International Journal of Animal Biology
Vol. 1, No. 3, 2015, pp. 86-92
http://www.aiscience.org/journal/ijab

Repellence Activity of Plant Oils against Red Flour Beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in Wheat

Hina Hanif Khanzada[1], Muhammad Sarwar[2, *], Muhammed Khan Lohar[1]

[1]Sindh Agriculture University, Department of Entomology, Tando Jam, Sindh, Pakistan
[2]Nuclear Institute of Agriculture, Department of Plant Protection, Tando Jam, Sindh, Pakistan

Abstract

The present studies were carried out on the repellence activity of plant oils against Red flour beetle, *Tribolium castaneum* (Herbst) in wheat. The four plant oils i.e., Mustard oil (*Brassica campestris*), Coconut oil (*Cocus nucifera*), Sesame oil (*Sesamum indicum*) and Rocket seed oil (*Eurica sativa*) were used for the grains treatment. It was observed that plant edible oils effected on developmental stages of red flour beetle that was responsible for causing heavy damage and weight losses to the grains of wheat. However, among oils, the Rocket seed oil, statistically gave better results for pest control when compared with other oils and check grain. The overall results presented showed that the minimum adult emergence of Red flour beetle was recorded in Rocket seed oil followed by Mustard oil, Coconut oil and Sesame oil, whereas, the maximum adult emergence observed in control treatment. Similarly, the minimum pest's fecundity was recorded in Rocket seed oil followed by mustard oil, coconut oil and sesame oil. On the other hand, the maximum fecundity was observed in control treatment of grain. The minimum grain's weight loss was seen in Rocket seed oil at its application rate of 0.25 ml per sample. On the other hand, the maximum weight loss was recorded in the control. However, sesame oil was the least effective in protecting grains followed by coconut oil. The data showed that the maximum temperature was recorded on the 3rd week of September, 2008 during experimentation. However, the minimum temperature was recorded on 4th week of November of the study year. Similarly, the maximum humidity was recorded on the 2nd week of August, whereas, the minimum humidity recorded during 2nd week of October. This suggests that the multiplication of red flour beetle *T. castaneum* in the months of August and September was faster when humidity and temperature were higher.

Keywords

Wheat, *Tribolium castaneum,* Plant Oil, Store Grain, Pest Control

Received: May 1, 2015 / Accepted: May 18, 2015 / Published online: June 30, 2015

1. Introduction

Cereals constitute a major part of food throughout the world and agro-based industries depend upon their production. Cereals as stored grains are subjected to insect's infestation and deterioration, and by fungal and bacteria attacks. Many grain insects are good fliers and move to stored grains from fields to infest grain bins. The insect pests move within the grain mass at a rate that is determined by season and grain temperature. During summer and fall, infestations are common on the upper surface of grains. In winter the pests congregate at the center and lower portion may escape from detection until high pest populations (Shemais, 2000). In cereal grains, the post harvest losses are further mainly carried out by birds, rats, diseases, rain, threshing and storage etc. The admixture of dry grain including trash, straw, dust, soil particles and grovels, may increase chance of store grain

*Corresponding author
E-mail address: drmsarwar64@yahoo.com (M. Sarwar)

pest attacks. The storage losses due to insects, rats and molds are up to 10-18%. The most favorable grain moisture range for storage insect pests is from 10 to 12% (Tunio, 2002). Almost all insect pests of stored grains have a remarkably high rate of reproduction, generations are short and the individual insects are long lived. It becomes favorable to stored grain pests when temperature is high and grains are moist. The *Trobolium castaneum* (Herbst) is fairly resistant to high temperatures and is more sensitive to low temperature. At 42˚C all stages of beetle die in 114 hours; in three hours at 52˚C adults die after 15 minutes, eggs after 30 minutes, larvae after 45 minutes and pupa after three hours (Mahroof et al., 2003).

Insects are a foremost cause of losses to wheat grain and ultimately to producers as a result of direct feeding or as carriers or vectors of certain diseases. Severe insect infections surely cause weight losses and deteriorate kernel quality, which can range from limited to state-wide in scope (Siddiqui and Sarwar, 2002; Sarwar, 2011; 2015; Sarwar and Sattar, 2012). Many insect pests attack on the stored grains, i.e., Confused flour beetle *Triolium confusum* (Duval), Khapra beetle *Trogoderma granarium* (Everts), Lesser grain borer *Rhyzopertha dominica* (F.), Angoumois grain moth *Sitotroga cerealella* (Olivier) and Red flour beetle, *Trobolium castaneum* (Herbst). Among these, red flour beetle *T. castaneum* is the main serious pest of wheat (*Triticum aestivum*) (Renteria et al., 2000; Sarwar, 2009; 2013; Sarwar et al., 2004). This beetle has chewing mouthparts, but do not bite or sting. The red flour beetle may elicit allergic response but is not known to spread disease, and does not feed on or damage the structure of a home or furniture (Alanko et al., 2000). This grain pest is found in temperate areas but can survive the winter in protected places, especially where there is central heat (Tripahti et al., 2001). The female of *T. castaneum* lays 300 to 400 eggs at random in the grains, which hatch into worm like larvae. The larvae are slender in shape and whitish yellow in color. At the posterior end of larva, there are two dark pointed projections. The life cycle of pest at 30˚C becomes complete in about 5 weeks. The adults are long lived and sometimes survive for a year or more (Lohar, 2001). Suresh et al., (2001) reported that *T. castaneum*, is a polyphagous, cosmopolitan pest, feeding mostly on stored flour and other milled cereal products, broken wheat and farm stored products. In severe infestation the flour turns grayish and mouldy and has pungent, disagreeable odor making it un-fit for human consumption. Earlier, Al-Jabr (2006) reported on the toxicity and repellency of seven plant essential oils from Georgia against the red flour beetle in stored products. However, in Pakistan very little work on repellence activity of plant oils against *T. castanium* has been conducted in wheat, which is a staple food and one of the major crops. However, Sarwar (2010) conducted research on some possibilities on the effectiveness of plant powders as grain protectants against cowpea weevil, *Callosobruchus maculatus* (Fabricius) Walp (Coleoptera: Bruchidae) infestation in chickpea. Moreover, Sarwar et al., (2013) assessed the potential of assorted plant powders on survival of *Caloglyphus* grain mite (Acari: Acaridae) in wheat grain. The current study is a preliminary attempt at Tandojam, Sindh and the basic information from these results will be helpful for the management of this storage pest. Therefore, the objectives of present studies were to determine the infestation by red flour beetle on wheat, effectiveness of plant oils and impact of temperature on beetle.

2. Materials and Methods

The present studies on repellence activity of plant oils against red flour beetle, *Tribolium castaneum* (Herbst) in wheat, were carried out under laboratory conditions in Postgraduate laboratory, Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam. The experiment was conducted from August 10 to November 30, 2008. Four different plant oils i.e., Mustard oil (*Brassica campestris*), Coconut oil (*Cocus nucifera*), Sesame oil (*Sesamum indicum*) and Rocket seed oil (*Eurica sativa*), which are commercially available in market, were purchased and mixed with wheat grains. The proposed concentration of each oil was 0.25 ml that was mixed with the two hundred and fifty grams (250) of wheat. In this way four treatments and control were kept for observation period.

The weighed wheat grains were kept in plastic jars, which were covered with muslin cloth and banded with rubber strips. The experiment was replicated four times including control (without treated grains). The culture of *T. castaneum* was obtained from the laboratory of Stored grain NARC, Karachi University. The samples of pure, clean and healthy seed grains of wheat were kept into the glass jars. The culture was developed by releasing, four pairs of adult beetles (one day old) of same age in each jar for repellency activity. The observations were taken at weekly intervals for observing the live number of beetles emerged in each jar and fecundity was also recorded randomly on ten (10) grains in each jar. The mode of damage by pest was recorded during the entire period of study. The number of eggs laid on grains was counted at 07 days after pest released. All adults were removed after counting the dead and live adults from jars. During experimentation the effects of temperature and relative humidity on population of red flour beetle were observed. Upon the termination of the experimental period (from August 10 to November 30, 2008) the parameters studied were adult emergence, fecundity and % grains weight

loss. The weight losses were calculated by subtracting the value of infested grain weight from the original weight. The percent weight loss was calculated by using the following formula:-

$$\text{Percent Weight loss} = \frac{\text{Initial weight of wheat grain} - \text{Final weight of wheat grain}}{\text{Initial weight of wheat grain}} \times 100$$

The data obtained for the present work was subjected to statistical analysis with student Stat Test.

3. Results and Discussion

The results of experiment conducted on repellence activity of plant oils against red flour beetle, *Tribolium castaneum* (Herbst) in wheat under laboratory conditions are given below: -

3.1. Adults Emergence of Red Flour Beetle in Treated and Untreated Wheat

The data in (Table. 1) show that due to repellence activity of mustard oil less population of adults' emerged was observed as compared to the control (maximum 119.75). The maximum (70.25) population of adults was emerged on 1st week of September, 2008, however, the minimum (1.00) emerged on 4th week of November. The adult's emergence due to repellent substance increased gradually and then the population of beetle was remained low up to November. Due to repellency of coconut oil maximum (63.5) population of adults was emerged on 4th week of August, however, the minimum (1.24) adults emerged on 2nd and 4th weeks of November. Due to repellency of sesame oil maximum (26.75) population of adults was emerged on 3rd week of September, while, the minimum (1.00) emerged on 2nd week of November. Due to repellency of rocket seed oil less population of adults emerged was observed as compare to the control, where maximum (4.50) population of adults was emerged on 3rd week of September, though, the minimum (1.00) population emerged on 4th week of November. Overall, the data indicate that all these treatments remained statistically significant (P> 0.05) as compared with control.

Table. 1. Effects of different plant oils on the adult emergence of Red flour beetle, *Tribolium castaneum* on wheat grain from August 10 to November 30, 2008.

Observation periods	Mustard oil	Coconut oil	Sesame oil	Rocket seed oil	Control
August-10	10.75	1.26	7.50	1.51	6.50
17	19.75	18.25	7.75	3.00	34.0
24	22.00	41.5	2.25	2.25	84.0
31	23.25	63.5	1.25	4.00	119.75
September-7	70.25	17.75	7.75	4.25	127.0
14	18.75	22.0	23.25	3.50	49.75
21	7.00	10.0	26.75	4.50	13.25
28	8.50	13.0	19.5	3.25	12.5
October-5	6.75	2.75	8.0	2.50	3.25
12	2.56	14.0	22.0	2.25	12.0
19	1.75	3.25	4.25	1.25	4.25
26	1.50	3.00	2.75	2.00	4.00
November-2	1.50	5.25	1.25	3.25	5.50
9	1.01	1.24	1.0	1.75	2.75
16	1.01	1.50	1.25	1.50	1.50
23	1.01	1.25	1.25	1.25	2.25
30	1.00	1.24	1.25	1.00	1.25
Mean± S.E	8.18±2.16	11.66±4.15	12.99±4.09	2.53±0.27	28.44±10.15

Table 2. Effects of different plant oils on the fecundity of Red flour beetle, *Tribolium castaneum* on wheat from August 10 to November 30, 2008.

Observations periods	Mustard oil	Coconut oil	Sesame oil	Rocket seed oil	Control
August-10	1.25	1.25	1.50	1.25	5.75
17	1.25	5.25	1.75	2.5.	10.75
24	1.50	11.25	2.5	1.50	13.25
31	5.50	8.50	4.25	2.0	20.0
September-7	17.0	5.25	11.75	1.75	34.0
14	25.25	4.25	5.25	2.5	50.25
21	3.50	5.75	5.25	2.75	30.75

Observations periods	Mustard oil	Coconut oil	Sesame oil	Rocket seed oil	Control
28	17.25	15.5	11.0	2.25	19.0
October-5	13.0	8.5	3.75	1.50	7.25
12	1.75	4.00	8.50	1.50	2.5
19	4.75	2.25	4.50	1.25	3.75
26	1.75	3.50	3.25	1.75	2.0
November-2	12.5	3.50	11.50	1.75	4.75
9	2.5	2.00	3.75	2.00	2.5
16	1.25	1.00	1.27	1.50	2.75
23	1.24	1.25	1.25	1.25	1.75
30	1.25	1.25	1.23	1.23	1.74
Mean± S.E	4.84±0.89	4.96±0.97	6.62±1.81	1.78±0.12	12.51±3.41

3.2. Fecundity of Red Flour Beetle in Treated and Untreated Wheat

The results in the data (Table. 2) revealed that less egg lying was recorded in mustard oil as compared to the control. The maximum numbers of eggs (25.25) were observed on 2nd week of September, 2008, on the other hand, the minimum eggs (1.24) recorded on 4th week of November. The results as well revealed that less number of eggs was recorded in coconut oil as compared to the control. The maximum numbers of eggs (15.5) were observed on last week of September; nonetheless, the minimum (1.00) was recorded on 3rd week of November. The results further revealed that less number of eggs was recorded in sesame oil as compared to the control. The maximum numbers of eggs (11.75) were observed on 1st week of September, conversely, minimum eggs (1.23) recorded on 4th week of November. Data revealed that less number of eggs was recorded with rocket seed oil as compared to the control. The maximum numbers of eggs (2.75) were observed on 3rd week of September, though; minimum (1.23) recorded on 4th week of November. Similarly, maximum fecundity (50.25) was observed on 2nd week of September and minimum fecundity (1.74) was recorded on 4th week of November in control treatment. Nevertheless, these results indicate that all these treatments were statistically significant (P> 0.05) as compared to untreated wheat grains.

3.3. Grain Weight Loss Caused by Red Flour Beetle in Treated and Untreated Wheat

The effect of plant oils on wheat grain weight loss by red flour beetle showed that all the plant oils at their used concentration rate significantly reduced the weight loss by red flour beetle when compared with the control (Table. 3). The minimum weight loss (7.92%) was seen in Rocket seed oil at its application rate of 0.25 ml. The maximum weight loss (87.44%) was recorded in the control. However, sesame oil was the least effective in protecting the wheat grain (45.0%) followed by coconut oil (27.28%) from the damage of red flour beetle when applied at the rate of 0.25 ml.

Table 3. Effects of different plant oils on the weight loss in wheat by *T. castaneum*.

Treatments	Initial weight (gm)	Final weight (gm)	Weight loss (gm)	% Losses
Mustard oil	250	225.7	24.3	9.72
Coconut oil	250	180.3	69.7	27.28
Sesame oil	250	135.8	114.5	45.00
Rocket seed oil	250	230.18	19.82	7.92
Control	250	231.4	18.6	87.44

3.4. Effects of Temperature and Relative Humidity on Population of Red Flour Beetle

Table 4. Weekly mean population of Red flour beetle, *T. castaneum* under laboratory temperature (°C) and relative humidity (%) from August 10 to November 30, 2008.

Month and Week	Mean population of beetle	Temperature °C	Relative humidity (%)
August -10	5.25	36.4	62.4
17	12.18	36.1	63.0
24	17.00	35.9	63.7
31	23.00	36.1	64.3
September-7	25.00	36.5	62.1
14	16.87	36.9	61.4
21	12.06	33.4	58.9
28	11.06	33.8	59.5
October-5	5.00	31.2	55.6
12	10.20	31.8	58.6
19	2.62	31.7	55.3
26	2.31	31.4	57.2
November-2	2.81	30.6	56.4
9	1.25	30.3	54.1
16	1.315	29.9	53.6
23	1.19	29.6	51.9
30	1.12	28.5	48.4

The data in Table 4 show that the maximum temperature (36.9°C) was recorded on the 2rd week of September, 2008. However, the minimum temperature (28.5°C) was recorded on 4th week of November 2008. Similarly, the maximum

humidity (64.3 %) was recorded on the last week of August. Contrary to this, the minimum humidity (48.4%) was recorded on last week of November. A positive correlation (r^2= 0.27) was observed between the temperature and pest population. However, the moisture did not show significant role (r^2 = 0.006).

The overall results in Tables 1 and 2 show that the minimum adult emergences (2.53±0.27) of red flour beetle was recorded in Rocket seed oil followed by in Mustard oil (8.18±2.16), Coconut oil (11.66±4.15) and Sesame oil (12.99±4.09). But, the maximum adults' emergence was observed in control (28.44±10.15) treatment. Similarly, the minimum fecundity (1.78±0.12) was recorded in Rocket seed oil followed by mustard oil (4.84±0.89), coconut oil (4.96±0.97) and sesame oil (6.62±1.81), on the other hand, the maximum (12.51±3.41) observed in control treatment.

During present studies it was observed that the repellent activity of plant oils was different on red flour beetle in wheat grain. During severe infestation due to attack of this pest, disagreeable odor was felt making grain unfit for human consumption. Besides that it also reduced the quality and quantity of grains. Similar to our results, Suresh et al., (2001) reported that red flour beetle, *T. castaneum*, is a polyphagous, cosmopolitan pest feeding mostly on stored flour and other milled cereal products, broken wheat and farm stored produces. While, Ali. et al., (2009; 2011) reported that *T. castaneum* was one of the destructive pests of stored wheat grain. These results are also close to the observations of Andronikashvili and Reichmuth (2003) who evaluated the repellency and toxicity properties of oils against *T. castaneum* and mentioned that the fecundity of surviving insect was reduced by the oils. All the essential oils gave an adequate toxicity to *T. castaneum* insect species tested. Pronounced increase of pest's mortality was observed for most of the essential oils during their time of exposure. Our results are further close to the results of Lee et al., (2002), Wang et al., (2006), Negahban and Moharramipour (2007), Waqas et al., (2007), and Upadhyay and Jaiswal (2007). These workers investigated the toxicity, repellency and reproductive inhibition induced by grounded leaves, water or acetone leaf extracts and essential oils against *T. castaneum* and other stored grain pests in the laboratory by using contact toxicity, grain treatment and repellency assays. They reported that all the tested substances were acutely toxic to *T. castaneum.* Further, they mentioned that essential oil was most potent and provided the highest protectant potential to grains against pest infestation. Obeng-Ofori and Freemam (2001) investigated the toxicity, repellency, and inhibition induced by grounded leaves, leaf extracts, and essential oil against *Sitophilus oryzae* and *Tribolium castaneum*. Grounded leaves and essential oil of the plant species were acutely toxic to *S. oryzae* and *T. castaneum*. The crude extracts and essential oil applied topically on the insects were most active, inducing 100 percent mortality of the two beetle species. Development of eggs and immature stages within grain kernels as well as progeny emergence were also inhibited in treated grain, and essential oil of the plants induced moderate repellency against the beetles. Of the materials tested, the essential oil was most potent and provided the highest protectant potential to grain against pest infestation. Acetone leaf extract was more effective than the aqueous extracts. The protecting potential of products derived from the plant species against insect pest infestation in traditional farm stored grain was argued.

Our results are also agreeable with the results of Dars et al., (2001) who reported that stored grains are subjected to insect's infestation and deterioration by pest's attack. High grain temperature and moisture along with broken kernels provided condition that accelerated mold and insect development. The most favorable grain moisture range for stored grain insects was from 9-12% (Shafique et al., 2006). Russo et al., (2004) reported the predatory activity of *Xylocoris flavipes* (Hempiptera: Anthocoridae) feeding on red flour beetle, *T. castaneum*. Survival of eggs and larvae was high at 24°C and 32°C, respectively. At 19°C none of the larvae survived longer than the first instar, whereas at 21°C the number of the larvae completing the immature stage was extremely low. Developmental time was significantly shorter at 32°C. Females lived longer at 21°C, but no differences were observed at 24°C and 32°C. Fecundity greatly reduced at 21°C and was higher at 32°C. At 21°C, the intrinsic rate of increase (rm)) reached the minimum (0.0004), and gradually increased with temperature (0.054 at 24°C and 0.137 at 32°C). At 24°C larvae consumed more prey during their development, but at 32°C the predation rate per day was higher. For adults both total development rate and predation rate per day were higher at 32°C. The performance of the anthocorid at the various temperatures is discussed in relation to its practical use as a control agent for stored product insects. Hence, it is examined that the weather parameters play a crucial role in governing the population build up of storage insects.

4. Conclusion

The conclusions from the current studies are derived that all the plant oils were comparatively better for keeping the red flour beetle below infestation level. Rocket seed oil (Jambho) proved more effective among the other oils as the minimum weight loss of grain was found in this seed oil treatment in wheat, while maximum observed in control. Population of adults emerged and fecundity increased in the months of

August and September. The temperature 36°C and humidity 61% were found favorable for pest's multiplication in wheat grains. Maintaining the lower and higher temperatures (below 20°C and above 40°C) would be better for management of flour beetle in storage. The recommendations are that the farmers should use the indigenous plant oils for the control of red flour beetle to protect wheat in storage. These plant oils are easy to apply, locally available, economical and safe for usage.

References

[1] Abro, G.H. 1996. Relative resistance of commercially grown varieties of different cereals to *Tribolium castaneum* (Herbst) attack. Pakistan Journal of Zoology, 28 (1): 39-44.

[2] Alanko, K., Tuemi, T., Vanhanen, M., Pajari, M., Buckas, L., Kanerva, K., Havu, K.S. and Bruynzeel. D.P. 2000. Occupation confusium (confused flour beetle) Allergy. 55: 879-882.

[3] Ali, A., Sarwar, M., Khanzada, S. and Abro, G.H. 2009. Reaction of certain wheat varieties to the action of Red Flour Beetle, *Tribolium castaneum* (Herbst) (Coleoptera) under insectary conditions. Pakistan Journal of Zoology, 41 (1): 51-56.

[4] Ali, A., Sarwar, M., Khanzada, S. and Abro, G.H. 2011. Evaluating Resistance of Wheat Germplasms to Attack by Red Flour Beetle, *Tribolium castaneum* (Herbst) (Coleoptera). Pakistan Journal of Zoology, 43 (4): 793-797.

[5] Al-Jabr, A.M. 2006. Toxicity and repellency of seven plant essential oils to *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) and *Tribolium castaneum* (Coleoptera: Tenebrioidae). Basic and Applied Sciences, 7 (1): 49-60.

[6] Andronikashvili, M. and Reichmuth, C. 2003. Repellency and toxicity of essential oils from *Ocimum gratissimum* (Lamiaceae) and *Laurus nobilis* (Lauraceae) from Georgia against the rust-red flour beetle (*Tribolium castaneum* Herbst) (Coleoptera: Tenebrionidae). Advances in stored product protection. Proce. of the 8th Inter. Conference on Stored Product Protection, York, UK, 22-26 July 2002. p. 749-762.

[7] Lee, B., Lee, S., Annis, P.C., Pratt, S.J. and Tumaalii, B.P. 2002. Fumigant toxicity of essential oils and monoterpenes against the Red flour beetle, *Tribolium castaneum* Herbst. Journal of Asia-Pacific Entomology, 5 (2): 237-240.

[8] Lohar, M.K. 2001. Pest of stored grain and their control. Applied Entomology, 2nd Edition, 13 (2): 99-115.

[9] Mahroof, R., Subramanyam, B. and Eustace, D. 2003. Temperature and relative humidity profiles during heat treatment of mills and its efficacy against *Tribolium castaneum* (Herbest) life stages. Journal of Stored Products Research, 39 (5): 555-569.

[10] Negahban, M. and Moharramipour, S. 2007. Efficiency of *Artemisia sieberi* and *Artemisia scoparia* essential oils on nutritional indices of *Tribolium castaneum* (Col: Tenebrionidae). Iranian Journal of Medicinal and Aromatic Plants, 23 (1): 13-22.

[11] Obeng-Ofori, D. and Freeman, F.D.K. 2001. Efficacy of products derived from *Ricinus communis* (L.) and *Solanum nigrum* (L.) against *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst) in stored maize. Ghana J. of Agricultural Science, 34 (1): 39-47.

[12] Renteria, G., Moreno, T.R., Martinez, E. and Hoys, J.M. 2000. Population growth of *Rhizopertha dominica* (F.) and *Tribolium castaneum* (H.) in different wheat varieties and groups commercially produced in Sonoro Mexico. Southwestern Entomol., 25 (3): 213-220.

[13] Russo, A., Cocuzza, G.E. and Vasta, M.C. 2004. Life tables of *Xylocoris flavipes* (Hempiptera: Anthocoridae) feeding on *Tribolium castaneum* (Coleoptera: Tenebrionidae). Journal of Stored Products Research, 40 (1): 103-112.

[14] Sarwar, M. 2009. Evaluating wheat varieties and genotypes for tolerance to feeding damage caused by *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Pakistan Journal of Seed Technology, 2 (13 & 14): 94-100.

[15] Sarwar, M. 2010. Some possibilities on the effectiveness of plant powders as grain protectants against cowpea weevil, *Callosobruchus maculatus* (Fabricius) Walp (Coleoptera: Bruchidae) infestation in chickpea. International Journal of Agronomy and Plant Production, 1 (2): 45-50.

[16] Sarwar, M. 2013. Development and Boosting of Integrated Insect Pests Management in Stored Grains. Research and Reviews: Journal of Agriculture and Allied Sciences, 2 (4): 16-20.

[17] Sarwar, M., Ahmad, N., Rajput, A.A. and Tofique, M. 2004. Search for Varietal Resistance within Stored Wheat Genotypes against the Infestation of Red Flour Beetle, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae). Proce. 4th Inter. Congress of Entomological Sciences, University of Agric., Faisalabad, September, 22-23. p. 23-27.

[18] Sarwar, M., Ashfaq, M., Ahmad, N. and Randhawa, M.A.M. 2013. Assessing the Potential of Assorted Plant Powders on Survival of *Caloglyphus* Grain Mite (Acari: Acaridae) in Wheat Grain. International Journal of Agricultural Science and Bioresource Engineering Research, 2 (1): 1-6.

[19] Sarwar, M. 2011. Effects of wheat and barley intercropping ecosystem on the prevalence of aphid (Hemiptera: Aphididae) population in canola (*Brassica napus* L.) crop. Biological Diversity and Conservation, 4 (1): 11-16.

[20] Sarwar, M. 2015. Species Diversity, Seasonal Variation and Abundance of Rodents (Mammalia: Rodentia) Along With Their Burrow Distribution Pattern in Wheat Farmland. Journal of Basic and Applied Research International, 5 (1): 48-55.

[21] Sarwar, M. and Sattar, M. 2012. Appraisal of Different Plant Products against *Trogoderma granarium* Everts to Protect Stored Wheat- A Laboratory Comparison. The Nucleus, 49 (1): 65-69.

[22] Shafique, M., Maqbool, A. and Chaudry, M.A. 2006. Feeding preference and development of *Tribolium castaneum* (Herbst) in wheat products. Pakistan J. of Zoology, 38 (1): 27-31.

[23] Shemais, S.A. 2000. Biological activity of neemazol powder and katelasous dust against *Trogoderma granarium* Everts adult (Dermestidae: Coleoptera). Egyptian Journal of Agric. Res., 78 (2): 643-651.

[24] Siddiqui, Q.H. and Sarwar, M. 2002. Pre and post harvest losses in wheat. Pakistan and Gulf Economist, XXI (6): 30-32.

[25] Suresh, S., White, N.D.G., Jayas, D.S. and Hulasare, R.B. 2001. Mortality resulting from interactions between the Red flour beetle and the rusty grain beetle. Proc. of the Entomol. Soc. of Manitoba, 57: 11-18.

[26] Tripathi, A.K., Pragapati, V., Aggarwal, K.K. and Kumar, S. 2001. Toxicity feeding deterrence and effect of activity of 1, 8, cinecola from *Artemisia unnica* on progeny production of *Tribolium castaneum* (Coleoptera: Tenebrionidae). J. Econ. Entomol., 94: 979-983.

[27] Tunio, S. 2002. Grain storage problems in Pakistan. Pakistan and Gulf Economist. www.pakistaneconomist.com/issue200236/i&e4.htm.

[28] Upadhyay, R.K. and Jaiswal, G. 2007. Evaluation of biological activities of *Piper nigrum* oil against *Tribolium castaneum*. Bulletin of Insectology, 60 (1): 57-61.

[29] Wang, J.Z., Zhou. F., Niu, X.M. and Lei, C.L.C.Y. 2006. Repellent and fumigant activity of essential oil from *Artemisia vulgaris* to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Journal of Stored Products Research, 42 (3): 339-347.

[30] Waqas, W., Mansoor-ul-Hasan, Faiza, B. and Sagheer, M. 2007. Comparative efficacy of different grain protectants against *Tribolium castaneum* under two sets of temperature and humidity. Bulletin OILB/ SROP., 30 (2): 273-279.