Advances in Bioresearch
Adv. Biores., Vol 13 (2) March 2022: 118-135
©2021 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.13.2.110117

Advances in Bioresearch

ORIGINAL ARTICLE

Effect of insect growth regulator, Novaluron and Chlorfluazuron on post- embryonic development of *Antigartra catalaunalis* Duponchel

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ABSTRACT
In respect of the influence of tested fourth generation insecticides on the duration of larval life, the results clearly show that each strength of novaluron and chlorfluazuron prolong the larval period under both methods of treatment. Barring 0.0001 per cent concentration, all other concentrations of both fourth-generation insecticides used in this investigation prolong the pupal period which increases with the advancing concentration of insect growth regulator. As regards the comparative efficiency of the fourth-generation insecticides in this context, based on the results of the higher concentrations, may be arranged as novaluron and chlorfluazuron in descending order.Contrary to the larval and pupal periods, every concentration of both insect growth regulators reduces the longevity of both male and female adults and reduction in life-span of either sex increases with increase in concentration of insect growth regulators. As per these results in the context of male's longevity reducing potential, the tested fourth generation insecticides may be arranged as novaluron and chlorfluazuron in declining sequence and both become moderately effective when applied by the adult feeding method and less effective when both chemicals administered as residue film.Besides affecting the male's longevity, the used insect growth regulators affect the life-span of the female too even at its lowest concentration and its longevity reducing potential progresses with the increasing concentration. In this respect, both used fourth generation insecticides are more effective under the adult feeding method as compared to its administration as the residue film. Hence, the oral administration produces more effect than the treatment with the residue film. Among its higher concentrations the used insecticides cause steep decline in the female life span. At its one per cent concentration, insecticides may reduce the female life-span to about one third of the natural longevity; some insecticides may reduce it to more than half the natural longevity. Depending on their longevity reducing potential, the tested insecticides may be arranged as novaluron and chlorfluazuron in descending order.
Key words: Novaluron, Chlorfluazuron, post- embryonic development, *Antigartra catalaunalis*

Received 22.08.2021 Revised 23.01.2022 Accepted 08.03.222

How to cite this article:
R Kumar, P Kumar and W Hasan. Effect of insect growth regulator, Novaluron and Chlorfluazuron on post- embryonic development of *Antigartra catalaunalis* Duponchel.. Adv. Biores. Vol 13 [2] March 2022: 118-135.

INTRODUCTION

Sesame (*Sesamumindicum* L., Pedaliaceae) is one of the oldest cultivated plants in the world. The major sesame producing countries are the United Republic of Tanzania, India, Sudan and China, followed by Myanmar, Nigeria, Burkina Faso, Ethiopia, Chad and Uganda [1]. Its seeds contain 52- 57 percent oil and 25 percent protein [2]. The important sesame growing countries are India, China, Sudan, Burma and Mexico. In India, the cultivation is mainly confined to Uttar Pradesh, Rajasthan, Madhya Pradesh, Andhra Pradesh, Odisha, Gujarat, Tamil Nadu and Karnataka. Sesame leaf webber and capsule bore, *Antigastra cataunalis* Duponchel is a major pest of oil crop (*Sesamum indicum*) and causing heavy loss (25- 90%) in seed yield [3]. Among 67 insect pests damaging sesame crop, the leaf insect pests, viz., leaf and capsule borer, *Antigastra catalaunalis* (Dup.); jassid, *Orosius albicinctus* Distant; whitefly, *Bemisia tabaci* (Genn.) and mirid bug, *Nesidiocoris tenuis* (Reuter) are considered to be key pests [4]. The *A. catalaunalis* is an important pest because this attack the crop in all the growth stages after about two weeks of emergence

[5]. Sesame leaf webber and capsule bore, *A. cataunalis*is a species of tropical origins, widespread in the Mediterranean region such as Spain, France, Italy, Malta, Greece and Cyprus [6, 7]. *A. cataunalis* infests the crop at leaf, flower and capsule stage and cause yield loss upto 90% [8,9].

A. catalaunalis is considered a serious pest of sesame in India [10,11]. Due to its ability to develop rapidly dense populations and its aggressive feeding behavior on sesame, macroscopic crop inspections at regular intervals are crucial for early detection of this species. *A. catalaunalis* attack on sesame is more severe during dry seasons and after initiation of flowering. It feeds on tender foliage by webbing the top leaves, bores into the pods and shoots [12]. On the other hand, in most of the Central European countries, *A. catalaunalis* occurs only as a very rare migrant (13,14). *A. catalaunalis* causes 10-70 percent infestation of leaves, 34-62 percent of flower buds/ flowers and 10-44 percent infestation of pods resulting in upto 72 percent loss in yield [10].

Owing to the socioeconomic importance of *A. catalaunalis*, the insect is subject to extensive research, much of which is envisioned to finding new ways to control it as a pest and to improve the effects of known pest control methods. At present, using insect growth regulators (IGRs) is considered as the possible alternative way of synthetic insecticides for controlling this pest (15). Insect Growth Regulators differ widely from the commonly used insecticides, as they exert their insecticidal effects through their influence on development, metamorphosis and reproduction of the target insects by disrupting the normal activity of the endocrine system [16, 17]. Novaluron is a relatively new benzoylphenyl urea IGR with low mammalian toxicity [18,19]. This compound has no appreciable effect on parasitoids and phytoseiids and has probably a mild effect on other natural enemies [19,20]. Their comprehensive effects and high selectivity as well as lower toxicity to non-target animals and the environment provide new tools for integrated pest management [21, 22]. Chitin synthesis inhibitors (CSIs) are usually classified in IGRs interfering with chitin biosynthesis in insects [23,24,25] and thus prevents moulting, or produces an imperfect cuticle [26, 27]. Novaluron and Chlorfluazuron has very little impact on natural enemies and pollinators insects. Gupta et. al. [28] studied the effect of diflubenzuron on the larvae of *Corcyra cephalonica* and reported that the early larval stages were found to be more susceptible to the compound than the advanced stages. At low concentration, diflubenzuron was ineffective in causing any mortality in 16- and 30-day old larvae, while development was completely arrested in 2-day old larvae, however, some pupal mortality was observed at these concentrations. The mortality rate was much higher when 16- and 30-days old larvae were fed on higher concentration, however, no adults emerged. Only males were found malformed.Reda *et. al*. [29] studied the toxicological and biological effect of chlorfluazuron on the 4th larval instar of rust red flour beetle, *Tribolium castaneum* at different concentration (0.1, 0.5, 1.5 and 10ppm) under laboratory conditions. The result show high significant mortality in larvae, pupae and adults. The obtained results showed significant decrease in adult emergence, fecundity and fertility. Chlorfluazuron caused also a significant prolongation in larval and pupal developmental period.

The possible use of insect growth regulators presents an intriguing and exciting area for research. In view of already proved efficacy of insect growth regulators as control measure in good number of insects and the notoriety of *Antigastra catalaunalis*. It was thought desirable to apply Novaluron and Chlorfluazuron against this pest hence this investigation. The work embodies the results relating to two insecticides (insect growth regulators) with reference to their effects on growth and development of *Antigastra catalaunalis.*

MATERIAL AND METHODS

Culture of Test Insect

Male and Female, *Antigastra catalaunalis* Dup. were collected in second week of July from sesame field. The insect was reared and maintained in the laboratory in order to ensure regular supply of the insect and its developmental stages during whole tenure of the present investigation. To begin with, the stock was established with the help of field collected moths. These moths were maintained on 10 per cent sugar solution in glass chimneys with tender sesame leaves (*Sesamum indicum*). Eggs obtained from them were kept as such for hatching. Larvae hatched from eggs were transferred on tender sesame leaves in petridishes (15 cm dia) and reared on them till pupation. The food supply to larvae was renewed twice a day in view of evaporation of water, which proceeds fast when leaves are detached from plants. The sesame leaves were treated with KM_nO_4 solution for five minutes followed by washing in running water. These leaves were dried under shade and provided to the experimental larvae. The larval period lasted for about 15.25 days. All possible precautions were taken to save larvae from bacterial and fungal infections. The first and second instars were reared in pertidishes but from third instar to pupations they were reared in pneumatic troughs (25 cm dia.) in small groups. When larvae acquired full growth and stopped feeding, they were transferred in separate pneumatic troughs having 6 inches thick moist soil layer on their bottoms. The larvae pupated in leaves made coverings. Pupae, thus obtained were kept as such for eclosion. Moths emerged from pupae were reared in pneumatic troughs as described above. In this way the progeny of moths of succeeding generations were reared generation after generation continuously till the tenure of the investigation. The laboratory reared insects and larvae were maintained throughout the tenure of investigation.

Sex identification

In size, the males and females are near about similar but sexual dimorphism is marked. The male moth show disk like puffy structure at the distal end of the femur of its fore legs.

Methods of application of insect growth regulators:

The present investigations were done under laboratory conditions of temperature and relative humidity. The insect was treated with different concentrations ie. 0.0001, 0.001, 0.01, 0.10, 0.50 and 1.00 per cent of insect growth regulators (Novaluron and Chlorfluazuron) used in this investigation by two methods namely- Adult feeding method (AFM) and Residue film method (RFM).

Residue Film Method (R.F.M.): In this method of treatment 1 to 2hr old adults were exposes to a thin film of residue of a concentration of a particular insect growth regulator. For obtaining the thin film of the chemical as residue, about 10 ml of a concentration of a chemical was poured in a petridish (10 cm dia.) and the petridish was tilted in different ways to spread the chemical on the whole floor area of the petridish and its raised periphery. Thereafter, the petridish was kept in the air for the evaporation of the solvent. This led to the formation of a thin film of a concentration of a insect growth regulator in the petridish as residue. Adults were left in petridishes having thin film of the insect growth regulator for 24 hours. The petridishes were covered by thin muslin cloth to prevent the escape of the adults. Such treated adults were employed in the different experiments as described later on. This method of treatment will be designated as RFM in the text from here onwards.

Adult Feeding Method (A.F.M.): In this method of treatment a concentration of a particular insect growth regulator was mixed in 20 per cent sugar solution which was supplied to adults for feeding. From here onwards this method of treatment will be referred as AFM in the text.

Effect of Insect Growth Regulators on Reproduction:

The preoviposition, oviposition periods and the number of eggs deposited by a female were studied separately by applying insect growth regulators to adults as described under.

Effect of Insect Growth Regulators on Reproductive Period and Fecundity under AFM:

Ten females and ten males were drawn at random from the laboratory stock. The females were maintained in glass chimneys with a male and twenty per cent sugar solution containing a strength of an insect growth regulator for oviposition. Each pair constituted a replicate. When the female of a replicate laid eggs for the first time, the pre oviposition period was recorded. The female was maintained as such to lay her eggs and when the last egg was deposited, the oviposition period were counted and their number was recorded. The above study was made separately for each strength of both the tested insect growth regulators and above-mentioned records were obtained for them. Besides a control experiment was also designed for each insect growth regulator to record the fecundity and reproductive period for the comparison purpose.

Effect of Insect Growth Regulators on Reproductive Period and Fecundity under RFM:

Ten females along with ten males were selected at random from the laboratory stock. Both males and females were compelled to contact a thin film of a strength of an insect growth regulator for 24 hrs. Thereafter, the females were maintained in glass chimneys with a male on twenty per cent sugar solution for egg laying and when the first egg was laid, the pre ovipostion period recorded. The females were maintained as such till the deposition of their last egg, after which the oviposition period was recorded. The total number of eggs laid during the oviposition period was recorded. The above-mentioned study was conducted separately for all concentrations of the tested growth regulators and the above-mentioned records were obtained for them also. The studies for an insect growth regulator were accompanied by one control experiment for the comparison.

Besides the above-mentioned records, the records pertaining to the reduction in the fecundity, net sterility and control over reproduction were also obtained as detailed below.

The reduction in the fecundity was calculated following the formula of Chamberlain (1962) as detailed below:

$$\%\text{Reduction in Fecundity} = \frac{\text{Eggs laid normal - Eggs laid in test}}{\text{Eggs laid in normal}} \times 100$$

The sterility was calculated following the formula of Abbot (1925) as described below:

$$\%\text{Net sterility} = \frac{\%\text{Sterility in test} - \%\text{ Sterility in normal}}{100 - \%\text{ Sterility in normal}}$$

The Control over the reproduction was calculated following the formula of Chamberlain (1962) as described below:

$$\%\text{Control over reproduction} = \frac{\text{Eggs hatched in normal} - \text{Eggs hatched in test}}{\text{Eggs hatched in normal}} \times 100$$

RESULTS AND DISCUSSION

Effect of Novaluron on Post-Embryonic Development of *Antigastra catalaunalis* under A.F.M.

The larvae of the adults of the untreated parents had considerably more survival (82.36%) as compared those of the adults treated earlier with any concentration of the novaluron (P<.01). In response to treatment of parent moths by feeding method, the survival of the larvae varied from 30.33 to 66.66 per cent decreasing with the increasing concentrations of the insecticide. But according to the statistical analysis, the percentage of the survival depended on the strength of the insecticide from 0.0001 to 0.50 per cent and the effect of the 1.00 per cent concentration was not statistically different from that of the 0.50 per cent (P<0.5). Further, the duration of the larvae in response to non- treatment of their adults was just 15 days, whereas this duration varied from 18.24 to 36.72 days in response to the earlier treated adults (parents) with different concentrations of this insecticide, appearing to increase with the increasing concentration. However, as per statistical analysis, concentration from 0.0001% to 0.10% did not influence the larval period differently (P<.05) but 0.50% and 1.00% concentration delayed the larval development considerably as compared any concentration from 0.001% to 0.10% and the latter of the two caused more delay (P<0.01).

The moths, not treated earlier exhibited 100 per cent emergence, whereas that treated at the same stage with any strength of the novaluron had far reduced emergence (P<0.01). In response to parent moth's treatment by feeding method with the different concentrations of this insect growth regulator, the emergence, varying from 16.66 to 60 per cent, tending to decrease with increasing concentration of used insect growth regulator, differed significantly with the strength of this fourth-generation insecticide (P<0.01). Further, the duration of the pupa of the untreated parent moths (11.65 days) was considerably shorter than that of the pupa of the earlier treated parent moths with any concentration of the novaluron (12.25 days to 29.68 days) (P<0.01) (Table-1).

Table 1. Effect of Novaluron on post-embryonic development in *Antigastra catalaunalis* Dup. at different concentrations under different modes of treatment.

Mode of treatment	Concentration %	Pupation (%)	Larval Pd. (days)	Emergence (%)	Pupal pd. (days)
	.0001	66.66	18.24±0.82	60.00	12.25±0.36
	.001	56.56	18.92±0.45	32.35	13.93±0.42
AFM	.01	45.00	19.23±0.84	29.63	1578±028
	.10	36.36	19.42±0.43	27.27	19.46±0.32
	.50	31.36	28.42±0.73	21.05	24.60±0.60
	1.00	30.33	36.72±1.44	16.66	29.72±0.88
	.0001	70.00	18.44±0.25	66.67	12.00±0.18
	.001	58.33	19.14±0.24	34.29	13.50±0.26
	.01	48.33	20.25±0.24	34.48	14.66±0.31
RFM	.10	40.00	21.32.0.15	29.17	18.72±0.36
	.50	36.36	28.56±0.45	27.27	23.46±0.32
	1.00	33.33	36.34±0.32	20.00	27.05±0.21
	Control	82.36	15.00±0.34	100.00	11.65±0.24

(Values are means ± S.E.)

The net mortality (Table-2) under the adult feeding treatment varied from 52 to 94 per cent increasing with the advancing concentration and the x^2 test detected it to depend on the concentration (P<0.05).The male adults obtained from the untreated parent moths had life-span more as compared the male adult obtained from the treated parent moths with any concentration of the novaluron and this fact was applicable to the female adult also (P<0.05). The longevity of the male adult, varying from 3.44 to 9.48 days and that of the female adult, varying from 4.38 to 12.48 days, tended to decrease with the increase in the concentration of the insecticide. However, the statistical analysis revealed that 0.0001% and 0.001% concentrations, inducing more longevity in the both sexes as compared any of the remaining concentrations, behaved identically in affecting the life of either sex differed with the concentrations from 0.01% to 1.00% ($P<0.05$) (Table-2).

The male adults obtained from the untreated parent moths had life-span more as compared the male adult obtained from the treated parent moths with any concentration of the novaluron and this fact was applicable to the female adult also ($P<0.05$). The longevity of the male adult, varying from 3.44 to 9.48 days and that of the female adult, varying from 4.38 to 12.48 days, tended to decrease with the increase in the concentration of the insecticide. However, the statistical analysis revealed that 0.0001% and 0.001% concentrations, inducing more longevity in the both sexes as compared any of the remaining concentrations, behaved identically in affecting the life of either sex differed with the concentrations from 0.01% to 1.00% ($P<0.05$) (Table-3).

Table 2. Net mortality in *Antigastra catalaunalis* Dup. caused by Novaluron at different concentrations under different modes of treatment

Mode of treatment	Concentration on applied	No. larvae reared	No. larvae died	Pupae died (no)	Total death (4+5)	% net mortality
1	2	3	4	5	6	7
	.0001	60	20	16	36	52
	.001	60	26	23	49	78
AFM	.01	60	33	19	52	84
	.10	60	38	16	54	88
	.50	60	41	15	56	92
	1.00	60	42	15	57	94
	.0001	60	18	14	32	44
	.001	60	25	23	48	76
	.01	60	31	19	50	80
RFM	.10	60	36	17	53	86
	.50	60	38	16	54	86
	1.00	60	40	16	56	92
Control	--	60	10	Nil	10	--
(Values are means ± S.E.)						

Table. 3. Effect of Novaluron on longevity of male and female *Antigastra catalaunalis* Dup.at different concentrations under different modes of treatment

Mode of treatment	Concentration %	Longevity (days)	
		Male	Female
	.0001	9.48±0.12	12.48±0.16
	.001	9.30±0.12	12.06±0.18
AFM	.01	7.35±0.22	10.36±0.14
	.10	6.70±0.14	8.72± 014
	.50	5.63±0.11	6.34±0.18
	1.00	3.44±0.16	4.38±0.11
	.0001	9.76±0.14	13.00±0.12
	.001	9.00±0.20	12.00±0.14
	.01	8.72±0.26	11.00±0.22
RFM	.10	8.24±0.42	10.42±0.32
	.50	7.36±0.12	8.24±0.16
	1.00	5.00±0.16	06.30±0.22
	Control	10.48±0.16	13.36±0.24
(Values are means ± S.E.)			

Effect of Novaluron on Post-Embryonic Development of *Antigastra catalaunalis* under R.F.M.

The larva of the parents treated with residue film of any strength of the novaluron acquired lesser survival than the larva whose parents remained untreated ($P<.05$). In response to parents' treatment with the residue films of this insecticide, the percentage of pupation, varying from 33.33 to 70.00 per cent and decreasing with the advancing concentration depended on the concentration ($P<0.005$) and the duration of the larva, being prolonged with the residue film of any concentration of this insect growth regulator as compared the non-treatment condition (ANOVA, P<0.05), varying from 18.44 to 36.34 days in response to residue films of different strengths and prolonging with the rise in the strength level, also differ with the concentration level of the novaluron (ANOVA, P<0.05). Further, the parents' treatment with the residue film of any concentration of this insecticide affected the percentage of the emergence (P<0.05) which varying from 20 to 66.67 per cent among residue film of different concentrations and tending to fall with the rise in the strength of the residue film, was found to depend on the concentration of the residue film applied to the parents (Anova, P<0.05). The pupal duration with the 0.0001 per cent concentration was not more as compared that under the non-treatment condition (P>0.05) but the residue film of any other concentration prolonged this condition (P<0.05). As regards the influence of the residue film of different concentrations (0.001% to 1.00%) on the pupal period, it varying from 13.50 to 27.05 days and increasing with the rising concentration level, differed significantly from concentration to concentration (P<0.05) (Table-1).

The adult male progeny of the untreated parents had more longevity as compared that of the parents treated with the residue film of any concentration of the novaluron (Anova, P<0.05). The longevity of the adult male progeny, in response to treatment of its progenitor adults with the residue films of different concentrations of this insecticide varying from 5 to 9.76 days and declining with the advancing concentration, depended on the concentration of the novaluron (P<0.05). In case of female adult's longevity barring 0.0001% the remaining residue films of different concentrations caused reduction in the longevity (P<0.05) and it was affected differently by the residue films of different strengths (Anova, P<0.05), decreasing with the increase in the strength of the residue film of this insect growth regulator.

Effect of Chlorfluazuron on Post-Embryonic Development of *Antigastra catalaunalis* under A.F.M.

Any concentration of the Chlorfluazuron except 0.0001 per cent applied earlier to the parent moths by feeding method reduced the larval survival and delayed the pupation as compared the untreated condition of parent moths (P<0.05). The larval survival, varying from 45.00 to 72.66 per cent among different concentrations from 0.001% to 1.00 per cent and appearing to be indirectly proportional to them, was affected differently by different concentrations of chlorfluazuron (P<0.05). Further, the larval period, varying from 16.56 to 23.56 days and prolonging with the advancing concentration of the chlorfluazuron, differed from concentration to concentrations applied earlier to the parent moths (P<0.05) (Table-4).

Table 4. Effect of Chlorfluazuron on post-embroyonic development in *Antigastra catalaunalis* Dup. at different concentrations under different modes of treatment

Mode of treatment	Concentration %	Pupa (%)	Larval Pd. (days)	Emergence (%)	Pupal pd. (days)
	.0001	82.33	16.56±0.24	66.00	12.20±012
	.001	72.66	17.30±0.28	62.79	12.36±016
AFM	.01	65.00	18.42±0.16	56.41	13.38±0.10
	.10	58.33	20.00±0.34	45.71	14.66±0.26
	.50	50.00	21.20±0.24	40.00	17.66±0.32
	1.00	45.00	23.65±0.28	30.76	20.66±0.44
	.0001	81.34	16.28±0.28	68.00	11.66±0.10
	.001	76.66	17.10±0.22	63.33	12.33±0.30
	.01	65.00	17.90±0.26	53.33	13.00±0.30
RFM	.10	58.33	17.90±0.26	48.57	14.24±0.18
	.50	56.66	20.80±0.36	41.18	17.33±0.32
	1.00	46.00	24.00±0.42	33.33	19.27±0.42
	Control	82.36	15.00±0.34	100.00	11.65±0.21

(Values are means ± S.E.)

Under A.F.M., the emergence was curtailed significantly by any concentration of the chlorfluazuron (P<0.05) and the pupal period was also prolonged significantly by any concentration of this insecticide other than 0.0001 per cent (Anova, P<0.05). In the concentration range of 0.001% to 1.00 per cent chlorfluazuron, the emergence, varying from 30.76 to 66.00 per cent and tending to decrease with the increasing concentration, differed from concentration to concentration significantly and likewise, the pupal period varying from 12.20 to 20.66 days among concentrations from 0.0001% to 1.00 per cent also depended on these concentrations but it exhibited the direct proportionality to the concentration of the chlorfluazuron under adult feeding treatment (Table-4).

In response to the different concentrations of the chlorfluazuron applied earlier to parent moths, the net mortality varying from 34.00 to 84.00 per cent and increasing with the advancing concentration, differed significantly from concentration to concentration (P<0.05) (Table-5).

Table 5. Net mortality in *Antigastra catalaunalis* Dup. caused by Chlorfluazuron at different concentrations under different modes of treatment.

Mode of treatment	Concentration on applied	No. larvae reared	No. larvae died	Pupae died (no)	Total death (4+5)	% net mortality
1	2	3	4	5	6	7
AFM	.0001	60	10	17	27	34
	.001	60	27	16	33	46
	.01	60	21	17	38	56
	.10	60	30	18	48	76
	.50	60	32	19	51	82
	1.00	60	34	18	52	84
RFM	.0001	60	10	16	26	32
	.001	60	14	17	31	42
	.01	60	21	18	39	58
	.10	60	25	18	43	66
	.50	60	26	20	46	72
	1.00	60	33	18	51	82
	Control	60	10	Nil	10	--

(Values are means ± S.E.)

The treatment of the parent moths with any concentration of the chlorfluazuron curtailed the longevity of progeny male adults (P<0.05). The concentrations from 0.0001% and 0.001% affected the life-span of male but other concentrations of the chlorfluazuron among which the longevity of the male varied from 5.46 to 9.78 days, affected it differently (P<0.05), causing progressive reduction. Barring the concentrations 0.0001% and 0.001% any other concentration of the chlorfluazuron applied to parent pupae reduced the longevity of the progeny female adults (P<0.05) which exhibited indirect proportionality to the concentration of the chlorfluazuron.

Effect of Chlorfluazuron on Post-Embryonic Development of *Antigastra catalaunalis* under R.F.M.

Except 0.0001% residue film, the residue films of other strengths of the chlorfluazuron reduced larval survival significantly (P<0.05). As regards the influence of residue films of the effective concentrations of this insect growth regulator on the pupation, these concentrations affected the larval survival differently (P<0.05) and the pupation declined with the advancing concentrations of the residue film of chlorfluazuron. The residue film of any concentration of the chlorfluazuron prolonged the larval stage. The larval period, varying from 16.28 to 24.00 days and prolonging with the increasing concentration of the residue film depended significantly on the residue film of different concentrations of the chlorfluazuron (P<0.05).

Barring 0.0001 per cent concentration, the residue film of any of the other concentrations prolonged the duration of the pupa (P<0.05). Among the residue films of different effective concentrations, the pupal period, varying from 12.33 to 19.27 days and prolonging with the increasing strength, differed significantly with these concentrations (P<0.05). The residue film of every concentration reduced the emergence (P<0.05) which varying from 33.33 to 68.00% among different strengths and prolonging with the advancing concentration was detected to differ with residue films of different concentrations of the chlorfluazuron (P<0.05) (Table-4).

The net mortality, varying from 32.00 to 82.00 per cent, among residue films of different concentrations of the chlorfluazuron and decreasing with the increasing concentration, was found to be dependent on the concentration of the residue film as per chi-square test (P<0.05) (Table-5).

Every concentration of the chlorfluazuron applied as residue film to the adult reduced the life-span of both male and female adults (P<0.05). As regards the influence of different concentrations of the chlorfluazuron as residue films on the longevity of adults, it varying from 6.66 to 10.43 days in male and from 6.94 to 13.82 days in female and declining with the advancing concentration, differently with the concentration of the residue film (P<0.05) (Table-6).

Table 6. Effect of Chlorfluazuron on longevity of male and female *Antigastra catalaunalis* Dup. at different concentrations under different modes of treatment.

		Longevity (days)	
Mode of treatment	Concentration %	Male	Female
	.0001	9.48±0.14	13.78±0.12
	.001	9.80±0.22	13.70±0.36
AFM	.01	8.88±0.26	11.78±0.36
	.10	7.28±0.30	9.86±0.22
	.50	6.48±0.16	7.30±0.22
	1.00	5.46±0.34	6.50±0.24
	.0001	10.43±0.24	13.82±0.34
	.001	9.88±0.28	13.76±0.20
	.01	9.00±0.22	11.80±0.42
RFM	.10	8.00±0.32	9.72±0.12
	.50	7.00±0.20	8.00±0.36
	1.00	6.66±0.16	6.94±0.34
	Control	10.48±0.16	14.30±0.32

(Values are means ± S.E.)

Effect of Novaluron on Reproduction of *Antigastra catalaunalis* Dup. Under A.F.M.

The sexual maturity of the adult, in response to earlier treatment of parent moths by adult feeding method with any concentration of the novaluron was delayed (P<0.05). In this respect, the concentrations from 0.0001% to 1.0 per cent affected the preoviposition period (3.02 to 3.08 days) identically (P>0.05) with less prolonging effect as compared to any of the concentrations from 0.0001% to 1.0% which delayed this period more but identically. The different concentrations of this insect growth regulator applied earlier to adults, shortened the oviposition period markedly (P<0.05 or 0.01) but on the basis of the statistical analysis considering their curtailing effect on the oviposition period, these concentrations could be arranged as 0.0001% or 0.001% or 0.01% or .10% or 0.50% or 1.0 per cent (Table-7).

The treatment of parent moths with any concentration of the novaluron by the adult feeding method, reduced the fecundity significantly (P<0.01). The concentrations from 0.0001% to 0.01% exerting almost identical effect on the fecundity (221.2 to 226.2 eggs/female, P>0.05) caused less decline in the fecundity as compared any of the other strengths 0.10% to 1% (P<0.01). Among the concentrations (0.001% to 1%), the fecundity, varying from 77.4 to 166.2 eggs/female and declining with higher concentration, differed strongly with them (P<0.01). The treatment of the insect by the A.F.M., reduced the percentage of hatching/female as compared the untreated condition (P<0.05). The percentage of hatching, varying from 33.3 to 86.2 per cent and decreasing with the increasing concentration under the A.F.M. differed significantly from concentration to concentration (X^2-P<0.05) (Table-8).

Every concentration of the novaluron applied by the A.F.M., prolongs the incubation period (P<0.05 in case of .0001%, .001% and .01% concentrations and P<0.01 in case of 0.10 to 1.00% concentrations). The concentrations, 0.0001% and .001% affected the incubation period identically (3.96 to 4.00 days; P<0.05), causing less delay in the incubation period as compared other remaining concentrations (0.01% to 1.0%) among which the egg stage, varying from 4.55 days to 7.26 days and delaying with the advancing concentration, differed from concentration to concentration significantly (P<0.05) (Table-9).

The reduction in the fecundity of the insect under the A.F.M. varied from 36.52 to 78.26 per cent among different concentrations of the novaluron but it was affected identically by the concentrations, 0.0001%, 0.001% and 0.01% of course to less extent as compare that induced by any concentration from 0.10 to 1.00% among which varying from 53.32 to 78.26 per cent and increasing with the advancing concentration, differed with them (P<0.05). Likewise, under the A.F.M. the net sterility, varying from 5.26 to 63.41 per cent and increasing with the rise in the concentration differed with the concentrations of the novaluron applied to parent moths by feeding method (P<0.005). The per cent control over the reproduction under the influence of different concentrations of the novaluron under A.F.M., varying from 39.88 to 92.03 per cent and increasing with the advancing concentration depended on the strength of the novaluron applied (P<0.05) (Table-10).

Table 7. Effect of Novaluron reproductive periods in *Antigastra catalaunalis* Dup.			
Mode of treatment	Concentration %	Pre-oviposition period (days)	Oviposition period (days)
AFM	.0001	3.02±0.12	8.14±0.23
	.001	3.04±0.14	8.00±0.12
	.01	3.06±0.14	7.12±0.22
	.10	3.06±0.26	4.36±0.24
	.50	3.07±0.22	3.32±0.32
	1.00	3.08±0.15	1.46±0.26
RFM	.0001	3.20±0.24	9.27±0.26
	.001	3.12±0.23	8.96±0.18
	.01	3.05±0.14	8.23±0.17
	.10	3.72±0.13	7.06±0.19
	.50	3.76±0.14	5.11±0.11
	1.00	3.84±0.18	2.68±0.19
	Control	1.26±0.24	9.46±0.33
(Values are means ± S.E.)			

Table 8. Effect of Novaluron on fecundity and fertility in *Antigastra catalaunalis* Dup.				
Mode of treatment	Concentration %	No. eggslaid by a female	No. of eggs hatched	% hatched
AFM	.0001	226.3±4.64	195.07±0.14	86.2
	.001	224.8±5.32	191.52±0.12	85.2
	.01	221.2±3.72	184.03±0.14	83.2
	.10	1.66.2±5.47	113.51±0.12	68.3
	.50	119.9±4.75	77.09±0.14	64.3
	1.00	77.4±6.84	25.77±0.12	33.3
RFM	.0001	225.1±4.42	194.71±0.14	86.5
	.001	226.6±4.34	193.96±0.18	85.6
	.01	222.0±3.62	178.48±0.12	80.4
	.10	198.32±5.32	133.46±0.12	67.3
	.50	143.6±2.26	86.44 ±0.11	60.2
	1.00	110.8±4.12	42.54 ±0.14	38.4
	Control	356.0±0.92	324.9±1.14	91.0
(Values are means ± S.E.)				

Table 9. Effect of Novaluron on fecundity and fertility in *Antigastra catalaunalis* Dup.		
Mode oftreatment	Concentration (%)	Incubation period (days)
AFM	.0001	3.96±0.14
	.001	4.00±0.18
	.01	4.55±0.12
	.10	5.46±0.12
	.50	6.50±0.11
	1.00	7.26±0.14
RFM	.0001	3.85±0.14
	.001	3.96±0.12
	.01	4.30±0.14
	.10	5.30±0.12
	.50	6.34±0.14
	1.00	6.66±0.12
	Control	3.06±0.42
(Values are means ± S.E.)		

Table 10. Percent reduction in fecundity, percent net sterility and percent control overreproduction in *Antigastra catalaunalis* Dup. caused by Novaluron under different modes of treatment.				
Mode of treatment	Concentration %	% reduction in fecundity	% net sterility	% control over reproduction
AFM	.0001	36.52	5.26	39.88
	.001	36.85	6.37	40.96
	.01	.37.84	8.57	43.80
	.10	53.32	24.34	64.97
	.50	66.32	29.34	76.20
	1.00	78.26	63.41	92.03
RFM	.0001	36.77	4.95	39.90
	.001	37.19	4.84	40.93
	.01	37.64	11.65	44.91
	.10	44.33	26.04	58.83
	.50	59.66	33.85	73.33
	1.00	69.88	57.8	86.88
(Values are means ± S.E.)				

Effect of Novaluron on Reproduction of *Antigastra catalaunalis* Dup. under R.F.M.
The preoviposition period was affected by every concentration of the novaluron as residue film (P<0.05). In response to adult's treatment with residue films of different concentrations of the novaluron the preoviposition period (3.20 to 3.84 days) was affected identically by 0.0001%, 0.001% and 0.01% concentrations (P<0.05) and likewise, it was also affected alike by 0.10, 0.50 and 1.00% concentrations, of course, with more prolongation. As regards the influence of the novaluron residue film on the oviposition period, the duration of egg laying was affected by every concentration of the novaluron and this period, varying from 2.68 to 9.27 days among residue films of different concentrations and decreasing with the increasing concentration, differed significantly with the residue film concentrations (P<0.05) (Table-11).

Table 11. Effect of Novaluron reproductive periods in *Antigastra catalaunalis* Dup.			
Mode of treatment	Concentration %	Pre-oviposition period (days)	Oviposition period (days)
AFM	.0001	3.02±0.12	8.14±0.23
	.001	3.04±0.14	8.00±0.12
	.01	3.06±0.14	7.12±0.22
	.10	3.06±0.26	4.36±0.24
	.50	3.07±0.22	3.32±0.32
	1.00	3.08±0.15	1.46±0.26
RFM	.0001	3.20±0.24	9.27±0.26
	.001	3.12±0.23	8.96±0.18
	.01	3.05±0.14	8.23±0.17
	.10	3.72±0.13	7.06±0.19
	.50	3.76±0.14	5.11±0.11
	1.00	3.84±0.18	2.68±0.19
	Control	1.26±0.24	9.46±0.33
(Values are means ± S.E.)			

The fecundity (eggs/female) was reduced by residue film of any concentration of the novaluron applied to the adult (P<0.05). The fecundity varied from 110.8 to 225.1 eggs/female in response to treatment with residue film of different concentrations and appearing to decrease with the advancing concentration but the concentrations from 0.0001% to 0.01% caused almost identical reduction in fecundity (P<0.05) but the fecundity, varying from 110.80 to 198.30 eggs/female in response to treatment with residue films of 0.10% to 1.00% concentrations of the novaluron and tending to be indirectly proportional to the concentration differed significantly with the concentrations. Any of these concentrations caused more reduction in the fecundity as compated 0.001% or 0.01% concentrations. As regards of residue films of different concentrations of novaluron, the fertility i.e., the per cent eggs hatched/female, varying from

38.4 to 86.5 per cent and decreasing with the increasing concentration, differed significantly with the residue films of different concentrations of the novaluron (P<0.05) (Table-12).

Table 12. Effect of Novaluron on fecundity and fertility in *Antigastra catalaunalis* Dup.

Mode of treatment	Concentration %	No. eggslaid by a female	No. of eggs hatched	% hatched
AFM	.0001	226.3±4.64	195.07±0.14	86.2
	.001	224.8±5.32	191.52±0.12	85.2
	.01	221.2±3.72	184.03±0.14	83.2
	.10	1.66.2±5.47	113.51±0.12	68.3
	.50	119.9±4.75	77.09±0.14	64.3
	1.00	77.4±6.84	25.77±0.12	33.3
RFM	.0001	225.1±4.42	194.71±0.14	86.5
	.001	226.6±4.34	193.96±0.18	85.6
	.01	222.0±3.62	178.48±0.12	80.4
	.10	198.32±5.32	133.46±0.12	67.3
	.50	143.6±2.26	86.44 ±0.11	60.2
	1.00	110.8±4.12	42.54 ±0.14	38.4
	Control	356.0±0.92	324.9±1.14	91.0

The residue film of every concentration of the novaluron increased the duration of the egg significantly (P<0.05). The incubation period, varying from 3.85 to 6.66 days among the direct proportionality to the concentration. But statistical analysis showed that concentrations, 0.0001% and 0.001% affected the oviposition period identically (P>0.05) and concentrations from 0.01% to 1.00% differed from 0.0001% or 0.01% concentrations in affecting this period. Among these concentrations, the oviposition period, varying from 2.74 to 8.23 days and decreasing with the increasing concentration, differed significantly from concentration to concentration (P<0.05).

Under residue film method, the per cent redution in the fecundity and the per cent sterility, varying from 36.77 to 69.88 per cent and from 4.95 to 57.8 per cent respectively and exhibiting direct proportionality to the concentration, differed significantly with the concentration of the novaluron (P<0.05). Further, as regards the effect of novaluron under this method of treatment on the per cent control of the reproduction it, varying from 39.90 to 86.88 per cent and exhibiting direct proportionality to the concentration, depended significantly on the concentration (P<0.05).

Effect of Chlorfluazuron on Reproduction of *Antigastra catalaunalis* under A.F.M.

The treatment of adults by feeding method with any concentration of the chlorfluazuron prolonged the pre-oviposition period significantly (P<.05). In response to earlier treatment of parent adults with different concentrations of this fourth-generation insecticide, the above-mentioned period varied from 2.44 to 3.02 days and appeared to increase with the rise in the concentration but as per statistical analysis, the concentrations from 0.0001% to 0.10% influencing it identically, caused significantly less prolongation in it as compared the 0.50% and 1.00% concentrations which also prolonged it identically. Further, every concentration of this insect growth regulator applied to the adults by feeding method also affected the oviposition period and in response to different concentrations of the chlorfluazuron applied as above, this period, varying from 3.56 to 8.94 days and reducing with the advancing concentration, depended on the concentration of this insect growth regulator (P<0.05) (Table-13).

Every concentration of the chlorfluazuron applied to parent adults reduced the fecundity and fertility both significantly (P<0.05) and in response to its different concentrations applied to adults by feeding method, these two varying from 108.6 to 262.3 eggs/ female and from 40 to 78.7 per cent respectively and exhibiting indirect proportionality to the concentration, differed from concentration to concentration (P<0.05) (Table-16). However, under such treatment, all concentrations were not effective in changing the incubation period; only 0.50% and 1.00% concentrations prolonged this period significantly (P<0.05). The latter was found more effective than the former one (P<0.05) (Table-6).

In response to parent's treatment with different concentrations of the chlorfluazuron the reduction in fecundity, net sterility and control over reproduction, varying from 26.32 to 69.66 per cent, from 13.52 to 65.93 per cent and from 36.30 to 86.87 per cent respectively and all decreasing with the advancing concentration, differed significantly with different concentrations (P<0.05) (Table-14).

Table 13. Effect of Chlorfluazuron on fecundity and fertility in *Antigastra catalaunalis* Dup.		
Mode of treatment	Concentration (%)	Incubation period (days)
AFM	.0001	3.13±0.16
	.001	3.26±0.14
	.01	3.30±0.12
	.10	3.34±0.11
	.50	3.75±0.13
	1.00	4.72±0.14
RFM	.0001	.3.10±0.12
	.001	3.19±0.12
	.01	3.40±0.11
	.10	3.46±0.12
	.50	3.70±0.14
	1.00	4.06±0.42
	Control	3.06±0.42
(Values are means ± S.E.)		

Effect of Chlorfluazuron on Reproduction of *Antigastra catalaunalis* Dup. Under R.F.M.

The residue film of any concentration of the chlorfluazuron applied to the female delayed the sexual maturity significantly (P<0.05) and in response to the females' treatment with residue films of different concentrations of this insect growth regulator, the preoviposition period, varying from 2.20 to 3.00 days, tended to prolong with the advancing concentration but the statistical analysis revealed that the concentrations from 0.0001% to 0.50% exerting identical influence, causes significantly less prolongation in pre-oviposition period as compared the 1.0 per cent concentration (P<0.05) (Table-14). Similarly, the oviposition period was also affected by every concentration of this insecticide applied as residue film to the female (P<0.05) and in response to the female's treatment with residue films of different strengths of this insecticide, the oviposition period, varied from 3.65 to 8.94 days and exhibiting direct proportionality to the concentration, differed significantly with different concentrations (P<0.05) (Table-14).

Table 14. Percent reduction in fecundity, percent net sterility and percent control over reproduction in *Antigastra catalaunalis* Dup. caused by Chlorfluazuron under different modes of treatment.				
Mode of treatment	Concentration %	% reduction in fecundity	% net sterility	% control over reproduction
AFM	.0001	26.32	13.52	36.30
	.001	32.50	21.76	45.43
	.01	35.23	28.24	53.52
	.10	4.034	33.63	60.40
	.50	52.11	50.33	76.20
	1.00	69.66	65.93	86.67
RFM	.0001	27.72	13.40	37.41
	.001	31.07	21.54	45.93
	.01	43.46	27.14	58.80
	.10	48.74	31.54	64.91
	.50	59.66	52.42	80.80
	1.00	69.02	62.20	88.30
(Values are means ± S.E.)				

The residue film of every concentration of the chlorfluazuron applied to the female, reduced considerably her fecundity and fertility (P<0.05) and in response to the female's treatment with residue films of different concentrations of the insect growth regulator, these two, varying from 110.3 to 257.4 eggs/female and from 34.4 to 78.8 per cent respectively and tending to decrease with the advancing concentration, depended significantly on the concentration of the insecticide (Table-15).

Table 15. Effect of Chlorfluazuron on fecundity and fertility in *Antigastra catalaunalis* Dup.				
Mode of treatment	Concentration %	No. eggs laid by a female	No. eggs hatched	% hatching
	.0001	262.3+4.63	206.4+3.42	78.7
	.001	248.3+3.24	176.8+5.10	71.2
AFM	.01	230.6+6.14	150.6+4.22	65.3
	.10	212.4+4.26	128.3+6.10	60.4
	.50	170.5+3.33	71.1+2.42	45.2
	1.00	108.6+2.22	43.3+1.42	40.0
	.0001	257.4+2.12	202.8+3.44	78.8
	.001	2.45.4+3.23	175.2+5.56	71.4
	.01	201.3+4.46	133.5+4.40	66.3
RFM	.10	182.5+2.35	113.7+5.10	62.3
	.50	143.6+5.26	62.2+3.43	43.3
	1.00	110.3+3.30	37.9+2.10	34.4
	Control	356.0+0.92	324.9+1.14	91.0
(Values are means ± S.E.)				

However, the residue films of the concentrations from 0.0001% to 0.10% did not affect the incubation period significantly but the 0.50% and 1.0% residue film concentrations prolonged this period (3.70 to 4.06 days) significantly, the former being more effective (P<0.05) (Table-14).

Further, the reduction in fecundity, net sterility and control over reproduction, varying from 27.72 to 69.02 per cent, from 13.40 to 62.20 per cent and from 37.41 to 88.30 per cent respectively among the residue films of different concentrations and increasing with the advancing concentrations, depended significantly on the strength of the residue film of this insect growth regulator (P<0.05) (Table-15).

Sterility Effect of Novaluron on Male and Female *Antigastra catalaunalis* Dup.

The mating between the female of the untreated adult parent and male of the treated parent, induced far reduced fecundity (89.2 eggs/female) as compared the mating between the male and female of the untreated parents (358 eggs/female) and, it caused 53.41 per cent net sterility, while the cross between the female of the treated parent moth and male of the untreated parent moth inducing almost similar fecundity (90.4 eggs/female) to that of the above mentioned mating but it caused comparative less reduction in the net sterility (50.44%). However, the mating when allowed between the male and female of the earlier treated parents by feeding method, there was further reduction in fecundity (77.4 eggs/female) without significance but the net sterility (63.41%) increased by 10 to 13 per cent as compared the above crosses (Table-16).

Table 16. Sex specific effect of Novaluron reproduction in *Antigastra catalaunalis* Dup.				
Mating between	No. Eggs laid (Mean ±S.E.)	No. Eggs hatched (Mean ±S.E.)	Hatching (%)	% Net sterility
UNT F x TRM	89.2±5.78	37.91±2.80	42.4	53.41
TRF x UNTM	90.4±3.46	41.22±2.36	45.6	50.44
TRF x TRM	77.4±6.81	25.8±1.12	33.3	63.41
UNT F x UNTM	358±5.46	324±4.32	91.0	-
(Control)				
(1 per cent Novaluron applied by AFM for 1 minute only) TR = Treatment; UNT = Untreated; F = Female and M = Male				

Sterility Effect of Chlorfluazuron on Male and Female *Antigastra catalaunalis* Dup.

The treated male's mating with the female of the untreated stock caused great reduction in the fecundity (175.6 eggs/female) as compared the mating of the male and female of the untreated stock (3.65 ggs/female) and induced 30.77 per cent sterility but mating between the earlier treated female and untreated male caused more fecundity (190.6 eggs/female) and induced more sterility (31.11 per cent). However, the mating between the male and female of the treated adults caused more decline in the fecundity (108 eggs/ female) and induced far more sterility (57.14 per cent).

In respect of the influence of tested fourth generation insecticides on the duration of larval life, the results clearly show that each strength of novaluron and chlorfluazuron prolong the larval period under both methods of treatment. Generally, at low concentration 0.0001 to 0.01 per cent the increase in larval period is about 3 to below 5 days but at higher concentrations, this increase is much more and insecticide specific; at 0.50% concentration, the novaluron and chlorfluazuron increase larval period by 13.40 to 13.50 days, and 5.80 to 6.00 days respectively under both modes of treatment and at one percent concentration, they increase this period by 19.82 to 21.36 days, 10.10 to 12.40 days, 10.90 to 12.40 days and 8.00 to 8.50 days respectively under both methods of their application. Usually, the adult feeding method found more effective in prolonging the larval duration, cause more increase in this period as compared to application of an insect growth regulator as residue film. Further, the larval period increases generally with increasing concentrations but in some cases the prolonging influence is identical at 0.0001, 0.0001 and 0.01 per cent concentrations. As regards the virulence of the fourth-generation insecticides in increasing the larval period, both chemicals may be arranged as novaluron and chlorfluazuron in descending order and both insect growth regulators are more effective under adult feeding method and the less effective when it is applied as residue film.

Barring 0.0001 per cent concentration, all other concentrations of both fourth-generation insecticides used in this investigation prolong the pupal period which increases with the advancing concentration of insect growth regulator. At higher concentrations, such as 1.0 per cent the pupal period becomes more than 1.5 times to about 2.5 times of the pupal period under natural condition and this concentration becomes the more effective under adult feeding method and less effective, if it is applied as residue film and the duration prolonging influence figures intermediate between these. As regards the comparative efficiency of the fourth-generation insecticides in this context, based on the results of the higher concentrations, may be arranged as novaluron and chlorfluazuron in descending order.

Contrary to the larval and pupal periods, every concentration of both insect growth regulators reduces the longevity of both male and female adults and reduction in life-span of either sex increases with increase in concentration of insect growth regulators. At higher concentrations, such as 0.50 and 1.0 per cent the reduction in life-span of both male and female is much pronounced. At higher concentrations, the reduction in the male's longevity varies from 3.20 to 4.78 days, and from 5.02 to 8.04 days respectively, of course, depending on the kind of the fourth-generation insecticide and the method of its application to the test moth. At one per cent concentration, the novaluron reduces the male's longevity to about one-third of the natural longevity of male. The results pertaining to male's longevity permit us distinctly to determine the comparative potential and comparative effectiveness of methods of treatment of the both fourth generation insecticides. As per these results in the context of male's longevity reducing potential, the tested fourth generation insecticides may be arranged as novaluron and chlorfluazuron in declining sequence and both become moderately effective when applied by the adult feeding method and less effective when both chemicals administered as residue film.

Besides affecting the male's longevity, the used insect growth regulators affect the life-span of the female too even at its lowest concentration and its longevity reducing potential progresses with the increasing concentration. In this respect, both used fourth generation insecticides are more effective under the adult feeding method as compared to its administration as the residue film. Hence, the oral administration produces more effect than the treatment with the residue film. Among its higher concentrations the used insecticides cause steep decline in the female life span. At its one per cent concentration, insecticides may reduce the female life-span to about one third of the natural longevity; some insecticides may reduce it to more than half the natural longevity. Depending on their longevity reducing potential, the tested insecticides may be arranged as novaluron and chlorfluazuron in descending order.

The insect growth regulators (Chemosterilants), as their name suggest are the potent compounds which affect sterility and consequently, aid in control of the pest population and the sterility is the manifestation of reduction of both the fecundity and fertility (viability of eggs laid by a female) and it depends on the stage of life cycle (eggs, larvae, pupae and adults). In this investigation, the young adults were selected to be treated. The selection of young stage is related to two facts -

(1) The young stage is one in which critical gonadal development takes place and,

(2) In many insects, the insect growth regulators applied at young stage have been successful in inducing sterility to a considerable extent [32, 33,34, 35, 36, 37, 38,39, 40, 41, 42, 9 and 43].

Both fourth generation insecticides, screened against *Antigastra catalaunalis* when applied to young stage are effective in causing sterility even at their lowest concentration in this insect. These induce sterility by reducing the fecundity by decreasing the viability of eggs laid by a female. The related results in the context of novaluron reveal that the fecundity decreases with increase in the concentration; however, concentrations from 0.0001 to 0.01 per cent reduce the fecundity identically. The results also show that under the influence of novaluron, fertility decreases distinctly with the advancing concentration and the data pertaining to the per cent reduction in fecundity and per cent net sterility confirm the above facts. Under adult feeding method of application, in case of the chlorfluazuron, reduction in the number of eggs laid by a female and the hatchability of laid eggs are distinctly concentration dependent; these decrease with the increasing concentrations of insect growth regulators. This trend is clearly witnessed by the data on per cent reduction in fecundity and the percent net sterility. Under the adult feeding method at one per cent concentration novaluron induce about more than 29-33 per cent net sterility whereas at one per cent concentration, the chlorfluazuron induces about 45 to 46 per cent net sterility. On the basis of their sterility inducing efficiency under the adult feeding method, the both insect growth regulators screened against *Antigastra catalaunalis* may be arranged as novaluron and (63.41%), Contrary to this, as per results of this investigation, *Antigastra catalaunalis*, a lepidopterous insect, responds fairly well at one per cent concentration of the insect growth regulator applied as adult feeding treatment. At one per cent concentration the used insecticides induce more than 50 per cent sterility.

Besides, the above-mentioned aspects of the reproduction in *Antigastra catalaunalis* the insect growth regulators applied through the adult feeding method also effect the preoviposition and ovi-position period. The preoviposition period prolong even with 0.0001 per cent concentration of both used fourth generation insecticides. This fact suggests that a fourth-generation insecticide delays the sexual maturity in *Antigastra catalaunalis*. In this insect the delay in sexual maturity increases with increasing concentrations of the both fourth generation insecticides. In context of the delay in sexual maturity, considering influence of one per cent concentration, the both fourth generation insecticides may be arranged as novaluron, and chlorfluazuron in descending sequence. Like the preoviposition period, when applied through adult feeding method both insecticides even at its lowest concentration (0.0001%) affects the oviposition period too and this period decreases with the increasing concentration. Since the decreased ovipoisition period is associated with decreased fecundity, this fact suggests that both insecticides retard or inhibit the oviposition in this investigation.

Under the above-mentioned methods of treatment, both of the screened insect growth regulators have potential to increase the incubation period but, in this respect, the effective concentration is dependent on the kind of the insecticide. In case of chlorfluazuron, the concentrations from 0.0001 to 1.00 per cent do not exert influence on the incubation period. In case of both fourth-generation insecticides the concentrations above the effective concentration cause proportionate increase in the incubation period depending on their strength. The above facts suggest that the insect growth regulators lower the speed of the embryonic development which becomes more and more slow with the progressive increase in the strength of the insecticide.

The literature reveals that among lepidopterous insects, the oral administrations of insect growth regulators in adults has led to the adverse influences on the reproduction, i.e., it leads to the sterility with different levels of success [30, 41, 42]. Our results also indicate that when both insecticides are administered orally in adults, they are able to induce sterility which exhibits direct proportionality to their concentration. However, the effective concentration which causes more than forty per cent sterility differs from insecticide to insecticide. Chlorfluazuron exerts such influence at 0.0001 per cent level and novaluron does not acquire it even at the latter level. However, at one percent concentration both four insect growth regulators are able to cause very high sterility but not cent per cent. At this concentration, the sterility inducing potential differs between them and on this basis; both can be arranged as novaluron (83.73%) and Chlorfluazuron (72.53%) in descending order. However, in case of both insect growth regulators, there is a progressive increase in the sterility with the advancing concentrations which decrease the fecundity and fertility accordingly. As per our results, at one per cent concentration of a fourth-generation insecticide which induces very high sterility and longevity of the female *Antigastra catalaunalis* is very much reduced but contrary to this, in Prodenia litura, the induction of complete or very high sterility does not affect the longevity of the female. Further, in cabbage looper moths fed on 0.0001 per cent diflubenzuron and penfluron, only partial and low sterility is acquired. In P.ricini also, fourth generation insecticides are able to induce similar sterility at 0.0001% concentration. The both fourth generation insecticides screened under this investigation are able to control the reproduction in *Antigastra catalaunalis* to the extent of about 93 to 97.44 per cent at one per cent concentration and in this respect, at one per cent concentration the novaluron is found more effective fourth generation insecticide and chlorfluazuron which exert similar influence in controlling the reproduction, is the less effective one under the adult feeding method.

When insect growth regulators are applied as their residue film, they affect preoviposition and oviposition periods with tendencies corresponding to those under oral administration method. As the residue film, every concentration of both insect growth regulators exert influence on the preoviposition and oviposition periods. Further, barring the residue films of 0.0001% and 0.001% concentrations of chlorfluazuron the residue films of other concentrations of this insecticide cause prolongation in the incubation period which generally increase with the increase in the concentration of the residue film of insect growth regulator. Further, as the residue film, every concentration of both insect growth regulators is able to reduce the fecundity and fertility; chlorfluazuron usually exhibits indirect proportionality to the concentration of the residue film of both insect growth regulators employed in this investigation.

Depending on their potential for causing the reduction in the fecundity and fertility, the residue films of different concentrations of fourth generation insecticides increase the sterility proportionately and accordingly, affect the control over the reproduction in *Antigastra catalaunalis* leaving chlorfluazuron the residue films of 0.0001 to 0.50 per cent concentrations of novaluron cause sterility much below (40%) which may be reckoned as partial sterility but the residue film of one per cent concentration of both insect growth regulators causes more than fifty per cent sterility; at this concentration of the residue film chlorfluazuron induces more than sixty per cent sterility.

The comparative sterilizing influence of insect growth regulators under the both methods of treatment is quite distinct at one per cent concentration. The results pertaining to the per cent sterility induced by an insect growth regulator, suggest that each strength of novaluron is more effective under its oral administration in adults than its application to other developmental stage. The residue film method causes less sterility as compared to adult feeding method but chlorfluazuron is equally effective with adult feeding methods than when it is applied as residue film to the adults. As regards the sterilizing potential of the both insect growth regulators used in this investigation when applied to adults through oral administration, the results clearly reveal that the chlorfluazuron which causes about 66 per cent sterility, and novaluron induce more than 70% sterility and in the context of their sterilizing efficiency in *Antigastra catalaunalis*, the insect growth regulators screened against this insect may be arranged as novaluron (83.73%), and chlorfluazuron (65.71%) in descending order.

In insects, the sex oriented sterilizing influence of the insect growth regulators has been reported by a good number of workers [30,39, 41,43]. This investigation also reveals the sex specific sterilizing influence of both insect growth regulators too. The results pertaining to the sterility of *Antigastra catalaunalis* obtained from the cross between the treated male and the untreated female, between the untreated male and treated female and between the treated male and the treated female are suggestive of three facts : (1) Both insect growth regulators induce sterility in both the sexes, [2] the cross between the treated male and female induces more sterility than that of a cross in which only one sex is treated, and (3) in inducing sterility, the insect growth regulators are differently effective in male and female. The novaluron and chlorfluazuron induce more sterility in male than in female. The chlorfluazuron induces about 11 per cent sterility in the male as compared to female and the remaining insect growth regulators induce about 3 to 8 per cent more sterility in the male in comparison to their sterilizing influence in the famale *Antigastra catalaunalis*. Apparently, both insect growth regulators are male specific in this insect as reported in other too [30,31,19,41,42,43].Bhattacharya *et. al*. [44] evaluated the toxicity of diflubenzuron against larvae of *Eublemma amabilis*. They used five concentrations ranging from 0.0125 to 0.2% by two methods, oral and topical. Diflubenzuron applied using both methods exhibited larvicidal action and caused ecdysial failure which adversely affected survival.

CONCLUSION

In the light of findings, obtained in the present investigation, the use of both insect regulators i.e. novaluran and chlorfluazuron may be undertaken with remarkable success to keep the pest population of *Antigastra catalaunalis* below economic threshold. It may be concluded that novaluron and chlorfluazuron are suitable for use in integrated pest management programmes against test insect, *Antigastra catalaunalis*.

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