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EFFECT OF INSECT GROWTH REGULATORS ON FECUNDITY, FERTILITY AND ADULT EMERGENCE OF *Triboliumcastaneum* (HERBST) AND *Trogoderma granarium* (EVERTS)

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Storage of grains and their merchandises are significant part of post-harvest maneuvers. Yearly losses of stored grains commodities as a result of numerous biotic factors are noteworthy in financial terms. There is a dreadful necessity to protect the stored cereals and their products against deterioration, particularly the quantitative as well as qualitative losses in storage. The herein reported experimentations were performed to examine the toxic potentials of various insect growth regulators (IGRs), viz., methoxyfenozide 240SC, buprofezin 25%WP, flufenoxuron 10DC, triflumuron 20SC, tebufenozide 20SC, pyriproxyfen 10.8ECandlufenuron 50EC against fertility, fecundity and adult emergence of *Triboliumcastaneum*(Herbst) and *Trogoderma granarium* (Everts). Outcomes of the bioassays disclosed that remarkable decrease in fertility and fecundity of the insects was noted as a result of adult contact with IGRs treated diet. Fecundity was notably abridged by application of tebufenozide treatment trailed by methoxyfenozide whereas pyriproxyfen and buprofezin showed slight impact on *T. granarium* and *T. castaneum*. The findings concerning to the impact of IGRs treated diet on fertility of adults showed that the pyriproxyfen was remained highly operative in reducing hatching of the eggs while tebufenozide was proven minimum operational for the control ofboth insects. The production of progeny was least in case of pyriproxyfen and highest in tebufenozide for the bioassayed insects. From results of the study, it is determined that use of the IGRs has proven highly operative for controlling the two target insect pests. So, these compound mainly pyriproxyfen,triflumeron, lufenuron and flufenoxuron should be included as an effective constituent in integrated pest management of insect pests of stored commodities.
Keywords: IGRs, Fecundity, Fertility, Adult emergence, *Trogoderma granarium* and *Triboliumcastaneum*.

INTRODUCTION

Beside usage of the synthetic chemical pesticides, aiming management of insect pests and to reduce losses triggered by them, populations of the insects remain the main contestants of human beings for foodstuff, shelter and space. In storage the grain losses provoked by stored commodities insects may ranges 10-40% (Raja *et al*., 2001; Phillips and Throne, 2010; Ali *et al.*, 2016a, Rehman *et al*., 2019). The infestationof stored products insect pestshas a direct impact on quantity and quality of storage commodity (Campbell and Arbogast, 2004). Among all the insect pests of stored commodities, *Trogoderma granarium*(Burges, 2008) and *Triboliumcastaneum* (Awais*et al*., 2019) are pests of economic importance. Both these insects can consume a broader range of stored commodities (Udo, 2011). So, in time management of both these pests is very important.

Existing insect pest management approaches comprise of application of traditional artificial fumigants and insecticides. However their recurrent practices have certain intrinsic harms linked with them like demolition of useful insects and ecological threats (Padin*et al*.,2002), development of resistance (Daglish, 2008; Arthur *et al*., 2009; Opit*et al*., 2012). Therefore, there is dire necessity to familiarize substitute management tactics that are greater operative, non-residual, with low harmfulness to beneficial flora and fauna, target-specific and comparatively eco-friendly (Rehman *et al*., 2018). In the exploration of innovative insect pests control strategies, Insect Growth Regulators (IGRs) have been getting a pronounced attention by stored commodities insects control researchers (Mishra *et al*., 2013). IGRs have an innovative way of action, upsetting normal ecdysis and developmental phenomena of insect pests (Oberlander and Silhacek, 2000; Mondal and Parween, 2001). They possess lethal effects on the developmental stages i.e. egg, larvae, pupae and F_1 adult offspring (Mian and Mulla, 1982; Ali *et al*., 2017).

Insect growth regulators are accountable for the preservation of larval stage of insect (Mamatha *et al*., 2008; Awais*et al*., 2019). Their application has been resulted into abnormalembryonic development and pupae inhibition in insects (Tunaz and Uygun, 2004). They also affect the breeding performance (Segura *et al*., 2009) and may affect the fecundity of adults (Chanbang*et al*., 2008). Their usage results in early production of insect cuticle and also induces feeding inhibition irrespective of the instar or age of insect (Wing and Aller, 1990; Ali *et al.*, 2016b). They possess chemo-sterilant action when female have exposed to them (Heller *et al*., 1992; Yasir *et al*., 2019). In view of the above facts, current study was executed to scrutinize the impact ofbuprofezin, lufenuron, methoxyfenozide, tebufenozide, pyriproxyfen, triflumuron and flufenoxuron on the fecundity, fertility and adult emergence of *T. granarium* and *T. castaneum*.

MATERIALS AND METHODS

***Collection and Rearing*:** The heterogeneous populations of *T. granarium* (Everts) and *T. castaneum* (Herbst) were gathered from grains markets and gowdons at Punjab Food Departments situated at numerous districts in Punjab province, Pakistan. *Trogoderma granarium*population was mass reared on fresh sterilized wheat grains, whereas that of *T. castaneum*was raised on sterilized wheat flour, ostensibly safe from insect pest attack. Mass rearing of the insects was carried out in plastic jars, each having capacity of one kg diet (wheat flour/grains). The jars were concealed with perforated (muslin) cloth and positioned in the laboratory at 30±2°C and 65±5% relative humidity with a photoperiod of 16:8 L:D. Pupae of both the target insect pests were detached from the mix aged populations obtained from the above-mentioned sites and kept back in the chilled incubator (Model: MIR-254, SANYO) with ideal growth situations till the emergence of adult stage. After 1-2 days, 1000 adults were freed into the plastic jars having rearing diet. Afterwards 3 days, adult insects were sieved out from the diet and thrown away. The ensuing rearing diet having eggs of the adult beetles were taken into the jars and incubated at optimal developmental situations to obtain a uniform age offspring. Lastly, the homogenous populations of both the target insect pests were taken for the bioassays.

***Insect Growth Regulators (IGRs)*:** Saleable formulations of seven (7) IGRs were applied which comprised of methoxyfenozide 240%SC (Runner), triflumuron 20%SC (Capture), flufenoxuron 10%DC (Cascade), tebufenozide 20%SC (Top Gun), buprofezin 25%WP (Buprofezin), lufenuron 50EC (Match) and pyriproxyfen 10.8%EC (Bruce).

An acetone standard solution having 10 mg of technical IGR/ml was prepared for every formulation. Aliquots of every solution were diluted to desired concentration of IGR i.e. 2.5, 5, 7.5 and 10 ppm for every treatment. The total stock of chemicals and dilutions was kept at 1°C when not in practice.

***Treatment application Procedure*:** A lot of 500 g of wheat was separated into five equal slots of 100 g. The four prepared insecticide dilutions of the IGRs were sprayed to the diet. Beside the four dilutions, a fifth treatment consisting of acetone (solvent) treated diet was used as a control experimental unit. The preferred relative humidity was maintained by means of a NaCl solution (Greenspan, 1977). The diet was taken in plastic jars into which the aforementioned dilutions were pipetted. It was assured that the solvent had vaporized from the treated and un-treated diet units by mingling and aerating the rearing diet for 24 h prior to the shifting of target insects to the treated diet (wheat/flour).

***Bioassay*:** In this reproduction inhibition experiment, thirty newly emerged adults of *T. granarium*and *T. castaneum* (aged 12-15 days old adults) were held on food (wheat) treated with a series of IGRs concentrations along with an untreated control, using four replicates for each treatment. After one week exposure to IGRs treated or untreated food, adults were removed from the treated and untreated diet. After removal of adults, the jars containing treated and untreated food along with egg masses laid by the adults, were placed into the incubator (Model: MIR-254, SANYO) under optimum conditions (i.e., Temperature 30±2°C; Relative humidity 65±5%; Photo-period 16:8 L:D). After 1 day, 24 hour old eggs were separated from the media (diet) and effect on fecundity, fertility and adult emergence was recorded for both of the insects.

***Statistical Analysis*:** All the treatment levels were replicated tetrad by Completely Randomized Design. Findings were recorded for number of eggs laid, egg hatching and adult emergence. The recorded findings were statistically analyzed with the help of statistical software (Stat Soft, 8.0) and comparison of treatment means was done by Tukey's HSD test ($p \leq 0.05$).

RESULTS

***Effect on Fecundity*:** The effect of all the tested IGRs on the egg laying ability of *T. granarium* and *T. castaneum* is shown in Fig. 1. Results indicate that in case of *T. granarium* the minimum number of eggs 76.47 was recorded in tebufenozide treatment followed by methoxyfenozide with 76.35 numbers of eggs. The highest number of eggs

125.61 was noted in buprofezin treatment followed by pyriproxyfen (123.50 eggs). In case of *T. castaneum,* tebufenozide was the most effective with 107.52 numbers of eggs and that was at par with methoxyfenozide with 107.86 numbers of eggs. The highest number of eggs 159.02 was recorded where buprofezin was applied to the diet. Due to the effect of triflumeron and flufenoxuron the number of eggs was 114.07 and 112.75, respectively.

The efficacy of different concentration on egg laying capacity of *T. granarium* and *T. castaneum* is shown in Fig. 2. Results revealed that all the concentration had statistically significant effect on the egg laying ability of both the test insects. In case of *T. granarium* the minimum no of eggs (73.58) was observed at 10 ppm concentration and was highest 87.78 at 2.5 ppm after control treatment (154.32). In *T. castaneum* the egg lying was 121.26, 128.92, 138.79 and 148.58 at 10, 7.5, 5 and 2.5 ppm concentrations, respectively.

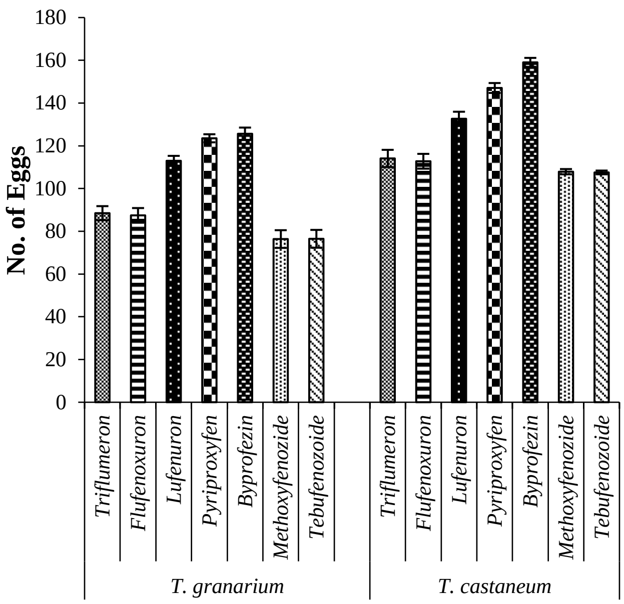

Figure 1. **Egg laying of *T. granarium* and *T. castaneum* against different IGRs**

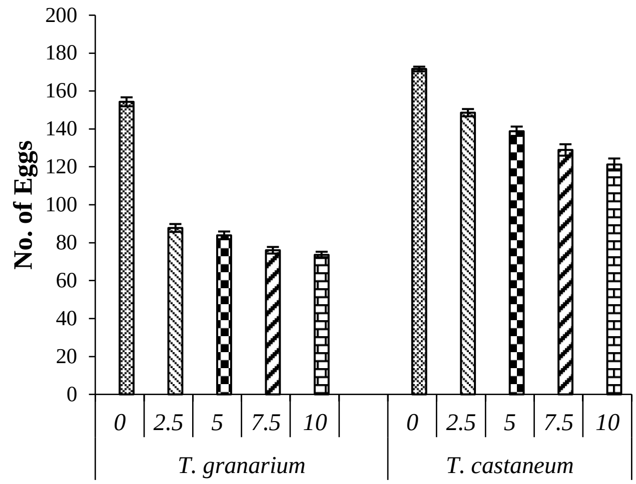

Figure 2. **Egg lying of *T. granarium* and *T. castaneum* against IGRs applied at different concentrations**

Effect on Fertility**:** The results regarding the IGRs have significant effect on the hatching of eggs that were laid by those adults which feed on IGRs treated diet for one week (Fig. 3). In *T. granarium,* the pyriproxyfen was the most effective in suppressing the egg hatching followed by lufenuron with values of 27.65 and 31.30 numbers of eggs, respectively. The hatchability values in flufenoxuron, triflumeron and buprofezin were 36.89, 37.09 and 42.14 number of eggs, respectively. Tebufenozide was the least effective having 49.07 number of eggs hatched followed by methoxyfenozide (47.12 number of eggs hatched). In *T. castaneum*(Fig. 3) the egg hatching was highest 75.81 in tebufenozide and was lowest 38.04 in pyroproxyfen, which means that the pyriproxyfen was the most effective and tebufenozide was the least effective for their ovicidal action.

The relative effect of concentrations on egg hatching (Fig. 4) revealed that all the test concentrations had significant effect on fertility of insects when they feed on IGRs treated diet. The results indicated that 10 ppm was the most effective one having values 22.29 and 54.26 number of eggs in *T. granarium* and *T. castaneum,* respectively. The 2.5 ppm was the least effective after control treatment. In *T. granarium* the hatching was 36.29, 32.60 and 24.73 numbers of eggs at 2.5, 5 and 7.5ppm concentrations, respectively. While in *T. castaneum* the hatching was in such order, 81.58 (2.5 ppm), 71.79 (5 ppm) and 61.92 (7.5 ppm). From these results it can be concluded that the fertility was decreased with the increase in concentration.

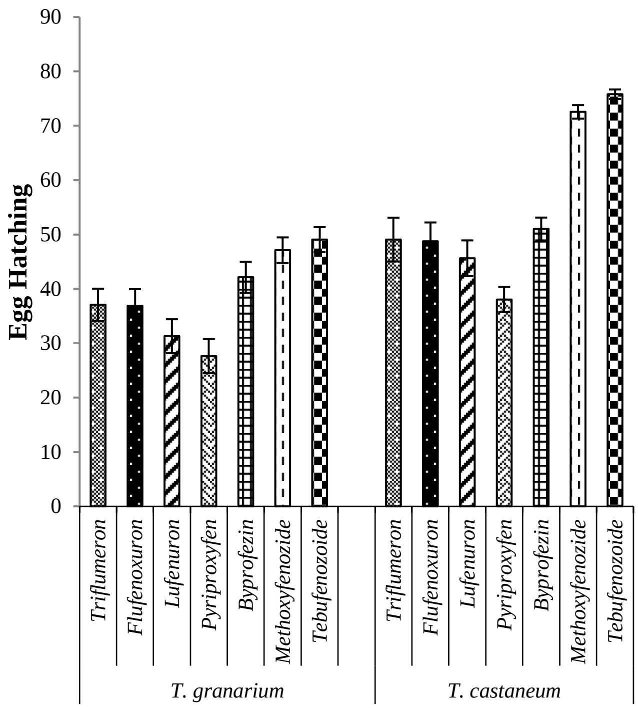

Figure 3. **Egg hatching of *T. granarium* and *T. castaneum* exposed to different IGRs**

***Effect on Adult Emergence*:** The comparative effect of the entire tested IGRs on adult emergence against *T. granarium* and *T. castaneum* is shown in Fig. 5. Results revealed that the lowest adult emergence (7.96 numbers of adults) was observed in pyriproxyfen followed by lufenuron (12.27) treatment application against *T. granarium*. Tebufenozide was the least effective against *T. granarium* with value 31.45 number of adults followed by methoxyfenozide (29.57 numbers of adults).

The adult emergence in *T. castaneum* was 43.49, 36.09, 31.57 and 29.55 numbers of adults due to the application of tebufenozide, methoxyfenozide, buprofezin and triflumeron, respectively (Fig. 5).

The comparative effect of all the concentrations revealed that 10 ppm was the most effective and 2.5 ppm was the least effective after control against both the test insects (Fig. 6). At 10 ppm the adult emergence was 4.61 and 9.22 against *T. granarium* and *T. castaneum*, respectively. The adult emergence in *T. granarium* was 18.49 at 2.5 ppm followed by 14.16 (5 ppm) and 7.45 (7.5 ppm). In case of *T. castaneum* the adult emergence was highest 38.57 at 2.5 ppm after control.

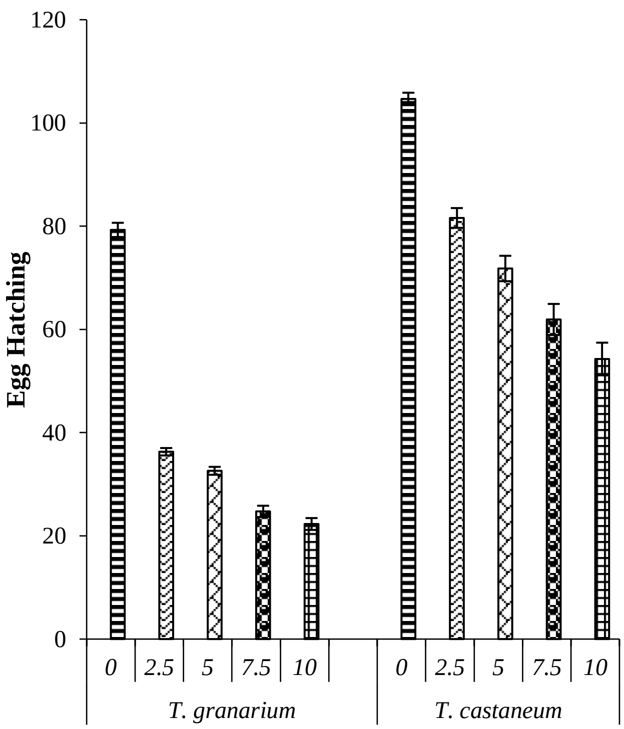

Figure 4. **Egg hatching of *T. granarium* and *T. castaneum* exposed to different concentrations of IGRs**

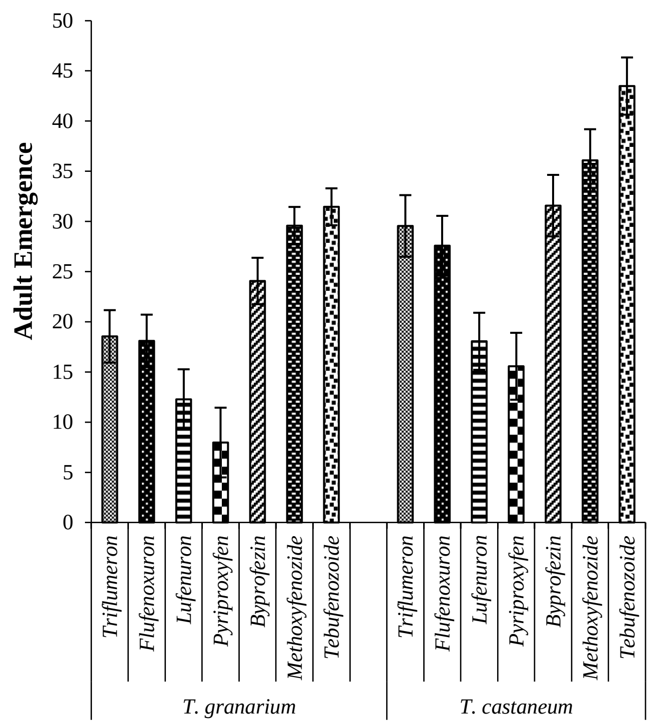

Figure 5. **Adult emergence of *T. granarium* and *T. castaneum* exposed to different IGRs**

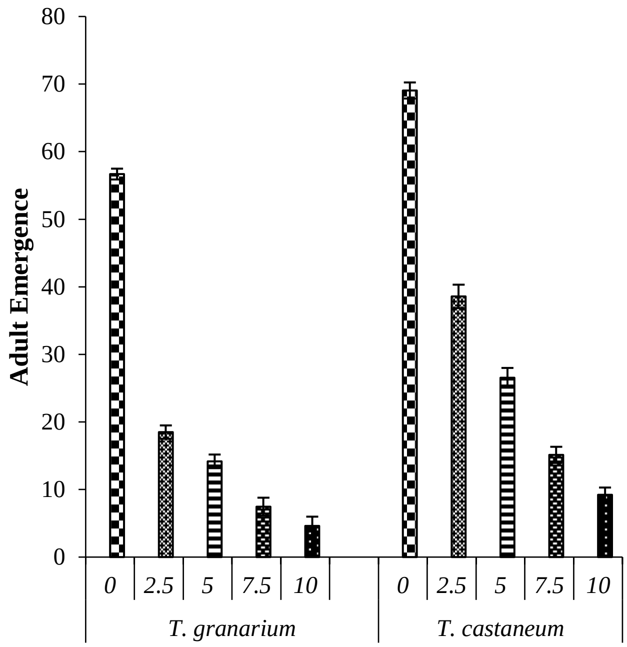

Figure 6. Adult emergence of *T. granarium* and *T. castaneum* against IGRs applied at different concentrations

DISCUSSION

The results regarding the effect of adult exposure to IGRs treated diet revealed that significant decrease in fecundity and fertility was observed against both insects under current studies. Fecundity was significantly reduced in tebufenozide treatment application followed by methoxyfenozide while buprofezin and pyriproxyfen had little effect against *T. castaneum* and *T. granarium.* Our results are supported by the finding of Edwards and Menn (1981), and Desmarchelier and Allen (1998) who concluded that JHAs (pyriproxyfen) had no profound effect on embryogenesis. Similarly, Parween (1996) and Yasir *et al*. (2012) reported that the triflumeron application to the adults of *T. castaneum* had resulted in reduction in egg laying and hatchability. Our findings are also in line with the results of Awais*et al.* (2019) who studied the effect of lufenuron against *T. castaneum*and found that there was significant reduction in egg laying and hatchability.

Our results regarding the effect on fertility of adults exposed to IGRs treated diet indicated that pyriproxyfen was the most effective in suppressing the egg hatching and tebufenozide was the least effective against *T. castaneum* and *T. graarium*. Our results are in conformity with those of Amos *et al*. (1978) and Ali *et al*. (2017) who reported the reduced productivity of *T. castaneum* when reared on methoprene incorporated diet. According to McGregor and Kramer (1976), Mian and Mulla (1982), Athanassiou*et al*. (2010) and Yasir *et al*. (2012) application of CSIs and JHAs against stored product insects had significantly reduced the adult fertility. These results are consistent with those of other studies (Elek and Longstaff, 1994; Oberlander *et al*., 1997;Elek, 1998; Kostyukovsky*et al*., 2000; Parween*et al*., 2001; Kostyukovsky and Trostanetsky, 2006). This phenomenon may be attributed to the activity of these compounds on the viability of eggs laid by females that were exposed to treated food.

In our results progeny production was minimum in pyriproxyfen and lufenuron and highest in tebufenozide treatment against both *T. granarium* and *T. castaneum*. Progeny production was also decreased with the increase of concentration. Similar results of inhibition of adult emergence had been reported by Strong and Diekman (1973) and Athanassiou*et al*. (2010) when stored grain insects were exposed to IGRs treated food media. Amos and William (1977), Bengston (1986) and Kavallieratos *et al*. (2012) also observed a significant reduction in adult emergence when *R. dominica* was exposed to IGRs treated diet. Similarly when *T. castaneum* adults were allowed to feed on Dimilin-treated sorghum and wheat, more than 79% adult emergence inhibition was obtained (Faragalla*et al*., 1985; Ali *et al*., 2017). Bell and Edwards (1999) and Ali *et al*. (2016b) reported reduced adult emergence when adults of *T. castaneum*, *T. confusum* and *E. cautella* were exposed to methoprene treated diet. Exposure of diflubenzuron and methoprene treated diet to adults of *S. oryzae* and *R. dominica*resulted in reduction in F_1 adult emergence (Daglish and Wallbank, 2005; Vassilakos and Athanassiou, 2012).

***Conclusion*:** From these findings, it is concluded that the use of IGRs have proved to be highly operative in term of reduction in fecundity, fertility and progeny production against both species under study. Hence, these compound particularly triflumeron, flufenoxuron, pyriproxyfen and lufenuron must be considered as an effective component in integrated pest management of stored commodities insect pests.

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