PREDATORY APTNESS OF ANTS AGAINST RED FLOUR BEETLE, *TRIBOLIUM CASTANEUM* HERBST (TENEBRIONIDAE: COLEOPTERA) IN WHEAT FLOUR

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ABSTRACT:- The red flour beetle (RFB), *Tribolium castaneum* is one of the most destructive pests of stored grains and other food products including wheat flour. Due to its severe infestation, the flour gets mouldy, turns yellowish, gets pungent odour and becomes unhealthy for human consumption. The infested samples of wheat flour by *T. castaneum* were collected from different localities and its culture was maintained in laboratory. Three ant species namely, *Dorylus labiatus, Camponotus rufipes* and *Monomorium minimum* were collected from forest and non-forest habitats and compared for their predation against different life stages of RFB. Results showed *D. labiatus* of forest habitat as an efficient pupal predator that consumed 91.66% pupae of RFB. It was significantly different from non-forest ant population and control with 73.33% and 11.66% pupal predation, respectively. *C. rufipes* from forest habitat showed maximum adult predation (25%), which was significantly higher than non-forest ant population and control jar with 15% and 3.33% adult predation, respectively. The forest population of *M. minimum* exhibited 56.66% larval predation that was significantly different from non-forest population with 41.66% larval consumption. Pupal stage was the highest vulnerable stage to the ant predation and was extremely predated by *D. labiatus* collected from forest habitats. The lowest predation was observed at larval stage by forest population of *M. minimum* (1.66%) that was significantly different from all the susceptible stages of RFB. These results indicate that ants could be used as biological control agents against RFB.

Key Words: Tribolium castaneum; Predation; Ants; Life Stages; Biological Control; Monomorium minimum; Dorylus labiatus; Camponotus rufipes; Pakistan.

INTRODUCTION

Wheat is principal food grain of Pakistan that occupies largest area under single crop. It contributes 10% to the value added in agriculture and 2.10% to the national GDP. During 2014-15, area under wheat cultivation was 0.918 mha with production of 25.4 mt and yield of 2,775 kg ha^{-1} (GoP, 2015).Wheat has important ingredients that make it a nutritious food with 55% carbohydrates and 20% food calories (Kumar et al., 2011).

There are biotic (insects, rodents, molds and birds) as well as abiotic (moisture content of grains, temperature and humidity) factors involved in post-harvest losses of wheat. Many physical factors, poor storage struc-

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tures and poor handling during storage are involved in its losses (Ali et al., 2009). Insect outbreaks stimulated by poor sanitation and unsuitable storage infrastructures have been reported to cause considerable damage to stored food products, particularly in developing countries (Vojoudi et al., 2012). Insect pests not only deteriorate quality of food grains but also cause significant quantitative loss of stored food products. Insect pests usually cause 5-10% losses of stored food grains worldwide. However, these losses could be as high as 50% in tropical countries during summer season when conditions of high temperature and relative humidity prevail (Adams, 1998; Ahmad and Ahmad, 2002; Raja et al., 2001).

Red flour beetle, *Tribolium castaneum* Herbst (Tenebrionidae: Coleoptera) is considered as the most destructive pest of wheat flour and other stored commodities (Campbell and Arbogast, 2004; Rajendran and Devi, 2004). The larvae obliterate 12.5-14.60% of the weight of single seeds and in the course of their growth; 88 grains are attacked per larva (Ali et al., 2011).It primarily attacks milled grain products such as cereals and flour and is known as bran bug. It does not feed on intact grains and causes considerable losses to flour (Li and Arbogast, 1991). As being a major pest of wheat, RFB has maximum rate of population growth noted for any pest of stored products (Ahmed et al., 2010).

The overuse of pesticides has detrimental effects on environment and non-target organisms (Agarwal et al., 2007). Although conventional biological control has attained marvelous achievements over the past century, however, more consideration is required to increase effect of natural enemies as bio-control agents (Greathead, 1991). The impact of classical biological control measures has led to significant reduction in pest populations (Lauda et al., 2002 and Michaud, 2002). Many ant species are important predators of agricultural pests and cause significant reduction in pest populations damaging orchards as well as annual crops (Mele and Cuc, 2001). Ants are considered among the most important biological control agents of various insect pests of stored grains such as *Callosobruchus chinensis*. Among ants, *Monomorium minimum* proved an excellent egg predator; *Camponotus rufipes* as most effective adult predator while *Dorylus labiatus* as the best larval and pupal predator of *C. chinensis* (Aslam et al., 2006). Pierre and Idris (2013) reported predatory effectiveness of ant, *Oecophylla smaragdina* on bagworm, which is a pest of oil palm. According to Cao et al. (2012), red imported fire ants (*Solenopsis invicta*) were pupal predators of oriental fruit fly, *Bactrocera dorsalis.*

To develop a biological control strategy that is one of the most appropriate strategies to manage *T. castaneum* in stored wheat flour, it is extremely important to investigate impact of ant predation on *T. castaneum.* The objective of the study was to determine predatory aptness of different ant species against *T. castaneum* and also to observe the inter-specific and intra-specific variation in predatory effectiveness of these ant species on different developmental stages of *T. castaneum.*

MATERIALS AND METHOD

The samples of wheat flour infested by *T. castaneum* were collected from different localities. Its culture was maintained in an incubator at 30±2°C, in the Department of Entomology, Pir Mehr Ali Shah - Arid Agriculture University, Rawalpindi. Three ant species namely *Dorylus labiatus* Shuckard, *Camponotus rufipes* Fabricius and *Monomorium minimum* Buckley were collected from forest and non-forest habitats and culture of each species from each habitat was maintained separately in rearing jars; hence cultures of six ant groups were maintained. Each ant group was collected from just one location to maintain its genetic uniformity. The ants were nourished followed by Aslam et al. (2006) and were also fed on artificial diet that was prepared followed by Carney (1970). Taxonomic identification of collected ants and reared *T. castaneum* was done at National Insect Museum, NARC, Islamabad, following Bingham (1903), Halstead (1963) and Umair et al. (2012).

For insect bioassays, six groups of ants of three different species collected from forest and non-forest habitats were evaluated for their predatory efficacy against different developmental stages viz., larva, pupa and adult of red flour beetle. Twenty one insect rearing jars were taken and 50g wheat flour was put in each jar. Twenty adults of RFB were transferred in each jar and mouths of all jars were closed with muslin cloth secured by rim of lid so as to disallow the entry or exit of any insect. Adults of RFB were allowed to oviposit for one week. After one week, ten ants from every culture of aforementioned six ant groups were released in separate jars whereas one jar was kept as control. All the treatments including control were replicated thrice. The control treatment included jars having red flour beetle adults and flour but no ants. The aptness tests were carried out in the incubator at 30±2°C and 70-75% relative humidity and laid down in completely randomized design. The ants were provided with supplemental food as described above. Ants dying naturally were replaced by fresh ones to ensure that the specified number of ants were present throughout the experimental period. The number of red flour beetle larvae emerged from hatched eggs was counted in each jar. The larval, pupal and adult predation by ants was calculated in percentages and compared with the jars without ants. Data were recorded to interpret inter-specific and intra-specific variation in predatory efficacy of ants.

The data were statistically analyzed using SPSS-21.0 for Windows and Duncan's Multiple Range Test (DMRT) was applied to compare the means.

RESULTS AND DISCUSSION

Inter-specific Variation in Predatory Efficacy of Ants against Red Flour Beetle

Predatory Aptness of Ants Collected from Forest Habitats

Larval Predation

D. labiatus showed larval consumption of 78.33% which indicates its potential as efficient larval predator. However, *M. minimum* showed 56.66% larval consumption followed by *C. rufipes* exhibiting 8.33% larval predation which was non-significantly different from control treatment with 5% larval predation (Figure 1).

Pupal Predation

D. labiatus consumed 91.66% RFB pupae which was significantly different from *M. minimum* with 46.66% pupal mortality. The pupal predation shown

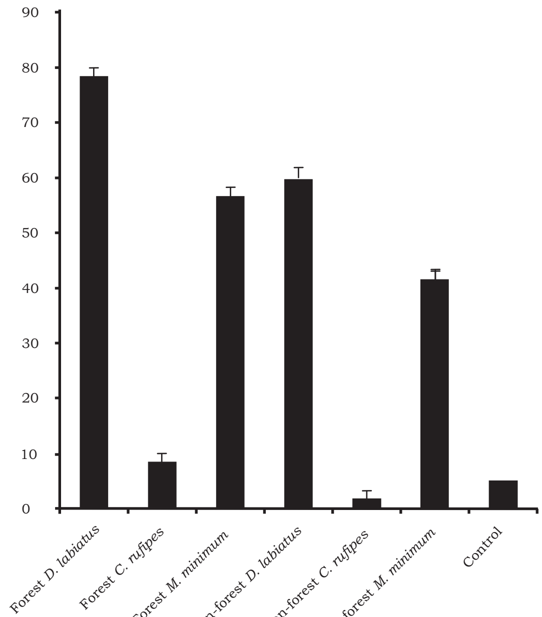

Figure 1. Predation of red flour beetle larvae by three ant species collected from forest and non-forest habitats

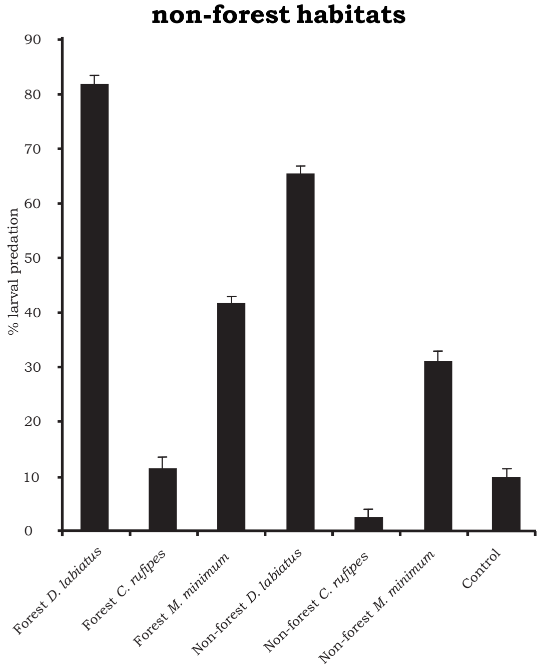

Figure 2. Predation of red flour beetle pupae by three ant species collected from forest and non-forest habitats

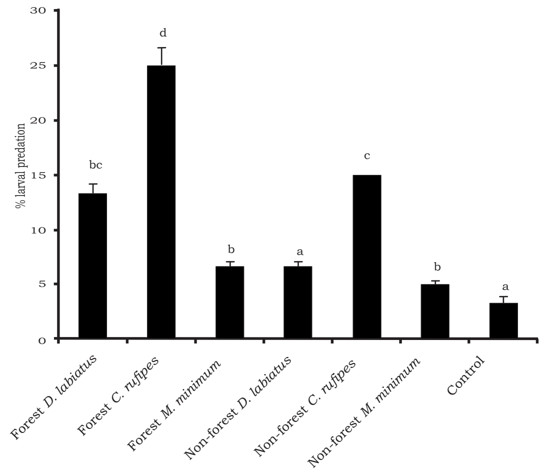

Figure 3. Red flour beetle adult predation by three ant species collected from forest and non-forest habitats

by *C. rufipes* was 13.33% which was statistically similar to the control, where 11.66% pupal consumption was observed (Figure 2).

Adult Predation

Maximum adults were consumed by *C. rufipes* (25%) making it significantly different from other two ant species and control treatment. The level of adult predation by *D. labiatus* and *M. minimum* was 13.33% and 6.66% which was non-significantly different from each other and the control with 3.33% adult predation (Figure 3).

Predatory Aptness of Ants Collected from Non-forest Habitats

Larval Predation

D. labiatus predated large number of larvae (60%) of RFB which was significantly higher than *M. minimum* with 41.66% larval consumption, *C. rufipes* with 1.66% and the control which showed 5% larval mortality. However, larval consumption by *C. rufipes* was non-significantly different from control (Figure 1).

Pupal Predation

D. labiatus was observed as an efficient pupal predator (73.33%), which was significantly higher than other two ant species and the control. *M. minimum* consumed 35% pupae which was statistically higher than *C. rufipes* with the level of 3.33% larval consumption. Pupal consumption by *C. rufipes* was non-significantly different from control with 11.66% pupal mortality (Figure 2).

Adult Predation

Maximum adult predation shown by *C. rufipes* was 15%, which was significantly different from other ant species and control treatment. *M. minimum* and *D. labiatus* have shown 5% and 3.33% adult predation, respectively which were not significantly different from control (3.33%) and also with each other (Figure 3).

The level of larval consumption was significantly higher (78.33%) where *D. labiatus* collected from forest habitat were released. Non-forest population of *D. labiatus* was statistically similar to the *M. minimum* collected from forest area with the level of 60% and 56.66% larval predation but significantly different from non-forest population of *M. minimum* (41.66%). *Camponotus* sp. of forest area caused significantly higher (8.33%) larval mortality as compared to non-forest population of *C. rufipes* (1.66%) but both were statistically similar to the control with 5% larval predation.

D. labiatus consumed 91.66% pupa of *T. castaneum,* which was significantly higher than non-forest population of *D. labiatus* (73.33%). *M. minimum* from forest area was significantly higher (46.66%) than non-forest population of *M. minimum* (35%). Forest population of *C. rufipes* was significantly different from non-forest population with the level of 13.33% and 3.33% pupal predation but similar to the control (11.6%).

Maximum adult predation was observed in *C. rufipes* of forest habitat (25%), which was statistically not similar to non-forest *C. rufipes* (15%) and with other species. Forest population of *D. labiatus* predate 13.33 adults while non-forest population consumed 3.33%, however, both were significantly different with each other but non-forest *D. labiatus* was non-significantly different from the control (3.33%). Forest population of *M. minimum* was statistically similar to non-forest area with the level of 6.66% and 5% adult predation, respectively.

Intra-specific Variations in Predatory Efficacy of Ants against Red Flour Beetle

Predatory Aptness of Dorylus labiatus

Larval Predation

Larval predation by *D. labiatus* collected from forest habitat was 78.33% which was statistically different from those of non-forest ant population (60%). Control showed 5% larval mortality which was lower as compared to ant species collected from both habitats.

Pupal Predation

D. labiatus proved to be an efficient pupal predator that consumed 91.66% pupae of *T. castaneum* which was significantly different from non-forest ant population and the untreated control. Non-forest population showed 73.33% pupal mortality while control showed minimum pupal predation (11.66%). These treatments were statistically different from each other.

Adult Predation

D. labiatus collected from forest habitat consumed 13.33% adults of *T. castaneum* that was statistically not similar with non-forest population (Figure 3). Ant population from non-forest areas showed 3.33% adult predation that was non-significantly different from control (3.33%).

Predatory Aptness of Camponotus rufipes

Larval Predation

C. rufipes consumed 8.33% larvae of RFB and was significantly higher than non-forest ant population (1.66%) but statistically similar to the control treatment that showed 5% adult mortality. Non-forest and control treatments were significantly different from each other.

Pupal Predation

C. rufipes consumed 13.33% pupae of RFB that was significantly different from non-forest population (3.33%) but statistically similar to control treatment (11.66%). Non-forest ant population showed significant difference from control treatment.

Adult Predation

C. rufipes collected from forest habitat showed maximum adult predation (25%) which was significantly higher than non-forest ant population. Ant population from non-forest areas showed 15% adult predation which was statistically different from control in which 3.33% adult predation was observed.

Predatory Aptness of Monomorium minimum

Larval Predation

Population of *M. minimum* exhibited 56.66% larval predation that was significantly different from non-forest population with the level of 41.66% larval consumption. In control jar where no ants were released, the rate of larval mortality was 5% which is significantly lower than larval predation by ant species.

Pupal Predation

M. minimum collected from forest areas showed 46.66% pupal mortality, which was significantly higher than non-forest population. The level of pupal predation by non-forest population of *M. minimum* was 35% and the control treatment showed 11.66% pupal mortality which was statistically different from ant populations of both habitats.

Adult Predation

Adult consumption of RFB by forest population of *M. minimum* was 6.66% which was statistically similar to the non-forest population and the control jar where adult mortality was 5% and 3.33%, respectively.

Data indicated that pupal stage was the most vulnerable stage to the ant predation. *D. labiatus* collected from forest habitat were the most efficient pupal predators (91.66%), which was significantly higher than the predation of all the other life stages of RFB by different ant species. The maximum larval predation (78.33%) was observed in forest population of *D. labiatus* that was statistically similar to the non-forest population of *D. labiatus* with the level of 73.33% pupal predation but significantly different with other life stages predate by different ant species.

The least susceptible stage of *T. castaneum* for ant predation was adult stage. Maximum adult predation (25%) was done by *C. rufipes* collected from forest area which was statistically higher than non-forest population of *C. rufipes* (15%) but significantly lower than other life stages of RFB. Results showed that the maximum predation was observed at the pupal stage. The lowest predation was observed at the larval stage by forest population of *C. rufipes* (1.66%) that is significantly different from all susceptible stages of RFB.

These results showed that *D. labiatus* is the most efficient pupal predator of RFB. *C. rufipes* is an excellent adult predator. *M. minimum* shows maximum larval predation and are in conformity with Aslam et al. (2006). Jaffe et al. (1990) inferred that *Monomorium* spp. and *Solenopsis* spp. were mainly predators of egg stage. *Camponotus* spp. and *Crematogaster* sp. were larval predators of unprotected eggs but had difficulties in finding the first instar larvae of *Diaprepes abbreviatus* on the ground, which seemed to produce chemical ant repellents. Jonker (2013) investigated that high ant density reduced damage by pine weevil on conifer seedlings. Paulson and Akre (1992) used *Formica neoclara* into pear orchard against pear psylla. *F. neoclara* gave 80% results as a biological control agent. Ant species collected from forest habitat have aggressive behavior than non-forest ant species and predation rate is significantly higher than non-forest ant population. Results showed that ants could be used as biological control agents against various insect pests of field and stored food products.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

S. No	Author Name	Contribution to the paper
1.	Dr. Farid Asif Shaheen	Concieved research
2.	Dr. Sadia Parveen	Conducted research
3.	Dr. Ahmed Zia	Data analysis and identification
4.	Dr. Ghulam Qadir	Analysed data
5.	Dr. Mureed Husain	Wrote manuscript
6.	Dr. Rifat Ullah Khan	Made graph and proof checking

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