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EFFECT OF FENOXYCARB ON THE GROWTH DURATION AND LONGEVITY OF ADULTS OF RICE MOTH, *CORCYRA CEPHALONICA* STAINT. (LEPIDOPTERA:PYRALIDAE) EXPOSED AS FIRST INSTAR LARVAE

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ABSTRACT: First instar larvae of rice-moth, *Corcyra cephalonica* were exposed to 0.001, 0.005, 0.01, 0.05, 0.10, 0.50 and 1.00 ppm concentrations of fenoxycarb. It was observed that increased concentrations of fenoxycarb caused a significant ($P < 0.01$) enhancement in growth duration and an insignificant reduction in adult longevity in both sexes.

KEYWORDS: *Corcyra cephalonica***,** Fenoxycarb, Growth duration, Longevity

INTRODUCTION

Control of insect pests is a puzzling problem since many decades. *Corcyra cephalonica* Stainton, commonly known as rice moth, is a severe pest of stored cereals and cereal products in Asia, Africa, Europe, North America and other tropical and subtropical regions of the world. Its larval stages cause serious damage to rice, gram, sorghum, maize, groundnut, cotton seeds, peanuts, linseeds, raisins, nutmeg, currants, chocolates, army biscuits and milled products[8,5,6,36,46,21,4,43] .

Ordinarily, the control measures in stores are based on fumigation with chemicals like hydrogen phosphate. Residues and insect resistance are reasons for potentially limiting the use of fumigation with chemicals in the near future[60]. In recent years, there has been great concern over the toxicity of pesticides on non-target organisms and the environment. Although, chemical pesticides are invaluable in controlling insect populations both in the field and storage, their indiscriminate use has resulted in the destruction of beneficial insects and has caused environmental hazards[40,28,44]. Moreover, insecticide resistance has already developed in many insects which is now a great concern in post-harvest ecosystems throughout the word[54,2]. Persistent use of synthetic organic insecticides affect immune system of insects, develop resistance and ofcourse pollute our own environment due to non-biodegradability, biomagnification and toxicity to non-target organisms.

In such condition, there is a need for new alternatives to traditional insecticides used in stored product pest management[2,11,30,3]. In this regard, the

insect growth regulators (IGRs)[16], which mimic insect's hormone and regulate the insect population through the disruption of moulting and metamorphosis[58,39] have captured the interest of stored product entomologists. The first use of IGRs against stored product pests was reported[56] but they have only been tested on a small number of insect species. The term IGR was designed[53] to describe a class of bio-rational compounds. Through selectivity of action, these compounds appear to fit the requirements for "Third Generation Pesticides"[59] that disrupt the normal development of several species of insects[20]. These compounds are highly effective against various insects attacking stored products and other pests that have become resistant to organic insecticides. Meanwhile, all these compounds are less toxic to mammals and non-target organisms because of their non-toxic effect and their quick disintegrating abilities[7,53,38,22,23,24,40] .

Recently, Pener and Dhadialla[42] proposed the use of term "Insect Growth Disrupters" instead of "Insect Growth Regulators". At this time, Williams[59] made the now famous statement, ''Third Generation Pesticides'' in describing the use of JHs as environmentally safe control agents to which the insect will be unable to develop resistance. The development of highly potent synthetic analogues of JH, which were several fold more active than the native hormone, gave credence to William's claim[20]. Role of JHAs on the growth duration of insects have also been reported in different insect species like *C. cephalonica* exposed to methoprene[10]; resistant strains of *T. castaneum* treated with methoprene[24]; *P. interpuctella* following exposure of pyriproxyfen[18]; *E. integriceps* treated with pyriproxyfen[33]; cowpea weevil, *Callosobruchus maculatus* exposed to hydroprene[47]. Adult longevity has also been found to be influenced by the exposure of IGRs as observed in case of *T. molitor* treated with diflubezuron[52]; *C. cephalonica, C. maculatus* and *T. castaneum* exposed to methoprene and hyroprene[37]; *R. dominica, S. oryzae* and *T. castaneum* following treatment with methoprene and pyriproxyfen[25]; *P. interpuctella* treated with pyriproxyfen[18]; *E. integriceps* exposed to pyriproxyfen[33]; *T. castaneum and T. confusum* following treatment with methoprene[57].

Fenoxycarb was the first JHA compound introduced to control agricultural pests[32] and has shown JHA activities against a variety of insect orders including Lepidoptera, Coleoptera, Homoptera, Dictyoptera, Diptera and Orthoptera[29]. Because of its high activity and foliar stability, fenoxycarb is especially effective for the control of lepidopteran pests in orchard and vine crops, e.g. *C. pomonella* and light brown

apple moth, *Epiphyas postvittana*[19]. Due to its effect on many species of several insect orders, specificity and low toxicity it is a desirable JHA for the use as postharvest protectant of stored agricultural commodities[3]. Ro-135223 affected several coleopterans (*S. oryzae, S. granarius, S. zeamais, T. confusum, T. castaneum, O. surinamensis, R. dominica, Cryptolestes pusillus* and *Trogoderma variabile*), and lepidopterans (*P. interpunctella, Sitotroga cerealella* and *E. cautella*) pests of stored products with good results[24]. Moreno et al.[35] observed the effect of topical application of fenoxycarb on *E. kuhniella* and found the supernumerary larvae, larval-pupal intermediate and morphogenetic abnormalities leading to very low (10-0%) adult emergence. It also exhibits some non JHA-specific effects on many insects[45]. Its application also found to be effective against the ontogeny of *T. castaneum*[14,55,9]; *O. surinamensis*[26,55,13,14]; *S. oryzae*[12,26,27,1]; *E. Kuehnilla* Zell.[35]; *R. dominica*[246,13,14,48]; *S. cerealella*[26,9,15] .

Scientific contribution in relation to juvenile hormone analogues (JHAs) influencing developmental stages of *C. cephalonica* has been explored[49] but their potential on growth duration and adult longevity is completely wanting. The acquisition of such knowledge in this area becomes essential for a comprehensive appreciation of the physiological relationship that exists between this pest and its host material (stored cereals and cereal commodities). This knowledge in turn, is likely to generate new insights into divising ways and means for controlling *C. cephalonica*, by disrupting its metabolic framework so that evolution of a new generation of this pest for the eventual establishment on stored cereals and cereal products can be considerably restricted. Hence, as an objective of such programme the present work for the first time, has been designed and conducted to examine into the impact of a juvenile hormone analogue (JHA) i.e. fenoxycarb on the growth duration and adult longevity of rice moth, *C. cephalonica.*

MATERIALS AND METHODS

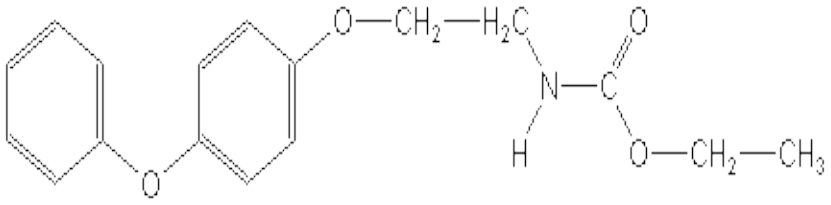
C. cephalonica Stainton adults were obtained from already existing laboratory stock culture maintained on normal dietary medium composed of coarsely ground jowar (*Sorghum vulgare*) mixed with 5% (w/w) powdered yeast inside large glass containers (150 mm diameter, 200 mm height) at temperature 26 ± 1^{0}C, relative humidity (R.H.) 93 ± 5% and a light regime of 12 h light and 12 h darkness. Such a standard culture was maintained throughout the year.

From the above culture whenever needed, newly emerged males and females were transferred to oviposition jars (35 mm diameter, 200

mm height). Since *C. cephalonica* individuals do not feed during their adult stage, no food was provided to them during their confinement in these vessels. Eggs laid by the females were collected and then placed in glass chambers (consisting of 250 ml beakers) with the help of zero number camel hair brush for hatching[49].

Fenoxycarb ethyl[2-(4-phenoxy-phenoxy)-ethyl]carbamate, molecular formula- $C_{17}H_{19}NO_4$, a non terpenoid juvenile hormone analogue, P-686N, Lot-20071 used throughout the experiment, was obtained from AccuStandard, New Haven, CT 06513, USA.

Chemical structure of fenoxycarb:



Fenoxycarb

Ethyl [2-(4-phenoxy-phenoxy)-ethyl] carbamate

Different concentrations of fenoxycarb, in dietary media,were prepared. For this purpose, a stock solution of known concentration of this JHA was prepared by dissolving it in acetone and then adjusted via serial dilutions to achieve its required concentrations. Now, required volume of different concentrations of fenoxycarb was thoroughly mixed with the required quantity of normal food (roughly ground jowar mixed with 5% w/w yeast powder) to get different desired concentrations i.e. 0.001, 0.005, 0.01, 0.05, 0.10, 0.50 and 1.00 ppm of fenoxycarb in dietary media. This treated food was then air dried at room temperature to eliminate completely the acetone. For control purposes, the normal food was thoroughly mixed with a required volume of acetone similar to that of treated food and then air dried in the same way.

Evaluation of the toxicity of various concentrations i.e. 0.001, 0.005, 0.01, 0.05, 0.10, 0.50 and 1.00 ppm of fenoxycarb against ontogeny of *C. cephalonica* as well as their consequences on developmental course and external morphology of larvae, pupae and adults were also observed[49] .

For evaluation of growth duration.at each concentration of

fenoxycarb, freshly hatched larvae of *C. cephalonica* were allowed to feed on anormal dietary medium for exactly four days and on the fifth day, 25 first instar larvae were transferred to each rearing chamber containing 50 g of dietary medium mixed and treated separately with different known concentrations of fenoxycarb. On completion of life-cycle, when adults emerged, their growth duration of both sexes were recorded (Table 1). The longevity of adults emerged from these treated food were also recorded from day of emergence to day of death of males and females (Table 1).

Experiments were replicated six times and the values have been expressed as mean ± SEM in days. Straight line regression equation was applied between different concentrations of fenoxycarb and their corresponding growth duration of males and females and longevity of adults to observe the significant correlation.[51]

RESULTS AND DISCUSSION

It was observed that the growth duration (time taken from egg laying to adult emergence) for the control moth was 37.67 ± 0.67 days for males and 40.83 ± 0.95 days for females. With the increase of fenoxycarb concentration, in the rearing medium, the growth duration was found to be significantly increased for both the sexes. In case males, the growth duration was recorded to be 41.33 ± 0.67 days at 0.001 ppm concentration of fenoxycarb that was found to be enhanced 86.50 ± 1.65 days at 0.10 ppm concentration of this JHA. The growth duration of females was observed to be increased 43.83 ± 1.01 days at 0.001 ppm concentration which was further enhanced to 87.33 ± 1.80 days at 0.10 ppm concentration of fenoxycarb. It is noteworthy that females had slightly prolonged growth duration than males in control.

Table 1. Effect of fenoxycarb on growth duration and longevity of adults of rice moth, *C. cephalonica* exposed as first instar larvae

Fenoxycarb Concentration (ppm)	Growth duration# of males (Days)	Growth duration# of females (Days)	Adult longevity# of males (Days)	Adult longevity# of females (Days)
Control	37.67 ± 0.67	40.83 ± 0.95	13.50 ± 0.42	8.50 ± 0.43
0.001	41.33 ± 0.67^{b}	43.83 ± 1.01	11.50 ± 0.62^{c}	7.67 ± 0.56
0.005	44.67 ± 1.52^{b}	48.17 ± 1.51^{b}	9.33 ± 0.42^{a}	7.00 ± 0.68
0.01	53.17 ± 1.60^{a}	54.83 ± 1.35^{a}	7.00 ± 1.95^{b}	4.67 ± 1.23^{c}
0.05	80.00 ± 2.14^{a}	82.83 ± 1.54^{a}	6.17 ± 1.66^{b}	4.33 ± 1.09^{b}
0.10	86.50 ± 1.65^{a}	87.33 ± 1.80^{a}	5.00 ± 0.86^{a}	4.00 ± 0.97^{b}
0.50	92.50 ± 1.88^{a*}	92.50 ± 1.88^{a*}	-	-
1.00	105.67 ± 3.51^{a*}	105.67 ± 3.51^{a*}	-	-

Values are expressed as mean ± SEM of six replicates.
a, b, c and d significantly different $p < 0.001$, $p < 0.01$ and $p < 0.05$ respectively compared with control when t- test was applied.
Straight line regression equation was applied between different concentrations of fenoxycarb and their corresponding growth duration of males and females longevity of adults to observe the significant correlation:

Growth duration of males	y = 43.63 + 491.37x;	r = 0.94	p < 0.01
Growth duration of females	y = 46.52 + 474.00x;	r = 0.94	p < 0.01
Longevity of male adults	y = 10.53 - 64.21x;	r = - 0.78	p insignificant
Longevity of female adults	y = 6.06 - 0.41x;	r = - 0.76	p insignificant

* Larval tenure since adults did not emerge, so these concentrations have not been accounted in correlation.

It is noteworthy that at 0.50 and 1.00 ppm concentrations of fenoxycarb adults did not emerge but larval period was much prolonged which lead to the production of giant larvae and supernumerary larvae, and their average life-span was recorded to be 92.50 ± 1.88 and 105.67 ± 3.51 days respectively (Table 1).

The longevity (life-span) of control moth was recorded to be 13.50 ± 0.42 days for males and 8.50 ± 0.43 days for females. With the increased concentration of this JHA the longevity of male and female individuals was found to be significantly reduced. At 0.001 ppm concentration of fenoxycarb male adult longevity was 11.50 ± 0.62 days while female adult longevity was 7.67 ± 0.56 days. But male and female adult longevity was observed to be 5.00 ± 0.86 and 4.00 ± 0.97 days respectively at 0.10 ppm concentration of fenoxycarb. It deserves mention that at 0.01, 0.05 and 0.10 ppm concentrations of fenoxycarb many of the emerged adults were died within 24 h of their emergence (Table 1).

JHA as a whole distrupts insect metamorphosis, hence, the developmental time for pupation and adult eclosion are considerably increased. Due to prolongation of larval period there was delayed pupation or adult emergence. Hence, overall duration of growth period was found to increase with increase in concentration of fenoxycarb in this experiment (Table 1). In the present investigation, application of fenoxycarb to the first instar larval stage of *C. cephalonica* caused significant influence on its growth duration (the time elapsing between egg laying to adult emergence). Enhancement in the growth duration was observed when first instar larvae were treated with higher concentration of fenoxycarb (Table 1). The growth duration of rice moth in control was observed as 37.83 ± 0.70 days for males and 45.83 ± 0.87 days for females while

this duration of first instar larvae treated with 0.10 ppm was 85.17 ± 1.81 days for males and 86.50 ± 1.98 days for females. Larval duration at 0.5 ppm fenoxycarb concentrations was much prolonged which enhanced to a maximum of 105.67 ± 3.51days at 1.00 ppm of fenoxycarb. At both these concentrations adults did not emerge. Similarly, methoprene at a dose level of 10 and 100 µg also influenced the time required for emergence of *C. cephalonica* when treated at 0-24 h old larval stage[10] but methoprene at a concentration of 0.5 ppm was found to be poorly effective in case of resistant strains of *T. castaneum* while its 0.1 ppm concentration was not effective[24]. Pyriproxyfen, a fenoxycarb derivative juvenile hormone analogue, with increased concentrations also increased growth duration effectively in case of the *P. interpunctella* even at poor concentrations[18] but the same compound was found to be poorly effective in case of *E. integriceps*[33]. Prolongation in the developmental period of *C. maculatus* has also been reported following exposure of hydroprene[47]. From these reportings, it is evident that toxicity of IGRs to developmental stages of insects is species specific. Since, in the present investigation, the duration of fenoxycarb exposure to the first instar larvae was more in comparison to that of second, third and fourth instar larvae[49] hence, the growth duration was found to be maximum in case of first instar treated larvae. Thus, even at the same concentration of fenoxycarb the growth duration of the insect increases with the decrease in the age related duration of exposure[49]. Fenoxycarb when exposed to second and third instar larvae of *O. nubilalis* had no significant effects on the duration of these instars while the duration of the first instar treated larvae increased significantly[17].

In the present work, the longevity of *C. cephalonica* adults emerged from fenoxycarb treated larvae was significantly reduced (Table 1). In the control, adult longevity was 13.50 ± 0.42 days for males and 8.50 ± 0.43 days for females whereas the longevity of adults emerged from first instar larvae treated with 0.10 ppm fenoxycarb was 5.00 ± 0.86 days for males and 4.00 ± 0.97 days for females. Similar findings also reported following the exposure of pyriproxyfen on *P. interpunctella* exposed to 0.3 ppm of pyriproxyfen[18] and on *E. Integriceps*[33]. When 6-day-old *T. molitor* pupae were treated with 0.1 µg JHA, adult life span was reduced to 4–6 days against the normal i.e. 14–16 days[31]. Methoprene and hydroprene also at the concentrations of 0.25, 0.5, 1 and 2 ppm reduced longevity in case of *C. cephalonica, C. maculatus and T. Castaneum*[37]. However, methoprene and pyriproxyfen act in a

different way i.e. they have no effect on the life-span of *R. dominica* and *S. oryzae*, but have a profound effect on *T. Castaneum*[24]. IGRs are not toxic to the adults themselves but long exposure to the early larval stages cause disruptions in the organ systems or interrupts adult ecdysis and reduces the adult life-span[34]. Fenoxycarb reduced adult life-span in other species than did malathion in stored rice[9]. Tucker et al.[57] (2014b) also determined the ability of *T. castaneum* and *T. confusum* to develop successfully when treated at late instar larval stage with methoprene. They stated that for *T. castaneum*, survival time for individuals exposed to methoprene was shorter than those exposed to control individuals, but the difference was singnificant for *T. confusum*.

Adult longevity also depends on healthy immature stages. Digestive disorders such as starvation, disturbance in metabolism, degeneration of peritrophic membrane and accumulation of faecal materials at the hind gut may be the cause of untimely adult mortality as a result of BPU exposure[52,41]. The toxic effect of fenoxycarb might be responsible for the reduction in the longevity of adults from treated culture (Table 6).The longevity of adults has also been found to be increased with the increase in the age related duration of treatment. Adults emerged from first instar larvae treated with fenoxycarb survived for shortest time in comparison to those adults emerged from second, third and fourth instars treated larvae[49].

Thus, it deserves mention that initial stage of *C. cephalonica* larva must be treated with fenoxycarb to facilitate lenthy duration of exposure for the effective control of this pest in particular and lepidopterous pests in general.

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