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Comparison of means of repellent, toxic and growth regulatory effects of essential oils of plants on different strains of *Tribolium castaneum*

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Abstract
The study was conducted to evaluate plant oils *Datura inoxia*, *Nigella sativa*, *Trachyspermum ammi* and *Amaranthus viridis* for their effectivity on three strains of *Tribolium castaneum*. The *T. castaneum* was reared in laboratory to obtain F_1. The essential oils of plants were obtained by Hot Continuous Extraction method. The repellency tests were carried out by area preference method. Whereas, the toxicity was studied by using diet incorporation method. Later on the growth regulatory effects of plant essential oils were studied by regularly recording the data of survivors. All the plant appeared to have repellency against insects. Highest mortality was exhibited by *D. inoxia* (25.02%). Larval emergence was lower when treated with *N. sativa* (21.7%) and *A. viridis* (22.8%). Pupal formation was minimum at *D. inoxia* (2.622).
Population build up was suppressed in all cases when compared with control. *D. inoxia* give maximum suppression (0.47% increase per insect).
Based on the above results it can be concluded that *D. inoxia* appeared to be toxic in most of cases causing direct mortality. *N. sativa* was found effective in reducing larval emergence and pupal formations. However population build up data exhibited varied results on different plants.

Keywords: *Tribolium castaneum*, strains, essential plant oils, *Datura inoxia, Nigella sativa, Trachyspermum ammi Amaranthus viridis*

Introduction
T. castaneum is most vicious and cosmopolitan pest having a extensive association with human beings and stored food, established in association with a broad range of stored products commodities causing severe losses [1]. *T castaneum* when colonizes the stock, it devours the endosperm and cause caking, stale reek and reduction in grain mass [2]. It also pollutes the flour by faeces and cast off exoskeletons. Both larvae and adults cause damage [3]. In case of severe invasion, the flour becomes greyish and mouldy having a pungent and unpleasant smell. It becomes unfit for human consumption [3]. This insect causes considerable loss in storage as for its elevated fecundity [4]. It causes economic damage of 34 and 40% of stored millet and wheat flour respectively [5]
Control of stored grain insect pests was principally reliant on constant application of insecticides, which has directed to evils like ecological turbulence, rising expenses of application, pest resurgence, pest resistance to pesticides and lethal effects on non-target organisms and also direct toxicity to user [6]
Researchers have been paying attention on the likelihood of applying essential oils of plants for use in stored commodities to manage insect pests [7, 8]. About 2000 plant species are acknowledged to have several insecticidal actions [9].
These botanicals degrade more quickly in the environment as compared to the chemicals and have increased specificity that favors beneficial insects [10] have low toxicity to mammals and are able to shield the crops from invasion by a broad range of insect pests [11]. Phytopesticide have the benefit of exhibiting novel modes of action thus reducing cross-resistance risks [6, 12]
The present study was carried out to compare the efficacy of repellent, toxic and growth regulatory effects of essential oils of plants on different strains of *Tribolium castaneum*. Also to find out the effective concentration and doses for the application of these plant oils

Materials and Methods

The research was done at the Grain Research, Training and Storage Management Cell, Department of Agri. Entomology, University of Agriculture Faisalabad, during the year 2010-2011.

Test Insects

Three of the strains of *T. castaneum* were checked for their mortality, toxicity, larval emergences, pupal formations and the population build up when treated with the plant oils.

Collection and Rearing/ Culturing Insects

Three of the strains of Tribolium castaneum were collected from local house level storages of Faisalabad, Bahawalpur and Dera Ghazi Khan. This initial population was cultured in the laboratory to get ample population for the research. The *T. castaneum* was reared on wheat flour sterilized at 60 °C for 30 minutes, 1% yeast was also added to it, in transparent plastic jars. The mouth of the jar was enclosed by muslin cloth tightened by rubber band, thus preventing the beetles from escape. The jars were placed in incubator at temperature 28±2 ºC and relative humidity 65±5%. After every five days the adults were sieved out from the flour, to another jar. And the flour with pure eggs of the insect was transferred to the jars. The same procedure was repeated throughout the rearing period. In this way the large number of F_1 adults was achieved to be used for the experiments.

Experimental Conditions

All experimental procedures will be carried out in incubators with ambient temperature 28±2 ºC, 65±5% relative humidity and L10:D14 regime.

Preparation of Essential Oils

Following plants were used for the experiments

Scientific name	Family	Parts used
Datura inoxia	Solanaceae	Fruits
Nigella sativa	Ranunculaceae	Seeds
Amaranthus viridus	Amaranthaceae	Leaves
Trachyspermum ammi	Umbelliferae	Seed

The fruit of *Datura inoxia* and *Amaranthus viridis* leaves were from field. They were than tap washed thoroughly to be cleaned and then dried in the shade. *Nigella sativa*, *Trachyspermum ammi* seeds were purchased from local market of Faisalabad In order to make seed free of contamination it will washed and then soaked in the water for 24 hour interval; then, dried in shade. The dry material was then grounded in the electrical grinder. A powder is formed.

Essential Oil Extraction

Hot Continuous Extraction method [13] (Soxhlet) was used. In this method, the finely 50 g of powder was placed in a porous bag of filter paper/ the bag was placed in the main chamber of the Soxhlet apparatus. The 250ml of acetone (used as an extracting solvent) was added in flask of soxhlet apparatus. By the use of power supply, it was heated and its vapors condensed in condenser. The condensed extractant dripped into the plant powder, and extracted it by contact. It took about 4-5 hours every time, while extracting the plants for oils. Essential oils thus obtained will be put in clean and air tight lid bottles. The samples will be stored in the refrigerator before use.

Preparation of Concentrations

Different concentration ranging from 2%, 4% and 6% were prepared in acetone by adding essential oils, in acetone in v/v. For the preparation of 2% concentration 2ml of stock solution was taken in the 100 ml flask and remaining flask was filled with acetone to make the volume and flask was shaken. This was 2% concentration. In the same way 4% and 6% concentration were prepared

Repellency Tests on Filter Paper

The repellent effects of the different essential oils against *Tribolium castaneum* was evaluated using the area preference method [14]. 1 ml of the test solution was applied on filter paper whatman's no. 48 (9 cm diameter) cut in half. The other half filter paper was kept untreated. Both the treated and untreated halves of filter paper was joined with staple pins and placed in Petri dishes. All experiments and control was dried for 10 minutes. Twenty adults were released in the centre of each Petri dish. Petri dishes were subsequently covered. The treatments will be replicated 3 times and the number of insects on the two half paper disks will be recorded after 24-hours interval.

Bioassay

The adult insects were checked against the essential oils. The experiment was laid out in Completely Randomized Design, consisting of three concentraions (2%, 4% and 6% concentration) of four insecticidal plant oils and a control for each. The study was done in small plastic vials by diet incorporation method. Sterilized wheat flour was treated with respective essential oils, allowed to dry for 24 hours. The control was treated with acetone and allowed to dry. On the next day 30 adult insects were released in each vial. Each concentration of the treatment was replicated three times. The data of mortality was recorded after 2, 4 and 6 days interval.

Growth and Fecundity Plummeting Effects

The growth regulatory effects were studied by recording the data regularly from the survivors of the treatment up to 60 days. The number of larvae and pupae was recorded weekly. The dead adult insects were counted and removed. The alive adults were also recorded. After 60 days the adult insect population build up was calculated and subjected to analysis by calculating per insect population increase.

Statistical Analysis

Data were corrected for mortality in the control by using Abbott's formula

$Pt= [(Po – Pc) / 100- Pc] \times 100,$

Results and Discussion

Table 1: Comparison of means of corrected percentage repellency on three strains of *Tribolium castaneum* exposed to three concentrations (conc.) of essential oils of *Nigella sativa*, *Trachyspermum ammi*, *Datura inoxia* and *Amaranthus viridis*

Strain	Plant	Repellency		
		2%	4%	6%
Bwp	*Datura inoxia*	83.183 ± 1.495 abc	91.416 ± 1.558 ab	100 ± 4.781 a
	Nigella sativa	66.432 ± 22.309 bc	88.670 ± 18.609 abc	100.326 ± 23.1333 a

	Amaranthus viridis	43.297 ± 5.342 c	72.694 ± 7.597 abc	91.605 ± 22.805 ab
	Trachyspermum ammi	48.282 ± 12.162 c	76.379 ± 3.045abc	100 ± 1.947 a
Dgk	*Datura inoxia*	71.088 ± 1.700 bc	74.489± 5.891 abc	77.891 ± 6.131 abc
	Nigella sativa	71.088 ± 3.401 bc	74.489 ± 5.102 abc	76.190 ± 4.499 abc
	Amaranthus viridis	79.591 ± 0.00 abc	81.292± 1.700 abc	88.095 ± 1.700 abc
	Trachyspermum ammi	72.789 ± 4.499 abc	76.190 ± 5.102 abc	79.591 ± 1.215 abc
Fsd	*Datura inoxia*	65.00 ±5.773 bc	71.666± 11.666bc	71.666±6.009 bc
	Nigella sativa	46.666±3.333 c	58.333±4.409bc	66.66±4.409 bc
	Amaranthus viridis	61.666±1.66bc	73.33±1.667abc	85.00±7.637abc
	Trachyspermum ammi	63.333±6.009bc	68.333±8.333ab	75.00±12.583 abc

Means followed by same letter do not differ significantly by Tukey-HSD test at P value ≤ 0.05.

Repellency of essential oils of *Nigella sativa, Trachyspermum ammi, Datura inoxia* and *Amaranthus viridis*

All the tested plant oils exhibited good repellent effects with no significant difference on the *T. castaneum*, showing repellency ranging from 66 to 95%, when comparing to the control.

The bahawalpur strain showed mean values of percentage repellency as high as 91.52% on *Datura inoxia* comparing the control. Lowest repellency appeared on *A. viridis*, (Table 1) the repellency increased with the increase in concentrations as reported by Ko *et al.* [15]. On the dgk strain there appeared a significant difference on plants. Maximum repellency appeared on *A. viridis*, contrary to the bwp strain. On the fsd strain, *A. viridis* exhibited maximum repellency like dgk and unlike bwp. Although none of the plant showing repellency varied significantly. All the plants appeared repellent to the *T. castaneum* (Table 1).

The concentration, the relation between strain and the plant and also strain and the concentration appeared significantly different from each other. The fsd appeared significantly different from the other two strains (Table 1). Some work has been reported regarding the plants repellent activity, Farhana *et al.* [16] reported *T. ammi* extract to have effective repellent activity. According to Ko *et al.* [15] the essential oil of *Litsea cubeba* strongly repelled *T. castaneum* even at lowest concentration. Generally repellency increased with the increase in concentration. 80-90% repellency was recorded one hour after application on *T. castaneum* at concentrations 0.16 to 0.63 µg/cm2.

Table 2: Comparison of means of corrected percentage mortality on three strains of *Tribolium castaneum* exposed to three concentrations (conc.) of essential oils of *Nigella sativa*, *Trachyspermum ammi*, *Datura inoxia* and *Amaranthus viridis*

Strain	Plant	Mean Mortality		
		2%	4%	6%
Bwp	*Datura inoxia*	6.889 ± 0.798 abcdefg	17.44 ± 1.759 hijk	41.718 ± 5.5032 o
	Nigella sativa	4.497 ± 0.839 abcd	12.144 ± 1.743 ghij	17.531 ±2.571 ijk
	Amaranthus viridis	4.88356 ± 1.332766 abcde	11.63883 ± 1.764894 fghi	23.61236 ± 3.494 klm
	Trachyspermum ammi	2.465± 0.732 a	5.368 ± 0.963 abcdef	9.780 ± 1.202898 cdefg
Dgk	*Datura inoxia*	2.592 ±1.446 ab	5.481 ± 1.290 abcdef	9.021 ±1.952 bcdefg
	Nigella sativa	3.849 ± 0.354 abc	4.678 ± 0.811abcd	6.303 ± 1.122 abcdefg
	Amaranthus viridis	6.656 ± 1.428 abcdefg	9.883± 1.959 cdefg	10.318 ± 2.085 cdefg
	Trachyspermum ammi	4.257 ± 1.203 abc	5.449 ± 0.918 abcdef	10.939 ± 2.950 defgh
Fsd	*Datura inoxia*	18.742 ± 2.949 kl	24.429 ± 2.638 lm	31.911 ± 2.366 n
	Nigella sativa	3.849 ± 0.354 abc	4.678 ± 0.811abcd	6.303 ± 1.122 abcdefg
	Amaranthus viridis	18.443 ±0.494 jkl	22.558 klm	27.796± 0.8153 mn
	Trachyspermum ammi	5.723 ± 1.683 abcdefg	8.342 ± 2.736 abcdefg	11.335 ± 3.722 efghi

Means followed by same letter do not differ significantly by Tukey-HSD test at P value ≤ 0.05.

Toxicity of essential oils of *Nigella sativa, Trachyspermum ammi, Datura inoxia* and *Amaranthus viridis*

When the toxicity of plant oils on *T. castaneum*-bwp was analyzed for variance, highly significant relationship was found among the intervals, plant oils, concentrations of the oils used and the interactions between the interval and the plants oils, intervals and the concentrations, plants and the concentrations, and interval plant and the concentrations. Highest mortality percentage comparing to the control was observed on the *D. innoxia* at 6% concentration with 41% corrected mortality, lowest mortality was observed on *T. ammi* with concentration of 2%. Mortality increased with the increase in exposure time, after 48 and 72 hours interval maximum mortality was observed (Table 2).

Analysis of variance of the *T. castaneum*-dgk revealed that the interval, plants and the concentrations varied highly significantly, however no significant differences among the interaction were observed. *A. viridis* showed highest mortality on the dgk strain, *N. sativa* appeared to be less toxic compared to others (Table 2). Hasan *et al.*, [17], observed 19.58% mortality on *A. viridis* against *T. granarium*

Highly significant differences were found upon the analysis of mortality of the *T. castaneum*-fsd by considering the factors like interval, plant, concentration. The interaction of all these factors also revealed highly significant results. Maximum corrected mortality was found on *D. inoxia* (Table 2) which was in contormity with Khalequzzaman and Islam[18] who reported that methanolic extract of *Datura metel* (*D. alba, D. fastuosa*) leaf was more toxic than other extracts on *T. castaneum*. Minimum results were obtained on *N. sativa*. Increase in Exposure time caused reduction in the toxic effects of plant oils. Unlike Hasan *et al.* [17] time appears to be more important. Further studies with longer exposure time and higher rates are likely to yield better results.

While comparing all the strains together for the susceptibility, the analysis of variance showed that the interval, plants,

strains as the insecticidal activity varied with insect species, concentrations of the oil and exposure time [19]. Concentration and their interactions appeared to be highly significant. With the increase in concentrations the mortality always increased the results were in conformity with Hasan *et al.* [17] revealed that maximum concentration (1.5%) gave the maximum mortality which was significantly different from the other two concentrations (0.5, 1.0%).

All the strains appeared to be significantly different from each other, the *T. castaneum*-fsd showed highest mortality while dgk appeared to be less susceptible. Rigaux *et al.* [20] observed wide variation in the susceptibility of *T. castaneum* strains to diatomaceous earth. After 7 days exposure some strains exhibited 10% mortality where as the others as high as 95% mortality.

Table 3: Comparison of mean larval emergence on three strains of *Tribolium castaneum* exposed to three concentrations (conc.) of four plant essential oils

Strain	Plant	Larval emergence			
		2%	4%	6%	Control
Bwp	*Datura inoxia*	4.222 ± 1.801 ab	0.000 a	0.000 a	9.111 ± 1.851 abcd
	Nigella sativa	5.333 ± 2.581 abc	0.222 ± 0.222	0.00 a	
	Amaranthus viridis	4.8889 ± 1.96104 ab	2.1111 ± 0.45474 ab	0.8889 ± 0.56383 ab	
	Trachyspermum ammi	3.666 ± 1.178 ab	2.555 ± 1.081 ab	0.666 ± 0.372 ab	
Dgk	*Datura inoxia*	72.666 ± 17.391 ij	46.111 ± 11.489 fghi	16.888 ± 3.743 abcdefg	127.000 ± 19.392 k
	Nigella sativa	62.444 ± 14.566 hij	40.666 ± 8.082 defghi	34.666 ± 8.482 bh	142.777 ± 19.596 k
	Amaranthus viridis	62.555 ±11.930 hij	50.555 ± 13.143 ghi	44.666 ± 10.832 efghi	131.777 ± 17.124
	Trachyspermum ammi	131.333 ± 19.282 k	87.222 ± 19.993 j	44.333 ± 12.588 efghi	134.222 ± 21.193k
Fsd	*Datura inoxia*	13.777 ± 2.989 Abcdef	10.666 ± 2.345 abcde	8.222 ± 2.060 abcd	39.555 ± 1.740 cdefghi
	Nigella sativa	13.111 ± 2.077 abcdef	9.666 ± 1.518 abcd	5.888 ±1.358 abc	39.555± 1.740 cdefgh
	Amaranthus viridis	29.888 ±4.018 abcdefgh	24.888 ±4.532 abcdefg	20.888 ±3.587 abcdefg	39.555 ±1.740 cdefghi
	Trachyspermum ammi	16.888 ± 2.855 abcdefg	12.777 ± 2.289 abcdef	11.333 ±3.316 abcde	39.555 ±1.740 cdefghi

Means followed by same letter do not differ significantly by Tukey-HSD test at P value ≤ 0.05.

Effect of plant essential oils on larval emergence of *Tribolium castaneum*

The ANOVA of the larval emergence of *T. castaneum*-bwp revealead that the interval, plant and concentrations have high significant effects on the larval emergence. The interaction between these factors are also highly significant. Over all, the larval emergence decreased over the time. As shown by the figure. Highest number of larvae vas found on D. inoxia and *T. ammi*. On the *T. castaneum*-dgk the ANOVA showed the highly significant realation between interval, plant and the concentration. Highest number of larvae were recorded on *T. ammi*. The larval emergence decreased with time duration (Table 3).

ANOVA of *T. castaneum*-fsd also exhibit significant differences among interval, plant oils and concentrations. Highest number of larvae was recorded on *A. viridis*. The *N. sativa* has minimum larval emergences.

When the three of strains were compared by means of analysis of variance highly significant differences were observed among interval, strain, plant, concentrations. *T. castaneum*-dgk showed much higher mean larval emergence. The larval emergence was minimum in *T. castaneum*-bwp (Table 3).

The results were contary to the findings of Epidi and Odili [21] who found no significant differences were found among powders of *Dracaena arborea* (dragon tree), *Vitex grandifolia* (Vitex) and phostoxin-treated seeds. And in accordance with the Kanvil *et al.* [22] tested for growth inhibiting effects against Tribolium castaneum and found that the number of hatched larvae in all the treatments of Saussurea lappa, Peganum harmala and Valeriana officianalis were significantly lower than those in control.

Table 4: Comparison of mean pupal formation on three strains of *Tribolium castaneum* exposed to three concentrations (conc.) of four plant essential oils

Strain	Plant	pupal formation			
		2%	4%	6%	Control
Bwp	*Datura inoxia*	0.111 ± 0.111 ab	0.000 a	0.00 a	7.727 ± 0.874 defghij
	Nigella sativa	2.555 ±1.281 abcdefg	0.222 ±0.146 ab	0.000 a	7.22 ±0.759 cdefghij
	Amaranthus viridis	0.666 ±0.372 abc	0.555 ±0.376 abc	0.000 a	7.111 ±0.904 cdefghij
	Trachyspermum ammi	1.11111 ±0.351 abc	0.222 ±0.146 ab	0.000 abc	6.555 ±0.929 abcdefghij
Dgk	*Datura inoxia*	18.000 ± 5.727 l	9.666 ± 2.967 hijk	2.333 ±2.211 abcdef	28.444 ± 4.288 m
	Nigella sativa	11.000 ±4.588 ijk	9.111 ±2.73 ghijk	8.111 ±2.903 efghij	28.444 ±4.288 m
	Amaranthus viridis	15.333 ±5.691 kl	12.333 ±5.131 jkl	9.00 ±4.189 fghijk	28.444 ±4.288 m
	Trachyspermum ammi	17.777 ±6.508 l	15.111 ±6.104 kl	7.222 ±3.076 cdefghij	28.44 ±4.288 m
Fsd	*Datura inoxia*	3.333 ±1.000 abcdefgh	2.888 ±0.904 abcdefg	1.333 ±0.500 abcd	13.142 ±1.549 jkl
	Nigella sativa	1.444±0.444 abcde	1.111± 0.388 abc	0.555 ± 0.242 abc	12.333 ± 1.301 jkl
	Amaranthus viridis	6.777 ±1.552 bcdefghij	5.222 ± 1.730 abcdefghi	3.00 ± 0.942 abcdefgh	12.333 ± 1.301 jkl
	Trachyspermum ammi	2.555 ± 0.765 abcdefg	1.888 ± 0.734 abcde	1.272 ± 0.359 abc	12.333 ± 1.301 jkl

Means followed by same letter do not differ significantly by Tukey-HSD test at P value ≤ 0.05.

Effect of plant essential oils on pupal formation of *Tribolium castaneum*

The analysis of variance of *T. castaneum*-bwp revealed highly significant difference in plant oil used. However, interval and the concentration remained non-significant. Maximum number of pupae was formed on the *A. viridis*. *D. inoxia* showed minimum pupal formation. On *T. castaneum*-dgk the plant showed non-significant variations, although all other

factors remained highly significant.

The ANOVA of *T. castaneum*-fsd revealed that the differences in factors like interval, plant, concentrations are highly significant. Maximum pupation occurred on *A. viridis*. *N. sativa* showed minimum pupation.

The comparison of all the three strains revealed significant differences among interval, strain, plant, concentration, and their interactions. Except for the interaction of strain and concentration, and the interaction between strain x plant x concentration which appeared non-significant. Maximum pupal formation occurred on the *T. castaneum*-dgk, bwp showed minimum pupation (Table 4). Not much work has been reported on number of pupa formed, Upadhay and Jaiswal [23] reported that the *Piper nigrum* oil also inhibits development of larvae into pupae.

Table 5: Comparison of mean population build up on three strains of *Tribolium castaneum* exposed to three concentrations (conc.) of four plant essential oils

Strain	Plant	population build up			
		2%	4%	6%	Control
Bwp	*Datura inoxia*	0.194 ± 0.043 abcd	0.061 ± 0.003 ab	0.00 a	1.655 ± 0.052 ghijklmn
	Nigella sativa	0.170 ± 0.010 abcd	0.119 ± 0.019 abc	0.038 ± 0.020 ab	1.655 ±0.052 ghijklmn
	Amaranthus viridis	0.441 ± 0.053 abcdef	0.335 ± 0.042 abcde	0.297 ± 0.081abcde	1.655 ± 0.052 ghijklmn
	Trachyspermum ammi	0.531 ±0.016 abcdefg	0.473 ±0.028 abcdefg	0.235 ±0.074 abcd	1.655 ±0.052 ghijklmn
Dgk	*Datura inoxia*	2.080 ± 0.083 ijklmn	1.765 ±0.133 hijklmn	0.183 ±0.037 abcd	2.466 ±0.069 lmn
	Nigella sativa	2.279 ±0.199 klmn	1.930 ± 0.097 hijklmn	1.219±0.494 bcdefghijk	2.466 ±0.069 lmn
	Amaranthus viridis	2.400 ±0.216 klmn	2.161 ± 0.141 j	1.550 ± 0.579 fghij	2.466 ±0.069 lmn
	Trachyspermum ammi	1.441 ±0.283 efghijklm	0.341 ±0.021 abcde	0.154 ±0.029 abcd	2.466 ±0.069 lmn
Fsd	*Datura inoxia*	2.746 ±0.480 n	1.628 ±0.174 fghij	0.938 ±0.137 abcdefghi	5.345 ±0.766 o
	Nigella sativa	1.333 ±0.0377 defghijkl	0.984 ±0.104 abcdefghij	0.873 ±0.126 abcdefgh	4.271 ±0.274 o
	Amaranthus viridis	2.606 ±0.220 mn	2.047 hijklmn	1.945 ±0.00 hijklmn	4.271 ±0.274 o
	Trachyspermum ammi	2.407 ±0.133 klmn	1.814 ±0.074 hijklmn	1.273 ±0.024 cdefghijkl	4.271 ±0.274 o

Means followed by same letter do not differ significantly by Tukey-HSD test at P value ≤ 0.05.

Effect of plant essential oils on population build up of *Tribolium castaneum*

The ANOVA of *T. castaneum*-bwp revealed the variation in plant, concentration and the interaction of plant oil and the concentration to be highly significant. Maximum population increase per insect was recorded on *T. ammi* and *A.viridis* as compared to the D. inoxia and *N. sativa*. The population increase in the control treatments were significantly higher as compared to those treated with the plant oils (Table 5). The population build up increased with the decrease in concentration of the plant, yet at minimum concentration of 2% the population still remained much lower as compared to the control treatments. The ANOVA of *T. castaneum*-dgk showed significant differences in the plants, concentration and also the interaction of the plant and the concentration. Maximum population build up was observed on *A. virdis* and minimum was recored on *D. inoxia*. All the treatments were significantly different from the control (Table5).

The ANOVA of *T. castaneum*-fsd exhibited significant differences in the plant, concentrations and the interaction between the plant and the concentration. The maximum population build up was recored on the *A. viridis* and mimimum was of *N. sativa*. However, the *D. inoxia* and the *T. ammi* appeared to be non-significantly different from the *A. viridis*. Maximum population build up per insect was recorded on the control treatment. The ANOVA of all the three strains revealed the significant differences among the strains, plant, concentration and their interactions. Maximum population build up was recored on the *T. castaneum*-fsd, whereas the *T. castaneum*-bwp showed minimum population build up.on the all the treatments the plants effectively reduced the progeny production (Table 5), Kanvil *et al*. [22] found that the *T. castaneum* adults when exposed to different batches of flour treated with plant extracts indicated significantly lower progeny.

Mostly *D. innoxia* appeared to be effective for the reduction in progeny of the bwp and dgk strains (Table 5). Insecticidal value of *Datura alba* has been reported by Shah and Ahmad [24] against insect pests of different crops. The plants are very effective in the recuction to the F1 of *T.castaneum*. various evidences are available Xie *et al.* [25] reported that *Melia toosedan* bark extracts significantly reduced the F1 adults of *T. castaneum*.

Conclusion

Based on the above results it can be concluded that D. inoxia appeared to be toxic in most of cases causing direct mortality expcept for the *T. castaneum*-dgk. In all cases *N. sativa* was found effective in reducing larval emergence and pupal formations. However population build up data exhibited varied results and different plant oils give varied results on each of the test insect. It can be suggested that the plant oils can be used as an effective tool in Integrated Pest Management.

References

1. Via S. Cannibalism facilitates the use of a novel environment in the flour beetle, *Tribolium castaneum*. Heredity. 1999; 82:267-275.
2. Davey PM, Hall DW, Conveney PL, Raymond WD. The effects of insect infestation on the quality of decorticated groundnuts with special reference to storage at low and high humidities. Tropical Sciece. 1959; 1:296-307.
3. Atwal AS, Dhaliwal. Agriculture pests of South Asia and their management (4rth Ed.). Khalyani Publishers, India. 2002, 498. Available at: mbao.org/2006/06Proceedings/110SaxenaRNeem-storedgrains.pdf
4. Prakash AJ, Rao, Pasalu IC, Mathur KC. Rice Storage and insect pests management. BR Publishing Corporation, New Delhi, 1987, 337.
5. Ajayi FA, Rahman SA. Susceptibility of some staple processed meals to red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) Pakistan Journal of

Biological Sciences. 2006; 9(9):1744-1748.
6. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology. 2006; 51:45-66.
7. Collins DA. A review of alternatives to organophosphorus compounds for the control of storage mites. Journal of Stored Products Research, 42, 395-426. commodities. Pesticide Outlook. 2006, 249-253.
8. De Carvalho, CCR, De Fonseca MMR. Carvone: why and how should one bother to produce this terpene. Food Chemistry. 2006; 95:413-422.
9. Jacobson M. Insecticides from plants: A review of the literature, agricultural handbook 461, US Department of Agriculture, Washington D.C. 1975; 138:1954-1971
10. Pillmoor JB, Wright K, Terry AS. Natural products as a source of agrochemicals and leads for chemical synthesis. Journal of Pesticide Science. 1993; 39:131-140.
11. Tapondjou AL, Adler C, Fontem DA, Bouda H, Reichmuth C. Bioactivities of cymol and essential oils of *Cupressus sempervirens* and *Eucalyptus saligna* against *Sitophilous zeamais* Motschlsky and *Tribolium confusum* du Val. Journal of Stored Product Research. 2005; 41(1):91-102.
12. Isman MB. Plant essential oils for pest and disease management. Crop Protection. 2000; 19:603-608.
13. Handa SS. An Overview of Extraction Techniques for Medicinal and Aromatic Plants. in: Handa, SS, SPS. Khanuja, G. longo, DD Rakesh (eds.). Extraction Technologies for Medicinal and Aromatic Plants. International Centre for Science And High Technology Trieste, Italy, 2008, 23-24.
14. Mohan S, Fields PG. A simple technique to assess compounds that are repellent or attractive to stored-product insects. Journal of Stored Product Research. 2002; 38:23-31.
15. Ko K, Juntarajumnong W, Chandrapatya A. Repellency, fumigant and contact toxicities of Litsea cubeba (Lour.) Persoon Against Sitophilus zeamais Motschulsky and *Tribolium castaneum* (Herbst). Kasetsart Journal (Natural Science). 2009; 43:56-63.
16. Farhana K, Islam H, Emran EH, Islam N. Toxicity and Repellent Activity of Three Spice Materials on *Tribolium castaneum* (Herbst) Adults. Journal of biological sciences. 2006; 14:127-130.
17. Hasan M, Sagheer M, Aman Ullah, Wakil W, Javed A. Response of *Trogoderma Granarium* (Everts) to Different Doses of *Haloxylon Recurvum* Extract and Deltamethrin. Pakistan Entomolist. 2005; 28(2):25-29.
18. Khalequzzaman M, Islam MN. Pesticidal action of Dhutura, Datura metel Linn. leaf extracts on *Tribolium castaneum* (Herbst). Bangladesh Journal of Zoology. 1992; 20(2):223-229.
19. Negahban M, Moharramipour S, Sefidkon F. Fumigant toxicity of essential oil from Artemisia Sieberi Besser against three stored product insects. Journal of Stored Products Research. 2007; 43:123-128.
20. Rigaux M, Haubrugel E, Fields PG. Mechanisms for tolerance to diatomaceous earth between strains of *Tribolium castaneum*. Entomologia Experimentalis et Applicata. 2001; 101:33-39.
21. Epidi TT, Odili EO. Biocidal activity of selected plant powders against Tribolium *castaneum* Herbst in stored groundnut (Arachis hypogaea L.). African Journal of Environmental Science and Technology. 2009; 3(1):001-005.
22. Kanvil S, Jilani G, Saljoqi AUR, Hussain N, Anwar M. Effects of Plant Extracts on Oviposition and Egg Hatching of *Tribolium Castaneum* Herbst (Coleoptera: Tenebrionidae). Sarhad Journal of Agriculture. 2009; 22(3):503-516.
23. Upadhay RK, Jaiswal G. Evaluation of biological activities of *Piper nigrum* oil against *Tribolium castaneum*. Bulletin of Insectology. 2007; 60(1):57-61.
24. Shah Zh, Ahmad S. Evaluation of Datura (*Datura alba*) extract as an insecticide. Pakistan Entomologist. 1983; 5(1, 2):5-8.
25. Xie YS, Fields PG, Isman MB. insecticidal activity of Melia toosendan extracts and Toosendanin against three stored-product beetles. Journal of Stored product Research. 1995; 31(3):259-265.