EFFECT OF SOME INSECTICIDES ON *TRICHOGRAMMA SPECIES*

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation in the thesis entitled **"EFFECT OF SOME INSECTICIDES ON *TRICHOGRAMMA SPECIES*"** or part there of has not been submitted for any other degree or diploma of any university, nor the data have been derived from any thesis / publication of any university or scientific organization. The sources of materials used and all assistance received during the course of investigation have been duly acknowledged.

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Date: / / 2021 Enrollment No- NN-2344

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF SOME INSECTICIDES ON *TRICHOGRAMMA SPECIES*"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Agriculture (Agricultural Entomology)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **NANOTE MANISHA WAMANRAO** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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Date: / / 2021

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(D) ABBREVIATIONS

%	-	Per cent
@	-	At the rate
a.i.	-	Active ingredient
BIPM		Biointensive insect pest management
BOD		Biological oxygen demand
CD	-	Critical difference
CV	-	Coefficient of variation
Dr. PDKV	-	Dr. Panjabrao Deshmukh Krishi Vidyapeeth
DAT	-	Days after treatment
EC		Emulsified concentration
et al.	-	et alia (and his associates)
FCRD.		Factorial Completely Randomized Design
Fig.	-	Figure
hrs.	-	Hours
i.e.	-	id est. (that is)
IPM		Integrated pest management
IOBC		International Organization of Biological Control
J.	-	Journal
RH	-	Relative Humidity
SC	-	Suspension concentration
SE (m) ±	-	Standard error of mean
SG		Soluble granules
Sig.	-	Significant
viz.,	-	Videlicet (Namely)

(E) THESIS ABSTRACT

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ABSTRACT

The present investigation entitled on “Effect of some insecticides on *Trichogramma species*” was conducted in order to study the toxicity of different insecticides to immature and adult stage of *Trichogramma*. The experiment was conducted during year 2020-2021 in the Bio-control Laboratory, Department of Entomology, PGI, Dr. P.D.K.V. Akola.

Experiment was conducted with four different insecticides combi-products (Novaluron 5.25% + Indoxacarb 4.5% SC, Profenophos 40% + Cypermethrin 4% EC, Indoxacarb 14.5% + Acetamiprid 7.7% SC, Pyriproxifen 5% + Fenpropathrin 15% EC) and one control treated on two *Trichogramma* species viz., *T. chilonis* and *T. bactrae* replicated thrice in Factorial Completely Randomized Design of experiment. Effect of these insecticides on per cent parasitization, per cent mortality of *Trichogramma* was studied, also the residual toxicity of these insecticides to adults of *Trichogramma* was investigated. The data on per cent parasitization revealed that Novaluron 5.25% + Indoxacarb 4.5% SC, Indoxacarb 14.5% + Acetamiprid 7.7% SC, Pyriproxifen 5% + Fenpropathrin 15% EC found harmless when irradiated and unirradiated *Corcyra* eggs were exposed to *Trichogramma* species had 70.50%, 68.50%, 65.33%, parasitization respectively. While Profenophos 40% + Cypermethrin 4% EC recorded as slightly harmful on irradiated and unirradiated *Corcyra* eggs as per the IOBC protocol.

In case of mortality of immature stages by insecticides combi-products treated on irradiated *Corcyra* eggs the Profenophos 40% + Cypermethrin 4% EC found slightly harmful (31.67%) and rest of the Insecticides were harmless when treatment was given on 3rd day of release and Novaluron 5.25% + Indoxacarb 4.5% SC had lowest mortality (18.83%).

The data on per cent mortality by insecticidal treatment on unirradiated *Corcya* eggs revealed that Novaluron 5.25% + Indoxacarb 4.5% SC found harmless (21.33%) according to IOBC protocol and rest of the insecticides found slightly harmful when treatment was given on 3rd day of release. Profenophos 40% + Cypermethrin 4% EC, Indoxacarb 14.5% + Acetamiprid 7.7% SC, Pyriproxifen 5% + Fenpropathrin 15% EC had (33.83%), (30.17%), (30.33%) mortality respectively.

Residual toxicity of four insecticides was tested, where in Profenophos 40% + Cypermethrin 4% EC and Pyriproxifen 5% + Fenpropathrin 15% EC was found slightly harmful to the adults of both the *Trichogramma* species on 1st day after release of adults. The Profenophos

40% + Cypermethrin 4% EC recorded highest adult mortality i.e., 35.83%, 32.00%, 19.67% and Novaluron 5.25% + Indoxacarb 4.5% SC caused lowest mortality i.e., 17.17%, 15.17%, and 11.33% on 1st, 5th and 10th day of treatment, respectively.

CHAPTER I

INTRODUCTION

1.1 Background Information

Biological control is the regulation of pest population using natural enemies, including predator, parasitoids, nematodes and microbial agents (Rosenheim and Jay, 1998; Bale *et al*. 2008). In biological control programmes natural enemies are introduced, which are encouraged to multiply by artificial means and disseminated by man with his own efforts and thus differs from natural control. Biological control of insect pest is advantageous because it is safe and poses no threat to human health and it is also an environment friendly.

Biological control has been a valuable tactic in pest management programs around the world for many years, but has undergone a resurgence in recent decades that parallels the development of IPM as an accepted practice for pest management. However, integrated pest management (IPM) is the better alternative to the conventional use of chemicals, where the manipulation of beneficial organisms remains a very important tool in IPM programmes for insects, worldwide (Orr, 2009).

Natural enemies have been utilized in management of insect pest of centuries. Where, these few decades have seen a dramatic increase in the use of natural enemies as well as in our understanding of how it can better be manipulated as part of effective, safe pest management systems. Despite long history of utilizing natural enemies. The term biological control was used for the first time in 1919 by late Harry Smith of the University of California (Smith, 1919).

Use of *Trichogramma* in many crops ecosystem has achieved appreciable pest control success and it’s role in the biological control programs of pest management is well understood (Smith, 1996; Sorokina, 1999; Hussain *et al*., 2010). By the establishment of Bio-intensive Pest Management Programs (BIPM), bio-control agents, such as *Trichogramma* species are integrated with other control methods without affecting the efficiency of bio-control agents (Tiwari and Khan, 2004) and is most widely used in Pakistan, India, China, Korea, Taiwan, Japan, Nepal and Reunion Island and as exotic species in Kenya, Spain, South Africa and Australia.

Among the various parasitoids used for the biological control programmes, *Trichogramma spp.* are most important egg parasitoids which are commonly distributed worldwide. These are minute endoparasitoids of insect eggs. The genus *Trichogramma* is one of the 80 genera in the family Trichogrammatidae which includes the smallest of insects ranging size from 0.2 mm to 1.5 mm. Within the genus *Trichogramma* there are 145 described species worldwide. The first species of *Trichogramma* reported from India was *Trichogramma semblidis* (Auriv.) from the eggs of *Tabanus macer* Bigot. (Nagarkatti,1977). Where, 20 species of *Trichogramma* and 6 species of old world Trichogrammatidae have been recorded from India, of which *T. chilonis* (Ishii), *T. japonicum* (Ashmead), *T. achaeae* (Nagraja) are widely distributed (Singh and Jalali ,1994).

1.2 Importance of study

A key principle of integrated pest management (IPM) is to maximize pest control through natural mortality factors such as predators and parasitoids.

Trichogramma spp. is used widely in IPM on many important pests of crop including spiny bollworm, *Earias insulana* Boisd. (Lepidoptera: Phalaenidae), a major serious pest of cotton crop which decreased the cotton yield worldwide. Their effectiveness can be significantly lower by insecticide applications that interfere with parasitism and parasite population growth.

Negative effect of Insecticides on populations of the parasitoids *Trichogramma* have been reported, whereas some studies showed that insecticides may increase the performance of natural enemies. Another study showed that the sub-lethal effect of insecticides can severely reduced the performance of biological control agents. Therefore, the present study i.e., effect of some insecticides on *Trichogramma* spp. is of much importance to know the safeness of new chemicals against performance of parasitoid *Trichogramma chilonis* and *Trichogrammatoidea bactrae* for sustainable pest management.

The conservation of beneficial organisms like natural enemies which are helpful in biological control practices is very necessary as it plays an important role in management of crop pests. Despite of the importance of biological control, the use of organic synthetic insecticides continues to be an important tool in integrated pest management system. The effectiveness of biological control practices can be improved by using insecticides in compatible manner without causing damage to bio control agents. Hence the knowledge of compatibility and the impact of insecticides on beneficial parasitoids species are of almost important for the effective integration of chemical and biological management programme. The most of the chemical insecticides are being replaced by low dose and less risked insecticides with low mammalian toxicity and various kinds of harmful effects of insecticides on *Trichogramma* spp. have been described by different workers (Hewa kapunge *et al*., 2003)

Trichogramma wasps are highly susceptible to most broad-spectrum insecticides. This is the reason that various attempts to suppress pest population by biological control measures have often failed because of deleterious effects of chemical on the beneficial insects. (Borgemeister *et al*., 1993). The integration of biological and chemical control practices require a through understanding of effects on biological control agent. A step wise assessment, moving from the laboratory to the field, with proper consideration of both direct and sublethal effects is recommended in the screening of pesticides against biological control agents (Croft,1990). The present investigation was undertaken to study the selective toxicity of different new insecticides against *Trichogramma chilonis* and *Trichogrammatoidea bactrae* under laboratory conditions with an objective to search for comparatively less toxic insecticide against *Trichogramma spp.* to be incorporated into IPM programs.

1.3 Objectives

1. To study the effect of newer insecticides combi-products on per cent parasitization by *Trichogramma species.*
2. To study the effect of newer insecticides on per cent mortality of different *Trichogramma species.*
3. To determine residual toxicity of newer insecticides against adult of different *Trichogramma species.*

1.4 Scope and Limitations of the Study

There is large scope of the present study of toxicity of some insecticides comdbi-products to *Trichogramma.* This study is important to determine the insecticides which are safer to *Trichogramma,* as it is one of the most important bio control agents. Among biological agents for stem borer, moth-egg, parasitoid, *Trichogramma* species is now most widely used for its control. A *Trichogramma* wasps belong to the family Trichogrammatidae of order Hymenoptera; these are tiny (0.5 mm long) parasitoids that attack the eggs of over 200 species, mostly Lepidopterans (Farmanullah *et al*. 2011). These occurs naturally but in most crop production system, the number of moths'eggs destroyed by native population of *Trichogramma* species is not sufficient to prevent pest population from damaging level. *Trichogramma* wasp are reared and released in the affected fields as a biological control agent. (Knutson,2000 and Shenhmar *et al*. 2003)

The reduction of these beneficial arthropods caused by non-selective insecticides may bring serious problems for crop all over the world. One of the problems is the resurgence of new pests and eruption of secondary pests. When resurgence occurs, the pest reappears in subsequent harvests, come from places of refuge and individuals that survived in the crop, in population levels higher than that of previous harvest. On the other hand, the eruption of pests is the change in the pest status: from secondary pest to key pest, especially due to the reduction of natural enemie that keep the pest below the level of economic loss (Fernandes *et al*. 2008).

One of the forms to avoid resurgence of pests is the use of selective insecticides, which were defined as the property of controlling the target pest, with the lowest possible impact on the other components of the ecosystem, namely, the insecticide must present low impact natural enemies, under the same condition in which the pest is successfully controlled (Degrande et.al.2002)

Works aiming to study the physiologic selectivity of different chemical groups of pesticides to *Trichogramma* spp. were accomplished. (Consoli *et al*.,1998)

Some earlier studies reported negative effects on *Trichogramma,* whereas some studies showed that lethal and sub-lethal insecticides are usually considered as high risk to beneficial species. (Croft 1990). The use of *Trichogramma* spp*.* Is potential key strategy in pest management but it's effectiveness largely depends on the use of insecticides that does not interfere with parasitism and parasitoid viability (Moura *et al*., 2004).

Hence, it is very important to preserve natural enemies, so that they may present a good performance in pest biological control, which is a critical control method used in the programs of integrated pest management (IPM).

1.5 Hypothesis

The present investigation was aimed to check the safetyness of newer insecticides combi-products with two species of egg parasitoid *Trichogramma* under laboratory condition. The assumption behind this hypothesis was to check the possible role of insecticides combi-products in reducing bio-control potential of *Trichogramma*. Effect of these insecticide combi-products on different life stages of *Trichogramma* on the basis of which we can arrange pesticide application schedule to escape them from deleterious effect of pesticides. While in case of using different *Trichogramma* species assumption was to compare the tolerance level of *Trichogramma* species against the insecticides.

Egg parasitoids belonging to genus *Trichogramma* are being used worldwide for innoculative and inundative release against lepidoptera pests (Smith and sandy, 1996). This wide range of adaptability is the most important attribute for a natural enemy such as *Trichogramma*. However parasitoid release and insecticide application at same time is not profitable as it may cause damage to parasitoid. For the purpose of conservation of natural enemies, the use of deleterious insecticides should be avoided, whereas all insecticides are not that hazardous to natural enemies, some of them are less hazardous and also safer to *Trichogramma* (Shukla *et al*., 1998; Brar *et al.,* 1991; Takada *et al*., 2001; Uma *et al*., 2014). Therefore, the chemicals safer and less hazardous to *Trichogramma* should be screened time to time as the new chemistry insecticides being available in market, so that these newer insecticides can be used in safer synchronisation along with parasitoid release in integrated pest management practices.

In the view of the above facts and looking the importance of proposed study, the experiment on "Effect of some insecticides on *Trichogramma* species*"* was undertaken at Department of Entomology, Dr. PDKV, Akola during 2020-21.

CHAPTER II

REVIEW OF LITERATURE

Large number of insecticides have been tested for their safety to *Trichogramma* species. Number of studies in this line have focused on hazardous effects of pesticides on natural enemies of insect pests in different part of the world and also revealed the urge for need based application of pesticides as a part of an integrated approach for pest management.

For planning the present research review of literature pertaining to these aspects was made and presented below.

2.1 To study the effect of newer insecticides combi-products on per cent parasitization by *Trichogramma* species

Sarode and Sonalkar (1999) reported that the insecticide belonging to pyrethroid and organophosphate group showed toxic effects on parasitization of *Corcyra cephalonica* eggs by *T. chilonis,* whereas, neem seed extract and endosulfan were moderately safe to the parasitoids.

Charles *et al*. (2000) reported the toxicity of lambda cyhalothrin, Cypermethrin, thiodicarb, Profenophos, spinosad, methoxyfenozide, and tebufenozide to *Trichogramma exiguum* emergence, adult survival, and fitness. Among the all insecticides, methoxyfenozide and tebufenozide found safe and other adversely affected *Trichogramma* emergence from *Helicoverpa zea* (Biddie) host eggs when exposed at different pre-imaginal stages of development (larval, pre-pupal, or pupal), Based on LC50 values, spinosad and profenophos were the most toxic compounds to female *T. exiguum* adults, followed by lambda cyhalothrin, cypermethrin, and thiodicarb.

Ingle *et al*. (2004) tested the susceptibility of four species of *Trichogramma* viz., *T. chilonis, T. japonicum, T. bactrae* and *T. pretiosum* to insecticides like carbaryl, deltamethrin, endosulfan and malathion. It was found *T. chilonis* was most tolerant strain amongst four and it may be genetically manipulated for endosulfan tolerance.

Sarkar *et al.* (2005) studied the adverse effect of insecticides viz. BHC, endosulfan, quinolphos, monocrotophos, cypermethrin, deltamethrin and fluvalinate on the rate of parasitization of F1 progeny of *Trichogramma chilonis* Ishii and *Trichogramma japonicum* Ashmead and observed that *T. japonicum* parasitized more host eggs when treated at larval stage than at pupal and adult stage whereas, *T. chilonis* parasitized more host eggs when treated on pupal stage, whereas in both cases adult stage was found most susceptible to insecticidal treatment. However, the descending order of toxicity towards parasitization were recorded as quinolphos > endosulfan > cypermethrin > fluvalinate > monocrotophos > BHC > deltamethrin > for *T. chilonis* whereas, quinolphos > cypermethrin > deltamethrin > fluvalinate > endosulfan > monocrotophos > BHC were recorded for *T. japonicum.*

Gelardo *et al*. (2010) studied toxicity of acetamiprid, Iufenuron, imidacloprid, novaluron, triflumuron, and pyriproxifen on the developmental stages of *Trichogramma.* The application of pyriproxifen, acetamiprid and imidacloprid to *T. pretiosum* during its egg-larval period was slightly harmful to the parasitization capacity of F1 generation females and the emergence rate of F1 and F2 generation adults. Acetamiprid and Lufenuron when applied at pupal stage of *T. pretiosum,* found slightly harmful to the parasitization capacity of F2 generation females. Novaluron and triflumuron during the immature stages to *T. pretiosum,* were harmless to its F1 and F2 generations.

Sattar *et al.* (2011) studied the toxicity of 6 insecticides viz., Emamectin benzoate, lufenuron, flubendiamide, spinosad, Indoxacarb and neem oil against all the life stages of the parasitoid *Trichogramma chilonis* under laboratory condition and found that flubendiamide, the most selective of all the tested Insecticides for the development, survival and fecundity of the wasp. Spinosad was closely followed by emamectin benzoate which severely curtailed adult survival and fecundity and to a lesser degree for the development of immature stages inside host eggs. Indoxacarb was reported “Slightly harmful” to all life stages, except the egg stage of the wasp, whereas lufenuron exhibited significantly higher level of toxicity against the larval stage, however neem oil found “harmless” to the eggs, pupae and adults but exerted. “Slightly harmful” effects on larval development and female fecundity.

Hussain *et al.* (2012) Evaluated the toxicity of some new insecticides viz., Spinosad, flubendiamide, chlorantraniliprole, emamectin benzoate and imidacloprid were tested against immature and adult stage of *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) under laboratory conditions. Exposure of spinosad to *T. chilonis* resulted in the lowest emergence at all the parasitism situations. The application of emamectin benzoate and lufenuron after 1 day parasitism, imidacloprid, emamectin benzoate and lufenuron after 3 days parasitism, imidacloprid, emamectin benzoate, flubendiamide and lufenuron after 4,5 and 7 days of parasitism, respectively showed minimum effect on the emergence of *T. chilonis* and were found to be safe to the parasitoid. After 8 days parasitism, Chlorantraniliprole resulted in the maximum emergence of *T. chilonis* and did not show significant difference with lufenuron and emamectin benzoate. Chlorantraniliprole shows maximum survival (42%) and did not differ significantly with lefunuron with 36% survival at 3h post application. Emamectin benzoate found to be a toxic Insecticide which resulted in the minimum survival of the parasitoid with 18.0% and did not show significant difference to those of imidacloprid with 22.0% survival. Al the insecticides showed non-significant difference with one another on the survival of *T. chilonis* adult recorded 24h post application and found toxic to the adult of *T. chilonis* regarding survival range between 8.0 to 14.0% as against control treatment with 92.0% survival of *T. chilonis.*

Madhusudan *et al*. (2014) evaluated the effect of five insecticides viz. flubendiamide @ 50, 60 and 70 g a.i. per ha, chlorantraniliprole 18.5 SC (75g a.i. per ha), thiodicarb 75WP (675 g a.i. per ha), fipronil 5 SC (75 g a.i. per ha) and chlorpyriphos 20EC (250 g a.i. per ha) against the reduction in per cent parasitisation of *Trichogramma chilonis,* which recorded 84.16, 80.20, 80.04, 75.86, 73.56, 73.23 and 67.38, percent respectively whereas, maximum per cent parasitisation reported from untreated check with 92.60%.

Bhargavi (2016) studied the effect of different insecticides viz. oxydemeton methyl, cypermethrin diamethoate, indoxacarb, emamectin benzoate malathion and dichlorvos on parasitisation potential of *T. japonicum.* Recorded oxydemeton methyl safer to *T. japonicum* before release, diamethoate, indoxacarb and emamectin benzoate could be used before *T. japonicum* release in the field with some safe period, while insecticides viz., malathion and dichlorvos found to be highly toxic for parasitisation.

Kumari *et al.* (2016) studied the parasitization capacity of *Trichogramma chilonis* and *Trichogramma pretiosum* on the eggs of *Corcyra cephalonica.* The parasitization capacity of *Trichogramma chilonis* ranged from 58.94 to 68.94 per cent with an average of 64.28 per cent and that of the *T. pretiosum* ranged from 41.56 to 46.48 with the average of 43.52 per cent suggesting the superiority of the *T. chilonis* over *T. pretiosum.*

Deshmukh *et al.* (2018) Experiment was conducted with four different insecticides (Chlorantraniliprole 18.5%SC, Flubendiamide 480 SC, Diafenthiuron 50% WP and Azadirachtin 1000 ppm) and a control on three different species of *Trichogramma* viz.*, T. chilonis, T. pretiosum* and *T. japonicum* in Factorial Completely Randomised Block design of experiment. Effect of these insecticides on per cent parasitization of *Trichogramma* species was studied. Results revealed that chlorantraniliprole, flubendiamide, Diafenthiuron, and Azadirachtin found harmless when irradiated *Corcyra* eggs were exposed to *Trichogramma* spp. and had 59.80%, 68.06%, 58.20%, 72.93% parasitization, respectively. While Chlorantraniliprole (59.49%) and Diafenthiuron (59.02%) registered as slightly harmful on unirradiated *Corcyra* eggs as per the IOBC protocol.

Sant *et al*. (2019) evaluated the parasitizing efficacy of four *Trichogramma* species against the eggs of pink bollworm *Pectinophora gossypiella* (Saunders). The results revealed that the maximum (>87%) and minimum (<36%) parasitization was obtained in the case of *Trichogramma*toidea *bactrae* and *Trichogramma japonicum,* respectively.

The increasing order of per cent adult emergence from the parasitized pink bollworm eggs were as *T. bactrae* (91.25) < *T. chilonis* (88.66) < *T. brasiliensis* (52.08) < *T. japonicum* (49.09). There was no significantly difference seen in the developmental period among the four species which ranged between 6.17 to 7.33 days. Our results indicated that *T. bactrae* and *T. chilonis* relatively more effective in parasitizing pink bollworm eggs. Hence these two species of *Trichogramma* can be safely included in bio intensive IPM programmes for managing insect pests in agro-ecosystem more effectively.

Schafer *et al.* (2020) assessed the efficiency of nine European *Trichogramma* species and compared them to *Trichogramma achaeae,* and verified species identity, host acceptance, host preference (*T. absulata vs.* rearing host *sitotroga cerealella* eggs) and host searching capacity were tested under laboratory conditions. Our results indicated that *T. nerudai, T. Pintoo and T. cacoeciae* achieve a similar level of parasitism on potted tomato plants as *T. achaeae.*

Pawar *et al*. (2020) studied some new insecticides viz., Chlorantraniliprole 18.5 SC (0.005%), flubendiamide 20 WG (0.005%), buprofezin 25 SC (0.05%), Lambda cyhalothrin 5 EC (0.003%), thiamethoxam 25 WG (0.005%), Dinotefuron 20 SG (0.006%), thiacloprid 21.7 SC (0.021%) and Azadirachtin 5% w/w (0.002%) were tested to know their effect on percent parasitization of UV irradiated and unirradiated *Corcyra cephalonica* eggs by parasitoids *Trichogramma japonicum* and to assess the residual toxicity of these insecticides on adult *T. japonicum* under laboratory conditions. The result indicated that lambda cyhalothrin was most harmful causing maximum reduction in parasitization, whereas minimum reduction in percent parasitization were observed under insecticide treatments Azadirachtin, buprofezin, flubendiamide and chlorantraniliprole in both UV irradiated and unirradiated eggs of *Corcyra cephalonica.* However, the insecticides differed considerably in their residual toxicity towards *T. japonicum.* Amongst them, Azadirachtin was recorded safest followed by chlorantraniliprole and buprofezin, whereas lambda cyhalothrin most affected survival of *Trichogramma japonicum* causing maximum adult mortality upto 10 days.

Singh *et al*. (2020) studied the efficacy of egg parasitoid, *T. chilonis* against *C. partellus* in kharif maize and recorded maximum egg parasitism by *T. chilonis* when released twice at highest rate (i.e., 1,25.000 and 100,000 parasitized eggs per hectare) However treatments with low release rate (one and two release @ 75,000 parasitized egg per hectare, one release @1,00,000 parasitized egg per hectare) experienced significantly plant and did not provide satisfactory monetary. In contrast, treatments with higher release rates (i.e. *chilonis @ 1,25,000* parasitized egg per hectare at 7 and 14 DAG; *T. chilonis* @ 1,00,000 parasitized egg per hectare at 7 and 14 DAG) effectively suppressed plant infestation, dead heart formation and leaf injury by *C. partellus.* These treatments were statistically comparable with chemical control (Diamethoate @ 660ml per hectare at 7DAG). It can be concluded that one release of *T. chilonis* is insufficient, and two released are required for effective although pesticides treated plots provide satisfactory monetary return, they are not environmentally compatible and ecologically viable for the long run.

2.2 To study the effect of newer insecticides on per cent mortality of ***Trichogramma*** species

Suh (2000) investigated the effect of insecticides viz. lambda cyhalothrin, cypermethrin, thiodicarb, profenophos, spinosad, methoxyfenozide, and tebufenozide on *Trichogramma exiguum.* All insecticides, with an exception of methoxyfenozide and tebufenozide, adversely affected *Trichogramma* emergence from *Helicoverpa zea* (Biddie) host eggs when exposed at different pre-imaginal stages of development (larval, pre-pupal, or pupal).

Bhardwaj and Gupta (2002) found *Trichogrammatoidea bactrae* reared on *Corcyra cephalonica* as an egg parasitoid of *Plutella xylostella* was carried out at 26+_1 C and 50-80 per cent relative humidity. From each parasitized egg of *C. cephalonica* up to 2 parasitoids emerged and there were almost equal chances of getting 1 or 2 parasitoids. Each female parasitized a mean of 4.6 and 6.4 eggs of *Plutella xylostella* and *C*.

cephalonica during its mean survival of 1.7 and 2.3 days, respectively, during post embryonic development, 38.1 and 31.9 percent mortality was observed and maximum mortality was in the pupal stage.

Nasreen *et al*. (2004) studied toxic effect of eight insecticides viz, Diafenthiuron, thiodicarb, imidacloprid, carbofuron, methamidophos, acetamiprid and thimethaxam against *T. chilonis* through leaf dip bioassay method under laboratory conditions. The results revealed that all concentrations of imidacloprid, carbosulfan, methamidophos and thiodicarb were toxic to *T. chilonis.* Lower concentration of acetamiprid and thiomethaxam were slightly harmful, while recommended and higher concentrations were found moderately harmful and harmful, respectively. All concentrations of buprofezin remained harmless. All the insecticides were found toxic after 48 hours except buprofezin.

Wang *et al*. (2011) studied toxicity of eleven insecticides of different categories on adults of *Trichogrammatoidea bactrae* and the sub-lethal effects of insecticides on their reproduction under laboratory condition were studied. The adults of *T. bactrae* were most susceptible to avermectin at 8 h after exposure, second susceptible to fipronil, chlorfenapyr, spinosad, cartap, betacypermethrin and diafenthiuron. The LC50 values of avermectin, chlorfenapyr, cartap, diafenthiuron, spinosad and fipronil had significant effect on the longevity and fecundity of *T. bactrae.* Chlorfluazuron, indoxacarb, *B. thuringienesis* and bufenozide are safe to *T. bactrae* and timing of application of these insecticides is critical.

Uma *et al.* (2014) eighteen insecticides evaluated for their toxic effects on the on the *Trichogramma japonicum.* Novel insecticides viz., emamectin benzoate, fipronil, imidacloprid, indoxacarb, buprofezin and chlorantraniliprole were rated as 'harmless' as per IOBC safety classification whereas spinosad, thiomethaxam and flubendiamide were found 'slightly harmful' to *T. japonicum.* Conventional organophosphates viz., acephate, chlorpyriphos and dichlorvos were 'moderately harmful'. Diamethoate, malathion, quinolphos carbaryl, fenvalerate and acetamiprid caused a mortality of 30-79 % leading them to be rated as 'slightly to adults of *T. japonicum.*

Craig *et al*. (2014) studied relative toxicities of insecticides on natural enemies (Aphidius colemani Viereck, Orius insidiosus [Say]. *Chrysoperla rufilabris* [Burmeister], and *Hippodamia convergence* [Gue'rin-Mene' ville]. Acetamiprid consistently caused significant acute effects, even after aging for 14 d. Methoxyfenozide, novaluron and chlorantraniliprole, which also are classified as reduced-risk insecticides, had low toxicity, and along with the organic products could be compatible with biological control.

Singhamuni *et al*. (2015) studied performance of *T. chilonis* under the exposure of profenophos, neem, Chlorfluazuron, they concluded profenophos was highly lethal to adult (74% mortality) and neem (7%) and Chlorfluazuron (5.2%) were relatively safer for them. Similarly, profenophos found highly lethal for immature stage (100% mortality) compared to Chlorfluazuron and neem. The residue effect of profenophos and Chlorfluazuron was significant upto 10 days and the ecosystem was safer for parasitoids after 15 days reported volatiles have less involvement in searching behaviour of *T. chilonis.* They concluded *T. chlonis* as a potential candidate for bio-control of *T. chilonis* through augmentation and release.

Madhusudan (2015), studied the effect of the insecticides avermectin (abamectin) and some organophosphates (chlorpyriphos, malathion, quinolphos, triazophos), oxadiazine (indoxacarb), and spinosyn (spinosad) as well as with pyrethroids (cypermethrin) to the egg parasitoid *Trichogramma chilonis* (Hyn: Trichogrammatidae. Chlorpyriphos, malathion, quinolphos, triazophos proved to be most lethal, abamectin and cypermethrin harmful and Indoxacarb and spinosad was found to be least harmful on the adult survival of the egg parasitoid.

Singh (2015) concluded diamides (flubendiamide/ chlorantraniliprole /cyazypyr), bacterial products (emamectin benzoate/ avermectins/milbemectin except, spinosad which is toxic), IGR's (buprofezin / novaluron / Lufenuron / pyriproxifen/other IGRs), dichloropropenyl (pyridalyl), pyridine azomethines (pymetrozine) and phenyl pyrazole (fipronil) have shown directly or indirectly safe impact either to the insect predators and or parasitoids.

Saha *et al*. (2017) reported the toxicity of insecticides viz., Cypermethrin 25EC (0.001%), Rynaxyper 20 SC (0.006%), Spiromesifen 240 SC (0.024%), imidacloprid 17.8 SL (0.005%), wettable sulphur 80 WP (0.24%), profenophos 50 EC (0.05%) and neemazal 1%EC (0.002%) against the pupal mortality of *Trichogramma chilonis* recorded 60.22, 27.59, 25.84, 26.97, 42.70, 37.08 and 7.87 percent pupal mortality respectively.

Yang *et al*. (2019) studied the response of *Trichogramma dendrolimi* and *Trichogramma japonicum* to four Insecticides (Chlorpyrifos, chlorantraniliprole, emamectin benzoate, and spinosad) were evaluated at Target sublethal concentration (TSC10 and TSC25, representing the LC10 and LC25 to the target pest) of the important rice pest, *Cnaphalocrocis medinalis* (Guenee). Each of the Insecticides led to the mortality of adult *T. japonicum* and *T. dendrolimi* at TSCs of spinosad treated host eggs, whereas the TSC10 was lower for emamectin benzoate at F1 for *T. japonicum.* The TSCs of Chlorpyrifos treated host eggs negatively influenced the emergence rates of *T. japonicum* at F1. Emamectin benzoate with TSC10 reduced the female ratio *T. japonicum* at F1. For *T. dendrolimi,* the two TSCs of Chlorpyrifos treated host eggs negatively influenced the emergence rates at F1. These finding indicates that *T. japonicum* and *T. dendrolimi* are affected by Insecticides of TSCs, and among the four Insecticides, chlorantraniliprole had the lowest mortality rates for *T. japonicum* and *T. dendrolimi* at TSCs.

Bhabani *et al.* (2020) studied the effect of insecticides viz., Chlorantraniliprole 18.5 SC, Diafenthiuron 50 WP, Cartap hydrochloride 50 SP, Spiromesifen 22.9 SC, Thiamethoxam 25 WG, Clothiandin 50 WDG, Flonicamid 50 WG, Azadirachtin 1500 ppm on the rate of adult emergence of *T. chilonis*, when applied during different developmental stages i. e. egg, egg-larval and pupal stages. Amongst all the insecticides understudy, Cartap hydrochloride was found most toxic causing the highest reduction in the emergence of adults, when applied after 1st, 3rd and 5th days after parasitization which coincide with the egg, egg-larval and pupal stages of *Trichogramma.* Whereas, diafenthiuron, was found least toxic upon application during egg and egg larval stage and Azadirachtin during the pupal stage.

Mahopatra *et al*. (2021) evaluated the contact toxicity of seven different insecticides against female adult of *Trichogramma japonicum*. The result indicated that none of the insecticide was found safer except control treatment to the female of *T. japonicum* under contact toxicity trial during the present investigation. However, insecticides viz., Flubendiamide 39.35 SC, Chlorantraniliprole 18.5 SC and lambda cyhalothrin 5 EC were found detrimental and grouped as harmful to the female of *T. japonicum* by causing per cent adult mortality.

Mohamed (2021) evaluated the efficacy of the egg parasitoid *Trichogramma* bactrae Nagaraja (Hymenoptera: *Trichogramma*tidae) as a bio-control agent against *S. littoralis* egg masses with different physical characteristics (number of egg layer and degree of scale density) in a no-choice and choice tests, under laboratory conditions. Also, the adult emergence per cent, parasitism per cent, developmental period, female offspring per cent, and longevity were investigated. The results revealed that *T. bactrae* wasp had a great ability to parasitized *S. littoralis* egg masses, but with different rates, related to their layers and scales thickness in both tests. The highest parasitism per cent was observed on one-layer eggs, followed by two layers. However, 3-layer eggs were least preferable one. High numbers of adult emergence (>80%) were observed in all tested egg masses, except in the case of 3 layers with high scales. Furthermore, female biased sex ratios were noticed at all examined eggs, with only the exception of high scaly eggs with a single layer that recorded the lowest rate (<=45%). Besides, the survival of adult female parasitoid was not significantly affected in both tests.

2. 3 To determine residual toxicity of newer insecticides against adult of different *Trichogramma* species

Suh (2000) studied the survival percentage of *T. exiguum* in two trials by residue bioassay method on cotton leaves under field condition. Adult survival on day 0 after spray was 5 % for thiodicarb, profenophos, and spinosad and it ranged from 4-16% for lambda cyhalothrin and cypermethrin treatments. In both trials, adult survival steadily increased at longer interval between insecticide application and exposure. Three days after spraying, spinosad and the control had similar level of survival, and by day 4 after spray, adult survival was similar along all treatments and whereas by day 5 after spray in the second trial, all insecticidal treatments with the exception of cypermethrin had similar levels of adult survival as the control, and by day 6, all of the treatments and control showed similar levels of adult survival.

Samanta *et al.* (2006) investigated the residual toxicity of different insecticides used in brinjal crop on *Trichogramma chilonis* Ishii and *Trichogramma japonicum* Ashmead. However alpha cypermethrin was found safe towards both the parasitoids whereas, on the basis of results recorded, it was recommended that both the parasitoids could be released in crop ecosystem after 3-5 days, 4-6 days and 6-7 days after spray of alpha cypermethrin, menomyl and quinolphos respectively.

Sattar *et al*. (2011) conducted a Persistency tests against *T. chilonis* by studying the effect of pesticide residues on the adult wasp after 0, 5, 15 and 25 days and reported that flubendiamide and lufenuron was "short lived", indoxacarb was "slightly persistent" and spinosad and emamectin benzoate were classified as "moderately persistent". Whereas, flubendiamide was considerably safe. Neem oil, indoxacarb and lufenuron were mildly toxic for the bio-control agent, while spinosad and emamectin proved highly toxic among all the insecticides.

Sidi *et al.* (2012) studied the effect of insecticide residues and spray volume application of the two botanical Insecticides azadirachtin (neemix 4.5 EC) and rotenone (rotenone 6.6 EC) against hymenopteran egg parasitoid *Trichogramma papilionis* in comparison with synthetic insecticides – cypermethrin (cyper 5.5 EC). Each Insecticides was sprayed in a pot using a knapsack sprayer fitted with the three different nozzles to deliver 100, 200 and 400 L/ha. Cypermethrin yielded 100 per cent mortality of *T. papilionis* @ 400 L/ha, whereas @200 L/ha, rotenone yielded 59.5 per cent mortality followed by cypermethrin (56.4 percent mortality) respectively and cypermethrin @ 100 L/ha yielded 82.6 per cent mortality followed by rotenone (64.4 per cent mortality). However, azadirachtin yielded the lowest mortality (13.4 percent) and found safer than cypermethrin and rotenone at all spray volume application rates.

Zhao *et al.* (2012) studied the toxicity of thirty Insecticides belonging to seven chemical classes viz. Organophosphates (chlorpyriphos, fenitrothion, phoxim, profenophos, and triazophos) and carbamates (carbaryl, carbosulfan, isoprocarb, metocarb and promecarb), antibiotics (abamectin, emamectin benzoate and evermectin), phenylpyrazoles (butane-fipronil, ethiprole and fipronil), pyrethroids (cyhalothrin, cypermethrin, fenpropathrin, and lambda cyhalothrin) and neonivotinoids (acetamiprid, imidacloprid, imidaclothiz, nitrnpyram, thiachloprid and thiamethoxam), insect growth regulator insecticides (Chlorfluazuron, fufenozide, hexaflumuron and tebufenozide) against *Trichogramma japonicum* and recorded organophosphates and carbamates as most toxic to *T. japonicum* followed by antibiotics, phenylpyrazoles, pyrethroids and neonicotinois, whereas insect growth regulators were found safe exhibiting lower toxicity to *T. japonicum.*

Singhamuni *et al.* (2015) evaluated the residual toxicity of profenophos, neem and chlorofuzorn on *Trichogramma chilonis.* The residual effect of profenophos and Chlorfluazuron was significant up to 10 days but safer for parasitoids after 15 days. Whereas, neem was found relatively safer than both of the insecticides.

Huggi and Malkapur (2016) evaluated the toxicity of Insecticides viz. Profenophos 50 EC, Indoxacarb 14.5 SC, acephate 75 SP, chlorantraniliprole 20 SC, emamectin benzoate 5 SG, spinosad 45 SP, lufenuron 5 EC, azadirachtin 2.5%, monocrotophos 36SL, flubendiamide 480 SC, chlorpyriphos 48 EC, cypermethrin 25 EC and malathion 50 EC to adults of *Trichogramma chilonis* by dry film residues method at 12, 24, and 48 hours after treatment and reported 92.50, 91.67, 92.50, 86.67, 80.83, 95.83, 81.67, 84.17, 95.83, 90.00, 96.67, 93.33, 85.83 mean per cent mortality, respectively.

Shelvaraj *et al*. (2017) Studied the effect of some newer molecular insecticides viz., Novaluron 10 EC @ 75 g a.i./ha, Flubendiamide

20 WG @ 40 g a.i./ha, Indoxacarb 4.6 SC + Novaluron 5.25 SC @ 80 g a.i./ha, Indoxacarb 14.5 SC @ 60 g a.i./ha, Acephate 75 SP@600 g a.i./ha, hydrochloride 50 SP @450 g a.i./ha and Rynaxyper 18.5 SC @ 30 g a.i./ha was tested against *Plutella xylostella* (Linnaeus) on Cauliflower. Cartap hydrochloride @ 450 g a.i./ha was found most effective in reducing the larval population (91.53%) and also recorded highest yield (27.25 t/ha) among all the 7 insecticides tested. Minimal yield was observed in the control plots (14.00 t/ha). Cartap hydrochloride also showed highest acute toxicity towards both the parasitoids with LC 50 value (0.0099& 0.0043) for *Trichogramma chilonis* Ishii *Chrysoperla zastrovi silemi* (Esben-Petersan), respectively.

Deshmukh *et al.* (2018) evaluated the effect of newer insecticides on parasitisation by *Trichogramma* species under laboratory condition. Experiment was conducted with four different insecticides (chlorantraniliprole 18.5%SC, Flubendiamide 480SC, Diafenthiuron 50%WP and Azadirachtin 10000 ppm) and a control on three different species of *Trichogramma* viz; *T. chilonis, T. pretiosum and T. japonicum* in Factorial Completely Randomized Block Design of experiment. Effect of these insecticides on per cent parasitization of *Trichogramma* species was studied. Result revealed that Chlorantraniliprole, Flubendiamide, Diafenthiuron and Azadirachtin found harmless when irradiated *Corcyra* eggs were exposed to *Trichogramma* species and had 59.80%, 68.06%, 58.20%

Wahengbam *et al*. (2018) investigated the effect of modern insecticides (Spiromesifen, Rynaxyper, Cyazypyr, Thiacloprid and Tolfenpyrad) on pupal stage of Hymenoptera parasitoids. The trial was arranged in Factorial Completely randomised Design consist of ten treatments excluding control with three replications. The experiment resulted that the 100 per cent mortality was obtained in application of Tolfenpyrad 15% EC @ on *Trichogramma chilonis* Ishii and *T*. *pretiosum* Riley. All new molecules, Spiromesifen, Rynaxyper, Cyazypyr and thiacloprid were observed harmless towards *Trichogramma species* and use as a IPM component. The interaction between insecticidal treatment and parasitoids species was non-significant. The first report of new formulation of Rynaxyper 35 WG was observed harmless effect on *T. chilonis* and *T. petiosum.*

Singh *et al*. (2018) studied the effect of persistent toxicity of different insecticides and plant products on parasitization and emergence of *Trichogramma chilonis* from parasitized *Corcyra* eggs revealed that *Parthenium* leaf extract 5% caused maximum egg parasitization of 70.00% in 2014 and 66.00% in 2015. Lowest parasitization (33.00% in 2014 and 29.5% in 2015) was found in *Corcyra* eggs treated with imidacloprid 17.8 SL. The emergence of *T. chilonis* was observed from 8 days after treatment (DAT) onwards and the overall emergence was maximum at 12 DAT. In this experiment Parthenium leaf extract 5% and Azadirachtin 5% were found most promising when compared with other insecticides. The least emergence of adult parasitoid was observed in treatment with imidacloprid 17.8 SL. (53.03% in 2014 and 52.54% in 2015), followed by emamectin benzoate 5SG (56.71% in 2014 and 56.45% in 2015).

Sant *et al.* (2019) evaluated residual toxicity of some newer insecticides against *Trichogramma chilonis* Ishii. The result revealed that the increasing order of residual toxicity of insecticides was as: Azadirachtin 1500 ppm <Spiromesifen 22.9 SL <Diafenthiuron 50% WP <buprofezin 25 SC <imidacloprid 17.8 <acephate 75% SC < lambda cyhalothrin 9.5% + thiamethoxam 12.6% ZC. Botanical insecticide had significantly less residual problem than chemical insecticides. Azadirachtin, a neem based botanical insecticide was found safest to *T. chilonis* in terms of its residual toxicity whereas, lambda cyhalothrin 9.5% + thiamethoxam 12.6% ZC recorded maximum residual toxicity. It was also observed that the insecticides residues persisted upto 10 days of treatment. Hence, it is advisable that release of *Trichogramma chilonis* should be with held at least upto 10 days of insecticide applications in field in order to achieve better parasitization of host insect.

Saber *et.al*. (2020) assessed lethal and Sublethal effect of three commonly used Insecticides on adult and immature stage of the egg parasitoid *Trichogramma brassicae* Bezdenko Hymenoptera:

Trichogrammatidae). Recommended field concentrations of Chlorantraniliprole, phosalone and spinosad caused mortality on preimaginal stages by 24, 87 and 98%, respectively. Lethal effects on parasitoid adult exposed to the Insecticides dry residues were estimated as median lethal concentration (LC50) that were 13.28, 0.25, and 0.03 ug a.i. per ml for chlorantraniliprole, phosalone and spinosad, respectively. The effect of low lethal concentration (LC30) of the compound were evaluated on various adult biological traits such as, longevity, fecundity, emergence rate, and other life table parameters. All compound caused detrimental effect on all the estimated demographical indexs. Chlorantraniliprole affected the net reproductive rate, mean generation time and doubling time in comparison to Control, while phosalone and spinosad adversely affected all assessed parameters. The result suggest that all compounds are not fully compatible with the activity of *Trichogramma brassicae and that the* inclusion of Chlorantraniliprole, phosalone and spinosadinto IPM involving this parasitoid has to be avoided.

CHAPTER III

MATERIAL AND METHODS

The present investigations entitled "Effect of some insecticides on *Trichogramma* species*"* were conducted in the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, during the year 2020-21 with following experimental and treatment details.

3.1 Experimental details

1. Season	-	Kharif
2. Type of experiment	-	Laboratory experiment
3. Laboratory condition	-	Ambient laboratory condition
4. Test insects	-	*Trichogramma chilonis*
		Trichogrammatoidea bactrae
5. No. of treatments	-	05 (five)
6. No. of replications	-	03 (Three)
7. Design	-	Factorial Completely Randomized Design

3.2 Treatment details

Four combi-products insecticides products with one untreated control viz., Novaluron 5.25% + Indoxacarb 4.5% SC, Profenophos 40% + Cypermethrin 4% EC, Indoxacarb 14.5% + Acetamiprid 7.7% SC, Pyriproxifen 5% + Fenpropathrin 15% EC were used in the experimentation. The details of these combi-products insecticides products have been given under Table 1.

The material used and methodology followed in the present investigations have been described under respective subheads.

3.3 Materials used

Table 1. Insecticides for treatments and their availability

Sr. No.	Ready-mix insecticide formulation	Trade name	Manufacturer	Field Dose (ml / L)
1	Novaluron 5.25% SC + Indoxacarb 4.5% SC	Plethora	Adama, Pvt.Ltd.	1.75
2	Profenophos 40% EC + Cypermethrin 4% EC	Profex super	Nagarjuna Agrichemicals	2.00
3	Indoxacarb 14.5% SC + Acetamiprid 7.7%SC	Kite	Gharda Chemicals	1.00
4	Pyriproxifen 5% EC + Fenpropathrin15% EC	Sumiprem pt	Sumitomo India Pvt. Ltd.	1.00

3.3.1. Insects used

1. Fresh eggs of *Corcyra cephalonica* (U.V. exposed and unexposed)

2. Culture of *Trichogramma chilonis*

3. Culture of *Trichogrammatoidea bactrae*

3.3.2 Plastic and glass wares used

1) Glass vials of about 15 × 2.5 cm size

2) Breakers of 100ml, 250ml capacity

3) Magnifying hand lens

4) Measuring cylinder

5) Glass beakers

3.3.3. Chemicals used

1. Sodium hypochlorite solution (0.2%) in water for disinfection of tools and table tops, 2. Alcohol (70%) solution in water for disinfection of brushes, scissors and washing of hands, etc

3.3.4. Other material and accessories used

1.Trichocards 2. Camel hair brush 3. Honey (Dabur), 4. Polythene bags 5. Forceps, 6. gum, 7. Scissor, 8. Arabic pins 9. Tissue paper, 10. Black paper sheets, 11. Sterile distilled water, 12. Rubber band 13. Needle 14. Caliberated nano bottle sprayer

3.3.5. laboratory equipments and instruments used

i. U.V. chamber for sterilizing *Corcyra cephalonica* eggs.

ii. Nikon make SMZ80 sterezoom microscope for observing parasitized eggs.

iii. Micropipette – for preparing insecticides dilutions or spray liquids of desired concentrations.

iv. Refrigerator – for cold storage of *Trichogramma* culture and insecticides dilutions.

v. BOD incubator – for maintaining required temperature and relative humidity.

All the above material and equipments were made available by the Head, Department of Agricultural Entomology, PGI, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, specially from Insect Biocontrol Laboratory.

3.3.6. Preparation of insecticidal solution

Stock solution of the different Insecticide under study were prepared by using following formula.

$$V = \frac{C \times A}{\%a.i.}$$

Where,

V = Volume of Insecticide

C = Concentration required

A= Quantity of water

% a.i. = per cent active ingredient

The concentrations of different insecticides were prepared on the day of treatment. The insecticides were applied at recommended field doses.

3.3.7. Method of collection of *Corcyra cephalonica*

I had collected fresh eggs of *Corcyra cephalonica* from laboratory of bio-control, Agricultural Entomology section, PGI, Dr. PDKV, Akola.

3.3.8. Methods of application of treatments and recording observations

Ultraviolet irradiated and unirradiated eggs of *Corcyra cephalonica* were used for conducting the experiment. The treatments were given by following the method suggested by Santharam and Kumaraswami (1985).

i) To study the effect of newer insecticides on per cent parasitisation of U.V. irradiated and unirradiated eggs of *Corcyra cephalonica* by *Trichogramma* species

U.V. irradiated and unirradiated fresh eggs of *Corcyra cephalonica* were glued to the egg cards separately and cards were cut into small strips of 5.0 × 2.0 cm size and sprayed with test insecticides @ 0.5 ml spray liquid per strip using calibrated nano bottle sprayer.

For control, water was used instead of insecticides. The sprayed egg cards were shade dried. The card strips containing U.V. exposed and unexposed eggs will be kept separately in glass vials of about 15.0 × 2.5 cm size @ one strip per vial for each treatment and replication. The treated egg cards were exposed to adults of *Trichogramma* (@ 5:1 host: parasitoids ratio) for 24 hrs for parasitisation. Each treatment was replicated thrice and experiment was conducted at ambient temperature and humidity conditions in the laboratory. The egg cards were examined for parasitisation after 5^{th} day of parasitoid release and the number of parasitized eggs were counted under Nikon make SMZ80 stereozoom microscope and per cenr parasitization was worked out by using following formula.

$$\text{Percent parasitization} = \frac{\text{Number of eggs parasitized}}{\text{Total number of exposed}} \times 100$$

ii) To Study the effect of newer insecticides combi-products on per cent mortality of *Trichogramma* species on U.V. irradiated and unirradiated *Corcyra* eggs.

U.V. irradiated eggs of *Corcyra cephalonica* was glued to the egg cards separately (@50 eggs per card strip) and were cut into strips of 5.0 × 2.0 cm size. These cards were exposed to the adults of different strains of *Trichogramma* (@ 5:1 host: parasitoids ratio) for 24 hrs to obtain adequate parasitization.

After 3rd day of parasitoid release, the card strips were sprayed with test insecticides @ 0.5ml spray liquid per card strip, using caliberated nano bottle sprayer.

For control, water was used instead of Insecticides. The cards were shade dried and kept on BOD for 24 hrs. Each treatment was repeated three times and the observations were recorded on mortality after 24 hrs of treatment.

iii) To study the residual toxicity of chemicals to adults of *Trichogramma* spp.

An experiment was undertaken to ascertain the residual effect of insecticides to adult parasitoid under laboratory conditions. The effect of insecticides residues on survival of adult *Trichogramma* was studied by glass vial bioassay method. For this purpose, the glass vials measuring about 15×4 cm size were taken.

Sufficient quantity of insecticidal solution at recommended concentrations of each insecticide were prepared. A thin, uniform film of each insecticide was applied to each vial by taking 1 ml of spray liquid in it and quickly rotating manually, so that vials get uniformly coated with the insecticides. The treated vials were shade dried to have insecticide residues as a dry film. Control will be taken by treating the vial with water only. After drying of vials, 20-25 newly emerged adults of *Trichogramma* were released inside each vial at an interval of 1st, 5th and 10th days after treatment to test residual toxicity. The adult was exposed to insecticides residues for 4 hours and observations were recorded on number of dead adults.

iv) Statistical Analysis –

The data so obtained on per cent parasitization, per cent adult emergence and per cent adult mortality related to various parameters under study were subjected to statistical analysis in FCRD two ways Analysis using online software (www.icar.goa.statastics) after appropriate transformation for interpretataion of the results, as well as using the textbook of Gomez and Gomez, (1984).

On the basis of per cent mortality reduction in parasitism or adult emergence, insecticides were classified in different categories IOBC/WPRS (Sterk *et.al*.,1999) as follows:

Table 2. Classification of toxicity level according to IOBC/WPRS

Toxicity class	Categorization	%mortality / reduction in either parasitism or emergence
Class 1	Harmless	Less than 30%
Class 2	Slightly harmfull	30% - 75%
Class 3	Moderately harmful	80% - 99%
Class 4	Harmful	More than 99%

(Sterk *et*. *al*., 1999)

Plate 1. Insecticides used for experiment

Plate 2 Unparasitized *Corcyra* eggs

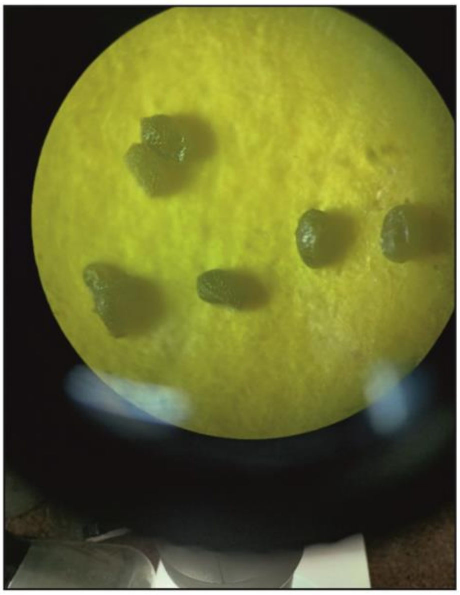

Plate 3 Parasitized Corcyra eggs observed under microscope

CHAPTER IV

RESULT AND DISCUSSION

Present investigations entitled "Effect of some insecticides on *Trichogramma* species" has been carried out in the bio-control laboratory of Department of Entomology Post Graduate Institute, Dr. PDKV Akola. The laboratory study in respect of different parameters i.e., influence of some combi-products insecticides on per cent parasitization, per cent mortality and survival of adults of two *Trichogramma* species have been carried out as per methodology described in previous chapters. The numerical data so obtained is subjected to statistical analysis and results are discussed aspect wise here under in the light of previous litrterature.

4.1 Effect of some newer insecticides combi-products on per cent parasitization by *Trichogramma* species

The results on per cent parasitization by two *Trichogramma* species viz., *Trichogramma chilonis* and *Trichogrammatoidea bactrae* as influenced by different insecticides on irradiated and unirradiated *Corcyra cephalonica* eggs have been presented in following tables under respective subheads.

4.1.1 Irradiated *Corcyra* eggs

The data on per cent parasitisation due to insecticides (Factor A), *Trichogramma* species (Factor B) and their interaction effects have been depicted in Table 3 and illustrated in Fig. 1 and discussed in light of available literature as below.

Table 3. Effect of newer insecticides combi-products on per cent parasitization of *Trichogramma* species (Irradiated)

Factor A / Factor B	Parasitization (%) of irradiated host eggs at 5 DAT					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 %+ Cypermethrin 4 %EC	**T3** Indoxacarb 14.5 %+ Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	
T. chilonis	72.33 (58.26)	54.33 (47.48)	70.67 (57.21)	67.33 (55.14)	86.33 (68.30)	58.50 (49.89)
T. bactrae	68.67 (55.96)	54.00 (47.29)	66.33 (54.53)	63.33 (52.73)	88.00 (69.73)	56.72 (48.86)
Mean (Insecticides)	70.50 (57.10)	54.17 (47.39)	68.50 (55.86)	65.33 (53.93)	87.17 (69.01)	

DAT- Days after treatment
(Figures in parentheses are corresponding Arc sine transformed values)

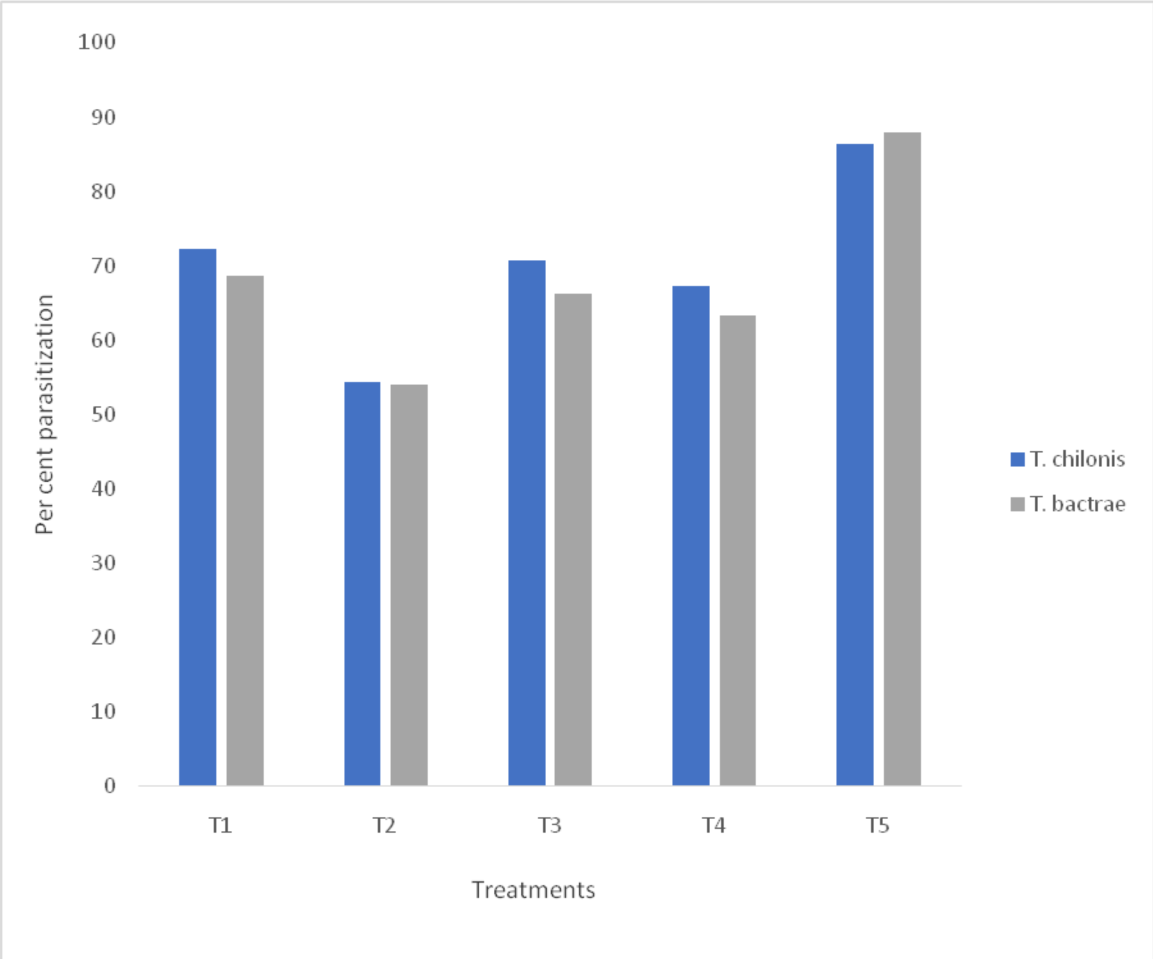

Fig. 1: Effect of newer insecticides combi-products on per cent parasitization of irradiated *Corcyra* eggs by *Trichogramma* species.

ANOVA TABLE:

Factors	'F' test	SE(m) ±	CD at 5 %	CV (%)
Factor A (Insecticides)	Sig.	1.27	3.67	4.5
Factor B (Species)	NS	0.73	-	
Interaction (A x B)	NS	1.79	-	

Factor A (Insecticides):

The data in table 3 revealed that the insecticidal treatment had significant effect on per cent parasitization by *Trichogramma* species over untreated control. Among the five treatments, comparatively lower parasitisation (54.17%) was recorded in treatment T2-Profenophos 40% + Cypermethrin 4% EC. It was followed by treatment T4-Pyriproxifen 5 % + Fenpropathrin 15 % EC (65.33%) next to T3-Indoxacarb 14.5 %+ Acetamiprid 7.7 % SC (68.50%) where, T4 and T1 both are at par withT3. And T2-Novaluron 5.25% + Indoxacarb 4.5 % SC with maximum parasitization (70.50%). It means that among the all insecticides Novaluron 5.25% + Indoxacarb 4.5% SC was found safer. According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2 - Profenophos 40 % + Cypermethrin 4 EC found slightly harmful.

Charles *et al*. (2000) reported the toxicity of insecticides to *Trichogramma exiguum* emergence, adult survival, and fitness. Among the all insecticides, Based on LC_{50} values, spinosad and profenophos were the most toxic compounds to female *T. exiguum* adults, followed by lambda cyhalothrin, cypermethrin, and thiodicarb.

Sarode and Sonalkar (1999) reported that the insecticidal belonging to pyrethroid and organophosphate group showed toxic effect on parasitization of *C. cephalonica* eggs by *T. chilonis* hence the finding supports the result of present investigations.

Factor B (Species):

The data in table 3 revealed that non-Significanat difference in tolerance to insecticides was found among both the *Trichogramma* species. Per cent parasitization in all the species ranged from (56.72 – 58.50%). *T. bactrae* recorded somewhat lowest parasitization 56.72%. Where, *T. chilonis* recorded highest parasitization 58.50%.

Ingale et. al. (2004) reported *T. chilonis* relatively more tolerant strain compared to the *T. japonicum*, *T. bactrae*, *T. pretiousum* which is in accordance with present investigation.

Interaction (Factor A×B):

The data in Table 3 revealed that non significant effect of different insecticides on both the *Trichogramma* species was recorded. However, Profenophos 40% + Cypermethrin 4% EC on *T. bactrae* recorded lowest parasitizat ion (54.00%). Whereas, Novaluron 5.25% + Indoxacarb 4.5% EC on *T. chilonis* had highest per cent parasitization (72.33%). In water dip control highest parasitization recorded in *T. bactrae* (88.00%).

4.1.2 Unirradiated *Corcyra* eggs.

Table 4. Effect of insecticides combi-products on parasitization of un-irradiated *Corcyra* eggs by *Trichogramma* species.

Factor A / Factor B	Parasitization (%) of un-irradiated *Corcyra* eggs at 5 DAT					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 %EC	**T3** Indoxacarb 14.5 %+ Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	
T. chilonis	74.00 (59.34)	56.33 (48.63)	72.67 (58.48)	69.33 (56.37)	88.67 (70.33)	60.16 (50.86)
T. bactrae	71.00 (57.41)	55.33 (48.05)	68.67 (55.96)	64.33 (53.32)	90.67 (72.30)	58.33 (49.80)
Mean (Insecticides)	72.50 (58.37)	55.83 (48.35)	70.67 (57.21)	66.83 (54.83)	89.67 (71.25)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

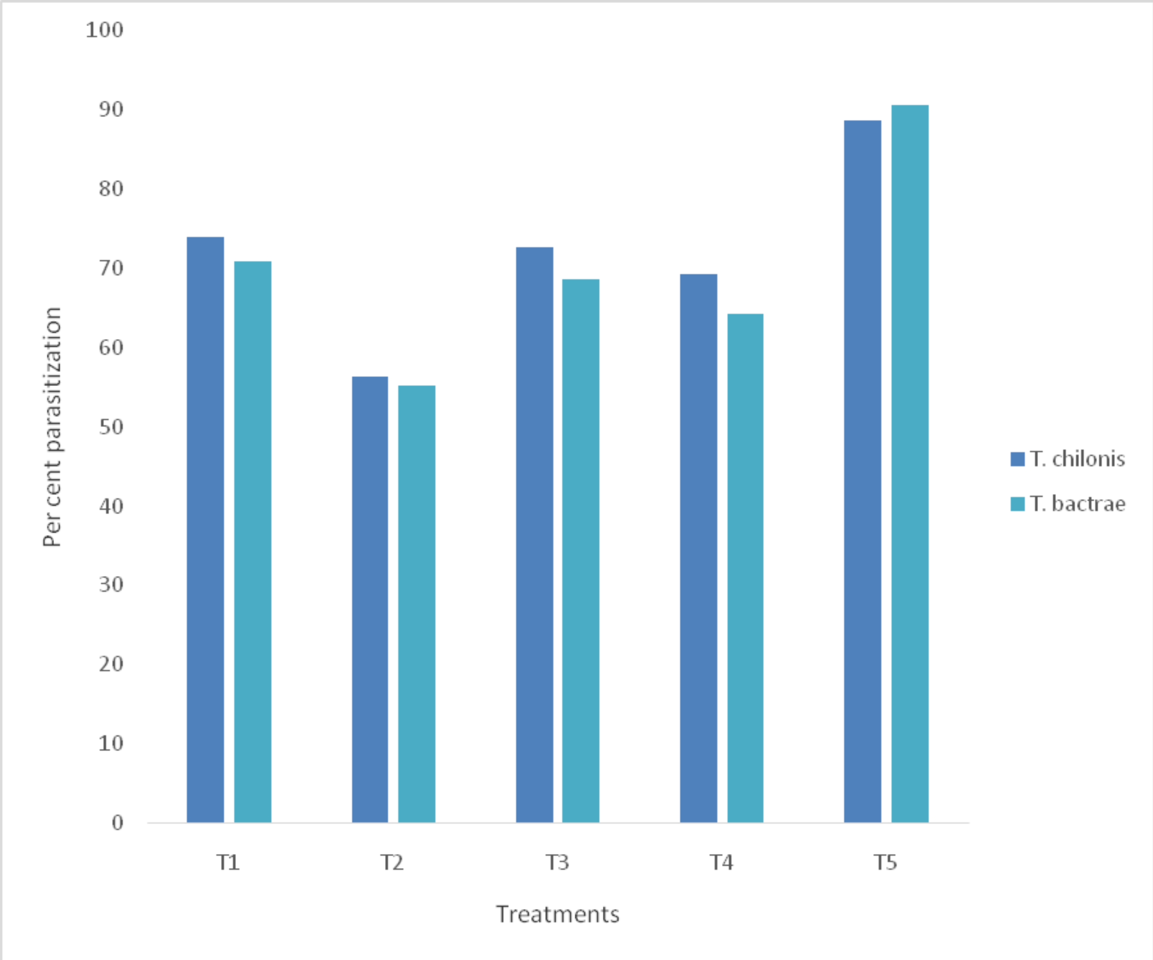

Fig. 2: Effect of some newer insecticides combi-products on per cent parasitization of unirradiated *Corcyra* eggs by *Trichogramma* species

ANOVA TABLE:

Factors	'F' test	SE(m) $^{+}_{-}$	CD at 5 %	CV %
Factor A (Insecticides)	Sig	1.37	3.97	4.74
Factor B (Species)	NS	0.79	-	
Interaction (A x B)	NS	1.94	-	

Factor A (Insecticides):

The data in table 4 indicates that, insecticidal treatments applied on unirradiated eggs of *Corcyra* significantly affected the per cent parasitization of *Trichogramma* species. Among the five treatments, comparatively lower parasitization was recorded in T2- Profenophos 40% + Cypermethrin 4% EC (55.83%) which was followed by T4- Pyriproxifen 5% + Fenpropathrin 15% EC (66.83%) next to T3-Indoxacarb 14.5% + Acetamiprid 7.7.% SC (70.67%) where T2-Novaluron 5.25% + Indoxacarb 4.5% SC had significantly highest parasitization (72.50%). Both the T4 and T1 were found at par with T3-Indoxacab 14.5% + Acetamiprid 7.7% SC (70.67%). According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2-Profenophos 40% + Cypermethrin 4% EC found slightly harmful.

Factor B (Species):

The data in Table 4 indicates that none of the *Trichogramma* species had shown significant difference in tolerance to insecticide toxicity. However lowest parasitization was recorded in *T. bactrae* (58.33%) and highest parasitization was recorded in *T. chilonis* (60.16%) incase of unirradiated *Corcyra* eggs.

Kumari *et al*. (2016) studied the parasitization capacity of *Trichogramma chilonis* and *Trichogramma pretiosum* on the eggs of *Corcyra cephalonica.* The parasitization capacity of *Trichogramma chilonis* suggesting the superiority of the over *T. pretiosum.*

Plate 4 Insecticides treated glass vials to determine the mortality of *Trichogramma*

Plate 5 Observation of adult emergence taken under microscope

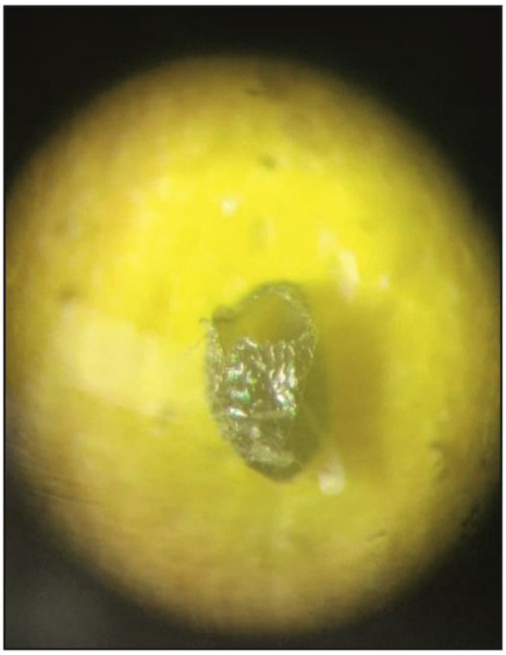

Plate 6 *Corcyra* egg showing emergence of adult

Interaction (A×B):

The data in table 4 indicates that non significant effect of different insecticides on both *Trichogramma* spp. recorded. However, Profenophos 40% + Cypermethrin 4%EC recorded lowest parasitization (55.33%) in *T. bactrae* Whereas, Novaluron 5.25% + indoxacarb 4.5% SC had highest parasitization (74.00%) in *T. chilonis*. Due to scanty availability of literature on interaction of newer insecticides and *Trichogramma* species it could not be discussed in the light of previous literature.

4.2A) Effect of newer insecticides combi-products on per cent mortality of *Trichogramma* species when treated on 3rd day of release (Irradiated *Corcyra* eggs)

Table 5. Effect of newer insecticides combi-products on mortality of *Trichogramma* species when treated on 3rd day of release (Irradiated Host eggs)

Factor A / Factor B	Mortality (%) on irradiated host eggs					
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 % EC	**T3`1`** Indoxacarb 14.5 % + Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	**Mean (Species)**
T. chillonis	19.00 (25.84)	32.67 (34.86)	26.33 (30.87)	26.33 (30.87)	3.33 (10.51)	17.94 (25.06)
T. bactrae	18.67 (25.60)	30.67 (33.63)	27.33 (31.52)	28.67 (32.37)	4.33 (12.01)	18.27 (25.30)
Mean (Insecticides)	18.83 (25.72)	31.67 (34.25)	26.83 (31.20)	27.50 (31.63)	3.83 (11.29)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

ANOVA TABLE:

Factors	'F' test	SE(m) $^{+}_{-}$	CD at 5 %	CV %
Factor A (Insecticides)	S	0.58	1.69	6.61
Factor B (Species)	NS	0.33	-	
Interaction (AxB)	NS	0.83	-	

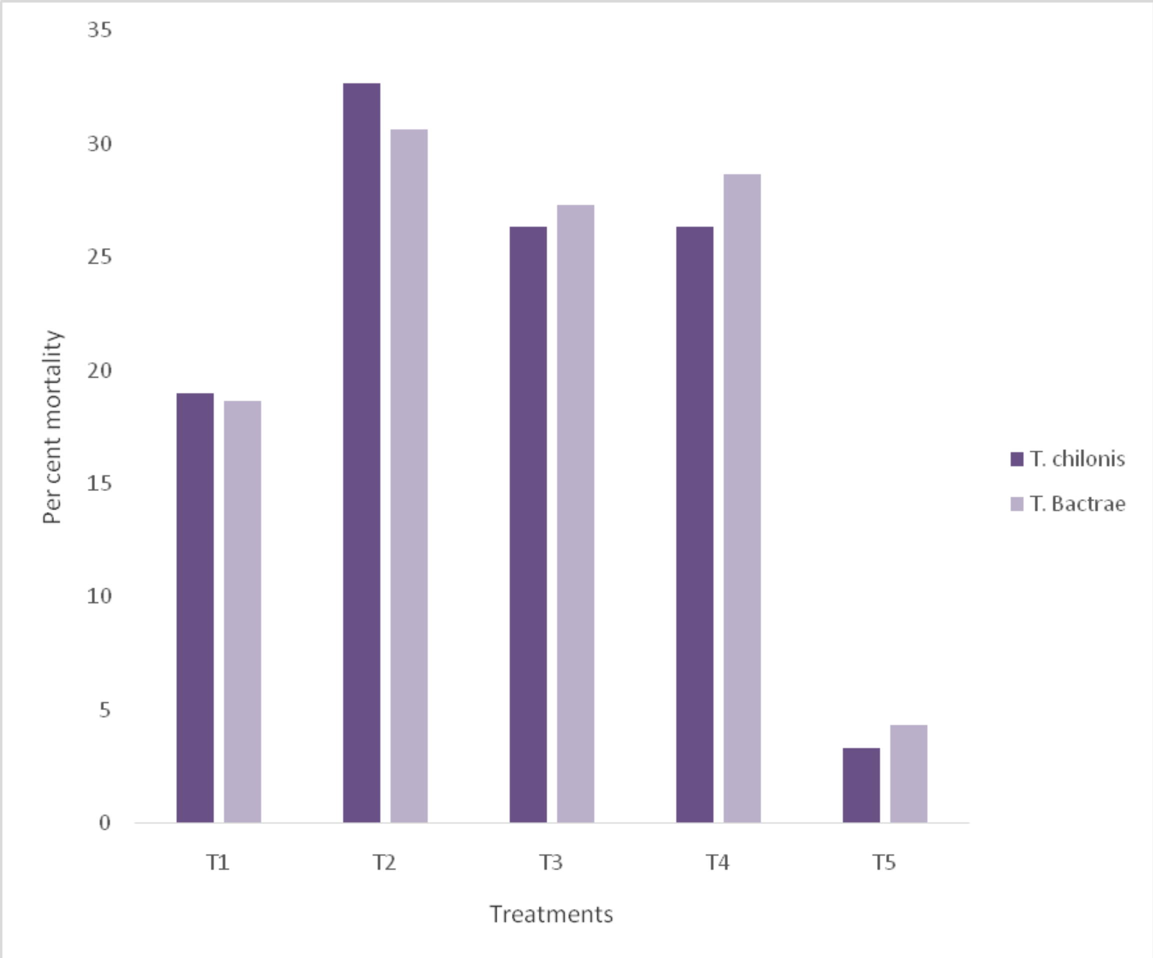

Fig. 3 Effect of newer insecticides combi-products on per cent mortality of *Trichogramma* species when treated on 3rd day of release on irradiated *Corcyra* eggs

Factor A (Insecticides):

The data in Table 5 indicates that the insecticidal treatments applied at 3rd day of release on irradiated *Corcyra* eggs had significant effect on mortality of *Trichogramma species* over the water spray control (3.83%). T2-Profenophos 40% + Cypermethrin 4% EC recorded significantly highest per cent mortality (31.67%) next to that T4-Pyriproxifen 5% + Fenpropathrin 15% EC (27.50%) mortality, third toxic effect was caused by T3-Indoxacarb 14.5% + Acetamiprid 7.7% EC (26.83%) where T3 is at par with T4. T1- Novaluron 5.25 % + Indoxacarb 4.5% SC recorded significantly less mortality (18.83%) than rest of the inseticides. According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2- Profenophos 40 % + Cypermethrin 4 EC found slightly harmful.

Singhamuni *et al*., (2015) studied performance of, they concluded profenophos was highly lethal to adult (74% mortality) and found highly lethal for immature stage (100% mortality) compared to Chlorfluazuron and neem.

Factor B (Species):

The results presented in Table 5 indicates that among the *Trichogramma* spp. none of the species shown significant tolerance to the treated insecticides. However, *Trichogramma chilonis* recorded lowest mortality (17.94%) and highest mortality was reported in *Trichogrammatoidea bactrae* (18.27%).

Ingale *et al*. (2004) tested susceptability of four species of *Trichogramma*, viz., *T. chilonis, T. bactrae, T. japonicum, T. pretiosum*. It was found that *T. chilonis* was most tolerant strain amongst four which is in line with present investigation.

Interaction (Factor A×B):

The result presented in Table 5 and depicted in fig 3 indicates that none of the treatment combination of *Trichogramma* species had significant effect on per cent mortality of. However, T2-Profenophos 40% + Cypermethrin 4% EC on *T. chilonis* caused highest mortality (32.67%).

Whereas, Novaluron 5.25% + Indoxacarb 4.5% SC on *T. bactrae* had lowest mortality (18.67%). Thus, the Novaluron 5.25% + Indoxacarb 4.5 % SC is safer to *T. bactrae.*

Table 6: Effect of newer insecticides combi-products on mortality of *Trichogramma* species when treated on 3rd day of release on un-irradiated host eggs

Factor A / Factor B	Mortality (%) on un-irradiated host eggs					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 % EC	**T3** Indoxacarb 14.5 % + Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water) combiproducts	
T. chillonis	21.33 (27.51)	35.33 (36.47)	30.67 (33.63)	29.00 (32.58)	2.67 (5.40)	19.83 (26.44)
T. bactrae	21.33 (27.51)	32.33 (34.65)	29.67 (33.00)	31.67 (34.25)	3.00 (9.97)	19.66 (26.32)
Mean (Insecticides)	21.33 (27.51)	33.83 (35.57)	30.17 (33.32)	30.33 (33.42)	2.83 (9.68)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

ANOVA TABLE:

Factors	'F' test	SE(m) ±	CD at 5 %	CV %
Factor A (Insecticides)	Sig.	0.48	1.41	5.0
Factor B (Species)	NS	0.28	-	
Interaction (A x B)	NS	0.68	-	

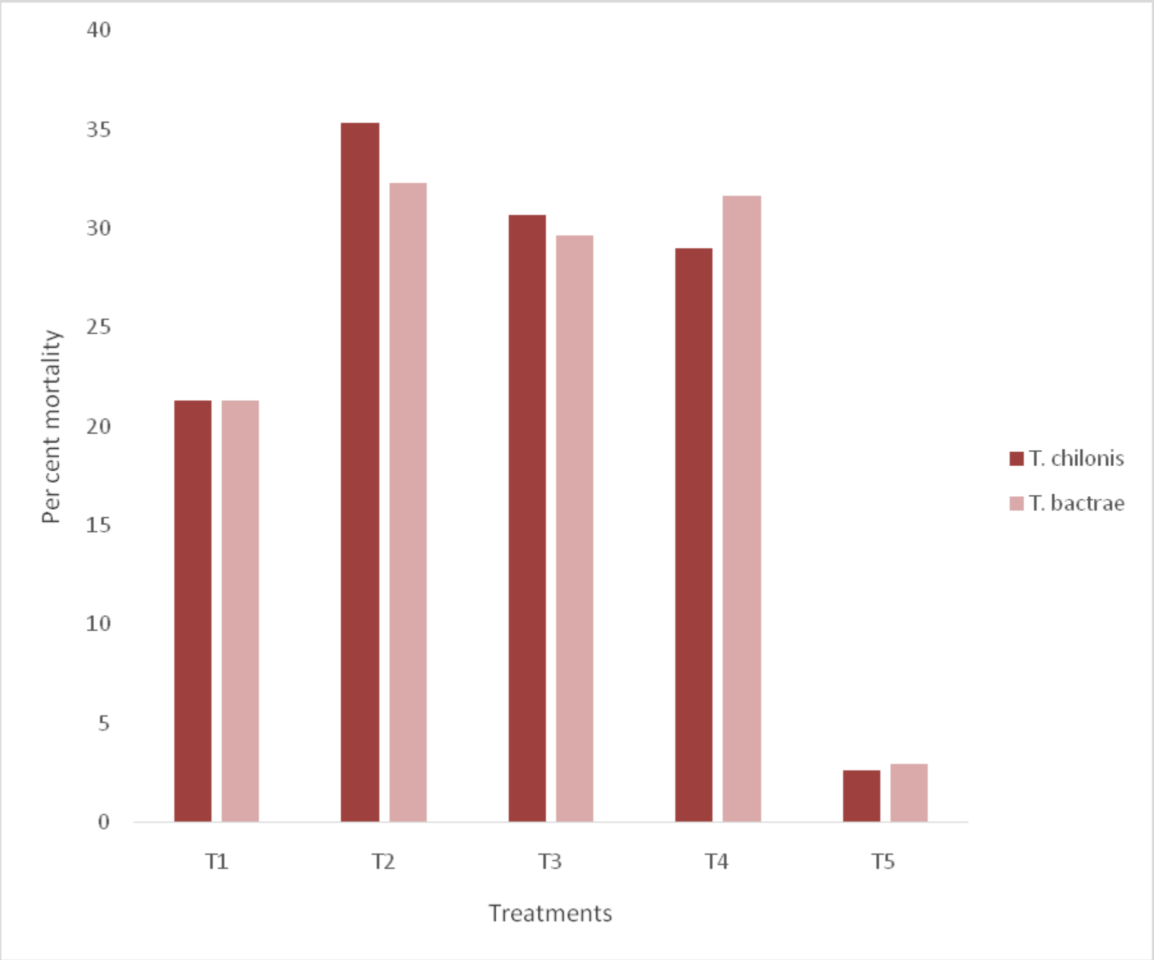

Fig. 4: Effect of some insecticides combi-products on per cent mortality of *Trichogramma* species when treated on 3rd day of release (unirradiated)

Factor A (Insecticides):

The result presented in Table 6 indicates that among all the insecticidal treatments conducted on 3rd day release on unirradiated *Corcyra* eggs had significant effect on percent mortality of *Trichogramma* species over the water dip control, T2-Profehnophos 40% + Cypermethrin 4%EC recorded significantly highest mortality (33.83%) next deleterious effect was caused by T4- Pyriproxifen 5% + Fenpropathrin 15 % EC (30.33%) followed by T3- Indoxacarb 14.5% + Acetamirid 7.7% SC (30.17%). Where, T3 is at par with T4. While, T1-Novaluron 5.25% + Indoxacarb 4.5% SC had less mortality (21.33%) and the mortality in water dip control was 2.83%.

Madhusudan (2015), studied the effect of the insecticides to the egg parasitoid *Trichogramma chilonis* where, (organophosphates) Chlorpyriphos, malathion, quinolphos, triazophos proved to be most lethal, Indoxacarb and spinosad was found to be least harmful on the adult survival of the egg parasitoid.

Factor B (Species):

The data in Table 6 indicates that, *Trichogramma* species had no significant difference in case of per cent mortality against the insecticides used during the experimentation. Per cent mortality in all the species ranged from 19.66-19.83%. *T. bactrae* recorded lowest mortality (19.66%) whereas, *T. chilonis* had highest mortality (19.83%)

Interaction (Factor A×B):

The data in Table 6 revealed that none of the treatment combination of *Trichogramma* species with different insecticides had recorded significant effect on per cent mortality. However, Profenophos 40% + Cypermethrin 4 % EC on *T. chilonis* caused highest mortality (35.33%). Whereas, Novaluron 5.25% + Indoxacarb 4.5% SC on both the species caused lowest mortality (21.33%). Mortality in water dip control was ranged from 2.67-3.00%.

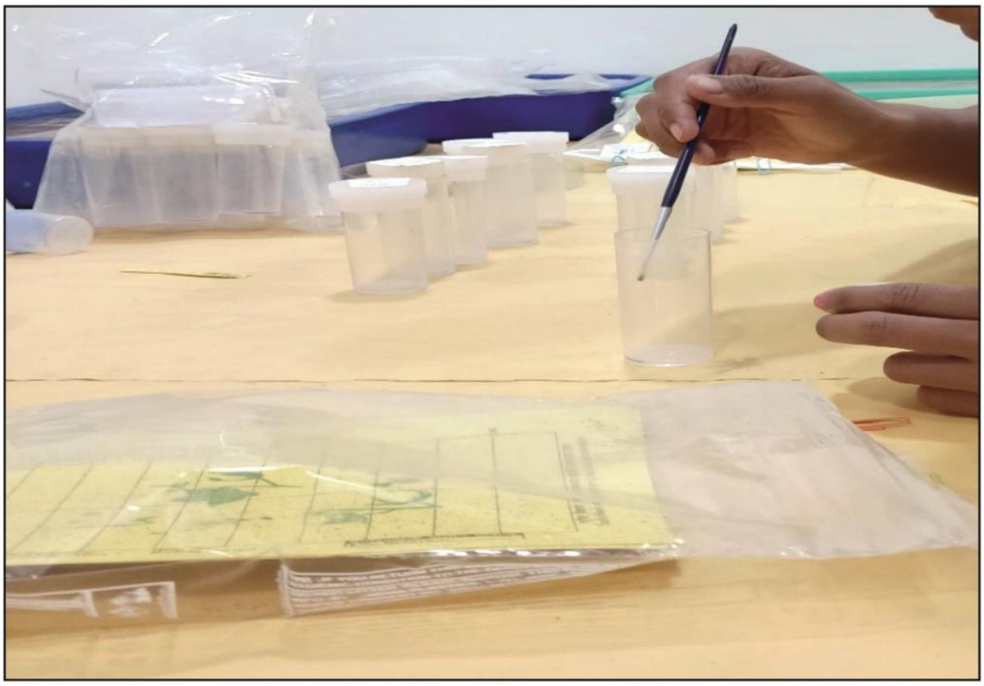

Plate 7 Releasing of Trichogramma to determine the residual toxicity

Plate 8 Insecticide treated glass vials to determine the residual toxicity

4.3 Effect of newer insecticides combi-products on adult survival of *Trichogramma* species released on 1st day of treatment

Table 7. Effect of newer insecticides combi-products on per cent mortality of adults of *Trichogramma* species released on 1st day of treatment

Factor A / Factor B	Mortality of adults of *Trichogramma* species on 1st DAT					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 %EC	**T3** Indoxacarb 14.5 S% + Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	
T. chillonis	18.67 (25.60)	36.67 (37.27)	26.33 (30.87)	31.33 (34.04)	1.33 (6.62)	19.05 (25.88)
T. bactrae	15.67 (23.32)	35.00 (36.27)	27.00 (31.31)	29.33 (32.79)	1.67 (7.43)	18.11 (25.19)
Mean (Insecticides)	17.17 (24.48)	35.83 (36.77)	26.67 (31.09)	30.33 (33.42)	1.50 (7.03)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

ANOVA TABLE:

Factors	'F' test	SE(m)±	CD at 5 %	CV %
Factor A (Insecticides)	Sig.	0.65	1.90	7.22
Factor B (Species)	NS	0.38	-	
Interaction (AxB)	NS	0.93	-	

Factor A (Insecticides):

The data in table 7 indicates that insecticidal treatments had significant effect on mortality of adults of *Trichogramma* species. Among all the insecticidal treatments the T2-Profenophos 40% + Cypermethrin 4% EC recorded highest mortality (35.83%) followed by T4-Pyriproxifen 5% +

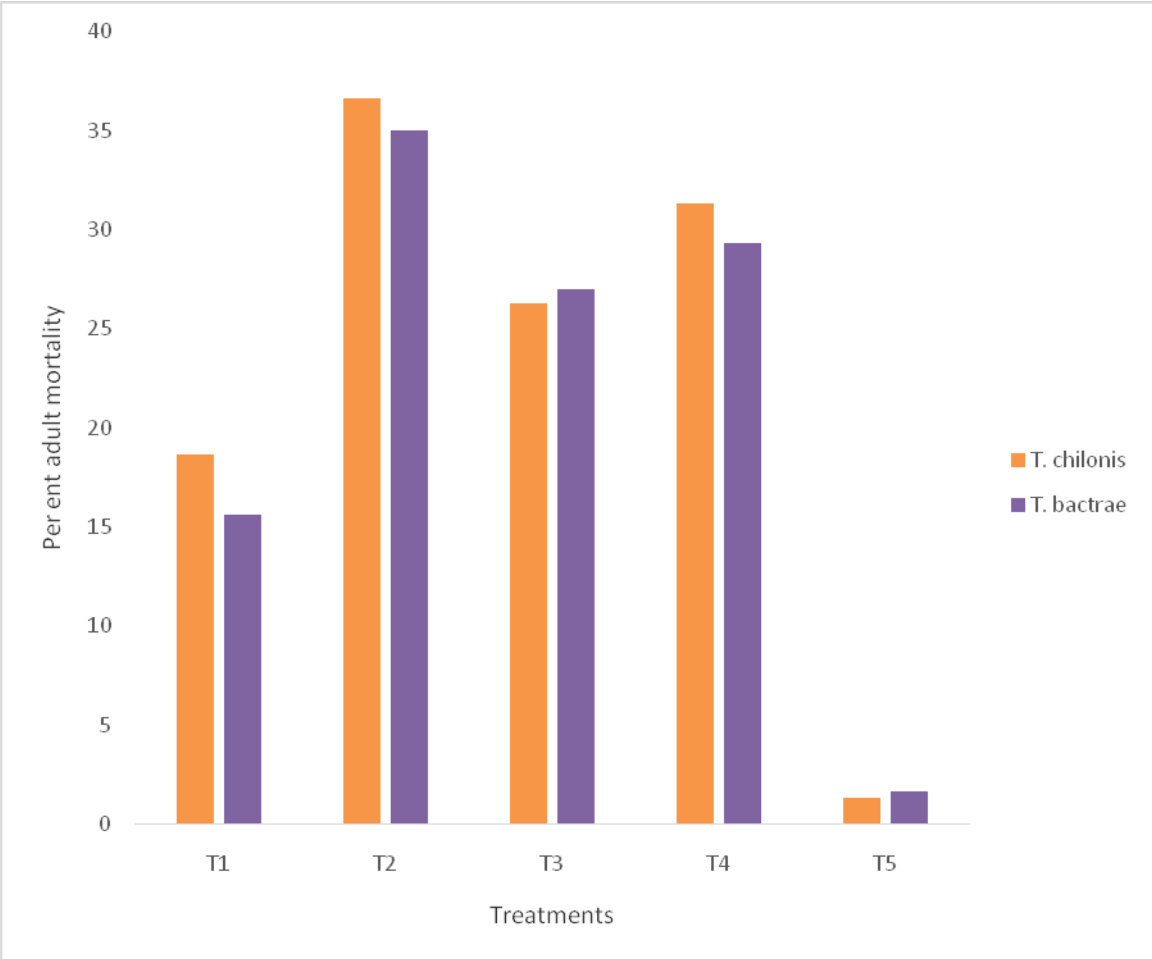

Fig. 5. Per cent mortality of adult of *Trichogramma* species as influence by insecticides combi-products on 1st day of treatment

Fenpropathrin 15% EC (30.33%) next to T3-Indoxacarb14.5% + Acetamiprid 7.7% SC (26.67%) where lowest mortality (17.17%) was recorded in treatment T2- Novaluron 5.25% + Indoxacarb 4.5% SC.

Zhao *et al.* (2012) studied the toxicity of insecticides belonging to chemical against *Trichogramma japonicum* and recorded organophosphates and carbamates as most toxic to *T. japonicum* followed by antibiotics, phenylpyrazoles, pyrethroids and neonicotinois, whereas insect growth regulators were found safe exhibiting lower toxicity to *T. japonicum.*

Factor B (Species):

The data in table 7 shows effect of newer insecticides on adults of *Trichogramma* species. None of the species registered significant tolerance to the insecticidal residues when parasitoids were released on 1st day of treatment. However, the adult mortality after residual effect ranged between 18.11-19.05% in both the species.

Interaction (Factor A×B):

The data in table 7 indicates that non significant effect of different insecticides on *Trichogramma* species recorded. However, Profenophos 40% + Cypermethrin 4% EC on *T. chilonis* recorded highest per cent adult mortality (36.67%) Whereas, lowest mortality was observed in Novaluron 5.25% + Indoxacarb 4.5% on *T. bactrae* recording 15.67%.

Factor A (Insecticides):

The data in table 8 indicates that insecticidal treatment had significant effect on adult mortality of *Trichogramma* species. Among all the insecticidal treatment the T2-Profenophos 40% + Cypermethrin 4% EC recorded highest mortality (32.00%) followed by T4- Pyriproxifen 5% + Fenpropathrin 15% EC (27.17%) next to T3-Indoxacarb 14.5% + Aetamiprid 7.7%SC (23.00%) mortality. Whereas, significantly lowest mortality was observed in T1- Novaluron 5.25% + Indoxacarb 4.5%SC (15.17%). According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2- Profenophos 40% + Cypermethrin 4% EC found slightly harmful.

Table 8. Effect of newer insecticides combi-products on per cenrt mortality of adults of *Trichogramma* species on 5th day of treatment

Factor A / Factor B	Mortality of adults of *Trichogramma* species on 5th DAT					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 %EC	**T3** Indoxacarb 14.5 % + Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	
T. chillonis	17.00 (24.35)	33.00 (35.06)	23.33 (28.88)	27.00 (31.31)	1.00 (5.74)	16.88 (24.26)
T. bactrae	13.33 (21.41)	31.00 (33.83)	22.67 (28.43)	27.33 (31.52)	1.33 (6.62)	15.94 (23.53)
Mean (Insecticides)	15.17 (22.92)	32.00 (34.45)	23.00 (28.66)	27.17 (31.42)	1.17 (6.21)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

ANOVA TABLE:

Factors	'F' test	SE(m) $^{+}_{-}$	CD at 5 %	CV %
Factor A (Insecticides)	S	0.59	1.71	7.38
Factor B (Species)	NS	0.34	-	
Interaction (AxB)	NS	0.84	-	

Singhamuni et al. (2015) evaluated the residual toxicity of profenophos on *Trichogramma chilonis.* The residual effect of profenophos was significant up to 10 days but safer for parasitoids after 15 days.

Factor B (Species):

Table 8 shows effect of newer insecticides on adult survival of *Trichogramma* species, among none of the species recorded significant

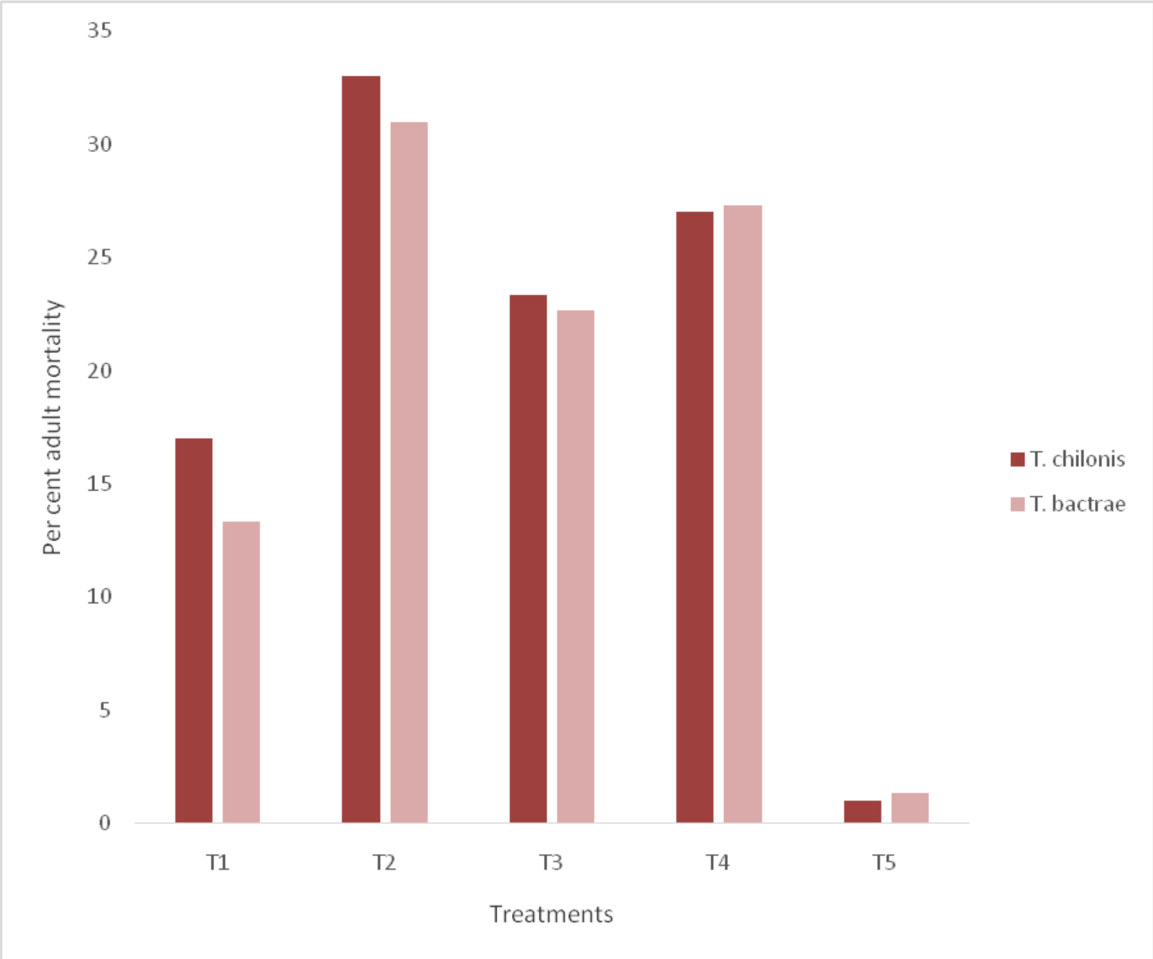

Fig. 6 Per cent mortality of adults of *Trichogramma* species as influenced by some insecticides combi-products on 5th day of treatment

difference in tolerance to the insecticidal residues when parasitoids were released on 5th day of treatment. However, the adult mortality after residual effect observed to be ranged between 15.94- 16.88% in both the species *T. bactrae* recorded as lowest mortality (15.94%) whereas, *T. chilonis* had highest mortality (16.88%).

Interaction (Factor A×B):

The data in table 8 indicates that non significant effect of different insecticides on *Trichogramma* species recorded. However, T2-Profenophos 40% + Cypermethrin 4% EC on *T. chilonis* recorded highest adult mortality (33.00%). Whereas, lowest mortality was observed in T1-Novaluron 5.25% + Indxacarb 4.5% SC (13.33%) on *T. bactrae*.

Table 9. Effect of newer insecticides combi-products on per cent mortality of adults of *Trichogramma* species release on 10th day of treatment

Factor A / Factor B	Mortality of adults of *Trichogramma* species on 10th DAT					Mean (Species)
	T1 Novaluron 5.25 % + Indoxacarb 4.5 % SC	**T2** Profenophos 40 % + Cypermethrin 4 % EC	**T3** Indoxacarb 14.5 % + Acetamiprid 7.7 % SC	**T4** Pyriproxifen 5 % + Fenpropathrin 15 % EC	**T5** Control (Water)	
T. chillonis	11.67 (19.98)	20.33 (26.80)	14.00 (21.97)	15.00 (22.79)	0.33 (3.29)	10.22 (18.64)
T. bactrae	11.00 (19.37)	19.00 (25.84)	14.67 (22.52)	15.00 (22.79)	0.67 (4.70)	10.05 (18.48)
Mean (Insecticides)	11.33 (19.67)	19.67 (26.33)	14.33 (22.24)	15.00 (22.79)	0.50 (4.05)	

DAT- Days after treatment

(Figures in parentheses are corresponding Arc sine transformed values)

ANOVA TABLE:

Factors	'F' test	SE(m) ±	CD at 5 %	CV %
Factor A (Insecticides)	S	0.48	1.41	9.8
Factor B (Species)	NS	0.28	-	
Interaction (AxB)	NS	0.68	-	

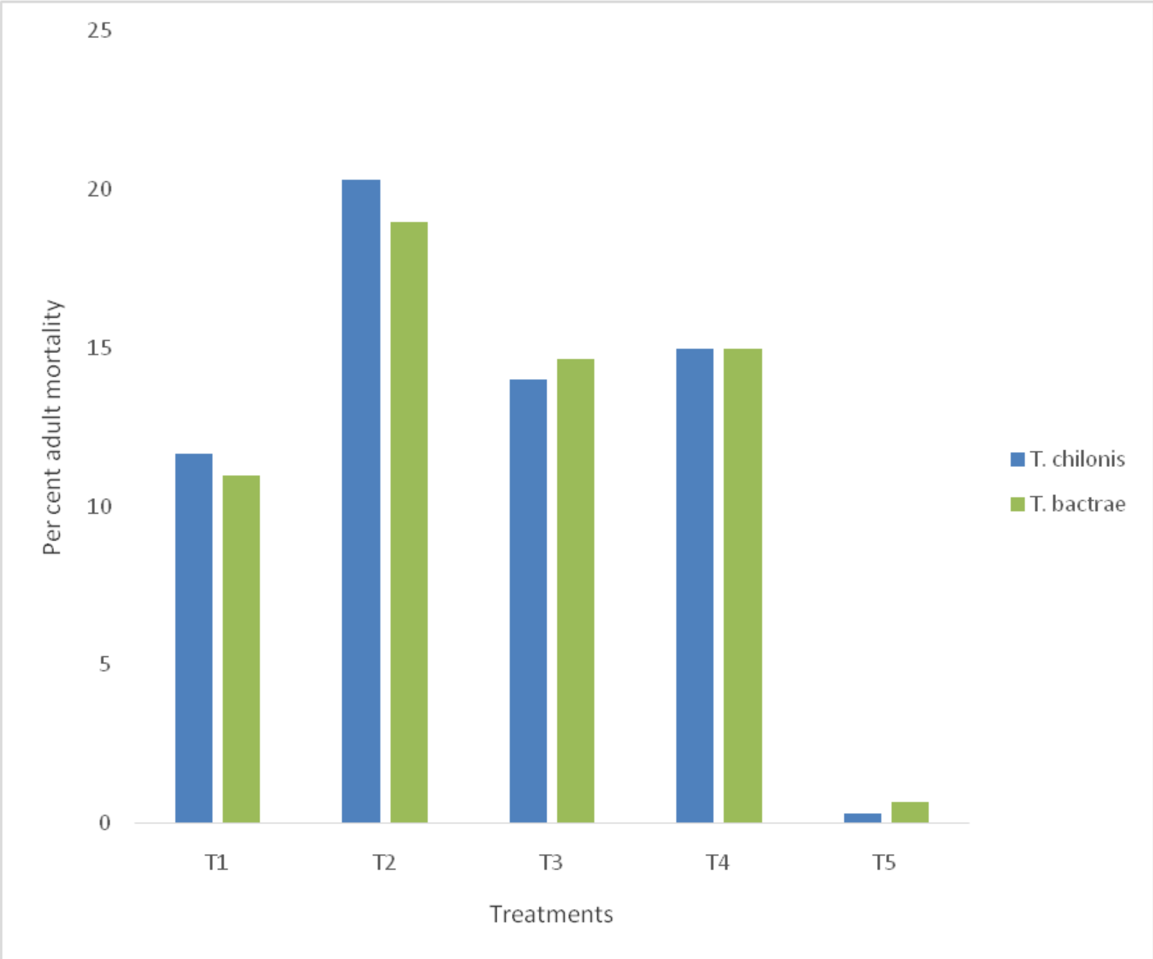

Fig. 7 Per cent mortality of adult of *Trichogramma* species as influenced by insecticides combi-products on 10th day of treatment

Factor A (Insecticides):

The data in Table 9 indicates that insecticidal treatments had significant effect on adults of *Trichogramma* species. Among all the insecticidal treatments the T2-Profenophos 40% + Cypermethrin 4% EC recorded highest mortality of the adult (19.67%) followed by T4-Pyriproxifen 5% + Fenpropathrin 15% EC (15.00%) next to T3-Indoxacarb 14.5% + Acetamiorid 7.7% SC (14.33%) significantly lowest mortality was observed in T1-Novaluron 5.25% + Indoxacarb 4.5% SC (11.33%) Where, T3 and T4 are found at par with each other.

Sant et al. (2019) to evaluate residual toxicity of some newer insecticides against *Trichogramma chilonis* Ishii. It was also observed that the insecticides residues persisted upto 10 days of treatment. Hence, it is advisable that release of *Trichogramma chilonis* should be with held at least upto 10 days of insecticide applications in field in order to achieve better parasitization of host insects.

Factor B (Species):

Table 9 shows effect of newer insecticides on adult survival of *Trichogramma* species. Among these none of the species recorded significant difference in tolerance to the insecticidal residues when parasitoid were released on 10th day of treatment. However, the adult mortality after residual effect ranged from 10.05-10.22% in both *Trichogramma* species. *T. bactrae* recorded lowest mortality 10.05%. Whereas, *T. chilonis* recorded 10.22%

Interaction (Factor A×B):

The data in Table 9 indicates that non significant effect of different insecticides on *Trichogramma* species recorded. However, T2-Profenophos 40% + Cypermethrin 4% EC on *T. chilonis* recorded highest per cent of mortality (20.33%). Whereas lowest mortality was observed in T1- Novaluron 5.25% + Indoxacarb 4.5% SC treatment on *T. bactrae* (11.00%) and recoded as safer to *Trichogramma* adults.

4.4. Safety of insecticides to *Trichogramma* spp. for parasitization.

The results on computation of safety indices for different insecticides for parasitization of two *Trichogramma spp* in table 10 and table 11 indicated that insecticides Novaluron 5.25% + Indoxacarb 4.5% SC, Indoxacarb 14.5% + Acetamiprid 7.7% SC and Pyriproxifen 5% + Fenpropathrin 15% EC are harmless to *T. chilonis and T. bactrae for parasitisation* purpose recording Toxicity Class 1 of IOBC.

Table 10: Safety of insecticides to *T. chilonis for parasitization*

Treatment	**Reduction in per cent parasitization**	**Toxicity Class**	**Categorization**
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	16.21	Class 1	Harmless
T2 - Profenophos 40% + Cypermethrin 4% EC	37.06	Class 2	Slightly harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	15.59	Class 1	Harmless
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	22.00	Class 1	Harmless

Table 11: Safety of insecticides to *T. bactrae for parasitization*

Treatment	**Reduction in per cent parasitization**	**Toxicity Class**	**Categorization**
T1 - Novaluron 5.25% + Indoxacarb 4.5% SC	21.96	Class 1	Harmless
T2 - Profenophos 40% + Cypermethrin 4% EC	38.63	Class 2	Slightly harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	24.62	Class 1	Harmless
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	28.03	Class 1	Harmless

4.4.2 Safety of insecticides for survival of *Trichogramma spp.*

The results on computation of safety indices for different insecticides for survival of the two *Trichogramma spp.* in table 12 and table 13 indicated that none of the insecticides are safe for survival of the two *Trichogramma* spp. and were categorized as Moderately Harmful with Toxicity Class 3 of IOBC.

Table 12: Safety of insecticides to *T. chilonis* for survival

Treatment	Per cent increase in mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	82.47	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	89.80	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	87.80	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	87.35	Class 3	Moderately Harmful

Table 13: Safety of insecticides to *T. bactrae* for survival

Treatment	Per cent increase in mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	76.80	Class 2	Slightly Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	85.88	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	84.15	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	84.89	Class 3	Moderately Harmful

4.4.3 Safety of insecticides for adult survival of *Trichogramma spp.* after treatment release

The results in table 14, 15, 16, 17, 18 and table 19 on computation of safety indices for different insecticides for adult survival of the two *Trichogramma spp.* after days of treatment exposure indicated that none of the insecticides are safe for survival of adults of the two *Trichogramma* spp. after 1st, 5th and 10th days of treatment exposure and were categorized as Moderately Harmful with Toxicity Class 3 of IOBC.

Table 14: Safety of insecticides to *T. chilonis* for adult survival on 1st day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	92.87	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	96.37	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	94.94	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	95.75	Class 3	Moderately Harmful

Table 15: Safety of insecticides to *T. bactrae* for adult survival on 1st day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	89.34	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	95.22	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	93.81	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	94.30	Class 3	Moderately Harmful

Table 16: Safety of insecticides to *T. chilonis* for adult survival on 5th day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	94.11	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	96.96	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	95.71	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	96.29	Class 3	Moderately Harmful

Table 17: Safety of insecticides to *T. bactrae* for adult survival on 5th day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	90.02	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	95.70	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	94.13	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	95.13	Class 3	Moderately Harmful

Table 18: Safety of insecticides to *T. chilonis* for adult survival on 10th day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	97.17	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	98.37	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	97.67	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	97.08	Class 3	Moderately Harmful

Table 19: Safety of insecticides to *T. bactrae* for adult survival on 10th day of treatment release

Treatment	Per cent increase in adult mortality over control	Toxicity Class	Categorization
T1- Novaluron 5.25% + Indoxacarb 4.5% SC	93.90	Class 3	Moderately Harmful
T2 - Profenophos 40% + Cypermethrin 4% EC	95.43	Class 3	Moderately Harmful
T3 - Indoxacarb 14.5% + Acetamiprid 7.7% SC	94.47	Class 3	Moderately Harmful
T4 - Pyriproxifen 5% + Fenpropathrin 15% EC	95.53	Class 3	Moderately Harmful

CHAPTER V

SUMMARY AND CONCLUSION

Biocontrol is one of the key components of Integrated pest management (IPM). Amongst the parasitoid, the genus *Trichogramma* has been studied extensively over the year due to its importance in pest management in order to check the effect of various chemicals used in pest control programmes efforts have been taken which could be helpful to select the safer chemicals which caused least harm to the natural enemies.

In view of the above, investigations were carried out to study the effect of some insecticides on *Trichogramma* species. The work was undertaken at Biocontrol laboratory, Department of Entomology, PGI, Dr. PDKV Akola, during 2020-2021.

The experiment was conducted in Factorial Completely Randomized Design (FCRD) Observations on parasitization and emergence were recorded under Nikon mak SMZ80 stereozoom microscope. The data were compiled and analyzed for variance. The results are summarized below.

5.1 Effect of newer insecticides combi-products on per cent parasitization of *Trichogramma* species.

5.1.1 Per cent parasitization on irradiated *Corcyra* eggs

Factor A (Insecticides):

The insecticidal treatment had significant effect on per cent parasitization by two *Trichogramma* species over untreated control. Among the five treatments, comparatively lower parasitization was recorded in T2-Profenophos 40% + Cypermethrin 4% EC (54.17%) followed by T4-Pyriproxifen 5 % + Fenpropathrin 15% EC (65.33%) next to T3- Indoxacarb 14.5 % + Acetamiprid 7.7 % SC (68.50%) where, T2-Novaluron 5.25% + Indoxacarb 4.5 % SC with maximum parasitization (70.50%). Where, T4 and T1 both are at par with T3. It means that among the all insecticides Novaluron 5.25%+ Indoxacarb 4.5% SC was found safer. According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2- Profenophos 40% + Cypermethrin 4% EC found slightly harmful.

Factor B (Species):

The non significant difference in terms of species tolerance to insecticides was noticed among the *Tricogramma* species

Interaction (Factor A×B):

Non significant effect of different insecticides on both the *Trichogramma* species was recorded.

5.1.2. Per cent parasitization on unirradiated *Corcyra* eggs

Factor A (Insecticides):

The Insecticidal treatments applied on unirradiated eggs of *Corcyra* significantly affected the per cent parasitization of *Trichogramma* species. Among the five treatments, comparatively lower parasitization was recorded in T2-Profenophos 40%+ Cypermethrin 4% EC (55.83%) which was followed by T4-Pyriproxifen 5% + Fenpropathrin 15% EC (66.83%) next to T3- Indoxacarb 14.5%+ Acetamiprid 7.7% SC (70.67%) where T2- Novaluron 5.25%+ Indoxacarb 4.5% SC had significantly highest parasitization (72.50%). Both the T4 and T1 were found at par with T3- Indoxacab 14.5% + Acetamiprid 7.7% SC (70.67%). According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2- Profenophos 40% + Cypermethrin 4% EC found slightly harmful.

Factor B (Species):

None of the *Trichogramma* species had shown significant difference in tolerance to insecticide toxicity.

Interaction (Factor A×B):

Non significant effect of different insecticides on both the *Trichogramma* species recorded.

5.2 Effect of newer insecticides combi-products on per cent mortality of *Trichogramma* species

5.2.1 Treatment on 3rd day of release on irradiated *Corcyra* eggs

Factor A (Insecticides):

The insecticidal treatments applied at 3rd day of release on irradiated *Corcyra* eggs had significant effect on mortality of *Trichogramma* species over the water spray control (3.83%). T2-Profenophos 40% + Cypermethrin 4% EC recorded significantly highest per cent mortality (31.67%) next to that T4- Pyriproxifen 5%+ Fenpropathrin 15% EC (27.50%) mortality, third toxic effect was caused by T3-Indoxacarb 14.5% + Acetamiprid 7.7% EC (26.83%) where T3 is at par with T4. T1- Novaluron 5.25% + Indoxacarb 4.5% SC recorded significantly less mortality (18.83%) that rest of the insecticides. According to IOBC classification of toxicity level all the three insecticides treatments found harmless (Class-1) except T2-Profenophos 40% + Cypermethrin 4% EC found slightly harmful.

Factor B (Species):

None of the *Trichogramma* species had significant difference in tolerance against insecticides used during the experimentation.

Interaction (Factor A×B):

Non significant effect of different insecticides on both the *Trichogramma* species recorded.

5.2.2 Treatments on 3rd day of release on unirradiated *Corcyra* eggs

Factor A (Insecticides)

The insecticidal treatments conducted on 3rd day release on unirradiated *Corcyra* eggs had significant effect on per cent mortality of *Trichogramma* species over the water dip control, T2-Profehnophos 40% +cypermethrin 4% EC recorded significantly highest mortality (33.83%) next deleterious effect was caused by T4-Pyriproxifen 5% + Fenpropathrin 15% EC (30.33%) followed by T3-Indoxacarb 14.5%+ Acetamirid 7.7% SC (30.17%). Where, T3 is at par with T4. While T1-Novaluron 5.25%+

Indoxacarb 4.5% SC had less mortality (21.33%) and the mortality in water dip control was 2.83%.

Factor B (Species):

None of the *Trichogramma* species had shown significant difference in case of per cent mortality by insecticidal treatment applied during the experimentation.

Interaction (Factor A×B):

None of the treatment combination of both the *Trichogramma* species with different insecticides had recorded significant effect on per cent mortality.

5.3 Effect of newer insecticides combi-products on adults of *Trichogramma* species

5.3.1. Release on 1st day of treatment

Factor A (Insecticides)

The insecticidal treatments had significant effect on mortality of adults of *Trichogramma* species. Among all the insecticidal treatments the T2- Profenophos 40% + Cypermethrin 4% EC recorded highest mortality (35.83%) followed by T4-Pyriproxifen 5 % +Fenpropathrin 15% EC (30.33%) next to T3-Indoxacarb14.5% + Acetamiprid 7.7% SC (26.67%) where lowest mortality recorded T2- Novaluron5.25% + Indoxacarb 4.5%SC (17.17%).

Factor B (Species):

Among both the species none of the species registered significant difference in tolerance to the insecticides residual toxicity.

Interaction (Factor A×B):

All the treatment combinations proved statistically non-significant.

5.3.2. Release on 5th day of treatment

Factor A (Insecticides):

The Insecticidal treatment had significant effect on adult mortality of *Trichogramma* species. Among all the insecticidal treatment the T2- Profenophos 40%+ Cypermethrin 4% EC recorded highest mortality (32.00%) followe by T4- Pyriproxifen 5% + Fenpropathrin 15% EC (27.17%) next to T3- Indoxacarb 14.5% + Aetamiprid 7.7%SC (23.00%) mortality. Whereas, significantly lowest mortality was observed in T1-Novaluron 5.25% + Indoxacarb 4.5% SC (15.17%) and registered as safer to *Trichogramma* species over rest of the insecticides

Factor B (Species):

Among both the species none of the species registered significant difference in tolerance to the insecticide residual toxicity.

Interaction (Factor A×B):

All the treatment combinations proved statistically non significant.

5.3.3. Release on 10th day of treatment

Factor A (Insecticides):

The Insecticidal treatments had significant effect on adults of *Trichogramma* species. Among all the insecticidal treatments the T2-Profenophos 40% + Cypermethrin 4% EC recorded highest mortality of the adult (19.67%) followed by T4- Pyriproxifen 5% + Fenpropathrin 15% EC (15.00%) next to T3-Indoxacarb 14.5% + Acetamiorid 7.7% SC (14.33%) significantly lowest mortality was observed in T1-Novaluron 5.25% + Indoxacarb 4.5% SC (11.33%) Where, T3 and T4 are found at par with each other.

Factor B (Species):

Among both the species none of the species registered significant difference in tolerance to the insecticide residual toxicity.

Interaction (Factor A×B):

All the treatment combinations proved statistically non significant.

5.4. Safety Categorization of Insecticides:

5.4.1 Safety of insecticides to *Trichogramma spp. for parasitisation*

The results on computation of safety indices for different insecticides for parasitisation of two *Trichogramma spp.* in table 9 and table 10 indicated that insecticides Novaluron 5.25% + Indoxacarb 4.5% SC, Indoxacarb 14.5% + Acetamiprid 7.7% SC and Pyriproxifen 5% + Fenpropathrin 15% EC are harmless to *T. chilonis and T. bactrae for parasitisation* purpose recording Toxicity Class 1

5.4.2 Safety of insecticides for survival of *Trichogramma spp.*

The results on computation of safety indices for different insecticides for survival of the two *Trichogramma spp.* in table 11 and table 12 indicated that none of the insecticides are safe for survival of the two *Trichogramma* spp. and were categorized as Moderately Harmful (toxicity Class 3)

5.4.3 Safety of insecticides for adult survival of *Trichogramma spp.* after treatment release

The results in table 14, 15, 16, 17, 18 and table 19 on computation of safety indices for different insecticides for adult survival of the two *Trichogramma spp.* after days of treatment exposure indicated that none of the insecticides are safe for survival of adults of the two *Trichogramma* spp. after 1st, 5th and 10th days of treatment exposure and were categorized as Moderately Harmful with Toxicity Class 3 of IOBC.

CONCLUSION -

From the present investigation, it is concluded that there is no much longer difference in parasitization of irradiated and unirradiated *Corcyra* eggs.

According to IOBC classification, (T2) that is Profenophos 40% + Cypermethrin 4% EC found Slightly harmful for parasitization while rest of the combi-products insecticides found harmless for parasitization of irradiated and unirradiated *Corcyra* eggs.

Whereas, Profenophos 40% + Cypermethrin 4% EC found to be slightly harmful for Mortality, adult emergence of *Trichogramma* species viz., *T. chilonis and T. bactrae*

In case of residual toxicity, all the tested insecticides except Profenophos 40% + Cypermethrin 4% EC were found safer on 1st and 5th day of release of adults and all the insecticides did not show any deleterious effect on *Trichogramma* species on 10th day on release of adults.

UV irradiation did not show significant effect on parasitization, Mortality, Adult emergence of both the species of *Trichogramma* viz., *T. chilonis* and *T. bactrae*.

Tolerance of both the species of *Trichogramma* were non significant against the insecticides tested.

From the safety indices studies it can be concluded that insecticides Novaluron 5.25% + Indoxacarb 4.5% SC; Indoxacarb 14.5% + Acetamiprid 7.7% SC and Pyriproxifen 5% + Fenpropathrin 15% EC are harmless to *T. chilonis and T. bactrae for parasitisation* purpose. However, none of these four tested products found safe for long survival of *T. chilonis and T. bactrae.*

CHAPTER VI

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