE for corrected mortality

P x T	Day			P x treatment interaction mean
	3 Days	6 Days	9 Days	
P1T2	19.05±1.19	22.61±1.19	24.70±1.24	22.12±1.02
P1T3	22.61±1.19	26.19±1.19	27.17±1.23	25.32±0.92
P1T4	26.19±1.19	28.57±0.00	32.10±1.24	28.95±0.99
P2T2	11.90±1.19	15.47±1.19	19.75±1.24	15.71±1.28
P2T3	15.47±1.19	19.04±1.19	23.47±1.24	19.33±1.30
P2T4	19.04±1.19	22.61±1.19	27.16±1.23	22.94±1.32
P3T2	15.47±1.19	19.04±1.19	23.46±1.24	19.32±1.30
P3T3	19.04±1.19	22.61±1.19	28.40±1.22	23.35±1.49
P3T4	22.61±1.19	26.19±1.19	30.86±1.24	26.55±1.34
P4T2	11.90±1.19	13.09±1.19	17.28±1.23	14.09±1.01
P4T3	15.47±1.19	19.04±1.19	23.46±1.24	19.32±1.30
P4T4	19.04±1.19	22.62±1.19	27.17±1.22	22.94±1.32
P5T2	8.33±1.19	9.52±1.19	13.58±1.23	10.48±1.00
P5T3	11.90±1.19	13.09±1.19	17.28±1.23	14.09±1.01
P5T4	15.47±1.19	16.66±1.19	20.98±1.24	17.70±1.03
P6T2	4.76±1.19	5.95±1.19	9.88±1.23	6.86±0.98
P6T3	8.33±1.19	9.52±1.19	13.58±1.23	10.48±1.00
P6T4	11.90±1.19	13.09±1.19	17.28±1.23	14.09±1.01
P7T2	5.95±1.19	8.33±1.19	12.34±1.23	8.87±1.11
P7T3	9.52±1.19	10.71±2.06	14.81±2.14	11.68±1.22
P7T4	11.90±1.19	13.09±1.19	17.28±1.23	14.09±1.01

P1= *Azadirachta indica*, P2= *Millia azadirak*, P3= *Kolosynthus citrullus*, P4= *Dhaturainoxia*, P5= *Fumaria indica*, P6= *Citrus reticulata*, P7= *Citrus paradesi*

An increased mortality for *T. granarium* was observed, treated with plant extracts with passage of exposure time. The highest percent mortality was observed for *Azadirachta indica* at 3 days (22.62%), while minimum insects were found dead, treated with citrus plant extracts (9.12% and 8.33% for *Citrus paradesi* and

Citrus reticulata respectively). The same trend of more mortality was observed after 6 days exposure time for *Azadirachta indica* (25.79%). Also the citrus plant extracts showed minimum mortality after 6 days of exposure; 13.09% and 9.52% for *Citrus paradesi* and *Citrus reticulata* respectively. The mortality results after the

exposure of 9 days showed that the maximum mortality was observed for *Azadirachta indica* (27.99%) as that was in 3 and 6 days exposure and minimum number of insects were dead for *Citrus paradesi* (14.81%) and *Citrus reticulata* (13.58%) respectively.

The means for interaction between exposure time and treatments concentrations are significantly differed to each other Table 2. With increased concentration of the treatments and prolonged exposure time, the mortality of *T. granarium* was also increased (13.92 ± 0.77 , 17.65 ± 0.80 and 21.04 ± 0.81 percent mortality for 5%, 10% and 15% concentrations respectively).

The interaction means given in Table 3 showing that the mortality of *T. granarium* at 15% concentration and 3 days exposure was the maximum for *Azadirachta indica* (26.1%) and the minimum (11.90%) for *Citrus paradesi* and *Citrus reticulata* species and the corrected mortality at 15% concentration and 6 days exposure was the greatest for *Azadirachta indica* (28.57%) and the minimum (13.09%) for *Citrus paradesi* and *Citrus reticulata* species. The corresponding figures for corrected mortality at 15% concentration and 9 days exposure was the greatest for *Azadirachta indica* (32.10%) and the minimum (17.28%) for *Citrus paradesi* species. The corrected mortality gradually increased with increasing concentration and longer exposure time in case of each plant extract and it was always the highest at 15% concentration and 9 days exposure time. It was observed the ranking of the plant species for the mortality of khapra beetle larvae as *Azadirachta indica* > *Kolosynthus citrullus* > *Millia azadirachta* > *Dhatura alba* > *Fumaria indica* > *Citrus paradesi* > *Citrus reticulata*.

Repellent Effects of Botanicals Against *Trogoderma granarium*: The results showed that repellency was affected by plant species, concentration and time allowed for larvae to feed on wheat grains. But the interactions between these factors were found insignificant except the interaction between treatments and their concentrations. ($df=2$, $F=81.45$, $P<0.01$ for exposure time), ($df=6$, $F=469.47$, $P<0.01$ for treatments), ($df=2$, $F=795.15$, $P<0.01$ for treatment concentrations) and ($df=12$, $F=23.51$, $P<0.05$ for treatment & concentration interaction), means in table 4.

Repellency of *T. granarium* toward botanicals increased with passage of exposure time. The maximum repellency was observed in groups treated with *Azadirachta indica* (66.67%) and minimum repellency was shown by *Citrus paradesi* (41.85%) and *Citrus reticulata* (41.48%) during initial observation of 24 hours. The same

trend was observed through 48-h and 72-h for all of these plant extracts toward *T. granarium* repellency.

The highest concentration of extracts (15%) produced maximum repellency (63.23%) followed by (56.88%) for 10% and (45.56%) for the 5% concentration. Different concentrations of various plant extracts showed various effects but *Azadirachta indica* extracts produced significantly higher repellency at each concentration. However for all of the plant extracts repellency toward *T. granarium* gradually increased with time and increased concentration (Table 5.7).

The interaction means for Px Tx Exposure time are given in Table 5.8. At 5% concentration after 24 hrs the maximum and the minimum repellency was shown by *Azadirachta indica* (Neem) (51.11%) and *Citrus reticulata* (37.78%) extracts respectively. The same pattern was observed at 10% i.e. maximum for *Azadirachta indica* (68.89%) and minimum for *Citrus reticulata* (42.22%) while at 15% concentrations maximum for *Azadirachta indica* (80.00%) and minimum for *Citrus reticulata* (45.56%). The increasing trend of repellency was also observed at 5% concentration. After 48 hrs repellency was shown by *Azadirachta indica* (Neem) as maximum repellency of 81.11% and minimum of 44.44% for *Citrus paradesi* and *Citrus reticulata* extracts respectively. The same pattern was observed at 15%, the maximum for *Azadirachta indica* (85.56%) and minimum for *Citrus reticulata* (44.44%). The results of repellency after the exposure of 72 hrs reflects that at the concentration of 5%, the maximum repellency of (60.00%) was observed for *A. indica* while minimum (41.11%) for *Citrus reticulata*. The trend for repellency at the 10% concentration was maximum (72.22%) for *A. indica* and minimum for *C. reticulata*. The highest 15% concentration for each extract showed maximum repellency however the maximum repellency was recorded for *A. indica* (85.56%) and minimum for *C. reticulata* (50.00%) (Table 5.8). It was concluded that the repellent action of the plant species against khapra beetle larvae as *Azadirachta indica* > *Kolosynthus citrullus* > *Millia azadirachta* > *Dhatura alba* > *Fumaria indica* > *Citrus paradesi* > *Citrus reticulata*. *Azadirachta indica* always lead these seven species in action.

Effect of Plant Extracts on Development of *Trogoderma granarium*: The percent inhibition of *T. granarium* pupae was affected by treatments and their concentrations and was significantly differed from control group ($df=6$, $F=269.81$, $P<0.01$ for treatments) and ($df=2$, $F=67.64$, $P<0.01$ for treatment concentrations), means in table 5.9.

Table 4: Percent Repellent effects (mean±SE) of botanicals against *Trogodermagranarium*(Exposure time x Treatments interaction)

Treatments	Time			Mean
	24-h	48-h	72-h	
<i>Azadirachtaindica</i>	66.67±4.27	69.63±3.62	72.59±3.76	69.63±2.21A
<i>Milliaazadraik</i>	57.78±3.51	61.11±3.51	63.70±3.40	60.86±1.99C
<i>Kolosynthuscitrollus</i>	61.11±4.01	63.33±3.69	66.67±3.77	63.70±2.17B
<i>Dhaturainoxia</i>	55.19±3.20	58.15±3.10	62.22±2.99	58.52±1.81D
<i>Fumariaindica</i>	43.33±1.92	45.19±2.09	48.15±1.68	45.56±1.13E
<i>Citrus reticulate</i>	41.48±1.48	42.96±1.52	45.93±1.55	43.46±0.92F
<i>Citrus pardesi</i>	41.85±1.26	44.44±1.47	48.15±1.13	44.81±0.88EF
Mean	52.49±1.62C	54.97±1.62B	58.20±1.61A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 5: Percent Repellent effects (mean±SE) of botanicals against *Trogodermagranarium*(Exposure time x Concentration interaction)

Treatment	Time			Mean
	24h	48h	72h	
5%	42.38±1.26	45.24±1.55	49.05±1.48	45.56±0.89C
10%	54.29±2.34	56.83±2.37	59.52±2.25	56.88±1.34B
15%	60.79±2.95	62.86±2.90	66.03±3.07	63.23±1.71A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 6: Days x plant x treatment interaction mean±SE for repellency

P x T	Day			P x treatment interaction mean
	D1	D2	D3	
P1T2	51.11±1.11	56.67±1.92	60.00±1.92	55.93±1.55F
P1T3	68.89±1.11	71.11±1.11	72.22±1.11	70.74±0.74C
P1T4	80.00±1.92	81.11±1.11	85.56±1.11	82.22±1.11A
P2T2	44.44±1.11	47.78±1.11	51.11±1.11	47.78±1.11GH
P2T3	61.11±1.11	64.44±1.11	66.67±1.92	64.07±1.08DE
P2T4	67.78±1.11	71.11±1.11	73.33±1.92	70.74±1.08C
P3T2	46.67±1.92	50.00±1.92	53.33±1.92	50.00±1.36G
P3T3	63.33±1.92	65.56±1.11	67.78±1.11	65.56±0.96D
P3T4	73.33±1.92	74.44±2.22	78.89±1.11	75.56±1.24E
P4T2	43.33±1.92	46.67±1.92	51.11±1.11	47.04±1.41GH
P4T3	57.78±1.11	61.11±1.11	64.44±1.11	61.11±1.11E
P4T4	64.44±1.11	66.67±1.92	71.11±1.11	67.41±1.21CD
P5T2	36.67±1.92	37.78±1.11	42.22±1.11	38.89±1.11J
P5T3	44.44±1.11	46.67±1.92	50.00±1.92	47.04±1.17GH
P5T4	48.89±1.11	51.11±1.11	52.22±1.11	50.74±0.74G
P6T2	36.67±1.92	37.78±1.11	41.11±1.11	38.52±0.98J
P6T3	42.22±1.11	44.44±1.11	46.67±1.92	44.44±0.96HI
P6T4	45.56±1.11	46.67±1.92	50.00±1.92	47.41±1.08GH
P7T2	37.78±1.11	40.00±1.92	44.44±1.11	40.74±1.21IJ
P7T3	42.22±1.11	44.44±1.11	48.89±1.11	45.19±1.13H
P7T4	45.56±1.11	48.89±1.11	51.11±1.11	48.52±0.98GH

Means sharing similar letter in a column are statistically non-significant (P>0.05). P1= *Azadirachtaindica*, P2= *Milliaazadraik*, P3= *Kolosynthuscitrollus*, P4= *Dhaturainoxia*, P5= *Fumariaindica*, P6= *Citrus reticulate*, P7= *Citrus pardesi*

The maximum percent pupal inhibition was observed at concentration 15% for all treatments as compared to their lower concentrations, 5% and 10%. However *Azadirachta indica* showed good percent inhibition of *T. granarium* (34.92%) at lower concentration and projected to 50 % at high concentration. This pupal inhibition was followed by *Dhaturainoxia*, *Kolosynthuscitrollus*, *Milliaazadraik*, *Fumariaindica*, *Citrus pardesi* and the minimum in case of *Citrus reticulata* (6.62%) and *Citrus pardesi* (7.72%) with significant difference.

A highly significant effect of Plant extracts and their different concentrations was observed for adult inhibition of *T. granarium* (df= 6, F =263.97, P<0.01 for treatments) and (df=2, F=120.37, P<0.01 for treatment concentrations), means in table 5.9.

Adult inhibition at 5% concentration was the maximum in case of *Azadirachta indica* (47.57%) and the minimum in case of citrus reticulata (9.52%). It gradually increased with increasing concentration. At the highest concentration of 15%, the increasing trend adult inhibition percentage was noted again in *A. indica* (75.66%) at maximum however the minimum adult inhibition (18.76%) was recorded. As compared to the pupal inhibition adults were found susceptible to all plant extracts however maximum average inhibition for adults was for *Azadirachta indica* and minimum for *Citrus reticulata* (13.89%).

Anti-Feedant Losses: All the treatments, their different concentrations, time duration and interaction of all these factors showed a significant difference within groups and between groups. (df= 6, F =424.79, P<0.01 for treatments) and (df=4, F=4311.36, P<0.01 for treatment concentrations), (df= 2, F =107262, P<0.01 for exposure time) and (df=36, F=7.99, P<0.01 for interaction), means in table 5.9.

The maximum losses were shown by *Citrus reticulata* and *C. pardesi* (5.60%) while minimum losses were recorded in wheat grains treated with *Azadirachta indica* extracts (4.70%) after 30 days. After 90 days the maximum loss (16.89%) in the grains treated with *Citrus reticulata* extracts and minimum for *A. indica* (15.14%) Table 5.14. The interaction means for concentration x time show that after 30 days the loss was maximum at 0% (control) that decreased gradually at 5% (0.38%), 10% (1.74%) and 15% (2.73%) concentration and the losses decreased with the increasing concentrations (Table 5.15). The loss decreased with increasing extract concentration. Same results were found. After 48 and 72 hrs of exposure again the minimum loss at 10 and 15% concentrations was noted in case of the Neem extract and the maximum in case of *Citrus* species. In each species the loss decreased by increasing extract concentration but increased with the longer exposure time.

Azadirachta indica (Neem) induced minimum loss while *Citrus pardesi* (Grape fruit) caused maximum loss (Table 5.2), showed that Neem extract was most effective to check khapra beetles. Other species showed intermediate effects between Neem and Grape fruits. As regards the concentration of extracts it was found that highest concentration (15%) gave maximum effects (Table 5.3). It was expected that anti-feedant loss would increase with the passage of time (Table 5.4) and it was significantly higher after 90 days. Different concentration of Neem extract significantly affected anti-feedant loss, the highest concentration (15%) was the most effective against khapra beetle. *Milliaazadraik*, *Kolosynthuscitrollus* and *Daturainoxia* showed nearly similar trends at different concentrations against Khapra beetles. Different concentrations of *Fumariaindica*, *Citrus reticulata* and *Citrus pardesi* produced little

Table 7: Treatment x plant interaction mean±SE for % pupal inhibition

Plant	Treatment			Mean
	5%	10%	15%	
<i>Azadirachta indica</i>	34.92±0.79	39.52±0.24	50.00±0.00	41.48±2.24A
<i>Milliaazadraik</i>	26.50±1.07	32.54±2.10	37.35±1.04	32.13±1.74C
<i>Kolosynthuscitrollus</i>	31.75±1.59	36.60±0.44	42.64±2.86	36.99±1.84B
<i>Dhaturainoxia</i>	32.45±3.26	36.11±1.73	40.92±2.83	36.49±1.82B
<i>Fumariaindica</i>	8.47±1.32	14.46±0.18	19.31±1.46	14.08±1.67D
<i>Citrus reticulata</i>	4.60±1.03	3.66±0.04	11.59±2.24	6.62±1.44E
<i>Citrus pardesi</i>	6.08±1.19	6.08±1.19	10.98±0.13	7.72±0.95E
Mean	20.68±2.87C	24.14±3.23B	30.40±3.38A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 8: Treatment x plant interaction mean±SE % inhibition adult

Plant	Treatment			Mean
	5%	10%	15%	
<i>Azadirachta indica</i>	47.57±0.57def	58.99±1.72bc	75.66±2.12a	60.74±4.16A
<i>Millia azadirak</i>	36.60±0.44fg	42.72±1.72ef	53.70±1.85b-e	44.34±2.61C
<i>Kolosynthus citrullus</i>	41.26±2.20f	52.52±2.24cde	63.68±2.99b	52.48±3.47B
<i>Dhaturainoxia</i>	38.70±2.96fg	43.73±0.71ef	54.99±0.57bcd	45.81±2.57C
<i>Fumaria indica</i>	11.11±0.00i	19.75±2.47hi	28.40±2.47gh	19.75±2.69D
<i>Citrus reticulata</i>	9.52±2.38i	11.90±2.38i	20.24±2.38hi	13.89±2.01E
<i>Citrus pardesi</i>	12.49±1.17i	16.19±3.16i	18.76±2.15hi	15.81±1.47DE
Mean	28.18±3.44C	35.12±3.97B	45.06±4.71A	

Means sharing similar letter in a row or in a column are statistically non-significant ($P>0.05$). Small letters represent comparison among interaction means and capital letters are used for overall mean.

Table 9: Day x plant interaction mean±SE for anti-feedant

Plant	Exposure time			Mean
	5%	10%	15%	
<i>Azadirachta indica</i>	4.70±0.36l	10.80±0.57i	15.14±0.57d	10.22±0.78E
<i>Millia azadirak</i>	5.10±0.25k	11.35±0.45gh	15.71±0.49c	10.72±0.77D
<i>Kolosynthus citrullus</i>	5.06±0.27k	11.14±0.54h	15.60±0.57c	10.60±0.78CD
<i>Datura innoxia</i>	5.08±0.25k	11.37±0.44g	15.55±0.53c	10.67±0.77C
<i>Fumaria indica</i>	5.45±0.15j	11.67±0.36f	16.56±0.33b	11.22±0.79B
<i>Citrus reticulata</i>	5.60±0.11j	12.28±0.20e	16.89±0.16a	11.59±0.79A
<i>Citrus pardesi</i>	5.60±0.10j	12.19±0.13e	16.85±0.15a	11.55±0.78A
Mean	5.23±0.09C	11.54±0.16B	16.04±0.17A	

Means sharing similar letter in a row or in a column are statistically non-significant ($P>0.05$). Small letters represent comparison among interaction means and capital letters are used for overall mean.

Table 10: Day x treatment mean±SE for anti-feedant

Treatment	Day			Mean
	D1	D2	D3	
T1	6.01±0.01i	12.89±0.04e	17.56±0.06a	12.15±0.60A
T2	5.76±0.03j	12.62±0.06f	16.91±0.10b	11.77±0.58B
T3	4.90±0.09k	10.80±0.17g	15.54±0.20c	10.41±0.56C
T4	4.24±0.17l	9.85±0.28h	14.16±0.33d	9.42±0.54D

Means sharing similar letter in a row or in a column are statistically non-significant ($P>0.05$). Small letters represent comparison among interaction means and capital letters are used for overall mean.

differences (Table 5.5) and appeared to be least effective against this beetle. Comparison of means for different factors are produced in Table 5.6. Time intervals were differing significantly, Neem extract differed from

other extracts significantly and some extracts were similar in response. Comparison of concentrations of different plant species produced significantly different results (Table 5.6).

Table 11: Days x plant x treatment interaction mean \pm SE for anti-feedant /Percent weight losses

P x T	Day			Day x treatment interaction mean
	30 Days	60 Days	90 Days	
P1T1	6.01 \pm 0.05WX	12.83 \pm 0.10JKL	17.57 \pm 0.12ABC	12.14 \pm 1.68AB
P1T2	5.50 \pm 0.05X-a	12.24 \pm 0.12MNO	15.98 \pm 0.12G	11.24 \pm 1.53E
P1T3	4.43 \pm 0.05de	10.07 \pm 0.06RS	14.60 \pm 0.19H	9.70 \pm 1.47I
P1T4	2.87 \pm 0.04g	8.05 \pm 0.03V	12.42 \pm 0.15LMN	7.78 \pm 1.38L
P2T1	5.97 \pm 0.02WXY	12.85 \pm 0.09J-M	17.44 \pm 0.17A-D	12.06 \pm 1.67AB
P2T2	5.69 \pm 0.03W-Z	12.40 \pm 0.09JKL	16.03 \pm 0.09DEF	11.89 \pm 1.64BCD
P2T3	4.70 \pm 0.03bcd	10.32 \pm 0.09R	14.92 \pm 0.05H	9.98 \pm 1.48H
P2T4	3.94 \pm 0.03ef	9.44 \pm 0.16T	13.45 \pm 0.10I	8.94 \pm 1.38J
P3T1	6.01 \pm 0.03WX	13.02 \pm 0.06IJ	17.76 \pm 0.09AB	12.29 \pm 1.71A
P3T2	5.75 \pm 0.02W-Z	12.53 \pm 0.04KLM	16.65 \pm 0.10DEF	11.68 \pm 1.62CD
P3T3	4.54 \pm 0.02d	10.51 \pm 0.03R	15.07 \pm 0.12H	10.04 \pm 1.48HI
P3T4	3.85 \pm 0.02f	8.69 \pm 0.02U	12.93 \pm 0.11I-L	8.49 \pm 1.31K
P4T1	6.00 \pm 0.02WX	12.90 \pm 0.05JKL	17.55 \pm 0.19ABC	12.15 \pm 1.68AB
P4T2	5.7 \pm 0.05W-Z	12.55 \pm 0.06J-M	16.46 \pm 0.16F	11.54 \pm 1.61D
P4T3	4.62 \pm 0.04cd	10.29 \pm 0.03R	14.88 \pm 0.07H	9.93 \pm 1.48HI
P4T4	3.96 \pm 0.01ef	9.55 \pm 0.03ST	13.02 \pm 0.04IJK	8.84 \pm 1.32J
P5T1	6.05 \pm 0.03W	12.93 \pm 0.10I-L	17.80 \pm 0.09A	12.26 \pm 1.70A
P5T2	5.80 \pm 0.03W-Z	12.65 \pm 0.08J-M	17.35 \pm 0.15A-E	11.97 \pm 1.68BCD
P5T3	5.16 \pm 0.04ab	11.85 \pm 0.06Q	16.00 \pm 0.08G	10.67 \pm 1.57G
P5T4	4.78 \pm 0.09bcd	10.14 \pm 0.04R	15.06 \pm 0.11H	10.00 \pm 1.48H
P6T1	6.00 \pm 0.02WX	13.01 \pm 0.08IJK	17.41 \pm 0.16A-D	12.14 \pm 1.66AB
P6T2	5.86 \pm 0.03W-Z	12.78 \pm 0.11JKL	17.06 \pm 0.14B-F	11.90 \pm 1.66BCD
P6T3	5.43 \pm 0.05Za	11.89 \pm 0.04OP	16.74 \pm 0.09F	11.35 \pm 1.64E
P6T4	5.11 \pm 0.03abc	11.45 \pm 0.13P	16.14 \pm 0.09G	10.90 \pm 1.60FG
P7T1	6.00 \pm 0.03WX	12.70 \pm 0.13J-M	17.38 \pm 0.12A-E	12.03 \pm 1.65ABC
P7T2	5.82 \pm 0.04W-Z	12.45 \pm 0.15LMN	17.06 \pm 0.05C-F	11.77 \pm 1.63CD
P7T3	5.45 \pm 0.03YZa	11.94 \pm 0.05NOP	16.87 \pm 0.09EF	11.42 \pm 1.65E
P7T4	5.13 \pm 0.05abc	11.66 \pm 0.14P	16.10 \pm 0.09G	10.97 \pm 1.59F

Means sharing similar letter in a row or in a column are statistically non-significant ($P>0.05$). Small letters represent comparison among interaction means and capital letters are used for overall mean. P1= Azadirachtaindica, P2=Milliaazadraik, P3=Kolosynthuscitrollus, P4= Datura inoxia, P5= Fumariaindica, P6= Citrus reticulata, P7= Citrus paradesi

DISCUSSION

Plant extract has been used from old age to repel insects and save food grains. People used a number of herbs and spices to control different insect pests. For instance red and black chillis have been extensively utilized to distract insects. Other herbal products include ginger, onion, garlic, turmeric, coriander, cumin, saffron etc. Chemical pesticides possess harmful effects and residual effects. The present research work was a trial to understand the efficacy of herbal pesticides against khapra beetle in order to establish a combating strategy to minimize qualitative as well as quatitative losses of stored wheat grains and set up a pattern of botanical

management. Less frequent instances are available in the country as far as wheat grains are concerned. [37] used powders of eleven plant species for botanical management of khapra beetles. The highest concentration (6%) caused the highest mortality of adults and larvae by some plant species while others have at all no effect. This study matched with present findings in that herbal pesticides can be used for controlling khapra beetles but she used different plant species than present styudy, therefore the differences could not be compared. [38] reported anti-feedant losses by the use of some herbal pesticides and showed that khapra beetle can be controlled by using plant extracts, coinciding with present findings to some extent. Use of neem seed and leaf

powder showed severe effects against khapra beetle as reported by [39]. They studied larval mortality, progeny emergence and seed damage and found that seed powder was more effective in causing mortality. Another important study that matched present findings on mortality was conducted by [40] who reported very high mortality (40%) of insect pests caused by plant extracts. They also reported antifeedant losses that are similar to present findings. Some studies reported lower value of mortality as compared to present findings. For instance [41] reported that Neem extract induced only 14.4% mortality in khapra larvae while *P. nigrum* caused only 6.78% mortality. The causes of these contradictory findings might be longer exposure time which reduces its efficacy due to high volatility and lesser persistency.

Diverse type of observations is reported in literature. [42] noted that that plant extracts/materials mainly act against eggs or early larval stages restrict their possible utilization in stored grains or grain stores. On the other hand [43] reported that plant material just hindered larval movement and reduced space between grains instead of some repellent effects. [38] reported that plant extracts were capable of introducing anti-feedant and growth inhibitory effects against khapra beetles. [44] was first to report that ethyl acetate extract had insecticidal activity against insects. Later [45] observed that methanol extract from seeds caused highest percent larval mortality [37] reported effects of plants insects on larval mortality of khapra beetle. Some plant extract caused powder of Neem on mortality and emergence of Khapra larvae was studied by [39] and they reported significant effects of seed powders on these parameters. Many researchers have reported repellent, antifeedant or pesticidal properties of neem seed and leaf powders against khapra beetle [46].

CONCLUSIONS

Herbal extracts are naturally biodegradable hence possess negligible residual effects. Most of them are human friendly and can be used at nearly any concentration without any harmful effects. It is hereby concluded that Neem extract can serve as the best pesticides against khapra beetles in stored grains. Other plant extracts can also be used effectively. These herbal extracts are cheaper, easily available and easy handling and safer in use. As these extract are organic in nature, their use should be enhanced. The plant extract are nearly effective at all stages of propagation of insects and can prove helpful not only in controlling the devastating

insect pests but also minimizing them to the harmless level thus saving the quality and quantity of cereal grains in stored conditions.

ACKNOWLEDGEMENT

This research is a part of PhD studies of Muhammad Zia-ul-Haq under Indigenous Scholar Program of Higher Education Commission of Pakistan.

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