MANAGEMENT OF MAJOR INSECTS PESTS OF *RABI* SORGHUM

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B.Sc. (Agriculture)

MASTER OF SCIENCE
IN
AGRICULTURE
(AGRICULTURAL ENTOMOLOGY)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, LATUR
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MANAGEMENT OF MAJOR INSECTS PESTS OF *RABI* SORGHUM

BY

YASHWANT SHUBHAM BABUSHA

B.Sc. (Agriculture)

A thesis Submitted to
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani
In partial fulfilment of the requirements of the degree of

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2022

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled, **"MANAGEMENT OF MAJOR INSECT PESTS OF *RABI* SORGHUM"** submitted by me is based on the actual work carried out by me under the guidance and supervision of **Dr. A.V. SABLE.** The extent of information derived from the existing literature have been duly cited and referenced. The existing research work or its any part is not submitted anywhere else for the award of any degree or diploma.

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"The struggle you are in today is developing the strength you need tomorrow"

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(SHUBHAM BABUSHA YASHWANT)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

%	Per cent
/	per
C.D.	Critical difference
C.V.	Coefficient of variation
S.E.	Standard error
g	Gram
@	At the rate of
DAG	Dys after germination
et al.	*Et alia*, and others
Fig.	Figure
etc.	Et cetera
m	meter
i.e.	*Id est*, that is
sp.	species
Qtl	Quintal
C:B	Cost benefit ratio
ICBR	Incremental cost benefit ratio
ms	Maharashtra
°c	Degree Celsius
a.i.	Active ingredient
PP	Pages
DBS	Day before spraying
No.	numbers
viz.	Videlicet, namely
f.b.	Followed by
Kg	Kilogram
gm	Gram
ha	Hectare
DAS	Days after sowing

THESIS ABSTRACT

Title of the thesis	: **Management of major insect pests of *rabi* sorghum**.
Full name of the candidate	: Shubham Babusha Yashwant
Full name of the Research Guide	: Dr. Anita Vittal Sable
Department	: Agricultural Entomology
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ABSTRACT

Studies on bio-efficacy of newer insecticides and residual toxicity of different insecticides against major insect-pests of sorghum were conducted at Department of Agricultural Entomology, College of Agriculture, Latur (Maharashtra) during *rabi* 2021.

All the insecticides were found to be significantly superior in recording minimum number of sorghum deadheart caused by shoot fly, *S.frugiperda*, leafhopper, over untreated control.

Among different insecticides, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly minimum population of deadheart**,** The incidence of fall armyworm *S.frugiperda* on sorghum plant was observed to be significantly decreased in the plots sprayed with Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* , also incidence of leafhopper, on sorghum plant was observed to be significantly decreased in the plots treated with Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* and proved best option for management. Imidalcloprid 48% FS seed treatment 5ml/kg and Thiamethoxam 30FS seed treatment 10ml/kg were observed to be safer to the natural enemies.

The present investigation revealed better response of Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* highest grain yield (32.19 q per ha) which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (31.01 q per ha) and Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (30.67 q per ha) to pest control which also reflected with higher grain yield. However, Imidalcloprid 48%FS (seed treatment) documented most economic treatment with highest ICBR (1:25.1).

Residual toxicity and persistence studies of different insecticides against aphids showed highest PT and LT_{50} values in Dimethoate 0.009 per cent. Thus, the results of these studies may be used as a basis for selection of label claimed insecticides for successful control of sorghum aphids.

(**Keywords:** Sorghum, Bioefficacy, Residual toxicity, Shoot fly)

CHAPTRER-I

INTRODUCTION

CHAPTER - I

INTRODUCTION

Sorghum (*Sorghum bicolour* (Linnaeus) Moench) an ancient crop belonging to the family Poaceae is a warm-season cereal of African origin, which was first cultivated in the region of Ethiopia or Chad over 5000 years ago and spread to India by 4000 years (Rosentrater and Evers, 2018). More than half of the world's sorghum is grown in the semi-arid regions and it is fundamental food for over 500 million people who live in the semi-arid tropics (Mohammed *et al.,* 2015). Sorghum is the world's fifth most important cereal after maize, rice, wheat and barley (Balakrishna *et al*., 2019).

There are four main classes of sorghum *viz*., grain sorghum, sweet sorghum, broom corns and grassy sorghum (Rosentrater and Evers, 2018). It is grown globally for human and animals for food, feed, fodder, fiber and fuel or bioenergy (Padmaja, 2016). Nutritionally sorghum (per 100 g) is rich in water (12.4 g), energy (329 kcal), protein (10.62 g), lipid (3.46 g), ash (1.43 g), carbohydrate (72.09 g), fibers (6.7 g), total sugar (2.59 g), Ca (13 mg), Fe (3.36 mg), Mg (165 mg), P (289 mg), K (363 mg), Na (2 mg), Zn (1.67 mg), Cu (0.284 mg), Mn (1.605 mg), Se (12.2 µg), folate (20 µg), vitamin B-6 (0.443 mg), vitamin E (0.5 mg), many phytochemicals, etc (Anonymous, 2021). Sorghum is one of the most important staple food crops of the world adapted to a wide range of ecological conditions and low input cultivation with diverse uses in industries for ethanol, adhesives, starch and paper production (Karthikeyan, 2017).

As a global food ingredient, sorghum is a versatile crop cultivated in more than 109 countries over 40.25 million ha producing 58.70 million tonnes of grains with an average productivity of 1458.5 kg per ha (Anonymous, 2021). In India, the area under sorghum crop is 5.5 million ha with the production of 4.7 million tonnes and the average yield of 866 kg per ha (Anonymous, 2021). Sorghum is mainly cultivated under rainfed conditions during *kharif* (rainy) as well as during *rabi* (winter) season mainly concentrated in the southern and central India. Sorghum is cultivated on an area of 1.75 and 2.34 million ha with 1.73 and 1.74 million tonnes of production and 989 and 744 kg per ha of productivity, during *kharif* and *rabi* season, respectively (INDIASTAT, 2021). The major sorghum growing areas are in the states of Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Tamil Nadu and Rajasthan. In Haryana, it is grown mainly for fodder purpose (Satpal *et al*., 2016). In Maharashtra, it is cultivated over an area of 2320 thousand hectares with production of 2186 thousand tonnes and with average productivity of 942 kg/ha during *kharif* and *rabi* season, respectively. In latur district, it is cultivated over an area of 2756 hectares with production of 2509 tonnes and with average productivity of 910 kg/ha during *rabi* season, respectively (Anonymous, 2021).

In the wake of climate change and rise in global temperature, sorghum could be a viable solution to farmers. However, sorghum is not immune to abiotic and biotic stresses but has potential to yield under unexpected weather conditions (Balakrishna *et al*., 2019). The biotic and abiotic factors play a vital role in deciding the production and productivity of sorghum. Low yields of sorghum have been attributed to variety of factors, of which loss caused by insect pests has been considerable (Kulkarni, 2001). There are at least 150 insect species that can infest sorghum worldwide (Guo *et al*., 2011). These insects target various parts of sorghum plants at developmental stages, (Jotwani *et al*.,1980) and they cause significant losses (Padmaja, 2016) of which the shoot fly (*Atherigona soccata* Rondani) and stem borer (*Chilo partellus* Swinhoe) cause enormous losses. Of these, the former is the most destructive at the seedling stage. The larva of this pest attacks on central whorl of the plant and cause dead heart formation. The damaged seedlings get killed and plant grows side tillers which are further attacked under high population leading to considerable loss.The incidence increase as the sowing is delayed. At boot stage, twisting of top leaves and emergence of panicle is prevented in case of severe infestation (Subbarayudu *et al*, 2002). The incursion of fall armyworm as an invasive pest into Asia was first reported in India on maize crop during May 2018 (Deshmukh *et al*., 2018). Though it is major pest of maize, it also attacks more than 80 species of different crops such as rice, millets, cotton (Anonymous, 2020) due to its polyphagous nature. At global level, important sorghum insect pests include leaf-sucking species, leaf-feeding species, stalk or stem borers, pests of the panicle and of the stored grain (Okosun *et al*., 2021). Shoot fly, stem borers (*Chilo partellus* Swinhoe and *Sesamia inferens* Walker), armyworms (*Mythimna separata* Walker and *Spodoptera frugiperda* Smith), aphids (*Melanaphis sacchari* Zehntner and *Rhopalosiphum* *maidis* Fitch), midge (*Contarhinia sorghicola* Coquillett), head caterpillars (*Helicoverpa armigera* Hubner), hairy caterpillars (Orygia sp., *Olene mendosa* Hubner and *Somena scintillans* Walker), shoot bugs (*Peregrinus maidis* Ashmead) and green stink bug (*Nezara viridula* (Linnaeus) are the major insect pests of sorghum in Maharashtra.

In sorghum fields, more than 35 per cent crops losses are reported due to insect pests estimated at $580 million in India (Reddy and Zehr, 2004). The early stage of the crop *i.e*. seedling stage was mainly attacked by shoot fly and flea beetle wherein the shoot fly was predominant (Patel and Purohit, 2015). Pawar *et al* (1984) reported maximum yield losses of 75.6 per cent in grain and 68.6 per cent in fodder. The peak incidence of shoot fly in *kharif* season was in the month of August while in *rabi* season it was in the month of October – November (Pawar *et al.*, 2015). The shoot fly, *Atherigona soccata* (Rondani) is one of the serious pests attacking sorghum in India. Shoot fly causes 23.3 to 36.5 % grain losses and 37.5 % fodder losses. Stem borer causes between 20-60 % losses (Prem Kishore, 1987).*Chilo partellus* causing 90-95 per cent of the total damage in *Kharif* season (Prakash *et al.*, 2017) The loss in grain and fodder yields due to aphid infestation varied from 11.74 to 26.13 per cent and 9.83 to 31.43 per cent with an overall average loss of 16.09 and 14.99 per cent, respectively (Balikai and Lingappa, 2004).

In view of its effects on plant stand and losses in grain yield, considerable research efforts have been made to develop strategies for its management, plant protection in early stage of crop is very much essential, as losses through early season of pest could be minimized by seed treatment of insecticides. It has minimal effect on beneficial insects, low toxicity towards mammals and does not produce teratogenic or mutagenic effects. Because of this selectivity, it is recommended for treatment of seeds.

Several insecticides have been recommended against sorghum insects-pests for their effective management. But according to several reports many of these label claimed insecticides could not give effective results. Hence newer insecticides should have to be revaulated against sorghum insects pests for effective management.

In addition, the residual toxicity resulting from foliar spray of insecticides could be great significance in indicating an effective period over which an insecticide could persist in biologically active stage and their periodic evaluation for effectiveness is also essential under field condition.

With this background, the present investigation was undertaken to investigate the bioefficacy and residual toxicity of different insecticdes against major insect pest of sorghum with following objectives.

1. To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum.

2. To study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum.

CHAPTER-II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The relevant review on the bioefficacy of newer insecticides against major insect pest and residual toxicity of major insect pest of *rabi* sorghum are presented under following headings.

2.1 To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum

2.1.1 Bioefficacy of newer insecticides against shoot fly

Sharma *et al*. (1996) evaluated the seeds of sorghum (var. CSH-9) were treated with imidacloprid 75 WS (7.5 g/100 g seed), carbofuran 3 G (2 g/m row), Profenofos [Curacron] 50 EC (1 ml/litre) and carbosulfan 25 ST (20 g/100 g seed) to assess their effectiveness in controlling infestations of *Atherigona soccata* in Madhya Pradesh, India. The results indicated that imidacloprid was the most effective chemical.

Karibasavaraja *et al*. (2005) studied the seed dress with thiomethoxam 70 WS @4 & 5 g a.i /kg seeds were very effective in reducing shoot fly dead hearts with 9.6 & 13.6 % respectively against 60.3% in standard check soil application of carbofuran 3G @ 3 g/m row.The grain yield in the respective treatments was 31.54, 30.00 & 17.12 q/ha. Thus the seed dress with thiomethoxam 70 WS @4 & 5 g a.i /kg seed proved to be best for the management of shoot fly and afforded highest protection .Thiomethoxam 70WS at any of the dosage tested , did not show any deleterious effect on seedling by recording non significant differences in respect of plant standard.

Kumar & Prabhuraj (2007) conducted field trial in Karnataka against shoot fly and shoot bug. The treatment with thiomethoxam 70WS at 2 gm/kg recorded lower infestation of dead heart (7.9%) with less shoot bug population (5.83/5 plant) and higher grain yield (31.93 q/ha) besides, higher fodder yield (56.92 q/ha). Imiadcloprid 70WS at 5 g/ha, endosulfan 35EC seed soaking (8hr) at 2 ml/kg and carbosulfan 25 DS at 40g/kg were the next best treatment and were on par with each other.

Balikai & Bhagwat (2009) conducted field trial was at the Regional Agricultural Research Station, Bijapur and revealed that, four treatments *viz.,* intercropping of chickpea (2:2) + seed treatment with thiamethoxam 70 WS @ 3 g/kg seed, seed treatment with thiamethoxam 70 WS @ 3 g/kg seed + spray of NSKE @ 5% at 45 days after emergence of crop (DAE), seed treatment with thiamethoxam 70 WS @ 3 g/kg seed + spray of endosulfan @ 0.07% at 45 DAE and seed treatment with thiamethoxam 70 WS @ 3 g/kg seed alone were effective in reducing the shoot fly, shoot bug and aphid incidence and there by harnessed higher sorghum grain equivalent yield, fodder yield and net returns. Intercropping of sorghum with chickpea (2:2 row proportions) was not a good option from point of insect pest suppression and higher returns.

Daware *et al.* (2010) studied effective and economical seed dresser for the management of sorghum shoot fly (Rondani). The treatment with thiamethoxam @ 3.1 g a. i./kg seed recorded significantly lowest shoot fly dead hearts (22. 66%) and gave maximum yield (3071. 59 kg/ha) which was at par with imidacloprid @ 8. 75 g a. i./kg seed.

Shahzad *et al.* (2010) evaluated the effective maize seed treatment against maize shoot fly *Atherigona soccata* (Rond.) and insecticide against maize borer *Chilo partellus* (Swinh.). Two seed treatments imidacloprid (confider) 70 WS and pensidor 72% WP (5 and 7 mg/kg seed) along with imidacloprid (confider) 200 SC @ 40 ml/acre in the trial against maize shoot fly whereas, flubendiamide 48%, emamection 1.9 EC, spinosad 240 EC, carbofuran 3 G, indoxacarb 150 SC, alpha cypermethrine 20 EC, monomehypo 5 G,bifenthrin 10 EC, cartap 4G, cyhalothrine 2.5 EC, cypermethrin 10 EC @ 20 ml, 150 ml, 40 ml, 8 kg, 150 ml, 200 ml, 5 kg, 150 ml, 6 kg, 250 ml and 300 ml per acre against maize borer were treated and compared with untreated controls. Treatments were repeated as borer infestation reached above 5% level. All the seed treatments showed significant control of maize shoot fly inspite of dose 5 or 7 mg/kg seed along with foliar spray of imidacloprid 200 SC. The insecticides viz. flubendiamide 48% SC, emamectin 1.9 EC, spinosad 240 EC and carbofuran 3 G, indoxacarb 150 SC, alpha cypermethrin 20 EC, not only gave the highest yields of 5765, 5294, 5289, 5215, 5168 and 5025 kg/ha respectively but also managed the maize borer below ETL.

Balikai (2011) reported that, the seed treatment with thiamethoxam 70 WS @ 3 g/kg seeds proved highly effective against shoot fly and significantly superior over rest of the treatments by recording 5.2 per cent dead hearts. The next best treatment in respect of shoot fly suppression was seed treatment with thiamethoxam 70 WS @ 2 g/kg seeds which in turn was on par with imidacloprid 70 WS @ 5 g/kg seeds. With respect to aphid incidence, three treatments *viz.*, whorl application of carbofuran 3 G @ 8 kg/ha at 35-40 days after sowing (DAS), spray with endosulfan 35 EC @ 0.07% at 35-40 DAS and seed treatment with thiamethoxam 70 WS @ 3 g/kg seeds with low aphid incidence of 9.3, 10.2 and 10.2 per cent aphid index, respectively were highly effective and significantly superior over rest of the treatments.

Siddique *et al*. (2011) reported that shoot fly oviposition was maximum in thiamethoxam 5 gm/kg seed treatment which at par with imidacloprid 10 g/kg seed treatment indicating more attractive for female flies to lay more eggs. Thiamethoxam 25 WG @ 0.005% spray was most effective in reducing shoot fly dead-hearts followed by imidacloprid 10 g/kg and thiamethoxam 5 gm/kg seed treatment. Maximum grain yield was obtained from thiamethoxam 0.005% spray at par with imidacloprid 10 g/kg and thiamethoxam 5 gm/kg seed treatment.

Anuradha.M. (2012) was conducted field experiment at Maize Research Centre, ARI, Rajendranagar, Hyderabad during *Kharif* 2009 and *Rabi* 2009-10 to evaluate the different doses of Thiamethoxam 30FS as seed treatment chemical for controlling maize stem borers, *Chilo partellus* Swinhoe and *Sesamia inferens* Walker. Among the doses tested, higher dose of thiamethoxam 30FS (8 ml/kg) proved superior resulting in 0.38 per cent dead hearts during *Kharif* and 6.43 per cent dead hearts during *Rabi* compared to 0.79 per cent and 14.76 per cent in untreated check. Thiamethoxam30FS @ 8 ml/kg resulted in higher grain yield of 5.4 t/ha during *Rabi*. Phytotoxic effects like necrosis, vein clearing, epinasty etc. were not observed even at the highest dose of 16 ml/kg.

Singh (2016) studied the three genotypes *viz*. PCS 2, PCS 3 & PCS 6 were found promising against *Atherigona soccata*. Seed treatment with thiomethoxam 30 FS @ 5 ml/kg and imidacloprid 600 FS @ 7 ml/kg seeds were found effective in reducing shoot fly incidence. Spray of carbaryl 50 WP @ 375 g/ha, imidacloprid 17.8 SL @75 ml/ha, indoxacarb 15.8 SC @125 ml/ha, chlorantraniliprole 18.5 SC @ 100 ml/ha and fipronil 5 SC @ 175 ml/ha at 3-4 leaf stage also reduced the dead hearts incidence by shoot fly.

Khandare *et al*. (2017) conducted research during 2013-14 at Entomology Section, College of Agriculture, Nagpur the results revealed that the recorded maximum numbers of shoot fly eggs in treatment cartap hydrochloride, chlorpyriphos and imidacloprid, in which 5.00, 4.75 and 4.16 eggs/plant were observed and found to be on par with each other and were significantly superior over control (2.75 eggs/plant). The yield data indicate that the treatment with thiamethoxam 35 FS @ 5 ml/kg seed produced highest grain yield (3462 kg/ha). The maximum net monetary returns 1:56.25 (ICBR) were realized by the treatment thaimethoxam 35 FS@5 ml/kg seed.

Kumar *et al*. (2017) carried out research, at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut and revealed that the treatments, Imidacloprid 70WS-NSKE was found best to reduce the number of eggs laid by *A. soccata i.e.* 0.00 eggs/plant (11 DAE) and 0.45 eggs/plant (22 DAE) followed by Thiamethoxam 70WS-NSKE with 0.45 eggs/plant (11 DAE) and 0.72 eggs/plant (22 DAE). However, the maximum number of eggs survival of *A. soccata* was recorded with untreated control 1.85eggs/plant (11DAE) and 2.30 eggs/plant (22 DAE). Result revealed that all the treatments were found significantly effective in reducing the incidence of shoot fly and thus increasing the yield as compared to control. The higher grain yield (42.93 q/ha) and cost benefit ratio (1:16.10) were also obtained from Imidacloprid 70WS-NSKE.

Patil & Bagde (2017**)** laid out experiment in randomized block design with seven treatment and four replications with view to find out the effective insecticides against sorghum shoot fly at Agronomy field, college of agriculture Kolhapur during *Rabi* 2016-17 found that the foliar treatment with Deltamethrin 2.8 EC @ 1ml/l at 28 DAE was significantly effective over chlorantraniliprole, deltamethrin, flubediamide, quinolphos & azadirachitin treatment for the control of sorghum shoot fly.

Prakash *et al*. (2017) evaluated the efficacy of some novel insecticide against maize stem borer, *Chilo partellus* (Swinhoe) at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during *kharif* 2016. The imidacloprid 17.8 SL was found most effective treatment followed by carbaryl SL, dimethoate 30% EC @ 1000 ml/ha (3.9 %) and acephate 75% @ 500 ml/ha (3.71 %) dead heart infestation, which was at par each other respectively. The highest dead heart infestation was recorded in control plot (24.8%). This was significantly higher than rest of the treatments and responsible for economic damage in maize crop. The highest grain yield (38.1 q/ha) was obtained from the imidacloprid 17.8 SL treated plot with maximum cost benefit ratio (1:8.75) followed by from carbaryl SL treated plot (36.8 q/ha) with cost benefit ratio (1:5.93)

Yadav *et al.* (2017) carried out research at Sorghum Research Station, SDAU, Deesa, Gujarat, to study the different management components against shoot fly. Among these components Imidacloprid (0.61) and carbofuran (0.76) were the most effective insecticides followed by the treatments thiamethoxam (0.88), early sowing (1.02) and phorate (1.14). Whereas, quinalphos (1.51) and high seed rate (2.22) were found to be significantly less effective regarding number of eggs per plant. While in case of per cent dead hearts that imidacloprid (5.13%) and carbofuran (6.89%) were the most effective treatment followed by thiamethoxam (7.91%) and early sowing (10.1%). NSKE (12.95%), chlorpyriphos (14.11%) and quinalphos (14.99%) were least effective treatment for managing the shoot fly incidence.

Kumar & Tiwana (2018) conducted research for two consecutive years during *kharif* 2015 and 2016 at Forage Research Farm, Punjab Agricultural University, Ludhiana, studied the effect of seed treatment on attack of sorghum shoot fly revealed the superiority of seed treatment with thiamethoxam 30 FS @ 10 ml per kg seed and closely followed by fipronil @ 10 ml per kg seed and imidacloprid @ 7ml per kg seed (7.71, 8.79 & 9.47% dead heart , respectively) in comparison to standard (Thiamethoxam 30 FS , Fipronil 2.8 EC, Imidacloprid 600 FS , Malathion 50 EC) (11.53%) and untreated control (17.08%). Economic analysis of different treatments revealed that protection against shoot fly damage lead to yield advantage of 93-153 q/ha.

Rawat *et al. (*2020) research was conducted for two consecutive years during *Kharif* - 2018 and *Kharif* -2019 with seven treatments including different insecticides and botanical at Entomological Research Block, College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G. Uttarakhand and the results revealed minimum (0.46%) number of eggs laid per plant was recorded when the seeds were treated with imidacloprid 600 FS @ 5ml/kg seed followed by thiamethoxam 70 WS @ 2g/kg seed (0.53) whereas, maximum (1.69%) number of eggs per plant was found in plants raised from untreated seeds. Two consecutive years' investigation revealed seed treatment with imidacloprid 600FS @ 5ml/kg as a promising treatment to control the shoot fly damage and at the same time resulted in higher yield of grain and fodder in barnyard millet in Uttarakhand hilly areas.

Sangle *et al*. (2020) conducted field experiments during *Rabi* 2018-19, evaluated the effect of seven newer insecticide molecules *viz*., profenophos 50 EC@ 30 ml, indoxacarb 14.5 SC @ 8.5 ml, emamectin benzoate 5 SG@ 4 g, spinosad 45SC @ 4 ml, thiamethoxam 12.6 + lambdacyhalothrin 9.5@ 2.5 ml, chlorantraniliprole 18.5 SC 3 ml and flubendiamide 49.35 SC @ 2.5 per 10 lit. of water respectively. Among the insecticides spraying, emamectin benzoate 5 SG was most effective treatment over control followed by chlorantraniliprole 18.5 SC, flubendiamide 39.35 SC, indoxacarb 14.5 SC, thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC, spinosad 45 SC and profenophos 50 EC. The highest yield was recorded in the treatment emamectin benzoate 5 SG @ (42.5 q/ha) followed by chlorantraniliprole 18.5% SC (40.01 q/ha), flubendiamide 39.35 SC (38.5 q/ha) and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (37.6 q/ha).

Gurmeet Singh (2021) conducted research during *kharif,* 2019 studied the efficacy of seed treatment with thiamethoxam 30 FS for the control of sorghum shoot fly, *Atherigona soccata* (Rondani) at Forage and Millets Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. Results showed seed was treated with 10 ml thiamethoxam 30 FS (Slayer) per kg seed. Seed treatment with thiamethoxam 30 FS @ 10 ml/kg seed was found better than spraying of malathion @ 625 ml/ha and control for the management of shoot fly in sorghum but seed treatment with thiamethoxam was not effective for the management of maize borer in sorghum. No phytotoxicity symptoms of the insecticide either by spraying or as seed treatment were observed in any of the treatment.

Parmar *et al. (*2021) evaluated field experiment for the management of major insect pests in pearl millet during *kharif* 2016-18 at Millet Research station, Junagadh Agriculture University, Jamnagar. Results showed that module-IV (seed treatment of imidacloprid 600 FS @ 8.75 ml/kg at the time of sowing, removal of shoot fly dead hearts, installation of fish meal traps @ 10/ha and spraying of dimethoate 30EC @ 0.03% at 35 days after germination was found effective against shoot fly. Whereas, module-II (seed treatment of imidacloprid 600 FS @ 8.75 ml/kg + removal of shoot fly dead hearts + fish meal trap @ 10/ha + spraying of novaluron 10 EC @ 0.01%, at 35 DAG) recorded lowest stem borer per cent incidence and *Helicoverpa* larval population at ear head stage of crop. But, looking to the cost of management, highest additional income (Rs. 20610/-), net return (Rs. 18961/-) and ICBR (1:12.50) was recorded in module-IV (Seed treatment 0@ 10/ha + spraying of dimethoate 30 EC 0.03 % at 35 DAG).

Saxena *et al.* (2021) evaluated six seed dressing chemicals along with soil application of carbofuran against shoot fly at Indoore. Significantly least dead heart (1.36 to 15.95%) was observed with thiamethoxam+ cyantraniliprole followed by thiamethoxam 30FS (1.61 to 21.76%). Soil application of carbofuran resulted in less efficacy (2.96 to 38.21%). The mean yield obtained was 29.13 q/ha in protected plots as against 16.20 q/ha in unprotected plots. Mean dead heart incidence was 11.59% in protected plots and 58.23% in unprotected plots. The avoidable loss in term of dead heart was recorded to be 80.10%.

Shid *et al.* (2022) evaluated the different insecticides for seed treatments against sorghum shoot fly during *Rabi* 2020-21 under randomized block design (RBD) at Sorghum Improvement Project, MPKV, Rahuri, Dist. Ahmednagar (M.S.). The results of experiment among the seven treatments at 28 DAE, the seed treatments with Thiamethoxam 30 FS @ 10 ml/kg seed (19.76%), Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS (21.00%) and Imidacloprid 17.8 SL (21.46%) recorded the lowest dead hearts caused due to shoot fly indicating that treatments were effective in controlling shoot fly infestation. The maximum ICBR 1:43.80 was obtained in seed treatment with Imidacloprid 17.8 SL @ 3 ml/kg of seeds followed by Fipronil 5 SC @ 5 ml/kg of seed treatment (1:41.69) and Thiamethoxam 30 FS @ 10 ml/kg of seeds (1:37.43).

2.1.2 Bioefficacy of newer insecticides against stem borer

Shahzad *et al*. (2010) evaluated the effective maize seed treatment against maize shoot fly *Atherigona soccata* (Rond.) and insecticide against maize borer *Chilo partellus* (Swinh.) Two seed treatments imidacloprid (confider) 70 WS and pensidor 72% WP (5 and 7 mg/kg seed) along with imidacloprid (confider) 200 SC @ 40 ml/acre in the trial against maize shoot fly whereas, flubendiamide 48%, emamection 1.9 EC, spinosad 240 EC, carbofuran 3 G, indoxacarb 150 SC, alpha cypermethrine 20 EC, monomehypo 5 G,bifenthrin 10 EC, cartap 4G, cyhalothrine 2.5 EC, cypermethrin 10 EC @ 20 ml, 150 ml, 40 ml, 8 kg, 150 ml, 200 ml, 5 kg, 150 ml, 6 kg, 250 ml and 300 ml per acre against maize borer were treated and compared with untreated controls. Treatments were repeated as borer infestation reached above 5% level. All the seed treatments showed significant control of maize shoot fly inspite of dose 5 or 7 mg/kg seed along with foliar spray of imidacloprid 200 SC. The insecticides *viz.* flubendiamide 48% SC, emamectin 1.9 EC, spinosad 240 EC and carbofuran 3 G, indoxacarb 150 SC, alpha cypermethrin 20 EC, not only gave the highest yields of 5765, 5294, 5289, 5215, 5168 and 5025 kg/ha respectively but also managed the maize borer below ETL.

Ramesh *et al*. (2012) conducted Field experiments to evaluate the bioefficay of botanical pesticides, entomogenous microbes, insect growth regulators and natural insecticides in the management of stem borer, *Chilo partellus* in maize Foliar application of spinosad (0.002%) and emamectin benzoate (0.002%) significantly reduced damage of *C. partellus* and the bioefficacy of these natural pesticides were found to be on par with that of monocrotophos@ 0.05% The marginal increase in maize grain yield was in the order of 38.66 and 31.93 per cent, respectively for the treatments spinosad (0.002%) and emamectin benzoate (0.002%) over untreated check.

Choudhary *et al*. (2014) carried out field experiment in a randomized block design during *kharif* season of 2009 and 2010 at the Research Farm, College of Agriculture, Indore (M.P.). Seven treatments along with a check were evaluated for sorghum pests and the seed treatment with thiamethoxam @ 3g/kg seed was recorded effective to manage sorghum shoot fly (*A. soccata*) and stem borer (*C. partellus*). The minimum dead hearts due to shoot fly was recorded at 7 and 28 DAE in the treatment i.e. intercrop plot ST + intercrop + NSKE @ 5 % spray (8.45 and 18.09%) and ST + intercrop (9.12 and 18.67%). The minimum leaf injury due to stem borer was also recorded in the same treatment. The maximum yield and minimum per cent of dead hearts due to stem borer after spray was observed in plot which was treated with ST+ lambda-cyhalothrin @30g ai/ha-1 spray which was at par with ST + fipronil @0.01%spray followed by ST +chlorpyriphos @ 0.05 % spray.

Saleem *et al*. (2014) conducted experiment at Agriculture Research Station Jarma, Kohat on Maize Stem Borer infestation. Results revealed that there was significant difference between Granules and insecticides. Carbofuron 3G was recorded the most effective followed by Fipronil 4G. Average dead hearts count for Carbofuron 3G were 3.167 per cent followed by 4.4 per cent for Fipronil 4G.

Arunkumara *et al*. (2017) research was conducted in the Agricultural research station, Hagari (Ballari) UAS, Raichur, Karnataka during *kharif* 2016 on management of spotted stem borer, *Chilo partellus* (Swinhoe) on maize by insecticides. The results revealed that, the insecticide viz., imidacloprid 60 FS - chlorantriniliprole 0.4 G, imidacloprid 60 FS - fipronil 0.3 G, imidacloprid 60 FS - carbofuran 3 G were found to be effective molecules against *Chilo partellus.* Next superior treatments in order of priority were chlorantriniliprole 0.4 G > imidacloprid 60 FS + flubendiamide 39.35 SC > fipronil 0.3 G > carbofuran 3 G >flubendiamide 39.35 SC >imdacloprid 60 FS.

Chouraddi & Mallapur (2017) carried out research at Main Agricultural Research Station, Dharwad during *kharif* & *rabi-summer* 2010-11 and 2011-12. Among the different newer molecules of insecticides evaluated, single spray of endosulfan 35EC @ 2 ml/l or emamectin benzoate 5SG @ 0.2 g/l or spinosad 45SC @ 0.2 ml/l at 25 DAS as well as whorl application of carbofuran 3G @ 7.5 kg/ha being on par with each other proved superior over untreated control. Maximum net profit was realised in carbofuran and endosulfan treatments (37851.00 and 37197.90 Rs./ha, respectively). The lower net profit was found in imidacloprid and thiomethoxam. The maximum IBC (Incremental Benefit: Cost ratio) ratio of 28.62 was registered in endosulfan followed by imidacloprid (23.13), carbofuran (17.19), emamectin benzoate (13.44), indoxacarb (11.22), spinosad (7.63) and thiodicarb (6.84) and the lower IBC ratio was recorded in flubendiamide (5.07) and thiomethoxam (6.72).

Deole *et al*. (2017) conducted the research during spring seasons of the year 2013-14 & 2014-15 at Research cum Instructional Farm, IGKV, Raipur (C.G.).Nine insecticide treatments are Buprofezin 25% SC, Carbofuran 3G @0.3 kg/ha ,Cartap hydrochloride 4G @0.3kg/ha ,Imidacloprid 70WG ,Chlorantraniliprole 18.5 SC, Spinosad 45 SC ,Fipronil 0.3 G @0.06 kg/ha, Emamectin benzoate 5 % SG,Thiamethoxam 25 % WG, from different groups were applied as foliar sprays (liquid formulations) and whorl application (granular formulations) on maize crop against pink stem borer *Sesamia inferens,* (Walker) The treatment was given at 15 days after germination of the crop when pink stem borer infestation was observed in the field. Among the insecticides evaluated, spinosad 45 SC proved to be highly effective in reducing the pink borer infestation with minimum leaf injury level (2.94) and tunnel length (2.31cm) resulting in higher grain yield(61.63 q/ha.).

Iqbal *et al*. (2017) tested four granular (carbofuran, fipronil, cartap, monomihypo), two foliar (emmamectin, deltamethrin) and two seed dressers insecticides (imidacloprid, thiamethoxam) against maize stem borer (MSB) on maize variety (R-2335) under field conditions. The data revealed that all insecticide significantly reduced MSB infestation at different level and have positive effect on maize yield. Least MSB infestation was observed with fipronil and imidacloprid (1DAT = 27.78%, 27.78%), monomihypo and cartap (3 DAT= 16.67%, 21.11%), monomihypo (7 DAT = 8.89%) after first insecticide application, respectively. Likewise, fipronil gave low MSB infestation (1 DAT= 17.78%) and imidacloprid high infestation (1 DAT= 26.67%) after second insecticide application. Afterwards, all insecticides exhibited very low but significantly at par MSB infestation at 3-7DAT. Furthermore, granular insecticides (fipronil=5778 kg/ha) gave high yield followed by carbofuran, monomihypo and cartap (5111, 4889, 4445 kg/ha), respectively. Taken together, granular insecticides were comparatively more effective with high maize yield. Seed dresser insecticide were more effective during early days of germination. Two-time application of foliar and granular insecticides may also be adopted to keep the MSB infestation below ETL.

Kulkarni *et al*. (2017) evaluated ten insecticides *viz.,* dichlorvos 76 EC, dimethoate 30 EC, acephate 75 WP, chlorofluzuron 25 EC, fipronil 5 SC, chlorantraniliprole 20 SC, phorate 10 G, neemazal 1.2%, carbofuran 3 G and emamectin benzoate 5 SG against maize stem borers, *Chilo partellus* and *Sesamia inferens* was evaluated during *kharif* 2013. The observations based on leaf injury, pest infestation, stem tunneling and grain yield revealed that whorl application of carbofuran 3 G@ 7.5 kg/ha and phorate 10 G7.5 kg/ha proved to be the best followed by emamectin benzoate 5SG @ 0.2 g/l which performed highly effective and economical in reducing the stem borers damage in maize.

Kumar & Alam (2017) tested the bio-efficacy of chlorantraniliprole 20 SC, novaluron 10 EC, flubendiamide 480 SC, deltamethrin 2.8 EC and carbofuran 3G against maize stem borer, *Chilo partellus* at research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur (Bihar) during *kharif* 2016 and studied the minimum and maximum mean per cent infestation (10.60 and 72.60) as well as mean per cent dead heart (3.75 and 23.50) were recorded in chlorantraniliprole 20 SC @ 0.3 ml/l followed by carbofuran 3G @ 7 kg/ha and untreated control, respectively. The highest benefit:cost ratio (1:13.96) was evinced in insecticidal treatment flubendiamide 480 SC @ 0.2 ml/*l* in sequence with carbofuran 3G @ 7 kg/ha. All the treatments were found significantly superior to untreated control in reducing the maize stem borer infestation and increasing the yield.

Sidar *et al*. (2017) investigated the bioefficacy of granular insecticide molecules against pink stem borer. The results revealed that the minimum per cent of dead heart damage was recorded with carbofuran 36.67% which was at par with flubendiamide 43.33% followed by rynaxypyr 45.50%, thiamethoxam 46.67%, emamectin benzoate 50.0%, and cartap hydrochloride 56.67% treated plots. The highest per cent dead heart damage was recorded with fipronil 60.0%. The grain yields was also significantly highly influenced by carbofuran 3 G followed by flubendiamide 20 WG, thiamethoxam 25 WG, emamectin benzoate 5 SG and cartap hydrochloride 4 G, rynaxypyr 0.4% G and fipronil 0.3% G.

Devananda *et al.* (2018) studied the relative efficacy of nine different insecticides against maize stem borer *Chilo partellus*at instructional farm J.A.U., Junagadh during the *kharif* 2017 and the results evaluated that Carbofuran 3G @ 0.3 kg a.i.ha-1, Spinosad 45SC @ 0.002 % and Chlorantraniliprole 18.5 SC @ 0.006% were found highly effective in reducing the larval population and dead heart and found on par to each other. The next best treatments were Indoxacarb 15.8 EC@0.015%, Flubendiamide 480 SC@0.016%, and Cartap hydrochloride 4G@0.75 kg a.i. /ha. Rest of the treatments was superior over control in reducing stem borer incidence.

Sulke *et al*. (2018) conducted experiment during *kharif* 2017 at SHUATS, Allahabad (U.P.) to compare the efficacy of selected insecticides against maize stem borer *Chilo partellus* (Swinhoe) of maize. The experiment was conducted in a Randomized Block Design with seven treatments; (T1) Fipronil 5EC, (T2) Carbofuran 3G, (T3) Lamda cyhalothrin 5EC, (T4) Novaluron 10EC, (T5) Flubendiamide 480SC, (T6) Quinalphos 25EC, (T7) Chloropyriphos 20EC and (T8) Control each of which was three replications. Among all the treatments lowest per cent infestation of dead hearts was recorded in Carbofuran 3G (8.79%), then followed by Fipronil 5EC (9.04%), Novaluron 10EC (9.19%), Flubendiamide 480SC (12.87%), Lamda cyhalothrin 5EC (20.01%), Chloropyriphos 20EC (21.08%), Quinalphos 25EC (22.62%) and is least effective among all treatments. The cost benefit ratio (CBR) showed that the application of Chloropyriphos 20EC was economically most viable treatment (1:1.68) followed by Fipronil (1:1.61).

Pateliya *et al.* (2019) conducted field experiment for the management of shoot fly and stem borer in pearl millet during *kharif* at Junagadh Agriculture University, Junagadh. The results showed that seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *Beauveria bassiana*WP @ 0.007% or seed treatment of clothianidin WDG @7.5 g/kg seed followed by spray of *B. bassiana*WP @ 0.007% recorded lower infestation of shoot fly and stem borer in pearl millet crop. The highest grain yield (2452 kg/ha) was obtained from the seed treatment with clothianidin WDG @ 7.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% and lowest yield of 1663 kg/ha was obtained from the control plot. The highest benefit cost ratio was obtained from the seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007%

(1:16.19) and seed treatment of clothianidin WDG @ 7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (1:15.35).

Alam *et al*. (2020) evaluated Diamide and Neonicotinoid group of insecticides against maize stem borer, *Chilo partellus* (Swinhoe) as seed treatmentat research farm, Tirhut College of Agriculture, Dholi during *kharif* 2018 with seven treatment T1 Untreated Control, T2 Tetraniliprole 480 FS @ 1.2 g/kg of seed, T3 Tetraniliprole 480 FS @ 2.4 g/kg of seed, T4 Tetraniliprole 480 FS @ 3.6 g/kg of seed, T5 Imidacloprid 48% w/w FS (Imidacloprid 600 FS) @ 6 g/kg of seed, T6 Thiomethoxam 30% FS @ 2.4 g/kg of seed, T7 Tetraniliprole 480 FS @ 7.2 g/kg of seed. The results revealed that treatment T4 was found to be the best among all insecticides tested with respect to number of damaged plant, minimum leaf injury, plant height and yield. However, treatment T2, T3, T5 and T6 were found safe to natural enemies among all the insecticides tested.

Poul *et al. (*2020)(b) carried out field experiment at the AICSIP, Sorghum Research Station, VNMKV, Parbhani (MS) during *Kharif* 2019-20 on sorghum variety Parbhani Shweta(PKV-801) conducted field experiment chlorantraniliprole 18.5% SC, flubendiamde 39.35% SC, emamectin benzoate 5% SG, cyantraniliprole 10.26% OD, thiomethoxam 12.6%+ lambda cyhalothrine 9.5% ZC, spinosad 45% SC and profenophos 50% EC were treated against stem borer, *Chilo partellus*. The results revealed that all the insecticidal treatments were significantly effective against stem borer over untreated control. Among them chlorantraniliprole 18.5% SC most effective treatment followed by flubendiamde 39.35% SC and emamectin benzoate 5% SG.

Juneja *et al.* (2021) showed that the seed treatment of clothianidin 50 WDG @ 7.5 g/kg seed followed by spray of fipronil 5 SC @ 0.01% at 35 days after germination was found effective against shoot fly. Whereas, the seed treatment of clothianidin 50 WDG @ 7.5 g/kg seed followed by spray of chlorantraniliprole 20 SC @ 0.006% at 35 days after germination was found effective against stem borer. The highest additional income (Rs. 17940/-) and net return (Rs. 15975/-) was recorded with the seed treatment of clothianidin 50 WDG @ 7.5 g/kg seed followed by spray of fipronil 5 SC @ 0.01% at 35 days after germination.

Kamakshi *et al*. (2021) studied the efficacy of insecticides against spotted stem borer *Chilo partellus* in sorghum, field trial was conducted during *rabi* 2016-17 and 2017-18 at the Regional Agricultural Research Station, Nandyal, Andhra Pradesh. Reported dead hearts were observed to be less with spinosad (4.0%) followed by carbofuran 3G (4.10%), chlorantraniliprole 18.5SC (4.95%) and chlorantraniliprole 0.4G (4.86%) applied at 25 days after sowing. The least infestation at 40 days after sowing was observed with chlorantraniliprole 18.5SC (6.2%), spinosad 45SC (7.0%), chlorantraniliprole 0.4G (7.3%) and carbofuran 3G @ 10 kg/ ha (8.0%). Lesser number of larvae in the stem tunnel were observed with chlorantraniliprole 18.5SC/ 0.4G, spinosad, carbofuran 3G, phorate 10G and flubendiamide. The incremental benefit cost ratio was maximum with carbofuran 3G (1:5.2), followed by chlorantraniliprole 0.4G (1:4.8) and chlorantraniliprole 18.5SC (1:4.2).

2.1.3 Bioefficacy of newer insecticides against fall armyworm

Hardke *et al*. (2011) evaluated results of a field trial against a native fall armyworm infestation in grain sorghum indicated that chlorantraniliprole reduced the number of infested whorls below that in the non-treated control and the lambda-cyhalothrin- and methoxyfenozide-treated plots at 3 days after treatment (DAT). At 7 DAT, no insecticides significantly reduced the number of infested whorls below that in the non-treated plots. In residual efficacy studies, exposure of fall armyworm larvae to chlorantraniliprole- and cyantraniliprole-treated tissue resulted in significantly greater mortality compared to those exposed to non-treated tissue and lambda-cyhalothrin-, flubendiamide-, novaluron-, and methoxyfenozide-treated tissues at 7 DAT. In addition, chlorantraniliprole and cyantraniliprole were the only compounds that resulted in >40% mortality at 28 DAT. These results indicate that newer insecticides are equal to or more efficacious against fall armyworm than traditional insecticides.

Mallapur *et al*. (2019) evaluated the Laboratory and field evaluation of new insecticide molecules against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on maize, field evaluation of newer insecticides were undertaken during late *kharif* 2018 at Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad and results revealed that spinetoram 11.7 SC and emamectin benzoate 5 SG were significantly superior over other treatments with per cent mortality at 60 hours after treatment. The field trial also indicated that spinoteram, emamectin benzoate and spinosad 45 SC were significantly superior over all other treatments with the larval reduction of 98.13, 96.26 and 96.26 per cent, respectively at 7 days after treatment. Among other tested molecules, thiamethoaxam 0.25%WG and fipronil 0.5 SC were least effective (68.65 and 73.14% mortality, respectively).

Bharadwaj *et al*. (2020) studied the bio- efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize under field condition during *kharif* season of 2019 at research farm of Oilseed Research Station, Latur (Maharashtra, India). The observations were recorded on total number of live *S. frugiperda* larvae per 25 plants on one day before spray and 3, 7 and 14 days after the spray. The treatments of different insecticides *viz.*, Chlorantraniliprole 18.5 SC @ 0.005 per cent, Emamectin benzoate 5 WG @ 0.002 per cent, Spinetoram 11.7 SC @ 0.011 per cent, Lambda Cyhalothrin 5 EC @ 0.025 per cent, Chlorantraniliprole 9.3 + Lambda Cyhalothrin 4.6 ZC @ 0.008 + 0.002 per cent and Thiomethaxam 12.6 + Lambda cyhalothrin 9.5 ZC @ 0.003 + 0.002 per cent were evaluated against *S. frugiperda* and revealed that Spinetoram 11.7 SC @ 0.011 per cent was found most effective treatment in reducing the population of *S. frugiperda* followed by emamectin benzoate 5 WG @ 0.002 per cent.

Ompraksh *et al.* (2020) carried out field experiment at Regional Agricultural Research Station, polasa, Jagtial, PJTSAU during *rabi*, 2018-19 and evaluated different modules for the management of Fall army worm in maize. Among different modules, Module IV (Seed treatment with imidacloprid 600FS, 20DAG- Chlorantraniliprole18.5SC ((0.3 ml/litre), 30 DAG – Spinetorum ((0.5 ml/litre), 40DAG- Poison bait with thiodicarb (100g/acre)) recorded lowest per cent plant damage (3) and per cent severity (1.57) with 95.45 and 96.08 per cent reduction over control respectively after the imposition of treatments during *rabi* 2018-19.

Poul *et al.(*2020) (a) conducted experiment at AICSIP, sorghum Research Station, VNMKV, Parbhani (MS) during *Kharif* 2019-20 investigated the efficacy of seven newer insecticide molecules. Emamectin benzoate 5 SG most effective against the *Spodoptera frugiperda*.

Suthar *et al*. (2020) tested of granular insecticides against fall armyworm in maize, an experiment at three different locations i.e., Entomology Farm, BACA, AAU, Anand, Agriculture Research Station, AAU, Sansoli and Main Maize Research Station, AAU, Godhra during *Kharif,* 2019. Different eight granular insecticides were evaluated against fall armyworm in maize. Results revealed that whorl application of chlorantraniliprole 0.4% GR and fipronil 0.6 % GR @ 20 kg/ha, first at appearance of fall armyworm and second after 15 days were found effective as it recorded lower larval population, plant damage and cob damage and incurred higher straw and grain yield.

Kumar *et al. (*2021) carried out trials for two years during *rabi,* 2018 - 19 and *kharif* 2019 at Maize Research Centre, ARS, Vijayarai, results revealed after two years of field trial against fall armyworm infestation in maize showed that chlorantraniliprole reduced the number of infested whorls (per cent plant infestation) below that in the untreated control and lambda-cyhalothrin+ thiamethoxam and carbofuran at 7 & 14 days after spraying. Highest reduction in per cent of mean plant infestation (% ROC) of 84.52 & 83.24% over control was recorded in chlorantraniliprole @ 250 ml/ha and 200 ml/ha after 2nd spraying respectively. Mean foliar damage was significantly lower with a scores of 1.4 and 1.2 at higher doses of chlorantraniliprole @ 250 ml and 200 ml/ha treated plots compared to other treatments *viz*., thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC and carbofuran 3% CG including untreated control, resulted in significantly higher yields. These results indicate that chlorantraniliprole @ 200ml and 250ml/ha are significantly effective against fall armyworm than other insecticides tested without showing phytotoxicity.

Nonci *et al*. (2021) studied the most effective insecticide to control FAW was Spinetoram followed by Emamectin Benzoate and Chlorantraniliprole. The average number of infested plants in the spinetoram treatment was: 24.2% at 4 weeks after planting (WAP), then 24.9% at 6 weeks after planting (WAP), 29.1% and 37.1% at 10 weeks after planting (WAP). The highest average yield was obtained in the insecticide treatment Spinetoram (10.7 t/ha) followed by Emamectin Benzoate (9.3 t/ha) and Chlorantraniliprole (8.9 t/ha), while the lowest yield was obtained in the control treatment (5.2 t/ha).

Ravikumar *et al*. (2022) revealed that cypermethrin 10% + indoxacarb 10% SC EC @ 2500 g a.i./ha recorded significantly least larval population (1.21 larvae/plant) and percent plant damage (6.45%) followed by lower dose of cypermethrin 10% + indoxacarb 10% SC @ 1562.5, 1250 and 1000 g a.i./ha. However, the highest larval population and percent leaf damage was recorded in the untreated control. All the chemical treatments were found numerically inferior but statistically on par with untreated control with respect to number of natural enemies such as spiders and coccinellids.

Rizvi & Deole (2022) resulted the bio-efficacy of seven insecticides against fall armyworm, *S. frugiperda* revealed that spinetoram 11.7% SC @ 30 ml a.i./ha was found most effective insecticide, which recorded the highest reduction in larval population i.e., 76.30% and 86.28% after first and second sprays, respectively followed by Chlorantraniliprole 18.5% SC @ 27.75 ml a.i./ha which recorded 71.67% and 82.30% reduction in larval population after first and second sprays, respectively. The overall mean population of *S. frugiperda* was recorded minimum in Spinetoram 11.7% SC having 0.41 larva/plant after first spray and 0.31 larva/plant after second spray followed by Chlorantraniliprole 18.5% SC having 0.49 larva/plant after first spray while 0.40 larva/plant after second spray.

Suganthi *et al*. (2022) evaluated bioefficacy of several seed treatment insecticides (Thiamethoxam, fipronil, tetraniliprole, chlorantraniliprole, cyantraniliprole + thiamethoxam, tetraniliprole + fipronil) against FAW. Chlorantraniliprole 62.5 FS @ 6 ml kg− 1 seed provided the highest protection followed by cyantraniliprole + thiamethoxam 19.8 FS, tetraniliprole 480 FS, and tetraniliprole + fipronil 240 FS. An increase in damage rating was observed 10 and 12 days post crop emergence at 10 and 12 days post crop emergence with treatments involving diamides, except for chlorantraniliprole. Thiamethoxam and fipronil seed treatments were ineffective in FAW larvae management. Chlorantraniliprole residues persisted for >26 days, and cyantraniliprole + thiamethoxam residues persisted for >16 days in maize seedlings.

Jambagi (2022) carried out research on sorghum shoot fly was carried out during *rabi* 2019-20 and 2020-21 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad India and studied one of the most effective management strategies for controlling shoot fly is the use of novel insecticides either as seed dressers, soil applicators or as foliar treatment. Under the field condition, seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed followed by a spray of cypermethrin 10 EC @ 0.5 ml/*l* has recorded least shoot fly oviposition (0.84 and 0.94 eggs/plant), dead heart (8.90% and 9.96%), more per cent productive tillers (79.68% and 79.50%), grain yield (32.22 and 31.27 q/ha) and BC ratio (1:2.05 and 1:1.99) as compared to the rest of the combinations during the investigation in *rabi*, 2019-20 and 2020-21, respectively.

2.1.4 Bioefficacy of newer insecticides against earhead midge

The insecticides in the decreasing order of their efficacy were lambda cyhalothrin >carbosulfan>fipronil >dimethoate >emamectin benzoate > Spinosad > indoxacarb > chlorpyrifos > quinalphos (Rafiq *et al*., 2014).

Among the various treatments, Spinosad 45 SC was found to be most effective against rice gall midge, with least of2.41% shoot damage/plant, highest grain yield (45.2 q/ha) and Benefit-Cost (BC) ratio 1:5.63, and maximum Net Profit amount (₹. 20191.00/ha). Flubendiamide 39.35% SC was next best treatment with 3.31shoot/plant, grain yield 43.1 q/ha (Kumar *et al*, 2020)

Moulya *et al*. (2022) evaluated the bio-efficacy of conventional and new insecticides, which were cost-effective and ecologically feasible against the management of sorghum grain midge, *C. sorghicola*. During 15 Days after Spraying (DAS), a lower population (3.45 midges/ear head) was observed in lambda cyhalothrin over newer molecules. Among the insecticide tested, the maximum per cent reduction of sorghum grain midge population was recorded in lambda cyhalothrin over other nsecticides *viz.* fipronil, Spinosad, emamectin benzoate and indoxacarb.

2.1.5 Bioefficacy of newer insecticides against earhead caterpillar

Poul *et al.* (a) *(*2020) investigated the efficacy of seven newer insecticide molecules. For earhead worm, (*Helicoverpa armigera*) lowest number of larvae recorded in the plants treated with chlorantraniliprole 18.5 SC followed by flubendiamde 39.35 SC and emamectin benzoate 5 SG.

Sapkal *et al* (2018) reported chlorantraniliprole 18.5 SC was the most effective against earhead worm at milking stage on sorghum.

Nagre *et al* (2018) found that emamectin benzoate 5 SG @ 3.5g/ 10 lit. of water recorded the lowest earhead worm population (0.82 ear head worm/panicle.

Hakiim *et al* (2012), reported that spinosad has been effective in reducing the number of chickpea larvae *Helicoverpa armigera*. In chickpea, flubendiamide 0.007%, spinosad 0.009% and emamectin benzoate 0.0015% were found to be the most effective in reducing the population of *Helicoverpa armigera* and pod damage (Deshmukh et al, 2018). Yogeeswarudu and Venkata 2014, examine the efficacy of different insecticides. Indoxacarb 14.5 SC @ 0.5 ml was found best with minimum population of *H. armigera* larvae/five plants at first spray among all the treatments. Rashid *et al*. 2003, investigated the effect of insecticides i.e. Chlorpyrifos, (2500ml/ ha), endosulfan (2500ml/ hac), indoxicarb (425 ml gac-1), profenofos (2500ml /ha) and spinosad (200ml/ ha) along with untreated check against gram pod borer (*H. armigera* Hubner). Among the various insecticides tested, Spinosad (Tracer) and Indoxicarb (Steward) were highly effective against gram pod borer.

2.1.6 Bioefficacy of newer insecticides against sucking pests

Surulivelu *et al*. (1998) reported that Imidacloprid seed treatment reduced the jassid populations by 65% in research station studies without affecting predator coccinellids. In farmer participatory trials aimed at area-wide management" of cotton pests during the past two seasons, it reduced jassids by 62-79% and aphids by 66-72% without affecting the predator coccinellids. It also substantially increased plant height (23-30%) up to eight weeks from planting and increased square production (32- 49%) during the initial fruiting period. Further, it helped to eliminate foliar sprays against sucking pests in 19 out of 20 farms for 40-50 days. Fields that did not receive seed treatment, required 1-3 foliar sprays to keep the sucking pests under check.

Patil *et al*. (2003) seed treatment also helped in controlling sucking pests up to 45 days after sowing compared to the untreated control. Among the genotypes, maximum increase in seedling vigor, rate of photosynthesis, stomatal conductance, rate of transpiration was found in DHH-11, followed by DHB105 and least in Sahana. It is inferred that imidacloprid treatment was efficient in increasing the seedling vigor and growth and controlled the incidence of early sucking pests, which improved the physiological and biophysical parameters as compared to untreated treatments.

Bhat & Baba (2007) carried out study at experimental field of faculty of agriculture, wadura, Sopore, SKUAST-K during *kharif* 2006 and 2007 on efficacy of different insecticides against maize stem borer *Chilo partellus* (Swinhoe) and maize aphid *Rhopalosiphum maidis* (Fitch) infesting maize result revealed that whorl application with granular formulations of chlorpyrifos 10 G @0.75 k.ga.i/ha and carbofuran 3G @ 0.3 kg a.i/ha was effective against *C. partellus* as the young larvae before gaining entry into the stem feed on the leaf whorl and get exposed to the insecticide placed in leaf whorls leading to their increased mortality, whereas the foliar applications with imidacloprid and cypermethrin were effective against maize aphid *Rhopalosiphum maidis* (Fitch). These two treatments recorded significantly highest yield than rest of all the treatment applications and resulted in maximum net returns.

Kumar & Prabhuraj (2007) conducted field trial in Karnataka, against shoot fly and shoot bug. The treatment with thiomethoxam 70WS at 2 gm/kg recorded lower infestation of dead heart (7.9%) with less shoot bug population (5.83/5 plant) and higher grain yield (31.93 q/ha) besides, higher fodder yield (56.92 q/ha). Imiadcloprid 70WS at 5 g/ha endosulfan 35EC seed soaking (8hr) at 2 ml/kg and carbosulfan 25 DS at 40g/kg were the next best treatment and were on par with each other.

Sajjan & Praveen (2008) reported that seed treatment with imidacloprid @ 12 ml per kg of seed or thiomethoxam @ 10 g per kg of seed were found effective in controlling leaf hoppers resulted in higher seed yield (642 and 620 kg per ha respectively). Where as foliar spray with fenvalerate @ 0.5 ml per liter was effective in controlling fruit borer infestation which in turn produced higher seed yield (799 kg/ha).

Balikai & Bhagwat (2009) conducted field trial at the Regional Agricultural Research Station, Bijapur and revealed that, four treatments *viz*., intercropping of chickpea (2:2) + seed treatment with thiamethoxam 70 WS @ 3 g/kg seed, seed treatment with thiamethoxam 70 WS @ 3 g/kg seed + spray of NSKE @ 5% at 45 days after emergence of crop (DAE), seed treatment with thiamethoxam 70 WS @ 3 g/kg seed + spray of endosulfan @ 0.07% at 45 DAE and seed treatment with thiamethoxam 70 WS @ 3 g/kg seed alone were effective in reducing the shoot fly, shoot bug and aphid incidence and there by harnessed higher sorghum grain equivalent yield, fodder yield and net returns. Intercropping of sorghum with chickpea (2:2 row proportions) was not a good option from point of insect pest suppression and higher returns.

Balikai (2011) reported that, the seed treatment with thiamethoxam 70 WS @ 3 g/kg seeds proved highly effective. With respect to aphid incidence, three treatments viz., whorl application of carbofuran 3 G @ 8 kg/ha at 35-40 days after sowing (DAS), spray with endosulfan 35 EC @ 0.07% at 35-40 DAS and seed treatment with thiamethoxam 70 WS @ 3 g/kg seeds with low aphid incidence of 9.3, 10.2 and 10.2 per cent aphid index, respectively were highly effective and significantly superior over rest of the treatments.

Deshmukh *et al*. (2018) reported the first time FAW causing severe damage on maize. that the effective insecticides were chlorantraniliprole 18.5 SC, followed by emamectin benzoate 5 SG, spinetoram 11.7 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, lambda cyhalothrin 5 EC, and novaluron 10 EC. Higher efficacy also was correlated with higher grain yield in comparison with the control. Chlorantraniliprole, emamectin benzoate, and spinetoram are suitable as one of the components of Integrated Pest Management of fall armyworm in India.

Hemadri *et al*. (2018) stated that application of imidacloprid 17.8 SL @ 0.5 ml/l was found superior over the other treatments with higher per cent reduction (85.21 per cent) of pest population, followed by acetamiprid 20 SP @ 0.5 g/l, thiamethoxam 25 WG @ 0.3 g/l, acephate 95 SG @ 0.3 g/l, clothianidin 50 WDG @ 0.25 g/l which recorded 84.21, 83.41, 77.48, 74.62 per cent reduction of pest population, respectively. The next insecticides which proven better were cyantraniliprole 10.26 OD @ 1 ml/l, oxydemeton methyl 25 EC @ 1.5 ml/l, imidacloprid 17.8 SL seed coating @ 4:20 ml/kg and thiamethoxam 25 WG seed coating @ 2:20 ml/kg which registered 60.25, 31.40, 22.14 and 17.23 per cent reduction, respectively.

Karabhantanal *et al*. (2018) conducted field experiment during *rabi*, 2015-16 at the Regional Agricultural Research Station, Vijayapur, Karnataka, India conducted different treatments on Phule yashoda variety seeds treated with imidacloprid 70 WS @ 3 g/kg seed followed by spraying of NSKE @ 5% at 45 days after emergence (DAE) was found to be best module as it recorded significantly lowest shoot fly dead hearts (6.74%), aphids (13.85/sq cm) and shoot bugs (8.63/plant) and was on par with other module comprising of intercropping with legume (4 rows of chickpea: 2 rows of sorghum) + seed treatment with imidacloprid 70 WS @ 3 g/kg seed. Further, highest yield (26.60 q/ha) was harvested from Phule yashoda variety with seed treatment of imidacloprid 70 WS @ 3 g/kg seed + spray of NSKE @ 5% at 45 DAE and was at par with Phule yashoda with seed treatment with potassium iodide + thiamethoxam 70 WS @ 3 g/kg (25.60 q/ha).

Kharade *et al*. (2018) reported that imidacloprid 0.0044 per cent was found most effective treatment in reducing the population of jassid (1.03 jassids/3 leaves) and whitefly (1.32 whiteflies/3 leaves) respectively. Followed by dimethoate 0.04 per cent which was found to be statistically at par with chlorantraniliprole 0.0074 per cent.

Potai *et al*. (2018) conducted Field experiment to evaluate the efficacy of some new insecticides against sucking insect pest's *viz*., leafhopper, aphid, Thrips and whitefly in okra. Two sprays of different insecticides viz., BAS 450 01 I 300 SC, Chlorantraniliprole 18.5% SC, Cypermethrin 10% EC, at three different concentrations of BAS 450 01 I 300 SC@ 18.5, 12.5 and 6.5 g.a.i./ha were made at 1,3,5,7 and 10 days interval. All the treatments registered significantly lower population of sucking pests as compared to untreated control. BAS 450 01 I 300 SC@18.5 g.a.i./ha proved the best treatment for the control of the sucking pest, however, treatments viz., BAS 450 01 I 300 SC@ 12.5 g.a.i./h and Chlorantraniliprole 18.5% SC @ 25 g.a.i./ha were also observed to be effective treatments in most of the observations.

Javalage *et al.* (2019) reported that the Imidacloprid 17.8 SL were most effective against management of sucking pests such as aphid, jassids and thrips population. Whereas, fipronil 5 SC and acephate 75 SP were equally reduced the aphids population. Thiamethoxam 25 WG, dimethoate 30 EC and trizophos 40 EC were superior against white flies. Imidacloprid 17.8 SL, acetamiprid 20 SP and thiamethoxam 25 WG not only proved to be effective against jassids but also did not showed its adverse effects on the population of lady bird beetle adult and grubs, Chrysopa larvae and spiders at 10 DAT. Imidacloprid 17.8 SL followed by acephate 95 SG and 75 SP was obtained highest seed cotton yield recorded highest ICBR (1: 14.13), indicating most cost effective treatment.

Bhamare *et al.* (2021) results concluded that all the insecticides under investigation were significantly superior over untreated control in minimizing the population of *E. kerri*. Among the treatments, profenophos 0.100 per cent was found to be the most effective insecticide in minimizing the population of *E. kerri* on soybean (3.83 and 2.60 jassids per three leaves) followed by quinalphos 0.050 per cent (4.03 and 2.90 jassids per three leaves), triazophos 0.050 per cent (4.47 and 3.50 jassids per three leaves), chlorantraniliprole 0.004 per cent (5.03 and 3.60 jassids per three leaves), indoxacarb 0.010 per cent (7.20 and 5.00 jassids per three leaves), emamectin benzoate 0.001 per cent (7.40 and 5.40 jassids per three leaves) and ethion 0.100 per cent (7.67 and 5.50 jassids per three leaves) after first and second sprays, respectively. The highest grain yield was achieved by chlorantraniliprole 0.004 per cent (34.87 q per ha) while quinalphos 0.050 per cent (1:19.72) exhibited highest incremental cost benefit ratio.

2.1.7 Effect of different insecticides against natural enemies

Nemade *et al*. (2009) stated that imidacloprid seed treatments were found most safer for natural enemies of *Earias vittella* in okra field. Among the foliar spray endosulfan spray was safe to natural enemies whereas fenvalerate was found most toxic. Foliar spray of imidacloprid was found safer to spiders but proved least safer to other natural enemies.

Mollah *et al.* (2012) evaluated the effect of some insecticides on the abundance and mortality of predacious lady bird beetles in country bean; Lablab purpureus L. ecosystem. Among the insecticides, Neem oil (fresh) @ 2.5 ml / L water, Curtap 50 SP @ 2.0 g / L water and Emamectin benzoate 5 SG @ 1.0 g / L water ensure highest number of lady bird beetle in the treated plot resulting 22.45, 17.97 and 15.63 adult lady bird beetles per plot area respectively. On the contrary, lowest number of lady bird beetle was found in Fenvalerate 20 EC @ 1 ml / L water, Cypermethrin 10 EC @ 1.0 ml / L water and Esfenvalerate 5 EC @ 1.0 ml / L water treated plots resulting 10.67, 11.43 and 12.72 adult lady bird beetle per plot area respectively. Neemoil (fresh) @ 2.5 ml / L water, Neemoil (stored) @ 2.5 ml / L water and Emamectin benzoate 5 SG @ 1.0 g / L water found least toxic to lady bird beetles confirming 9.37, 17.45 and 19.04 % mortality respectively. fenvalerate 5 EC @ 1.0 ml / L water, Cypermethrin 10 EC @ 1.0 ml / L water and Deltramethrin 2.5 EC @ 1.0 ml / L water found highly toxic to lady bird beetle resulting 33.78, 31.76 and 28.42 % mortality respectively.

Hossain *et al.* (2013) observed activity of natural enemies, such as ladybird beetle, lacewing, syrphid, and spider population on the sucking pests attacking cotton cultivar CB9 and yield of cotton were recorded. Ladybird beetles, lacewings, syrphids, and spiders were abundant in the field but their population decreased in the treated plots compared to untreated control. The CB9 cotton cultivar produced significantly higher yield (1.73 t/ha) with a benefit cost ratio 12.47 when seeds were treated with Imidacloprid at 5.5 g/kg fuzzy seed. This study indicated that Imidacloprid (Gaucho 70 WS) used as a seed treatment may be suggested to the cotton growers for controlling sucking pests.

Chavan *et al*. (2016) stated that no population of lady bird beetle was recorded at 3rd DAS in treatment imidacloprid 17.8 SL which was found more toxic to coccinellid than all other insecticidal treatments. After second spray minimum population of ladybird beetle was recorded in treatment fipronil 5 SC (0.13/plant) which was found more toxic to coccinellids. After third spraying no population of lady bird beetle was recorded at 3rd day in treatment imidacloprid 17.8 SL and clothianidin 50 WDG. Survival population of spider recorded after first spraying revealed that no population of spiders was recorded at 3rd DAS in treatment fipronil 5 SC. Population of spiders recorded after second spraying minimum population of spiders was recorded in treatment difenthiuron 50 WP (0.20/plant). Population of spiders recorded after third spraying revealed that the minimum population of spiders was recorded in treatment fipronil 5 SC (0.07/plant) and which was found much toxic to spider than all other insecticidal treatments.

Kaushik *et al.* (2016) reported that all the treatments exerted significant impact on the populations of natural enemies (coccinellids, syrphid flies and spiders). However, thiamethoxam 30 FS was found to be relatively safe insecticide against these natural enemies. Combinations (seed treatment with thiamethoxam 70 WS + spray with imidacloprid 17.8 SL, seed treatment with thiamethoxam 30 FS + spray with imidacloprid 17.8 SL, seed treatment with imidacloprid 17.8 SL + spray with thiamethoxam 30 FS), imidacloprid 17.8 SL and spinosad 45 EC were moderate toxic while quinalphos 25 EC was the most toxic for the same. Thus, thiamethoxam, imidacloprid or their combinations as seed treatment and spray, and spinosad can be used in cowpea ecosystem for better pest management as they are less toxic for natural enemies.

Selvaraj *et al.* (2017) stated that the new formulation was found to be safer to spiders and coccinellids at all concentrations tested. The highest population was recorded in plots treated with Cholrantraniliprole 4.3% + Abamectin 1.7% SC @ 24 g a.i. ha^{-1} followed by Cholrantraniliprole 4.3% + Abamectin 1.7% SC @ 30 g a.i. ha-1 . The present findings revealed that natural enemy population was noticeably lower up to 5 days after application of insecticides. Thereafter, the natural enemy populations had gradually increased from chlorantraniliprole+abamectin treated plots at different doses during both the years.

Sumalatha *et al.* (2017) studied insecticidal treatment of flonicamid 50 SG @ 75 g a.i ha-1 and spinosad 45 SC @ 73 g a.i ha^{-1} were found promising regarding its safety to predators. The highest bulb yield was recorded in spinosad 45 SC @ 73 g a.i ha-1 (18.03 t/ha) treated plots followed by fipronil 5 SC @ 50 g. a.i. ha-1 (16.78 t/ha), indicating the significance of thrips management in *Kharif* onion.

Bisht (2018) reported that two foliar applications of various treatments were given and it was observed that the population of spiders was higher in control plot ranging between 1.0 to 2.64 per plant after first spray while the population range was observed 1.0 to 2.34 after second spray. Immediately after application the treatment had clearly reduced the pest population and favored the spider population, subsequently the population kept decreasing with time.

Potai *et al*. (2018) revealed that chemical treatments with BAS 450 01 I 300 SC@12.5g.a.i./ha and BAS 450 01 I 300 SC@18.5g.a.i./ha found to be safer insecticides to natural enemies. While the molecules namely, Cypermethrin 10% EC@70g.a.i./ha were moderately safer to natural enemies while Chlorantraniliprole 18.5% SC@25g.a.i./ha was highly toxic which need to be avoided its usage in okra ecosystem.

Kumar (2018) reported that the root treatment done with Imidaclorprid 70 WS solution @ 3 g/L of water for 30 minutes followed by one spray with Imidaclorprid 17.8 SL@ 0.3 ml/L and second spray with Dimethoate 30 EC @1.5ml/L water was more effective in reduction of whitefly population to obtain higher fruit yield of tomato than by seed treatment done with Imidaclorprid 70 WS @ 3g/kg of seed and 2 sprays done with Dimethoate 30 EC @1.5ml/L water. Both the insecticides showed no or minimum suppression of coccinellid & spider population.

Humane *et al*. (2019) reported that control plot contains more number of natural enemies and proved significantly superior overall treated plots followed by chlorantraniliprole 18.5% SC and cyantraniliprole 10% OD. Likewise, cartap hydrochloride 75% SG also better than emamectin benzoate 5% SG and flubendiamide 39.36% SC found less toxic to natural enemies.

Khandare *et al*. (2019 recorded highest population of Ladybird beetles on untreated control and amongst the treatments, seed treatments with imidacloprid 70 WS at 10 g/kg recorded comparatively higher population of ladybird beetles i.e. 0.47 per plant. This was followed by treatments with acephate 50 + imidacloprid 1.8 SP @ 1:20, clothianidin 50 WDG @ 1:20, clothianidin 50 WDG @ 1:10 and imidacloprid 48 FS @ 1:20. The all treatment insecticides application by stem smearing of and seed treatment is found safer for maintain population of ladybird beetle in cotton ecosystem.

Singh *et al*. (2020) recorded the maximum pooled population of spiders was recorded in untreated control with 2.00 and 3.83 spiders per five plants and followed by *Bacillus thuringiensis* @ 2.0 gm per liter of water, neem oil (1500 ppm) @ 5.0 ml per litre of water, Emamectin benzoate 5% SG @ 0.5 gm per liter of water, Indoxacarb 14.5 SC@ 1.0 ml per liter of water, spinosad 45% SC @ 0.3 ml per liter of water, Profenophos 50EC @ 2.0ml per liter of water, Lambda- cyhalothrin @

1.0 per liter of water and Quinalphos 20EC @ 2.0 ml per of water plants, respectively. The most harmful treatment was Quinalphos 20EC @ 2.0 ml per of water with spiders population of 2.67, 2.33, 2.17, 1.83, 1.67 0.67, 0.33 and 0.50 spiders per five plants, respectively. After seven days of spray the minimum population of spiders was found in treatment Quinalphos 20EC @ 2.0 ml per of water plants water with 0.50 spiders per five plants. the maximum adults population of spiders was recorded with *Bacillus thuringiensis* @ 2.0 gm per liter of water, neem oil (1500 ppm) @ 5.0 ml per litre of water, Emamectin benzoate 5% SG @ 0.5 gm per liter of water, Indoxacarb 14.5 SC@ 1.0 ml per liter of water, spinosad 45% SC @ 0.3 ml per liter of water, Profenophos 50EC @ 2.0ml per liter of water, Lambda- cyhalothrin @ 1.0 per liter of water and Quinalphos 20EC @ 2.0 ml per of water plants, respectively. The lowest population was recorded in the treatment Quinalphos 20EC @ 2.0 ml per of water. The treatments, *Bacillus thuringiensis* @ 2.0 gm per liter of water and neem oil (1500 ppm) @ 5.00 ml per liter water were found safe against spiders population.

Ingle *et al.* (2021) evaluated the effect of conventional and newer insecticides *viz*., carbofuran 3%G @ 750 g a.i./ ha, thiamethoxam 25%WG @ 25 g a.i./ ha, fipronil 5%SC @ 50 g a.i./ ha, lambda-cyhalothrin 5%EC @ 20 g a.i./ ha, neem (Azadirachtin 0.15%EC) @ 4 ml/ l., flubendiamide 20%WG @ 25 g a.i./ ha, chlorantraniliprole 18.5%SC @ 30 g a.i./ ha, acetamiprid 20%SP @ 35 g a.i./ ha, dinotefuran 20%SG @ 40 g a.i./ ha and pymetrozine 50%WG @ 7.5 g a.i./ ha on spiders inhabitants of rice system. Except lambda-cyhalothrin 5%SP nearly all the insecticidal treatments showed slight effects against the spiders occurring in rice ecosystem. The results revealed that flubendiamide 20%WG @ 25 g a.i./ ha was the least toxic, allowing maximum occurrence of spiders (excluding untreated control). Thus, it can be considered in IPM for the best control of insect pests. Similarly, chlorantraniliprole 18.5%SC @ 30 g a.i./ ha followed by fipronil 5%SC @ 50 g a.i./ha were also found safe to spiders.

2.2 To study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum

Horowitz *et al.* (1998) studied comparative bioassays of acetamiprid and imidacloprid, against the whitefly *Bemisia tabaci* (Gennadius), in cotton using foliar and systemic applications under laboratory conditions and in field trials. Adult whiteflies were slightly more sensitive to imidacloprid than acetamiprid, resulting in LC_{50} of 0.7 and 1.6mg a.i./l and LC_{90} of 4.5 and 12.8 mg a.i./*l* respectively. Under controlled conditions, acetamiprid was 10 and 18fold more potent than imidacloprid. The residual activity of acetamiprid on whitefly adult was higher than imidacloprid with 96% mortality after 3 days and 60% mortality at 17 days after treatment. The imidacloprid foliar treatment was inferior and gave 76, 56 and 25% mortality on 3, 10 and 17 days respectively. Field residual activity of acetamiprid to whitefly lasted for approximately 10 days, compared with 3 days for imidacloprid.

Nair *et al.* (2007) studied the relative toxicity of six insecticides to third instar larvae of *Spilarctia obliqua* (Wlk) in the laboratory condition. On the basis of LC_{50} values (% ai), the descending order of toxicity was: emamectin benzoate 5 SG (0.00005), cypermethrin 10 AF (0.00013), indoxacarb 14.5 SC (0.00053), endosulfan 35 EC (0.00323), fenvalerate 20 EC (0.00340) and fenpropathrin 30 EC (0.00513). Considering the LC_{50} value of fenpropathrin 30 EC as unity (being least toxic), fenvalerate 20 EC, endosulfan 35 EC, indoxacarb 14.5 SC, cypermethrin 10 AF and emamectin benzoate 5 SG were 1.51, 1.59, 9.68, 39.46 and 102.6 times, respectively, more toxic than fenpropathrin 30 EC.

Khalequzzaman & Jesmun Nahar (2008) evaluated cypermethrin, imidacloprid and azadirachtin against four important crop infesting aphid species, *Aphis craccivora* Koch, *Aphis gossypii* Glover, *Myzus persicae* (Sulzer) and *Lipaphis erysimi* (Kaltenbach), reared on bean, brinjal, potato and cauliflower plants respectively using residual film technique in the laboratory. Malathion was the least toxic to all aphids having LC_{50} as 327.97, 333.92, 305.26 and 313.77 µg cm^{-2} for *A. craccivora, A. gossypii, M. persicae and M. persicae* respectively. Cypermethrin was the most toxic showing LC_{50} as 12.55, 12.29, 12.55 and 12.10 µg cm-2 in the above mentioned species of aphid respectively. Carbosulfan and imidacloprid showed moderate toxicity. Azadirachtin as a natural plant origin insecticide proved to be the most toxic having LC_{50} as 0.41 µg cm^{-2} for *A. craccivora*, 0.34 µg cm^{-2} for *A. gossypii* and 0.44 µg cm^{-2} for both *M. persicae* and *L. erysimi*.

Preetha *et al.* (2009) studied the persistent toxicity of commercial formulations of imidacloprid 17.8 SL, thiamethoxam 25 WG and methyl demeton 25 EC was estimated against *Aphis gossypii* and *Amrasca biguttuala* on bhendi crop. The insecticidal treatments differed considerably in their persistence, period of efficacy and index of persistent toxicity (PT value) against both the insects. Of different treatments, the higher dose of imidacloprid showed longest persistence up to 27 days for aphids and 29 days for leaf hoppers. This was followed by recommended dose of imidacloprid and thiamethoxam irrespective of the insect species. The conventional insecticide methyl demeton showed shorter persistence for a period of 13 and 17 days against aphids and leafhoppers, respectively.

Sabahi *et al.* (2010) evaluated the toxicity of three insecticides to *Lysiphlebus fabarum* (Marshall) a parasitoid of *Aphis fabae* Scopoli. Abamectin 1.8 EC, imidacloprid 350 SC, and pymetrozine 25 WP were tested under laboratory conditions at recommended field rates. Abamectin, imidacloprid, and pymetrozine caused 44.8, 58.5, and 14.5% mortality of mummies, respectively. One day old residues of abamectin, imidacloprid, and pymetrozine produced 52.5, 90.0 and 57.0% mortality, respectively, and 5 day old residues produced 28.1, 77.0 and 18.6% mortality. Sixteen day old residues produced 8.8, 22.4 and 13.6% mortality, whereas 30 day-old residues produced 0.0, 3.2 and 1.1% mortality respectively.

Shinde *et al*. (2011) reported that the highest persistent toxicity to first and third instar nymphs of *A. gosssypii* in terms of PT values to the extent of 489.65 and 425.6 was observed due to the application of cypermethrin 0.01 and imidacloprid 0.004 per cent, respectively. Highest PT values were recorded due to imidacloprid 0.004 per cent (431.55) for first instar and cypermethrin 0.01 per cent (370.3) for third instar nymphs of *A. gossypii*. On the basis of LT_{50} values cypermethrin 0.01 per cent and imidacloprid 0.004 per cent persisted in biologically active stage to the highest extent of 2.98 and 2.41 days against first and third instar nymphs of *A. gossypii*, respectively.

Anjumoni & Aalh (2012) studied efficacy, relative toxicity, residual toxicity and dissipation behaviour of imidacloprid and bifenthrin were evaluated against mustard aphid *Lipaphis erysimi* (Kalt.) during 2006-07 and 2007-08. The highest mortality of aphids and marketable yield was registered by imidacloprid @ 60 g ai/ha, while highest cost benefit ratio was found in imidacloprid @ 20 g ai/ha and proved sufficient to optimize the yield. The LC_{50} values were 0.00017 and 0.00015 for imidacloprid, 0.00152 and 0.00122 for bifenthrin, 0.00199 and 0.00134 for deltamethrin, after 24 and 48 hr of treatment, respectively.

Ghadage *et al.* (2012) conducted investigation on chemical control of jassid, *Empoasca kerri* Pruthi on coriander Cv. Gujarat Coriander-2 during *Rabi* 2007. The results revealed that the treatments with methyl-o-demeton 0.03 per cent, dimethoate 0.03 per cent, endosulfan 0.07 per cent and imidacloprid 0.005 per cent were proved to be the most effective against the pest followed by acetamiprid 0.004 per cent, polytrin-C 0.044 per cent, profenofos 0.05 per cent and phosalone 0.07 per cent. Methyl-o-demeton 0.03 per cent gave the higher yield of 438.31 kg/ha, while, dimethoate 0.03 per cent was the most economic treatment with the highest cost benefit ratio (1:28.47).

Shreevani *et al.* (2012) investigated the toxicity of nine insecticides, i.e. thiamethoxam 25 WDG at 0.2 g/l, acetamiprid 20 SP at 0.2 g/l, pyriproxyfen 10 EC at 1.0 ml/l, acephate 75 SP at 1.0 g/l, clothianidin 50 WDG at 0.12 g/l, oxydemeton-methyl 25 EC at 1.5 ml/l, imidacloprid 17.8 SL at 0.3 ml/l, dimethoate 30 EC at 1.75 ml/l and lambda-cyhalothrin 5 EC at 0.5 ml/l, to third nymphal instars of *A. biguttula biguttula* was assessed on *Bt cotton* under laboratory conditions. Mortality data were recorded at 24, 48, 72 and 96 hr after spraying. Percentage mortality of the leaf hopper was maximum (50.67%) in thiamethoxam with non-significant difference with imidacloprid (46.67%). Clothianidin was the next best treatment. The cumulative toxic effect at 48 hr after spraying was highest for thiamethoxam (82.67%) and imidacloprid (80.00%). This was followed by clothianidin and lambda-cyhalothrin. Such toxic effects were persistent even at 72 and 96 hr after application. Observations pertaining to best treatments for nymphal mortality at 24, 48, 72 and 96 hr after treatment were subjected to probit analysis. Thiamethoxam was the most toxic to the third instar nymphs of the leaf hopper, with LC_{50} value of 0.001%. The next best insecticide was imidacloprid with LC_{50} value of 0.007% and clothianidin with LC_{50} value of 0.041%.

Abd-Ella (2013) reported the strain of cowpea aphid, *Aphis craccivora* Koch, was treated by selected neonicotinoid insecticides to evaluate their toxicity and persistence against this pest in Assiut governorate, Egypt. Under faba bean field conditions, acetamiprid, imidacloprid, thiamethoxam and dinotefuran registered significantly high percent reduction of the pest at one, seven, fifteen and 21 post treatment. The residual effects of these insecticides showed that the LT_{50} for acetamiprid, imidacloprid, thiamethoxam and dinotefuran were 5.8, 6.2, 6.95 and 4.2 days, respectively. The toxicity of these neonicotinide insecticides were tested against field strain of cowpea aphids using leaf-dib bioassay under field and laboratory conditions. The toxicity index showed that thiamethoxam, acetamiprid and imidacloprid have the highest aphicidal activity, with LC_{50} 0.60, 0.71 and 1.16 mg/L, respectively, while dinotefuran was the least toxic one with LC_{50} 23.41 mg/L. Results of this study indicated that neonicotinoid insecticides were highly effective against cowpea aphid under field and laboratory conditions.

Awasthi *et al.* (2013) conducted experiments in the laboratory to evaluate relative toxicity of six insecticides, *viz*., Spinosad 45 SC, Indoxacarb 15.8 EC, Emamectin benzoate 5 SG, Acephate 75 SP, Acetamiprid 20 SP and Imidacloprid 17.8 SL against cotton aphid *Aphis gossypii* Glover and different stages of predatory coccinellids. On the basis of LC_{50} values, acetamiprid was the most toxic whereas; spinosad was the least toxic insecticide to cotton aphid. The order of relative toxicity of insecticides over spinosad was acetamiprid >acephate> imidacloprid >emamectin benzoate > indoxacarb, with their relative toxicity values being 82.28, 23.04, 16.18, 1.57 and 1.45, respectively.

Ghosal *et al.* (2013) conducted experiment to observe the efficacy of some neonicotinoids against aphid of okra during pre- *kharif* season of 2010 and 2011 at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya. Imidacloprid 17.8 SL @ 50 g a.i. ha^{-1} was found as a most effective neonicotinoid insecticide against aphid. It recorded least aphid infestation and 84.54 % reduction of population over control. To control aphid population of okra the other two neonicotinoids viz., thiamethoxam 25WG @ 50 g a.i. ha^{-1} and acetamiprid 20SP @ 40 g a.i. ha^{-1} were also found at par with imidacloprid and showed better result than acephate 75WP and dimethoate 30EC.

Rouhani *et al.* (2013) evaluated imidacloprid, thiamethoxam, thiacloprid and flonicamid against *A.punicae* under controlled conditions. The LC_{50} value for imidacloprid, thiamethoxam, thiacloprid and flonicamid were calculated: 0.24 µl/ml, 0.31mg/ml, 0.48 µl/ml and 0.05 mg/ml, respectively. Probit analysis data revealed that the sensitivity of the insects to the pesticides was imidacloprid > thiacloprid >flonicamid> thiamethoxam. The results showed that imidacloprid and thiacloprid at 1 µl/ml, thiamethoxam at 0.35 mg/ml and flonicamid at 0.1 mg/ml had the highest mortality.

Chandra *et al.* (2014) experiment was conducted during 2008-09 and 2009-10 for determining the efficacy and economics of newer insecticides for the management of mustard aphid (*Lipaphis erysimi* Kaltenbach) on Indian mustard (*Brassica juncea* (L.) Lower aphid intensity of 7.2 and 8.2 aphids/plant were recorded with imidacloprid 17.8 SL treatment, which produced highest seed yield of 2487 and 2377 kg/ha during first and second year, respectively. Application of dimethoate 30 EC was second best treatment with 8.7 and 9.7aphids plant providing seed yield of 2377 and 2353 kg ha^{-1} in the respective years. Maximum net return of ` 30425 ha^{-1} and cost: benefit ratio of 1:15.7 was gained from the application of imidacloprid 17.8 SL, followed by INMR of 28714 ha^{-1} and cost: benefit ratio of 1:14.8 from dimethoate 30 EC treated mustard crop. The ranking of insecticides for the management of aphid was imidacloprid 17.8 SL < acetamiprid 20 SP <dimethoare 30 EC <thiomethoxam 25 WG < clothianidin 50 WDG < fipronil 5 <Spind 45 SC.

Das & Islam (2014) conducted experiments in winter season with brinjal to evaluate the efficacy of some new generation insecticides against two important sucking insects, *Amrasca devastans* (jassid) and *Bemicia tabaci* (white fly). Four newer insecticides (fipronil, imidacloprid, buprofezin and thiamethoxam + emamectin benzoate) were selected from different groups with different mode of action to evaluate their comparative potency. Among four, fipronil, imidacloprid and buprofezin were found to be most effective while thiamethoxam + emamectin benzoate was least effective. At 1 day after treatment application, the mortality was significantly increased in the plots those were treated with fipronil and imidacloprid although the maximum mortality was recorded from 3 days which persisted up to day 7. Imidacloprid, fipronil and buprofezin proved to be the superior against jassids or white flies while thiamethoxam + emamectin benzoate was moderately effective against white fly but almost ineffective against jassids in their time-oriented mortality.

Kolhe *et al.* (2015) studied persistence and residual toxicity of different insecticides against Groundnut jassids, *Empoasca kerri* Pruthi and found that the highest persistence toxicity was exhibited by imidacloprid 0.003 per cent to the nymphs and adults of *E.kerri* in term of PT values to the extent of 1459.63, 1431.49 and 1382.47, 1283.94 at first and second spray, respectively. On the basis of LT_{50} values imidacloprid 0.003 per cent persisted in biologically active stage to the highest extent of 9.26, 8.77 and 6.83, 9.73 days against nymph and adult of *Empoasca kerri* at first and second spray, respectively. Imidacloprid 0.003 per cent concentration showed comparatively higher percentage mortality and residual toxicity against nymph and adult of *Empoasca kerri*.

Shaikh *et al.* (2015) studied the efficacy and relative persistency of different insecticides under field as well as labrarotary condition. Among them cypermethrin (0.025%) emerged as most effective by recording significantly higher thrips *thrips tabaci* L. on onion mortality and bulb yield followed by profenofos (0.05%). Economics of various insecticides showed that acetamiprid (0.004%) registered the highest cost benefit ratio and found effective and most economical treatment whereas, spinosad (0.014%) and difenthiuron (0.1%), showed comparatively low cost: benefit ratio. All the insecticides under investigation gave complete control up to 6 days and then after the effect were decreased with increase in time. However, profenofos (0.05%), chlorpyriphos (0.05%) and spinosad (0.014%) showed longer persistence up to 14 days.

Roy *et al.* (2016) evaluated the highest aphid mortalities were recorded in case of flonicamid (90.5%) followedby imidacloprid (90.2%), thiacloprid (89.3%) and pyriproxyfen (88.2%), where, flonicamid followed by pyriproxyfen, imidacloprid and thiacloprid registered 77.3%, 69.5%, 67.6% and 64.5% mortality of aphid population respectively at 19 days after first spray. After the second spray, flonicamid (97.6%, 98.2% and 91.8% reduction) followed by pyriproxyfen (94.2%, 95.1% and 84.5% reduction) and imidacloprid (93.1%, 89.7% and 80.1% reduction) found superior even after 10, 14 and 19 days respectively. Flonicamid followed by pyriproxyfen found very soft against *Coccinella septempunctata* (8.4-10.0% and 9.1-12.3% reduction) and *Episyrphus baltiatus* (5.2-8.4% and 6.8-10.0% reduction) in contrast to neonicotinoids (13.7-30.3% reduction) and organophosphates (18.1-41.7% reduction).

Sonune & Bhamare (2016) studied residual toxicity of seven label recommended insecticides *viz.*, quinalphos at the rate of 0.070 per cent, indoxacarb at the rate of 0.0105 per cent, emamectin benzoate at the rate of 0.0022 per cent, spinosad at the rate of 0.0070 per cent, flubendiamide at the rate of 0.0070 per cent, chlorantraniliprole at the rate of 0.0055 per cent and azadirachtin at the rate of 0.00015 per cent against first instar larvae *Helicoverpa armigera* (Hubner) infesting pigeonpea. Emamectin benzoate at the rate of 0.0022 per cent revealed the highest (PT) value of (925.08, 920.52 and 898.60) and LT_{50} values (7.63, 7.52 and 7.27)days against first instar larvae of pod borer after first, second and third spray, respectively as compared to the other insecticides.

Begum *et al.* (2017) determined the residual toxicity of oxydemeton methyl dimethoate and that of fenetrothion were evaluated on the basis of PT index and LT_{50} values against grubs and adults of *Coceinella septempunctata* L. predating on aphid infesting rapeseed crop variety Binasharisha-9 during 2008-2009. It was found that dimethoate was relatively less toxic than corresponding formulation of oxydemeton methyl to all the stages of the beetles.

Patil *et al.* (2018) demonstrated the persistent toxicity of commercial formulations of seven selected insecticides was conducted against cowpea aphid *A. craccivora*, using pot culture in the green house of Department of Entomology, College of Agriculture, Rajendranagar, and PJTSAU. Of different treatments, highest persistence was shown by the imidacloprid (19 and 20 days) followed by acetamiprid (15 and 16 days) > dimethoate (13 and 14 days) > thiamethoxam (11 and 19 days) >diafenthiuron, spiromesifen and chlorfenapyr (9 days each and 10 days each) at 24 and 48 hours of exposure, respectively. The PT (product of toxicity) of test insecticides were in the order: Imidacloprid, acetamiprid, dimethoate, thiamethoxam, diafenthiuron, spiromesifen and chlorfenapyr at 24 and 48 hours, respectively, which indicated that imidacloprid was more persistent followed by acetamiprid and dimethoate than the remaining insecticides.

Dake *et al*. (2019) studied bio-efficacy, persistence and residual toxicity of different newer insecticides against aphids on sunflower The residual toxicity of seven label recommended insecticides *viz*., Imidacloprid 0.003 per cent, spinosad 0.007 per cent, indoxacarb 0.05 per cent, chlorantraniliprole 0.005 per cent, emamectin benzoate 0.002 per cent, fenpropathrin 0.01 per cent and flubendiamide 0.007 per cent was evaluated against aphids *Aphis gossipii* (Glover) infesting sunflower. Imidacloprid 0.003 per cent revealed the highest persistent toxicity index (PT) value of (889.63 and 877.80) and LT_{50} values 6.62 and 6.44 days against aphids *A. Gossypii*. (Glover) after first and second spray, respectively as compared to the other insecticides.

Routray & Misra (2019) conducted experiments to study the persistence toxicity of Thiamethoxam 25 WDG (@20g, 25g, 30g and 35g a.i./ha), Imidacloprid 17.8% SL and Dimethoate 30%EC against adult apterous black legume aphids in cowpea as foliar spray. After 24 hr of exposure, Thiamethoxam persisted for 11, 15, 15 and 23 days when applied at dosages of 20 g a.i., 25 g a.i., 30 g a.i. and 35g a.i./ ha respectively. Imidacloprid and Dimethoate persisted for 21 and 13 days when applied at 25 ml a.i. and 300 ml a.i./ha respectively. After 48 hr of exposure, Thiamethoxam persisted for 14, 16, 16 and 24 days when applied at dosages of 20g a.i., 25g a.i., 30g a.i. and 35g a.i./ha respectively. Imidacloprid and Dimethoate persisted for 22 and 14 days when applied at 25 ml a.i. and 300 ml a.i./ha respectively. The median lethal time (LT_{50}) was least in Thiamethoxam @20g a.i./ha (4.74 days) followed by Dimethoate @300ml a.i./ha (6.69 days), Thiamethoxam @25g a.i./ha (6.79 days), Imidacloprid @25ml a.i./ha (7.83 days), Thiamethoxam @30g a.i./ha (8.12 days) and Thiamethoxam @35g a.i./ha (9.02 days).

Bhamare *et al.* (2020) determined persistence and residual toxicity of different insecticides *viz*., chlorantraniliprole 0.004 per cent, ethion 0.100 per cent, triazophos 0.050 per cent, indoxacarb 0.010 per cent, emamectin benzoate 0.001 per cent, quinalphos 0.050 per cent and profenophos 0.100 per cent against *Spodoptera litura* (Fabricius) infesting soybean. The results on residual toxicity of different insecticides against *S. litura* infesting soybean indicated that chlorantraniliprole 0.004 per cent and emamectin benzoate 0.001 per cent had highest persistent toxicity index (PT) (913.01 and 860.89, respectively) and LT_{50} values (7.59 and 6.69, respectively) against early instar larvae of *S. litura* after spray as compared to the other insecticides.

Kumar *et al.* (2020) evaluated the bio-efficacy and economics of thirteen botanicals insecticides against mustard aphid, *Lipaphis erysimi* Kalt. of Indian mustard. The per cent aphid reduction over control after seven days of application was found to be maximum (93.2 %) in Dimethoate 30 EC @ 625 ml/ha followed by Azadirachtin 10000 ppm @ 1.0 ml per litre of water (81.6%), Azadirachtin 1500 ppm @ 1.0 ml per litre of water (78.49%), neem oil 3% (76.4%) and neem seed kernel extract (NSKE) 5% (71.4%). The highest BCR (1:7.6) was obtained from treatment Dimethoate 30 EC followed by Azadirachtin 1500 ppm (1:5.4), Azadirachtin 10000 ppm (1:4.1) and NSKE 5% (1:3.1). Therefore, Azadirachtin 1500 ppm @ 1.0 ml per litre of water may be recommended as most economical, and ecofriendly alternative to chemical insecticides for the management of mustard aphid.

Ramana *et al.* (2020) conducted experiment to evaluate the persistent toxicity of insecticides *viz*., methyl-o-demeton, spinosad, acetamiprid, chlorfenapyr, and fipronil against neonate mustard aphid, *Lipaphis erysimi*. Mean aphid mortality of mustard aphid revealed that methyl-o-demeton (0.03%) exerted superior mortality (93.75%) after 1 hour of spraying but acetamiprid was the most effective insecticide after one, three, seven and ten days of spraying. Fipronil and chlorfenapyr were at par with methyl-o-demeton (0.03%). Whereas, spinosad was the least effective insecticide. Mean aphid mortality on twigs has also revealed that acetamiprid was the most promising insecticide. Based on persistence toxicity values the order of persistent toxicity (PT) was acetamiprid (612.9) > methyl-o-demeton (593.8) > fipronil (530.4) >chlorfenapyr (482.8) >spinosad (459.2).

Sreedhar (2020) reported per cent mortality of aphids within 4 days in flupyradifurone, sulfoxaflor and flonicamid whereas 8 days for rest of the treatments except thiamethoxam. Higher yield parameters were recorded in flupyradifurone, sulfoxaflor and flonicamid. Studies on persistent residual toxicity indicated that sulfoxaflor was the most persistent (PTI 2332.98) followed by flupyradifurone (PTI 2149.68), flonicamid (PTI 2082.08) and pymetrozine (PTI 1946.16). Studies on safety of the insecticides to the natural enemies of aphid in tobacco ecosystem revealed, that pymetrozine, flonicamid and sulfoxaflor were found relatively less toxic to the predators of tobacco aphid. Based on the studies flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% can be good alternatives to the neo nicotinoids, imidacloprid and thiamethoxam for management of aphids in Virginia tobacco.

CHAPTER-III

MATERIALS AND METHODS

CHAPTER -III

MATERIALS AND METHODS

Present investigation on sorghum was carried out to study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum and to study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum, at College of Agriculture (Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani), Campus Latur, Dist: Latur (MS)-India during *rabi* season 2021-2022.The details of materials used and the methodology adopted during the course of investigation are described under the following heads.

3.1 To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum

3.2 To study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum

3.1 To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum

3.1.1.1 Field layout

The field experiment with sorghum crop using variety Parbhani Moti in *rabi* 2021 was conducted at the Research Farm of Department of Agricultural Entomology, College of Agriculture (Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani), Campus Latur, Dist: Latur (MS)-India during *rabi* season 2021-2022.

The experiment was conducted in a randomized block design with nine treatments including untreated control replicated with four replications. The sorghum crop was sown on 31^{th} Oct 2021 in a gross plot of 2.7 × 3.0 sq. m maintaining net plot of 364.5 sq. m. The row to row distance of 45 cm and plant to plant distance of 15 cm was maintained.

3.1.1.2 Sowing

Sowing was done manually and two seed was sown per hill (seed rate 10-12 kg/ha) with a spacing of 45 × 15 cm during last week of October.

3.1.1.3 Cultural Practices

All the agronomic practices were followed as per the recommendations of VNMKV, Parbhani in raising sorghum crop during the experimental period.

3.1.1.4 Fertilization

The fertilizers were applied @ 100:50:50 NPK kg/ha as per the recommendations.

3.1.1.5 PROGRAMME OF RESEARCH WORK

1. Crop	:	Sorghum
2. Design	:	Randomized Block Design (RBD)
3. No. of quadrate	:	36
4. Size of quadrate	:	2.70 m x 3 m
5. Spacing	:	45 cm X 15 cm
6. Fertilizer dose	:	100:50:50 NPK kg per ha
7. Cultivar	:	PARBHANI MOTI

Table No.3.1:Details of insecticides used in the experiment

Sr. No	Common name with formulation	Mode of action	Mode of entry	Group of insecticides	Chemical Name
1	Imidalcloprid 48%FS	Imidacloprid binds to post- synaptic nicotinic acetylcholine receptors in the central nervous system of insects. Following binding, these impulses are simultaneously discharged at first followed by failure of the neuron to propogate any signal sustained activation of receptor results from the inability af AChE to breakdown the pesticides. The binding process is irreversible.	Contact or ingestion	Neonicotinoids	l-(6-chloro-3-pyridylmethyl)-N-nitroimidazolidin-2-ylideneamine.
2	Thiamethoxam 30FS	The compound gets in the way of information transfer between nerve cells by interfering with nicotinic acetylcholine receptors in CNS & eventually paralyzes the muscles of the insects.	Direct contact	Neonicotinoids	3-(2-chloro-triazol-5-ylmethyl)-5-methyl-[1,3,5] oxadiazinan-4-ylidene-N-nitroamine.
3	Chlorantraniliprole-18.5 %SC	Chlorantraniliprole has a novel mode of action and acts by binding to and activating insect ryanodine receptors is active as a larvicide and activating the unregulated release of internal calcium stores, which leads to Ca^{2+} depletion, feeding cessation, lethargy, muscle paralysis, and insect death.	Contact or ingestion	Diamide	3-Bromo-N-[4-chloro-2-methyl-6-(methylcarbaoyl)phenyl] -1-(3-chloropyridine-2-yl)-1H-pyrazol-5-carboxamide.
4	Emamectin Benzoate 5% SG	The mechanism of action is unique in the panorama of insecticides. In facts, it inhibits muscle contraction, causing a continuous flow of chlorine ions in the GABA and H-Glutamate receptor sites.	Contact or ingestion	Avermectin	4″-Deoxy-4″-epi-methylamino-avermectin B1; Epi-methylamino-4″-deoxy-avermectin;

Table No.3.2: Insecticides treatments

Tr.No	Treatments	Doses
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg
T3	Chlorantraniliprole-18.5 %SC	3 ml /10 *l*
T4	Emamectin Benzoate 5% SG	4g/10 *l*
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml /10 *l*
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml /10 *l*
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*
T9	Untreated (control)	-

Detail schedule of insecticidal spray.

Two sprays of respective insecticidal treatment were made on 15 and 30 days after emergence of crop. The spray was given using manually operated knapsack sprayer. The incidence of shoot fly, fall armyworm, jassids, ladybird beetles and spiders were recorded a day prior of spray and 1, 3, 7 and 14 days after spray.

3.1.6 Methods of recording observations

1. Shoot fly eggs: Total No. of eggs on randomly selected five plants were observed.

2. Per cent deadheart due to shoot fly: Three rows of 1m length were selected randomly. From those rows total plants and plant showing deadheart symptoms were be counted. From these count, per cent deadheart were be worked out.

3. The population of *Spodoptera frugiperda* larvae were recorded from randomly selected three rows of 1m length from each treatment plot.

4. The population leaf hoppers were recorded from three leaves of randomly selected five plants in each plot.

5. The population of natural enemies of the pests *viz*., lady bird beetle and spiders were recorded from randomly selected three rows of 1m length.

6. All the above observation were recorded one day before and 1,3,7, and 14 days after each spray.

7. Plotwise harvesting were carried out and the yield were be expressed as q/ha.

3.1.7 Statistical analysis

The data in respect of bio-efficacy of different insecticides against deadheart *Atherigona soccata*, *Spodoptera frugiperda*, *A. biguttula biguttula*, and effect on ladybird beetles and spiders were statistically analyzed by standard 'analysis of variance'. The null hypothesis was tested by 'F' test of significance at 5 per cent level (Gomez and Gomez, 1984).

3.2 To study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum

3.2.1 Method of recording observations

1. The residual toxicity of different insecticides was investigated against nymphs and adults of *Melanaphis sacchari*. In each quadrant randomly 10 plants were selected for spraying two insecticides from first objective i.e Chlorantraniliprole 18.5 SC, Emamectin benzoate 5SG and Dimethoate-30 EC, Quinalphos 25EC and Neem oil were used in this experiment.

2. The entire plant was covered while application of insecticides. The required numbers of leaves receiving application of insecticides were tagged for investigations on residual toxicity of insecticides.

3. The tagged leaves were brought to the laboratory at the prescribed day intervals. The treated leaves were kept in plastic container.

4. The petiole of leaf was covered with moistened cotton wool in order to retain their turgidity for 24 hours. The number of test insects used for the bioassay studies was ten for each treatment in each replication. Aphids were slightly disturbed allowing them to draw their proboscis from the host plant and then released on treated leaf kept in the plastic container. The numbers of dead or moribund test insects will be counted after 24 hours of exposure.

5. Similarly control mortality of test insects was observed by releasing them on untreated leaves of sorghum plant.

3.2.3 Statistical analysis of data

Data obtained were subjected to statistical analysis which consisted of following steps.

3.2.3.1 : Correction on percentage mortality

The observations on mortality of test insects were converted into percentage mortality. The average percentage mortality was calculated from the observations in three replications. The observations on percentage mortality thus obtained were corrected with Abbott's (1925) formula as follows.

$$P = \frac{T-C}{100-C} \times 100$$

Where,

P = Corrected percentage mortality

T = Percentage mortality in treatment

C = Percentage mortality in control

3.2.3.2 : LT_{50} values

The values of LT_{50} (time required to give 50 per cent mortality) for different insecticides applied on sorghum plants was calculated by using software of probit analysis as suggested by Finney (1971) and OPSTAT software.

The product (PT) of average residual toxicity (T) and the period (P) for which the toxicity persisted was used as an index of persistent toxicity. The values of corrected percentage mortalities at various specified periods were added. This sum will be then divided by number of observations in order to obtain residual toxicity (T).

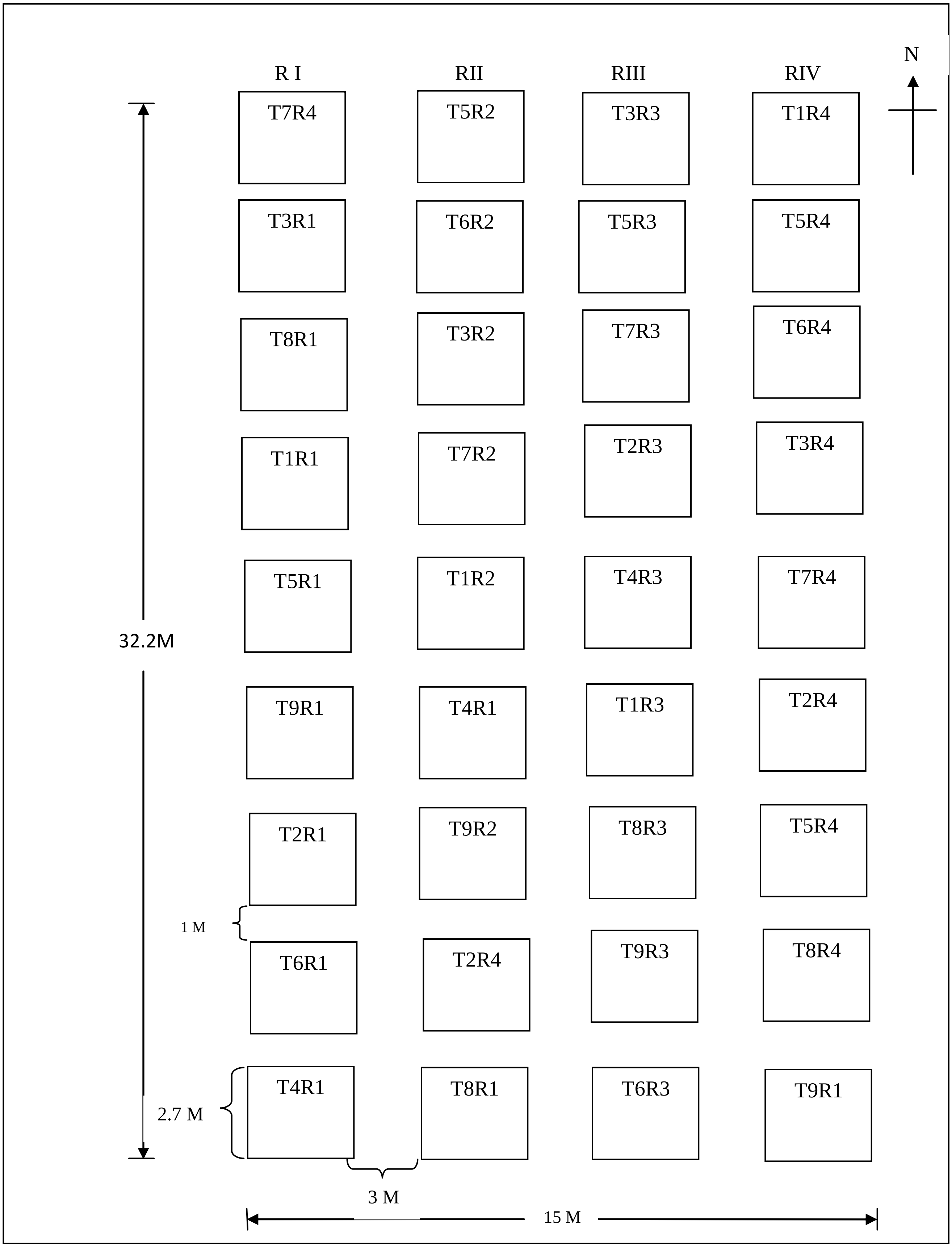


Plate 3.1 : Layout of experimental field

Plate 3.2: Experimental field of *rabi* sorghum

Aphid – *Melanaphis sacchari*

Plate 3.3: Experimental setup on residual toxicity

Egg

Maggot

Pupa

Adult

Dead heart

Plate 3.4: Life stages of *Atherigona soccata*

Egg mass

Larvae

Pupa

Adult

Plate 3.5 : Life stages of *S. frugiperda*

Leafhopper

Plate 3.6: Leafhopper

Eggs

Grub

Coccinella transversalis

Plate 3.7: Ladybird beetle

Coccinella septempunctata

Cheliomenes sexmaculata

Spider

Plate 3.8: Natural enemies

The procedure followed by Saini (1959) and elaborated further by Pradhan (1967) and Sarup *et al.* (1970) will be utilized.

3.2.3.3 Comparison of log LT_{50} values

Log LT_{50} values obtained for different insecticides were compared by employing the ‘t’ test. The ‘t’ values for comparing two different insecticides were calculated as follows.

$$\text{Log } LT_{50} \pm \text{S. Em}$$

Insecticides

A) Chlorantraniliprole 0.005 per cent

B) Emamectin benzoate 0.002 per cent

$$\text{S.Ed} = \sqrt{(S.Em.A)^2 + (S.Em.B)^2}$$

$$'t' = \frac{\text{Log } LT_{50}\text{A} - \text{Log } LT_{50}\text{B}}{\text{S.Ed}} = \text{ Calculated 't', Value}$$

d.f. = $(n_1 + n_2) - 2$ where n_1 and n_2 represent number of observations used in calculation of LT_{50} for each insecticide.

CHAPTER-IV

RESULTS AND DISCUSSION

CHAPTER- IV

RESULTS AND DISCUSSION

Study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum and to study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum, at College of Agriculture (Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani), Campus Latur, Dist: Latur (MS)-India during *rabi* season 2021-2022. The results obtained during the present investigations are reported here under following heads.

4.1 To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum

4.2 To study residual toxicity of newer insecticides against major insect pests of *rabi* sorghum

4.1 To study bioefficacy of newer insecticides against major insect pests of *rabi* sorghum

4.1.1. Effect of application of different insecticides on number of eggs of shoot fly on *rabi s*orghum

4.1.2. Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum

4.1.3 Effect of application of different insecticides on number of larvae of fall armyworm *S. frugiperda* on *rabi* sorghum

4.1.4 Effect of application of different insecticides on number of leafhopper

4.1.5 Effect of application of different insecticides on population of ladybird beetle

4.1.6 Effect of application of different insecticides on population of spiders.

4.1.7 Effect of newer insecticides on yield of sorghum

4.1.8 ICBR ratio

4.2 Residual toxicity of different insecticides against major insect pests of sorghum

4.1.1 Effect of application of different insecticides on number of eggs of shoot fly on *rabi s*orghum

4.1.1.1 First spray

The results revealed that all the insecticides found to be significantly superior over untreated control in reducing population of eggs of shoot fly at 1, 3, 7 and 14 days after first application of insecticides on 7 DAS &14 DAS there is no egg population of sorghum shoot fly in the field as depicted in Table.4.1 and Fig 4.1.

The plots treated with Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* recorded significantly minimum number of eggs per five plants 4.25, 5.00, 0.00 & 0.00 recorded at 1, 3, 7 and 14 days after spraying, respectively over rest of the insecticides.

At first days after first spray, Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* evidenced significantly least population of eggs per five plants (4.25) which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.50), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.00). All these treatments were found to be statistically at par with each other. Next effective treatment were Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.50), Thiamethoxam 30 FS seed treatment 10 ml/kg (5.75), Imidalcloprid 48% FS seed treatment 5ml/kg (6.00), Emamectin Benzoate 5% SG 4g/10 *l* (8.25) and Chlorantraniliprole-18.5 % SC 3ml/10 *l* (8.75).

Similar trend of results were obtained at three days after first spray Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* recorded significantly lowest population of eggs per five plants the tune of (5.00). Subsequently effective treatments were Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.25), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (6.25), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (6.75), Thiamethoxam 30 FS seed treatment 10 ml/kg (7.25), Imidalcloprid 48% FS seed treatment 5ml/kg (8.00), Emamectin Benzoate 5% SG 4g/10 *l* (9.25) and Chlorantraniliprole-18.5 %SC 3ml/10 *l* (9.75).

Due to the scanty literature pertaining to combination of seed treatment with foliar spray of investigated insecticides, the information available on usage of chemicals as a sole application also has been considered.

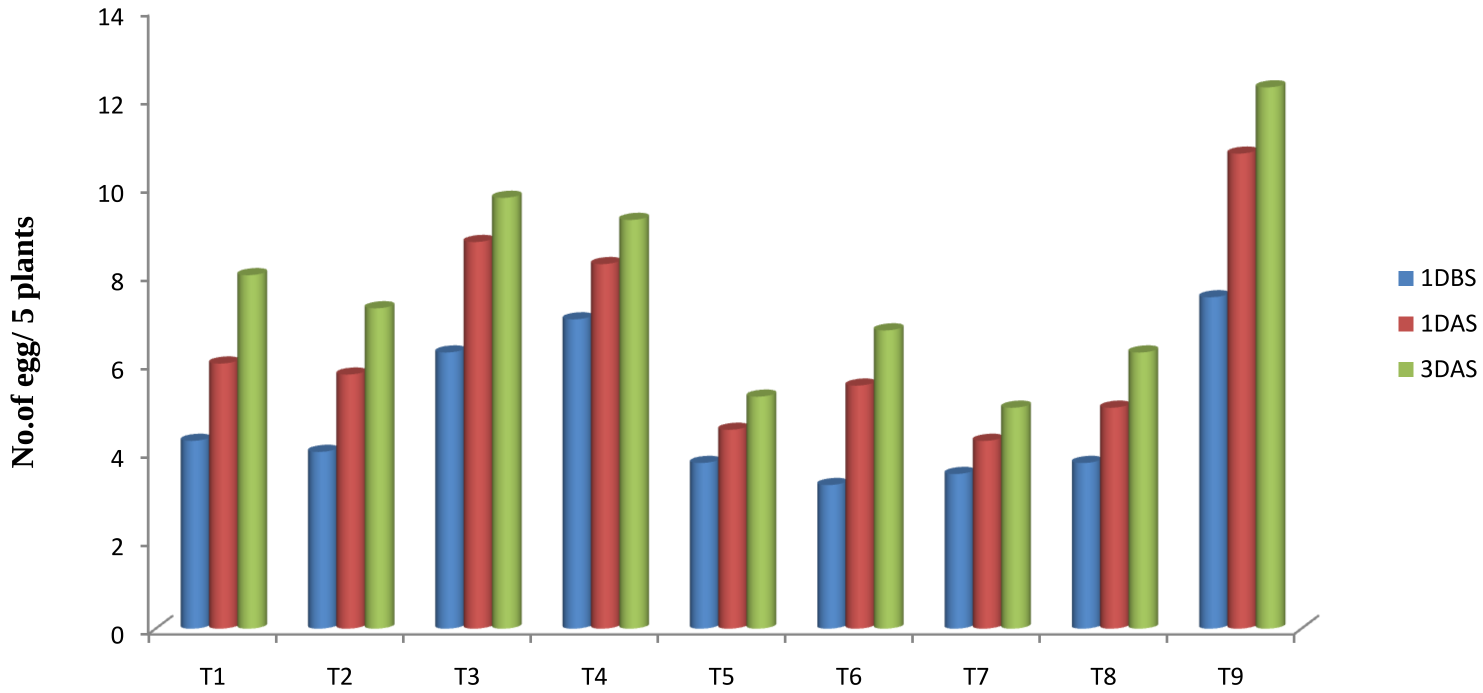
Jambagi *et al* (2021) studied effect of combinations of novel insecticides for the management of wheat shoot fly *Atherigona approximata*. Their result showed that at 15 DAS, thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of cypermethrin 10 EC @ 0.5 ml/l recorded least shoot fly oviposition (0.84) and the plot with the treatment thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of emamectin benzoate 5 SG 0.2 gm/*l* of was on par with it (1.11). Only the seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed was less effective (2.02 eggs/plant) than these treatments but significantly better over untreated check (2.97 eggs/plant). Pooled data of three years field studies by Sonalkar *et al* (2018) reported that at 14 days after emergence, no significant difference in the shoot fly egg load on the sorghum plots with seed treatment with imidacloprid 70 WS @ 10 ml/kg seed and imidacloprid 48 FS 12 g/kg and it was on par with untreated check. Patil and Bagde (2017) recorded significantly lower no of shoot fly eggs in sorghum sprayed with chlorantraniliprole 18.5 SC**.** Siddique *et al* (2011) reported that shoot fly oviposition was maximum in thiamethoxam 5 gm/kg seed treatment which was at par with imidacloprid 10 g/kg seed treatment indicating more attractive for female flies to lay more eggs.

Studies by Biradar and Shekharappa (2019) showed that the seed treatment of Imidacloprid 70 WS (5 g/kg) was the best in reducing egg load by sorghum shoot fly (0.73/plant) over all other insecticides used in the experiment viz. spinosad 45 SC (2 ml/kg) (0.97 eggs/plant), acetamiprid 20 SP (5 g/kg) (1.07 eggs/plant) and fipronil 5 SC (5 ml/kg) (1.17 eggs/plant). Kumar and Tiwana (2018) reported that the there was no difference in the eggs laid by shoot fly in sorghum plots treated with Thiamethoxam 30 FS 10 ml/Kg and Imidacloprid 70 WS @ 7 ml/kg and untreated seed. Jindal and Kumar (2017) found no effect on egg laid by shoot fly *Athergona naqui* in the seed treatments of thiamethoxam 70 WS, clothianidin 50 WG and imidacloprid 600 FS on maize. Shid *et.al* (2022) The minimum number of eggs per five plants were recorded in treatment seed treatment with Thiamethoxam 30 FS @ 10 ml/kg of seed (4.00). Rawat *et.al* (2020) Minimum (0.46) number of eggs laid

Table.4.1: Effect of application of different insecticides on number of eggs of shoot fly on *rabi* sorghum (first spray)

Tr. No	Treatments	Dosage	Shoot fly egg / 5 plant				
			1DBS	**1DAS**	**3DAS**	**7DAS**	**14DAS**
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	4.25 (2.17)	6.00 (2.54)	8.00 (2.89)	0.00 (0.71)	0.00 (0.71)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	4.00 (2.11)	5.75 (2.50)	7.25 (2.78)	0.00 (0.71)	0.00 (0.71)
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	6.25 (2.59)	8.75 (3.04)	9.75 (3.19)	0.00 (0.71)	0.00 (0.71)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	7.00 (2.74)	8.25 (2.96)	9.25 (3.12)	0.00 (0.71)	0.00 (0.71)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3ml/10 *l*	3.75 (2.06)	4.50 (2.23)	5.25 (2.40)	0.00 (0.71)	0.00 (0.71)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	3.25 (1.93)	5.50 (2.44)	6.75 (2.69)	0.00 (0.71)	0.00 (0.71)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3ml/10 *l*	3.50 (1.98)	4.25 (2.17)	5.00 (2.35)	0.00 (0.71)	0.00 (0.71)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	3.75 (2.05)	5.00 (2.34)	6.25 (2.60)	0.00 (0.71)	0.00 (0.71)
T9	Untreated (control)	-	7.50 (2.81)	10.75 (3.35)	12.25 (3.57)	0.00 (0.71)	0.00 (0.71)
	SE±		0.11	0.09	0.09	-	-
	CD 5 %		0.32	0.26	0.28	-	-
	CV %		9.72	7.05	6.86	-	-

Figures in the parenthesis are square root (x+0.5) transformed values.



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig.4.1: Effect of application of different insecticides on number of eggs of shoot fly on *rabi* sorghum (first spray).

per plant was recorded when the seeds were treated with imidacloprid 600 FS @ 5ml/kg seed followed by thiamethoxam 70 WS @ 2g/kg seed (0.53).

4.1.2 Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum

4.1.2.1 First spray

Data pertaining to effect of different newer insecticides on population of sorghum deadheart by shoot fly after first spray are presented in Table 4.2 and Fig. 4.2.

The results revealed that all the insecticides found to be significantly superior over untreated control in reducing population of sorghum deadheart by shoot fly at 1, 3, 7 and 14 days after first application of insecticides.

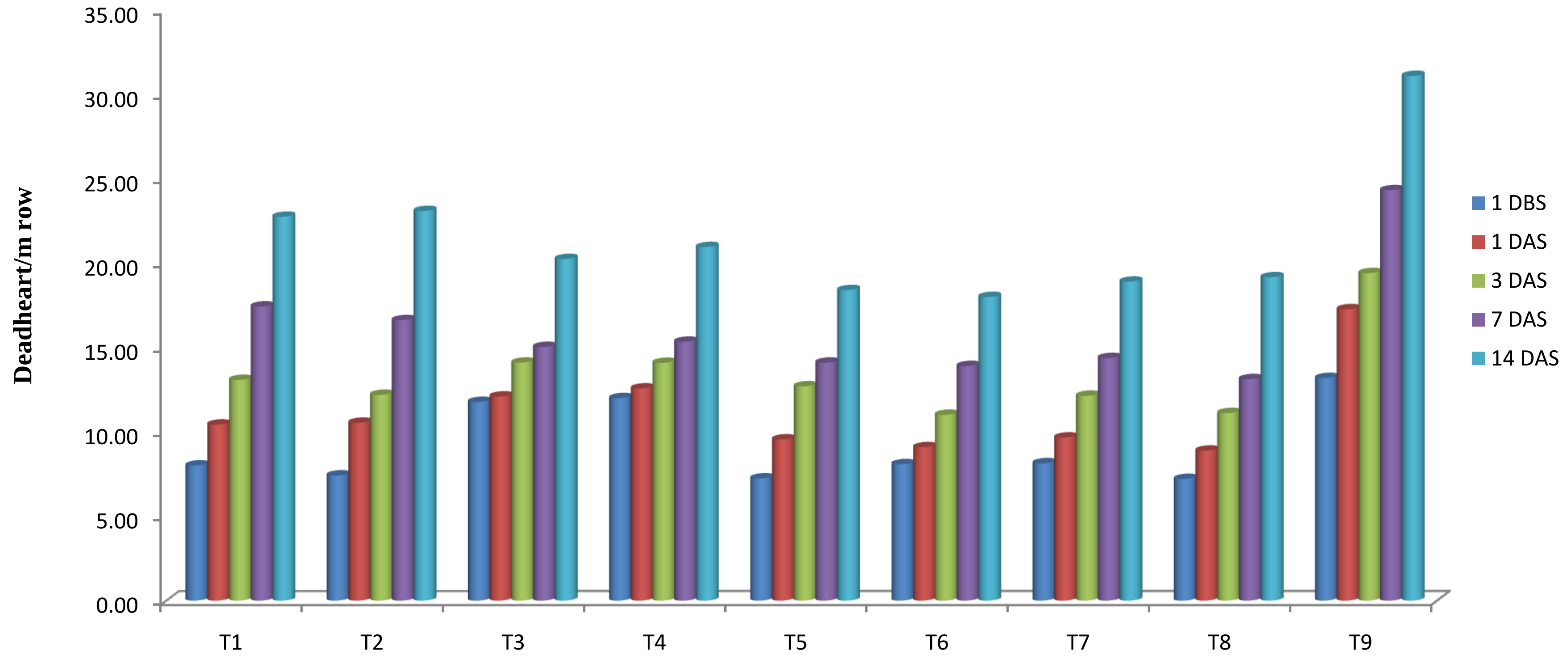
At one day after first spray, significantly minimum population of deadheart (8.89%) was registered from the plots treated with Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* followed by Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (9.09%), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (9.55%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* (9.66%), Imidalcloprid 48% FS seed treatment 5ml/kg (10.43%) Thiamethoxam 30FS seed treatment 10ml/kg (10.54%), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (12.09%) and Emamectin Benzoate 5% SG 4g/10 *l* (12.57%). All these treatments were found to be equally effective in reducing deadheart population.

Similar trend of results were obtained at three days after first spray, Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly lowest population of deadheart to the tune of (11.01%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (11.11%), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (12.13%), Thiamethoxam 30 FS seed treatment 10 ml/kg (12.39%), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (12.69%), Imidalcloprid 48% FS seed

Table.4.2: Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum (first spray)

Tr. No	Treatments	Dosage	Mean deadhearts due to shoot fly (%)				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	8.00 (16.34)	10.43 (18.79)	13.07 (21.14)	17.42 (24.61)	22.74 (28.46)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	7.41 (15.69)	10.54 (18.90)	12.39 (20.38)	16.61 (24.02)	23.08 (28.68)
T3	Chlorantraniliprole-18.5 %SC	3 ml/10 *l*	11.77 (20.91)	12.09 (20.26)	14.10 (21.98)	15.03 (22.77)	20.24 (26.69)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	11.99 (21.10)	12.57 (20.72)	14.08 (21.99)	15.33 (23.02)	20.94 (27.12)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3ml/10 *l*	7.24 (11.55)	9.55 (17.92)	12.69 (20.79)	14.10 (21.98)	18.39 (25.37)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	8.08 (16.39)	9.09 (17.50)	11.01 (19.35)	13.90 (21.85)	17.99 (25.06)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3ml/10 *l*	8.14 (16.54)	9.66 (18.07)	12.13 (20.35)	14.37 (22.17)	18.89 (25.68)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	7.21 (15.53)	8.89 (17.30)	11.11 (19.42)	13.12 (21.09)	19.16 (25.91)
T9	Untreated (control)	-	13.18 (21.26)	17.26 (24.53)	19.40 (26.09)	24.31 (29.50)	31.08 (33.37)
	SE±		1.17	1.25	1.40	1.41	1.57
	CD 5 %		3.40	3.65	4.09	4.11	4.58
	CV %		9.30	9.16	9.31	8.49	8.11

*Figures in parentheses are Arc sign transformed values.



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.2: Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum (first spray).

treatment 5ml/kg (13.07%), Emamectin Benzoate 5% SG 4g/10 *l* (14.08%) and Chlorantraniliprole-18.5 %SC 3ml/10 *l* (14.10%).

At seven days after first spray, Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (13.12%), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (13.90%), Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (14.10%), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (14.37%), Chlorantraniliprole-18.5 % SC 3ml/10 *l* (15.03%), Emamectin Benzoate 5% SG 4g/10 *l* (15.33%), Thiamethoxam 30 FS seed treatment 10 ml/kg (16.61%) and Imidalcloprid 48% FS seed treatment 5ml/kg (17.42%). All these treatments were found to be statistically at par with each other.

At 14 days after first spray, significantly minimum population of deadheart (17.99%) was registered from the plots treated with Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (18.39%), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (18.89%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (19.16%), Chlorantraniliprole-18.5%SC 3ml/10 *l* (20.24%), Emamectin Benzoate 5% SG 4g/10 *l* (20.94%), Imidalcloprid 48%FS seed treatment 5ml/kg (22.74%) and Thiamethoxam 30FS seed treatment 10 ml/kg (23.08%). All these treatments were statistically at par with each other.

4.1.2.2 Second spray

The date revealed that all the insecticides under investigation were observed to be significantly superior over untreated control in reducing the population of sorghum deadheart by shoot fly at 1,3,7 and 14 days after second spray are presented in Table 4.3 and Fig. 4.3.

At one day after second spray, significantly minimum population of deadheart (18.04%) was recorded from the plots treated with Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (18.78%), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (19.31), Thiamethoxam 30 FS seed treatment

Table.4.3: Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum (second spray)

Tr. No	Treatments	Dosage	Mean deadhearts due to shoot fly (%)				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	22.74 (28.46)	26.58 (31.02)	29.07 (32.61)	32.01 (34.40)	38.98 (38.62)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	23.08 (28.68)	26.34 (30.82)	29.00 (32.53)	31.52 (34.11)	38.21 (38.17)
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	20.24 (26.69)	21.93 (27.91)	22.01 (27.92)	25.18 (30.08)	28.25 (32.00)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	20.94 (27.12)	22.34 (28.06)	23.13 (28.60)	26.28 (30.79)	29.49 (32.77)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	18.39 (25.37)	18.78 (25.44)	19.07 (25.88)	20.26 (26.72)	24.78 (29.80)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	17.99 (25.06)	18.04 (25.13)	19.94 (26.45)	21.18 (27.37)	25.02 (29.94)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	18.89 (25.68)	19.31 (26.05)	19.72 (26.32)	20.22 (26.65)	24.24 (29.45)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	19.16 (25.91)	19.76 (26.34)	20.11 (26.63)	21.75 (27.76)	26.01 (30.64)
T9	Untreated (control)	-	31.08 (33.37)	33.80 (35.52)	35.46 (36.54)	39.43 (38.88)	46.66 (43.07)
	SE±		1.57	1.74	1.74	1.81	1.97
	CD 5 %		4.58	5.10	5.08	5.29	5.76
	CV %		8.11	8.68	8.41	8.34	8.25

*Figures in parentheses are Arc sign transformed values.

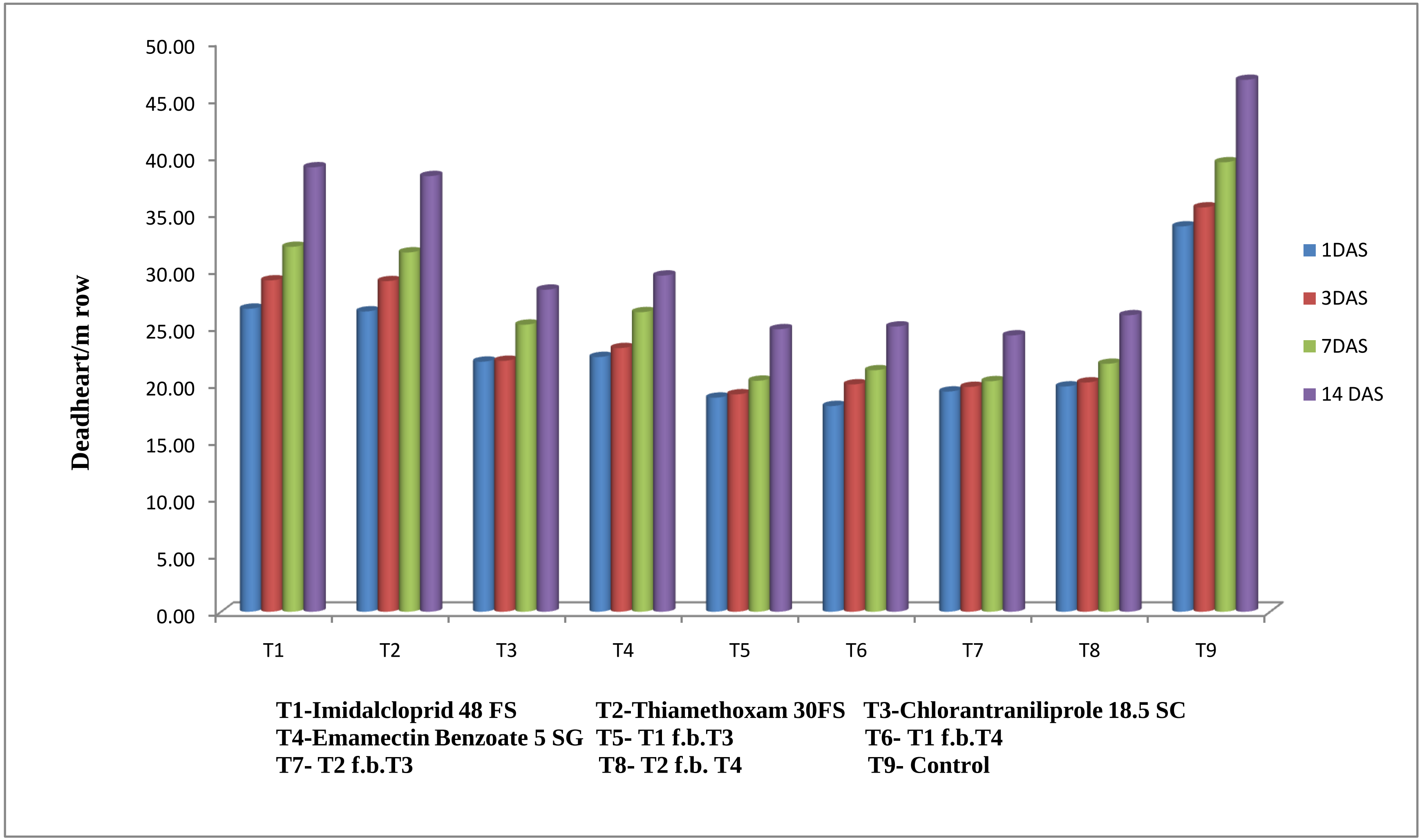


Fig. 4.3: Effect of different insecticides on number of deadheart caused by shoot fly on *rabi* sorghum (second spray).

10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (19.76%), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (21.93%) and Emamectin Benzoate 5% SG 4g/10 *l* (22.34%). All these treatments were statistically at par with each other. The next effective treatments were Imidalcloprid 48%FS seed treatment 5ml/kg (26.58%), Thiamethoxam 30FS seed treatment 10 ml/kg (26.34%).

At three days after second spray, Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (19.07%), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (19.72%), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (19.94%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (20.11%), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (22.01%) and Emamectin Benzoate 5% SG 4g/10 *l* (23.13%). All these treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg (29.00%) and Imidalcloprid 48%FS seed treatment 5ml/kg (29.07%).

At seven day after second spray, significantly minimum population of deadheart (20.22%) was registered from the plots treated with Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (20.26%), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (21.18%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (21.75%), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (25.18%) and Emamectin Benzoate 5% SG 4g/10 *l* (26.28%). All these treatments were found to be equally effective in reducing deadheart population. Subsequently effective treatments were Imidalcloprid 48%FS seed treatment 5ml/kg (32.01%), Thiamethoxam 30FS seed treatment 10 ml/kg (31.52%).

At 14 days after spraying, significantly lowest population of deadheart was noted in Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* recorded significantly lowest population of deadheart to the tune of (24.24%). Subsequently effective treatments were Imidalcloprid 48% FS seed treatment 5ml/kg f.b.Chlorantraniliprole-18.5 % SC 3ml/10 *l* (24.78%), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (25.02%), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (26.01%), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (28.25%) and Emamectin

Benzoate 5% SG 4g/10 *l* (29.49%).All these treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg (38.21%), Imidalcloprid 48%FS seed treatment 5ml/kg (38.98%).

The present findings are in close agreement with the earlier reports of Shid *et al.* (2022) who exhibited that least deadhearts due to shoot fly was noted in the plots with the seed treatments with Thiamethoxam 30 FS @ 10 ml/kg seed (19.76%), Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS (21.00%) and Imidacloprid 17.8 SL 3 ml/kg (21.46%). However, Saxena *et al.* (2022) observed maximum reduction deadhearts due to shoot fly was recorded in the seed treatments with Thiamethoxam (19.8 w/w) + Cyantraniliprole (19.8 w/w) (1.36 to 15.95%) followed by seed treatment wih Thiamethoxam 30 FS ((1.61 to 21.76%) Analogously, Kumar and Tiwana (2018) reported that seed treatment with thiamethoxam 30 FS @ 10 ml per kg seed was the most superior to reduce deadhearts due to soot fly (7.71%) followed by Imidacloprid 70 WS @ 7ml per kg seed (9.47%) compared to untreated check (17.08%).

Similar trends of results were also pointed out by many authors in different crops as discussed below. Sridhar *et al.* (2016) indicated least deadhearts due to shoot fly in sweet sorghum at 30 days after emergence in the seed treatment with Imidacloprid 70 WS followed by Thiamethoxam 25 WG. While, Jambagi *et al* (2021) that at 15 DAS,thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of cypermethrin 10 EC @ 0.5 ml/*l* recorded least shoot fly deadhearts (9.12%) and the plot with the treatment thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of emamectin benzoate 5 SG 0.2 gm/*l* of was on par with it (9.25%). Only the seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed was less effective (21.86%). Based on the results of the investigations by Chanu and Sontakke (2016), two applications of rynaxypyr 0.4 SG and chlorantraniliprole 18.5 SC as well as emamectin benzoate 5 SG in recorded least incidence of stem borer causing deadhearts an hite ear by stem borer in rice. Jindal and Kumar (2017) observed that seed treatment with thiamethoxam 70 WS at 5 & 7 g/kg and imidacloprid 600 FS 6 ml/kg proved very effective in reducing deadhearts by shoot fly *Athergona naqui* in maize. In the same way, Siddique *et al* (2011) reported that Thiamethoxam 25 WG @ 0.005% spray was most effective in reducing shoot fly dead-hearts followed by imidacloprid 10 g/kg and thiamethoxam 5 gm/kg seed treatments. Patil and Bagde (2017) recorded significantly lower no of shoot fly deadhearts in sorghum sprayed with chlorantraniliprole 18.5 SC.

Sonalkar *et al* (2018) observed significantly minimum dead hearts 28 days after emergence were in seed treatment with imidacloprid 70 % WS @ 10 g/kg seed f.b. quinalphos 25 % EC spray @ 20 ml/10 lit water (34.75) followed in seed treatment with imidacloprid 48 FS @ 12 g/kg seed followed by quinalphos 25 % EC spray @ 20 ml/10 lit water. Seed soaking in thiamethoxam 25 % WG @ 2.0 g/ l + CaCl2 @ 2% proved the best for reducing shoot fly deadhearts in sorghum at 30 days after emergence (Kharbhantanal *et al*, 2022).

However, Rathod *et al* (2022), imidacloprid 48FS @ 12 ml/ kg seed followed by quinalphos 25EC @ 2 ml/ *l* spray (15.22% deadhearts) proved the best treatment followed by seed treatment with imidacloprid 30FS @ 12 ml/ kg seed with 13.68 and 16.29% deadhearts, respectively; it was followed by seed treatment with thiamethoxam 48FS @ 12 ml/ kg seed. While, Biradar and Shekharappa (2019) exhibited highest efficacy 28 DAE the treatment with the seed treatment of Imidacloprid 70 WS (5 g/kg) and chlorpyriphos 20 EC (5 ml/kg) recorded significantly less deadhearts (14.83% and 15.17%, respectively). Poul *et.al* (2020), showed that chlorantraniliprole 18.5% SC 3ml/10lit most effective insecticides against management of stem borer, *Chilo partellus* on sorghum followed by emamectin benzoate 5% SG, flubendiamide 39.35% SC, thiamethoxam 12.6 + lambda cyhalothrin 9.5% ZC and spinosad 45% SC.

4.1.3 Effect of application of different insecticides on number of larvae of fall armyworm *S. frugiperda* on *rabi* sorghum

4.1.3.1 First spray

Data pertaining to effect of different insecticides on larval population of fall armyworm , *Spodoptera frugiperda* after first spray presented in Table 4.4 and Fig. 4.4.

The results revealed that all the insecticides were found to be significantly superior over untreated control in reducing population of fall armyworm at 1,3,7 and 14 days after first application of insecticides.

The plots treated with Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly lowest larval population of fall armyworm on sorghum to the extent of 3.50, 3.00, 2.25 and 3.75

larvae/m row at 1, 3, 7 and 14 days after spraying, respectively over rest of the insecticides.

At one day after first spray, significantly minimum larval population of fall armyworm (3.50 larvae/m row) was recorded from plot treated with Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.00 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (4.75 larvae/m row. All these treatments were found statistically at par with each other. The next effective treatments were Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.00 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (6.00 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.75 larvae/m row), Thiamethoxam 30FS seed treatment 10ml/kg (7.25 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (8.25 larvae/m row).

At three days after first spray, Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* minimum larval population of fall armyworm (3.00 larvae/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.25 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (4.00 larvae/m row) which were found statistically at par with each other. The subsequent order of effectiveness was Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (4.50 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.75 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.00 larvae/m row), Thiamethoxam 30FS seed treatment 10ml/kg (8.50 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (8.75 larvae/m row).

At seven days after first spray, Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* evidenced significantly effective treatment in minimizing larval population of fall armyworm (2.25 larvae/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.75 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (3.25 larvae/m row). All these treatments were found significantly superior and statistically at par with each other. The subsequent order of effectiveness was Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (3.75

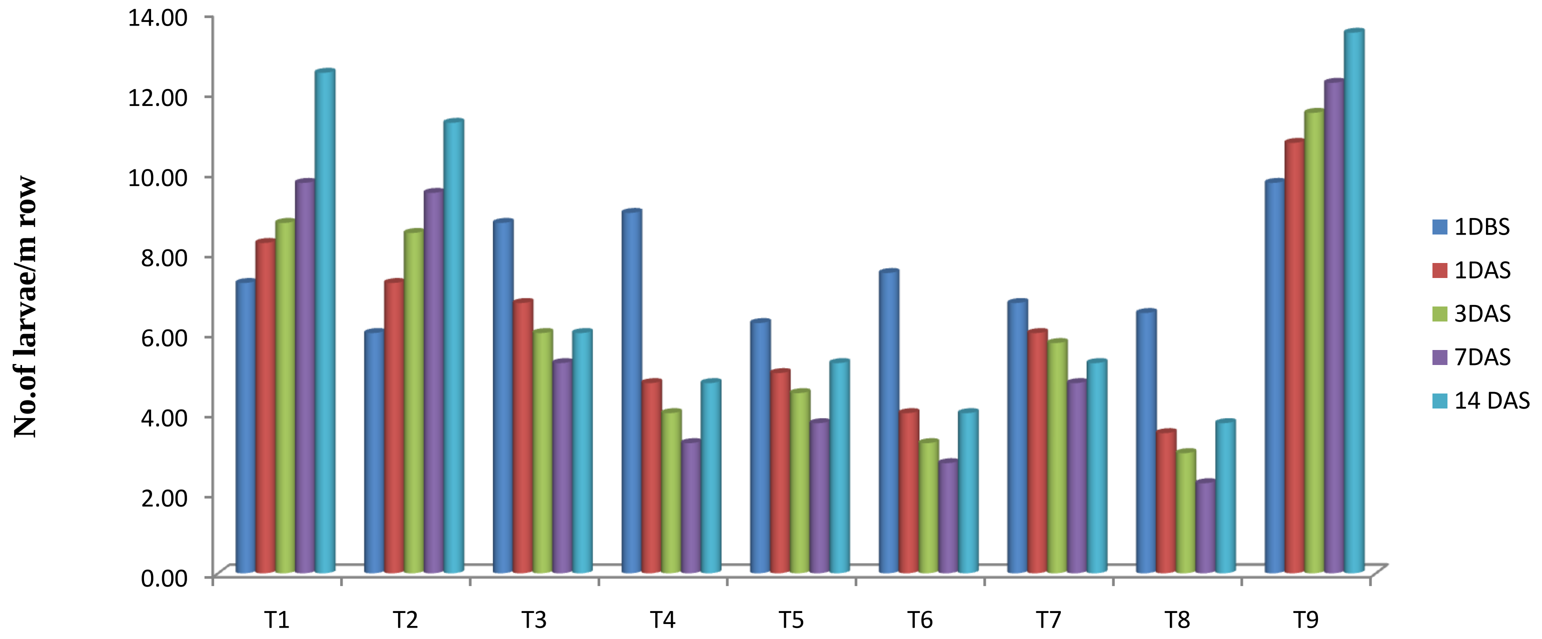
larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.75 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.25 larvae/m row), Thiamethoxam 30FS seed treatment 10ml/kg (9.50 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (9.75 larvae/m row).

At 14 days after first spraying, significantly lowest larval population of *Spodoptera frugiperda* was noticed in Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.75 larvae/m row) which was found to be at par with Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.00 larvae/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.75 larvae/m row). However, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.25 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.25 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.00 larvae/m row). Thiamethoxam 30FS seed treatment 10ml/kg (11.25 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (12.50 larvae/m row) are at par with untreated.

Table.4.4: Effect of different insecticides on number of larvae of fall armyworm on *rabi* sorghum (first spray)

Tr.No	Treatments	Dosage	No. of larvae/m row				
			1DBS	**1DAS**	**3DAS**	**7DAS**	**14DAS**
T1	Imidalcloprid 48%FS (seedtreatment)	5 ml/kg	7.25 (2.77)	8.25 (2.94)	8.75 (3.04)	9.75 (3.20)	12.50 (3.60)
T2	Thiamethoxam 30FS (seedtreatment)	10 ml/kg	6.00 (2.53)	7.25 (2.78)	8.50 (3.00)	9.50 (3.16)	11.25 (3.43)
T3	Chlorantraniliprole-18.5 %SC	3 ml/10 *l*	8.75 (3.04)	6.75 (2.69)	6.00 (2.55)	5.25 (2.39)	6.00 (2.55)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	9.00 (3.08)	4.75 (2.29)	4.00 (2.11)	3.25 (1.92)	4.75 (2.26)
T5	Imidalcloprid 48%FS (seedtreatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	6.25 (2.60)	5.00 (2.34)	4.50 (2.23)	3.75 (2.04)	5.25 (2.39)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	7.50 (2.79)	4.00 (2.11)	3.25 (1.93)	2.75 (1.77)	4.00 (2.11)
T7	Thiamethoxam 30FS (seedtreatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	6.75 (2.69)	6.00 (2.55)	5.75 (2.47)	4.75 (2.28)	5.25 (2.39)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	6.50 (2.62)	3.50 (1.99)	3.00 (1.83)	2.25 (1.64)	3.75 (2.04)
T9	Untreated (control)	-	9.75 (3.20)	10.75 (3.35)	11.50 (3.46)	12.25 (3.57)	13.50 (3.74)
	SE±		0.145	0.10	0.12	0.11	0.11
	CD 5 %		NS	0.30	0.35	0.33	0.33
	CV %		10.31	8.15	9.80	9.38	8.36

Figures in the parenthesis are square root (x+0.5) transformed values.



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.4: Effect of different insecticides on number of larvae of fall armyworm on *rabi* sorghum (first spray).

4.1.3.2 Second spray

The results in respect of effect of different insecticides on larval population of *Spodoptera frugiperda* was noticed after second spray presented in Table 4.5 and Fig. 4.5.

The data revealed that all the insecticides under investigation were observed to be significantly superior over untreated control except Thiamethoxam 30FS seed treatment 10ml/kg and Imidalcloprid 48% FS seed treatment 5ml/kg in reducing larval population of fall armyworm on sorghum at 1, 3, 7 and 14 days after second spray.

At one day after second spray, significantly minimum larval population of fall armyworm (2.75 larvae/m row) was recorded from the plots treated with Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.25 larvae/m row), Emamectin Benzoate 5% SG 4g/10 *l* (3.75 larvae/m row) which were statistically at par with each other. Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (4.00 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.75 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.00 larvae/m row), Thiamethoxam 30FS seed treatment 10ml/kg (12.25 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (13.25 larvae/m row) were subsequently effective treatments.

At three days after second spray, Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly effective treatment in minimizing larval population of fall armyworm (2.00 larvae/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.75 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (3.00 larvae/m row). All these treatments were found significantly superior and statistically at par with each other. The subsequent order of effectiveness was Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (3.75 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.00 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (4.25 larvae/m row). Thiamethoxam 30FS seed treatment 10ml/kg (13.25 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (14.50 larvae/m row) at par with untreated plot.

At seven days after second spray, Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* evidenced significantly least larval population of fall armyworm (1.75 larvae/m row) which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.25 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (2.75 larvae/m row). However, all these treatments were at par with each other. Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (3.00 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.25 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (4.00 larvae/m row), Thiamethoxam 30FS seed treatment 10ml/kg (16.00 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (17.25 larvae/m row) were subsequently effective treatments

Similar trend of results were obtained at 14 days after second spray. Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly lowest population of *Spodoptera frugiperda* larvae to the tune of (3.75 larvae/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.75 larvae/m row) and Emamectin Benzoate 5% SG 4g/10 *l* (5.00 larvae/m row). However, all these treatments were statistically at par with each other. Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.75 larvae/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (6.00 larvae/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.25 larvae/m row). Thiamethoxam 30FS seed treatment 10ml/kg (21.75 larvae/m row) and Imidalcloprid 48% FS seed treatment 5ml/kg (22.25 larvae/m row) are non significantly with untreated plot.

The trend of results found in the present investigations coincides with Poul *et al*. (2020) who documented that Emamectin benzoate 5 SG most effective against the fall armyworm, *Spodoptera frugiperda* which was at par with chlorantraniliprole 18.5 S. However, Bharadwaj *et al.* (2020) reported that Spinetoram 11.7 SC @ 0.011 per cent was found most effective treatment in reducing the population of *S. frugiperda* followed by Emamectin benzoate 5 WG @ 0.002 on maize. While, Mallapur *et al*. (2019) reported that spinoteram, emamectin benzoate and spinosad 45 SC were significantly superior over all other treatments with the larval reduction of 98.13, 96.26 and 96.26 per cent, respectively at 7 days after treatment imposition.

Among other tested molecules, thiamethoaxam 0.25%WG and fipronil 0.5 SC were least effective (68.65 and 73.14% mortality, respectively) against fall armyworm, *Spodoptera frugiperda* on maize. Similarly, Lad and Pawar (2022) Emamectin benzoate 5 SG (2.25 larva/10 plant) proved effective with minimum infestation of Fall armyworm and found at par with Spinetoram 11.7 SC (2.65 larva /10 plant) and Chlorantriniliprole 18.5 SC (3.22 larva /10 plant), Thimethoxam 12.6 + Lambda cyhalothrin 9.5 ZC (4.86 larva /10 plant), Indoxacarb 14.5 SC (5.50 larva /10 plant), Spinosad 45 SC (5.64 larva /10 plant) and Profenophos 50 EC (7.33 larva/10 plant). Maximum infestation of Fall armyworm was recorded in water spray (19.10 larva /10 plant). According to Ahir *et al,* (2021) three sprays of chlorantraniliprole 18.5 SC were found most effective treatment against *S. frugiperda* and gave the better results with maximum reduction of larval population, lowest plant damage (%), lowest leaf damage (%), lowest cob damage (%) and highest grain yield. It is followed by emamectin benzoate 5 SG and found at par at 5th day after each spray. Similarly, Sangle *et al*, (2020) revealed that emamectin benzoate 5 SG was most effective treatment over control followed by chlorantraniliprole 18.5 SC,in reducing *S. frugiperda* larval population on maize crop. Analogously, In maize crop Dobariya and Sisodiya (2022), proved that lowest larval population was also observed in seed treatment with cyantraniliprole 19.8 + thiamethoxam FS 19.8 at 6 ml/kg seed and incidence of FAW was not observed up to 14 days after germination and showed seed treatment with cyantraniliprole19.8 + thiamethoxam 19.8 FS @ 6 ml/kg of seed was recorded significantly lower plant damage (29.97%). Maximum plant damage (%) was registered in plot having seed treatment with fipronil 5 SC @ 6ml/kg of seed (61.72%), fipronil 5 SC @ 8ml/kg of seed (61.64%), thiamethoxam 30 FS @ 6 ml/kg of seed (59.99%) and imidacloprid 600 FS @ 6 ml/kg of seed (58.30%).

Whereas, similar trend of results were also pointed out by many authors in different crops as discussed below. Rizvi and Deole (2022) evidenced bio-efficacy of seven insecticides against fall armyworm, *Spodoptera frugiperda* revealed that spinetoram 11.7% SC @ 30 ml a.i./ha was found most effective insecticide, which recorded the highest reduction in larval population i.e., 76.30% and 86.28% after first and second sprays, respectively followed by Chlorantraniliprole 18.5% SC @ 27.75 ml a.i./ha which recorded 71.67% and 82.30% reduction in larval population after first and second sprays, respectively. While, Suthar *et al*, (2022) suggested that whorl application of chlorantraniliprole 0.4% GR and fipronil 0.6 % GR @ 20kg/ha, first at appearance of fall armyworm and second after 15 days were found effective as it recorded lower larval population. Analogously, Deshmukh *et al*. (2021) revealed that the effective insecticides were chlorantraniliprole 18.5 SC, followed by emamectin benzoate 5 SG, spinetoram 11.7 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, lambda cyhalothrin 5 EC, and novaluron 10 EC. Higher efficacy also was correlated with higher grain yield in comparison with the control. Chlorantraniliprole, emamectin benzoate, and spinetoram are suitable as one of the components of Integrated Pest Management of fall armyworm in India.

Table.4.5: Effect of different insecticides on number of larvae of fall armyworm on *rabi* sorghum (second spray)

Tr. No	Treatments	Dosage	No. of larvae/m row				
			1DBS	**1DAS**	**3DAS**	**7DAS**	**14DAS**
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	12.50 (3.60)	13.25 (3.71)	14.50 (3.87)	17.25 (4.21)	22.25 (4.77)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	11.25 (3.43)	12.25 (3.56)	13.25 (3.71)	16.00 (4.05)	21.75 (4.71)
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	6.00 (2.55)	5.00 (2.34)	4.25 (2.16)	4.00 (2.11)	6.25 (2.59)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	4.75 (2.26)	3.75 (2.06)	3.00 (1.86)	2.75 (1.79)	5.00 (2.34)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	5.25 (2.39)	4.00 (2.09)	3.75 (2.05)	3.00 (1.87)	5.75 (2.49)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	4.00 (2.11)	3.25 (1.91)	2.75 (1.80)	2.25 (1.64)	4.75 (2.29)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	5.25 (2.39)	4.75 (2.26)	4.00 (2.11)	3.25 (2.93)	6.00 (2.55)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	3.75 (2.04)	2.75 (1.79)	2.00 (1.56)	1.75 (1.49)	3.75 (2.06)
T9	Untreated (control)	-	13.50 (3.74)	14.75 (3.90)	15.75 (4.02)	18.50 (4.35)	23.25 (4.87)
	SE±		0.11	0.14	0.11	0.12	0.13
	CD 5 %		0.33	0.43	0.33	0.35	0.38
	CV %		8.36	11.36	9.05	9.30	8.23

Figures in the parenthesis are square root (x+0.5) transformed values.

4.1.4 Effect of application of different insecticides on number of leafhopper

4.1.4.1 First spray

Data pertaining to effect of different insecticides on population of sorghum leaf hopper after first spray are presented in Table 4.6 and Fig.4.6.

The results revealed that all the insecticides were found to be significantly superior over untreated control in reducing population of sorghum leaf hopper at 1, 3, 7 and 14 days after first application of insecticides.

The plots treated with Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* recorded significantly lowest population of leafhopper on sorghum to the extent of 5.50, 4.75, 3.75 and 3.00 leafhopper per 5 plants at 1, 3, 7 and 14 days after spraying, respectively over rest of the insecticides.

At one day after first spray, significantly minimum population of leafhopper (5.50 per 5 plants) was recorded from the plots treated with Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.75 leafhopper/5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg (6.50 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (6.75 leafhopper/5 plants). These treatments were found to be statistically at par with each other. The next effective treatments were Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (7.00 leafhopper/5 plants), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (7.25leafhopper/5 plants), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (7.50 leafhopper/ 5 plants) and Emamectin Benzoate 5% SG 4g/10 *l* (7.75 leafhopper per 5 plants).

At three days after first spray, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.75 leafhopper/ 5 plants), followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.25 leafhopper/ 5 plants), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.75 leafhopper/5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg (6.25 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (6.50 leafhopper/5 plants). All these

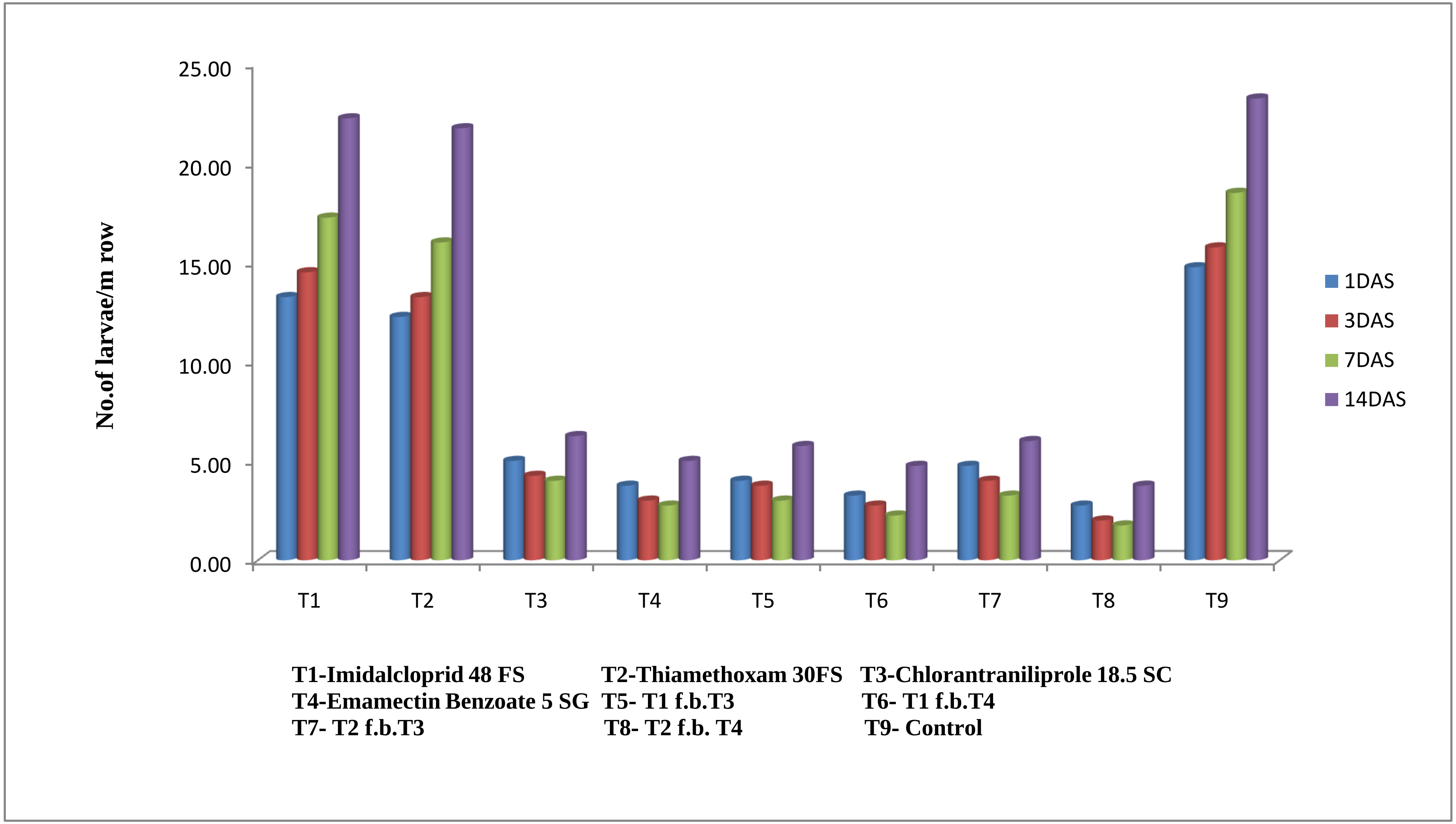


Fig. 4.5: Effect of different insecticides on number of larvae of fall armyworm on *rabi* sorghum (second spray).

treatments were found to be statistically at par with other. The subsequent order of effectiveness was Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (6.50 leafhopper/5 plants), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (7.00 leafhopper/ 5 plants) and Emamectin Benzoate 5% SG 4g/10 *l* (7.25 leafhopper per 5 plants).

At seven days after spraying, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* evidenced significantly effective treatment in minimizing leafhopper population (3.75 leafhopper/ 5 plants) which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.00 leafhopper/ 5 plants), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.25 leafhopper/5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg (5.50 leafhopper/5 plants). All these treatments were found to be significantly superior and statistically at par with each other. Subsequently effective treatments in reducing population of sorghum leafhopper were Thiamethoxam 30FS seed treatment 10ml/kg (5.75 leafhopper/5 plants), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (6.00 leafhopper/5 plants), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.75 leafhopper/ 5 plants) and Emamectin Benzoate 5% SG 4g/10 *l* (7.00 leafhopper per 5 plants).

At 14 days after spraying, significantly lowest population of leafhopper was noted in Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.00 leafhopper per 5 plants) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.75 leafhopper/ 5 plants). Both these treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.00 leafhopper/5 plants), Thiamethoxam 30FS seed treatment 10ml/kg (5.25 leafhopper/5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg(5.50 leafhopper/5 plants), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.75 leafhopper/5 plants), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (7.25 leafhopper/ 5 plants) and Emamectin Benzoate 5% SG 4g/10 *l* (8.00 leafhopper per 5 plants).

Table 4.6 : Effect of application of different insecticides on number of leafhopper (first spray)

Tr. No	Treatments	Dosage	Mean Population of Leaf hopper/5 plants				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	6.25 (2.60)	6.50 (2.60)	6.25 (2.60)	5.75 (2.50)	5.50 (2.45)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	6.75 (2.68)	6.75 (2.69)	6.50 (2.53)	5.50 (2.39)	5.25 (2.39)
T3	Chlorantraniliprole-18.5 %SC	3 ml /10 *l*	9.00 (3.08)	7.50 (2.83)	7.00 (2.74)	6.75 (2.68)	7.25 (2.77)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	9.25 (3.12)	7.75 (2.87)	7.25 (2.78)	7.00 (2.74)	8.00 (2.91)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	6.25 (2.59)	5.50 (2.45)	4.75 (2.28)	3.75 (2.04)	3.00 (1.86)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	6.50 (2.62)	5.75 (2.50)	5.25 (2.39)	5.00 (2.34)	3.75 (2.06)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	7.50 (2.81)	7.25 (2.78)	5.75 (2.50)	5.25 (2.40)	5.00 (2.35)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	7.25 (2.78)	7.00 (2.74)	6.50 (2.69)	6.00 (2.55)	5.75 (2.50)
T9	Untreated (control)	-	11.50 (3.46)	12.75 (3.64)	14.00 (3.80)	15.25 (3.96)	16.50 (4.12)
	SE±		0.10	0.10	0.11	0.13	0.10
	CD 5 %		0.31	0.31	0.34	0.40	0.29
	CV %		7.48	7.70	8.85	10.45	7.89

Figures in the parenthesis are square root (x+0.5) transformed values.

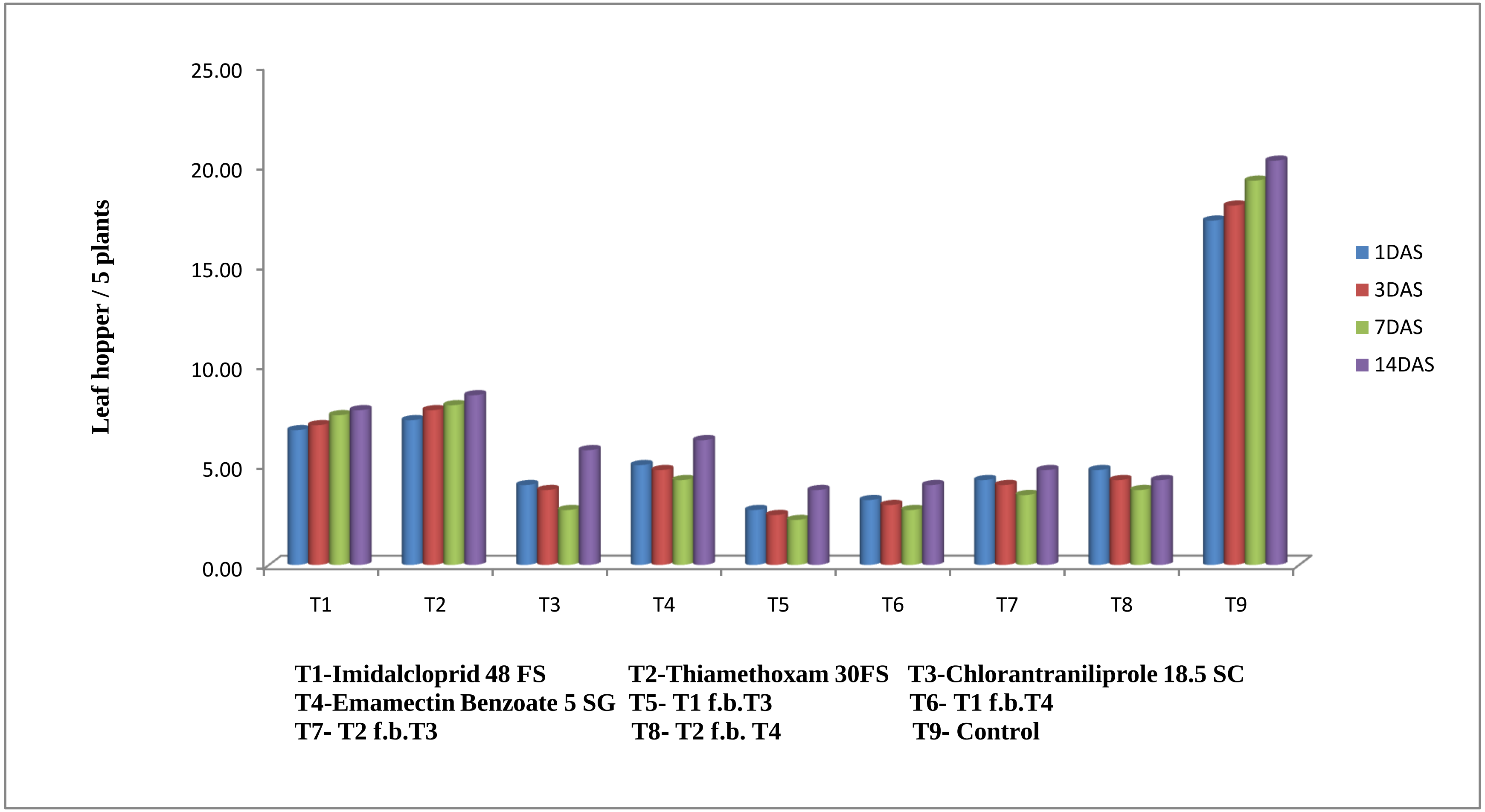


Fig. 4.6: Effect of application of different insecticides on number of leafhopper (first spray).

4.1.4.2 Second spray

The results in respect of effect of different insecticides on population of leafhopper after second spray are presented in Table.4.7 and Fig. 4.7.

The date revealed that all the insecticides under investigation were observed to be significantly superior over untreated control in reducing the population of leafhopper on sorghum at 1,3,7 and 14 days after second spray.

The plots treated with Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* recorded significantly lowest population of leafhopper on sorghum to the extent of 2.75, 2.50, 2.25 and 3.75 leafhopper per 5 plants at 1, 3, 7 and 14 days after spraying, respectively over rest of the insecticides.

At one day after second spray, significantly minimum population of leafhopper recorded in Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.75 leafhopper per 5 plants) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.25 leafhopper/ 5 plants). Both these treatments were statistically at par with each other.The next effective treatments in lowering leafhopper population Chlorantraniliprole-18.5 %SC 3ml/10 *l* (4.00 leafhopper/ 5 plants), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.25 leafhopper/5 plants), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.75 leafhopper/5 plants), and Emamectin Benzoate 5% SG 4g/10 *l* (5.00 leafhopper per 5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg(6.75 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (7.25 leafhopper/5 plants).

Similar trend of results were obtained at three days after second spray. Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* recorded significantly lowest population of leafhopper to the tune of (2.50 leafhopper per 5 plants) followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.00 leafhopper/ 5 plants). Subsequently effective treatments were Chlorantraniliprole-18.5 %SC 3ml/10 *l* (3.75 leafhopper/ 5 plants), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.00 leafhopper/5 plants), Thiamethoxam 30 FS seed treatment 10

Table.4.7: Effect of application of different insecticides on number of leafhopper (second spray)

Tr. No	Treatments	Dosage	Mean Population of Leafhopper/5 plants				
			1DBS	**1DAS**	**3DAS**	**7DAS**	**14DAS**
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	5.50 (2.45)	6.75 (2.69)	7.00 (2.74)	7.50 (2.83)	7.75 (2.87)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	5.25 (2.39)	7.25 (2.78)	7.75 (2.87)	8.00 (2.92)	8.50 (3.00)
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	7.25 (2.77)	4.00 (2.12)	3.75 (2.03)	2.75 (1.79)	5.75 (2.50)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	8.00 (2.91)	5.00 (2.35)	4.75 (2.28)	4.25 (2.16)	6.25 (2.57)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3ml/10 *l*	3.00 (1.86)	2.75 (1.79)	2.50 (1.72)	2.25 (1.56)	3.75 (2.05)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	3.75 (2.06)	3.25 (1.93)	3.00 (1.87)	2.75 (1.80)	4.00 (2.11)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3ml/10 *l*	5.00 (2.35)	4.25 (2.17)	4.00 (2.11)	3.50 (2.00)	4.75 (2.25)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	5.75 (2.50)	4.75 (2.28)	4.25 (2.18)	3.75 (2.04)	4.25 (2.18)
T9	Untreated (control)	-	16.50 (4.12)	17.25 (4.21)	18.00 (4.30)	19.25 (4.44)	20.25 (4.55)
	SE±		0.10	0.08	0.10	0.10	0.12
	CD 5 %		0.29	0.24	0.31	0.30	0.36
	CV %		7.89	6.66	8.80	8.76	9.27

Figures in the parenthesis are square root (x+0.5) transformed values.

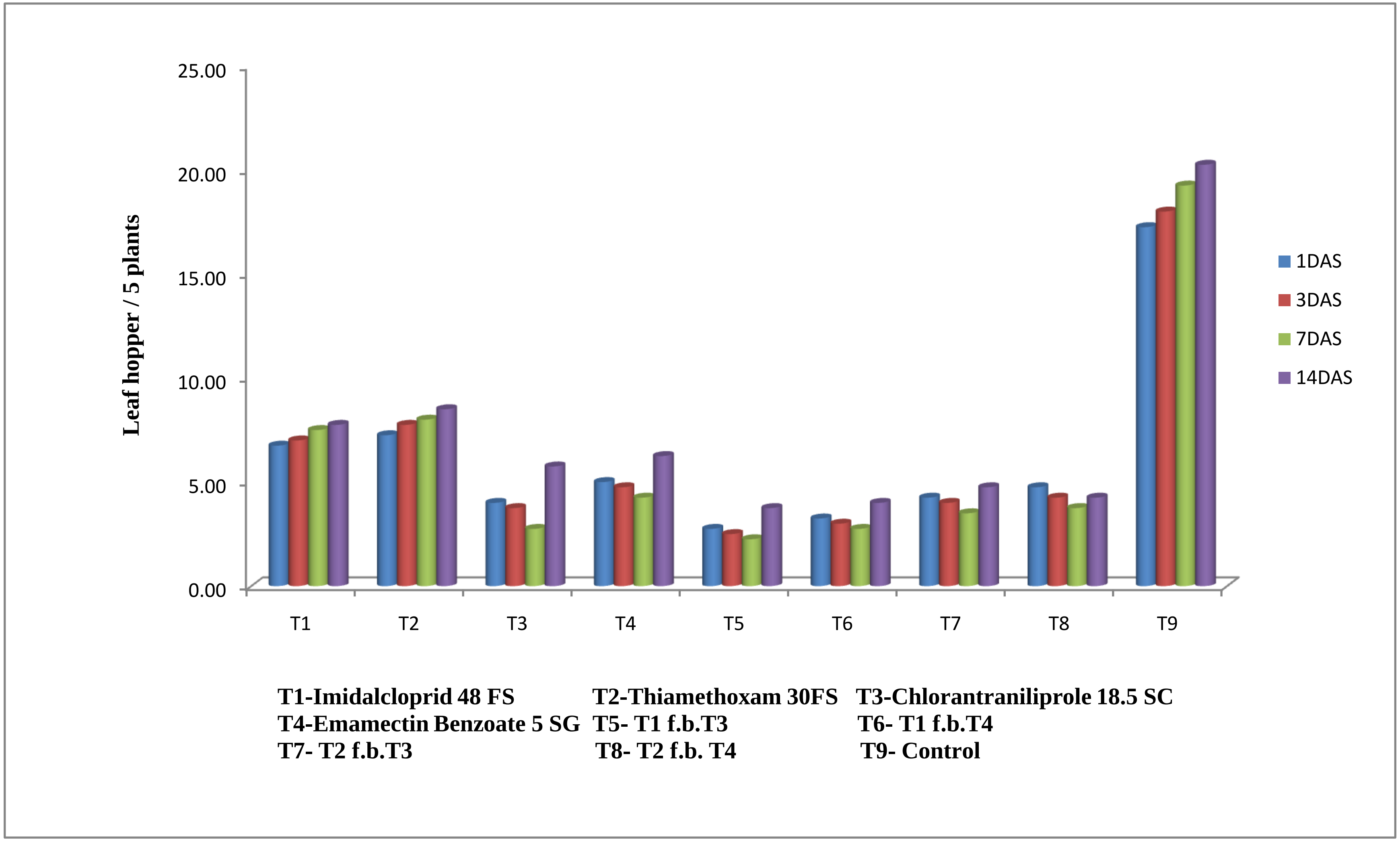


Fig. 4.7: Effect of application of different insecticides on number of leaf hopper (second spray).

ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.25 leafhopper/5 plants), and Emamectin Benzoate 5% SG 4g/10 *l* (4.75 leafhopper per 5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg(7.00 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (7.75 leafhopper/5 plants).

At seven days after second spray, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* evidenced significantly least population of leafhopper (2.25 leafhopper per 5 plants) which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.75 leafhopper/ 5 plants), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (2.75 leafhopper/ 5 plants). These three treatments were found to be statistically at par with each other. Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.50 leafhopper/5 plants), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.75 leafhopper/5 plants), and Emamectin Benzoate 5% SG 4g/10 *l* (4.25 leafhopper per 5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg(7.50 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (8.00 leafhopper/5 plants) were subsequently effective treatments.

At 14 days after second spray, significantly minimum population of leafhopper (3.75 leafhopper/5 plants) was registered from the plots treated with Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.00 leafhopper/ 5 plants), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.25 leafhopper/5 plants). These treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.75 leafhopper/5 plants), Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.75 leafhopper/5 plants), Emamectin Benzoate 5% SG 4g/10 *l* (6.25 leafhopper per 5 plants), Imidalcloprid 48% FS seed treatment 5ml/kg(7.75 leafhopper/5 plants) and Thiamethoxam 30FS seed treatment 10ml/kg (8.50 leafhopper/5 plants).

The trends of results found in the present investigation coincides with Hemadri, *et al* (2018) who reported lowest incidence of leafhopper in Okra with imidacloprid 17.8 SL @ 0.5 ml/l was found superior over the other treatments with higher per cent reduction (85.21 per cent) of pest population, followed by acetamiprid 20 SP @ 0.5 g/l, thiamethoxam 25 WG @ 0.3 g/l, acephate 95 SG @ 0.3 g/l, clothianidin 50 WDG @ 0.25 g/l which recorded 84.21, 83.41, 77.48, 74.62 per cent reduction of pest population, respectively.

Sajjan and Praveen (2008) revealed that seed treatment with imidacloprid @ 12 ml per kg of seed or thiomethoxam @ 10 g per kg of seed were found effective in controlling leaf hoppers in okra. Similarly, Surulivelu *et al*. (1998) indicated Imidacloprid seed treatment reduced the jassid populations by 65% in research station studies without affecting predator coccinellids. While, kharade *et al*. (2018) documented different insecticides *viz*., imidacloprid 0.0044 per cent, dimethoate 0.04 per cent, quinalphos 0.05 per cent, emamectin benzoate 0.002 per cent, chlorantraniliprole 0.0074 per cent and indoxacarb 0.019 per cent were evaluated against jassid,in brinjal.In the same way, Potai *et al*. (2018) registered significantly lower population of major sucking pests as compared to untreated control. BAS 450 01 I 300 SC @18.5g a.i./ha proved the best treatment for the control of sucking pests however, treatments viz. BAS 450 01 I 300 SC @6.5g a.i./ha and Chlorantraniliprole 18.5% SC @ 25g a.i./ ha. However, Javalge *et al*.(2010) reported that Imidacloprid 17.8 SL, acetamiprid 20 SP and thiamethoxam 25 WG in okra crop.

4.1.5 Effect of application of different insecticides on population of ladybird beetle

4.1.5.1 First spray

The observations on population of ladybird beetles were recorded on sorghum at different intervals after first spray and the data are presented in Table 4.8 and Fig. 4.8.

One day after treatment, untreated control plot was recorded highest population of ladybird beetle (7.50/m row). Among the treatment Thiamethoxam 30FS seed treatment 10ml/kg (7.25/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg(6.25/m row),Chlorantraniliprole-18.5 %SC 3ml/10 *l* (6.00/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.75/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b.

Table. 4.8 : Effect of application of different insecticides on population of ladybird beetle (first spray)

Tr. No	Treatments	Dosage	Mean Population of ladybird beetle/m row				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	6.00 (2.55)	6.25 (2.60)	6.75 (2.69)	7.25 (2.78)	7.75 (2.87)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	7.00 (2.74)	7.25 (2.78)	7.50 (2.82)	8.00 (2.91)	8.25 (2.96)
T3	Chlorantraniliprole-18.5 %SC	3 ml/10 *l*	6.50 (2.64)	6.00 (2.55)	5.50 (2.45)	5.25 (2.39)	5.75 (2.50)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	5.75 (2.50)	5.25 (2.38)	4.75 (2.25)	4.25 (2.15)	5.00 (2.34)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	5.75 (2.50)	5.50 (2.45)	5.25 (2.39)	5.00 (2.32)	5.50 (2.44)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	6.00 (2.52)	5.00 (2.33)	4.50 (2.22)	4.00 (2.10)	4.75 (2.28)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	6.25 (2.59)	5.75 (2.49)	5.00 (2.34)	4.50 (2.22)	5.25 (2.39)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	5.00 (2.34)	4.75 (2.29)	4.25 (2.17)	3.50 (2.00)	4.50 (2.22)
T9	Untreated (control)	-	6.75 (2.68)	7.50 (2.83)	8.00 (2.91)	8.50 (3.00)	8.75 (3.04)
	SE±		0.11	0.10	0.13	0.13	0.09
	CD 5 %		NS	0.29	0.38	0.40	0.27
	CV %		9.02	7.97	10.54	11.34	7.22

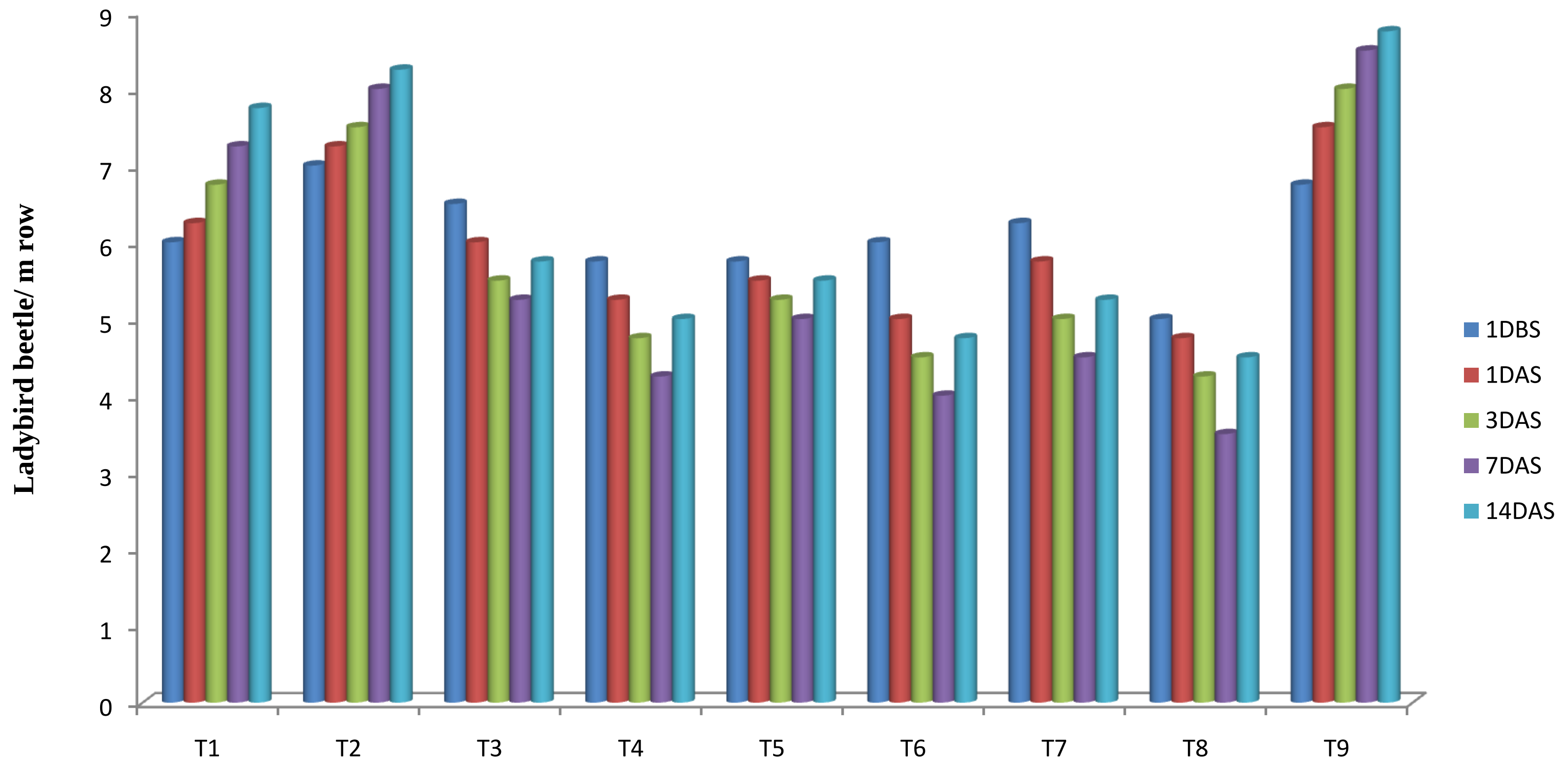
Figures in the parenthesis are square root (x+0.5) transformed values.

-18.5%SC 3ml/10 *l* (5.50/m row), Emamectin Benzoate 5% SG 4g/10 *l* (5.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.00/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.75/ m row).

At three days after treatment untreated control was recorded highest population of ladybird beetle (8.00/m row). Later on, seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg recorded comparatively higher population of ladybird beetles i.e. (7.50/m row). This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg(6.75/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.50/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.25/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.00/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.75/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.50/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.25/ m row).The population recorded in the treatments was in the range of 7.50 to 4.25 per m row.

At seven days after first spray untreated plot was recorded highest population of ladybird beetle (8.50/m row). Next treatments, seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg (8.00/ m row) recorded comparatively higher population of ladybird beetles. This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg(7.25/ m row),Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.25/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.00/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.50/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.00 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.50/ m row).The population recorded in the treatments was in the range of 7.25 to 3.50 per m row.

At 14 days after first spray, untreated plot was recorded highest population of ladybird beetles (8.75/ m row). Among the treatments, seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg recorded comparatively higher



T1-Imidalcloprid 48 FS T2-Thiamethoxam 30FS T3-Chlorantraniliprole 18.5 SC
T4-Emamectin Benzoate 5 SG T5- T1 f.b.T3 T6- T1 f.b.T4
T7- T2 f.b.T3 T8- T2 f.b. T4 T9- Control

Fig. 4.8: Effect of application of different insecticides on population of ladybird beetle (first spray).

population of ladybird beetles i.e. (8.25/m row). This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg(7.75/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.75/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.50/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.25/m row), Emamectin Benzoate 5% SG 4g/10 *l* (5.00/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.75/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.50/ m row).

4.1.5.2 Second spray

The observations on population of ladybird beetles were recorded on sorghum at different intervals after first spray and the data are presented in Table 4.9 and Fig. 4.9.

One day after second spray control plot was recorded highest population of LBBs (9.25/ m row). Among the treatment Thiamethoxam 30FS seed treatment 10ml/kg (8.75/ m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg(8.50/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.25/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (5.00/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.00/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.50/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.25 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.00/ m row).

At three days after second spray untreated plot was recorded highest population of LBBs (9.75/m row). Next seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg (9.00/ m row) recorded comparatively higher population of ladybird beetles. This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg(9.00/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.00/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (4.75/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.50/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l*

(4.00 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.50/ m row).The population recorded in the treatments was in the range of 9.00 to 3.50/ m row.

At seven days after second spray untreated control was recorded maximum population of ladybird beetles (8.75/ m row). Among the treatments, seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg (8.25/ m row) recorded comparatively higher population of ladybird beetles. This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg (8.00/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (4.50/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.25/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (4.25/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.00/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.50 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (3.25/ m row).

At 14 days after treatment untreated control was recorded highest population of LBBs (7.75/m row). Among the treatments, seed treatments with Thiamethoxam 30FS seed treatment 10ml/kg (7.50/ m row) recorded comparatively higher population of ladybird beetles. This was followed by treatments Imidalcloprid 48% FS seed treatment 5ml/kg(7.25/ m row),Chlorantraniliprole-18.5 %SC 3ml/10 *l* (5.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (5.00 /m row) Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (5.00/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (4.75/m row), Emamectin Benzoate 5% SG 4g/10 *l* (4.50/m row), and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (4.25/m row).

According to Narayan *et al*. (2019) revealed that control plot contains more number of natural enemies and proved significantly superior overall treated plots followed by chlorantraniliprole 18.5% SC and cyantraniliprole 10% OD. Likewise, cartap hydrochloride 75% SG also better than emamectin benzoate 5% SG and flubendiamide 39.36% SC found less toxic to natural enemies in brinjal crop. According to Mollah *et al* (2012) studied that insecticides, Neemoil (fresh) @ 2.5

ml / L water, Curtap 50 SP @ 2.0 g / L water and Emamectin benzoate 5 SG @ 1.0 g / L water ensure highest number of ladybird beetle in the treated plot resulting 22.45, 17.97 and 15.63 adult ladybird beetles per plot area respectively. Khandare *et al* (2019) reported that seed treatment with imidacloprid 70 WS @ 10g/kg recorded comparatively higher population of LBBs i.e. 0.51/plant, followed by treatments of acephate 50 + imidacloprid 1.8 SP @ 1:20, clothianidin 50 WDG @ 1:20, clothianidin 50 WDG @ 1:10 and imidacloprid @ 1:20, recording, 0.39, 0.33, 0.26 and 0.24 per plant of LBBs population, respectively. Whereas, Govindan *et al* (2013) reported that emamectin benzoate 5 SG was found safer to coccinellids. However, Chavan *et al*. (2016) revealed that no population of ladybird beetle was recorded at 3 DAS in treatment imidacloprid 17.8 SL which was found more toxic to coccinellid than all other insecticidal treatments. After second spray the minimum population of ladybird beetle was recorded in treatment fipronil 5 SC (0.13/plant) which was found more toxic to coccinellids. Kaushik *et al* (2016) revealed that all the treatments exerted significant impact on the populations of natural enemies (coccinellids, syrphid flies and spiders). However, thiamethoxam 30 FS was found to be relatively safe insecticide against these natural enemies. Combinations (seed treatment with thiamethoxam 70 WS + spray with imidacloprid 17.8 SL, seed treatment with thiamethoxam 30 FS + spray with imidacloprid 17.8 SL, seed treatment with imidacloprid 17.8 SL + spray with thiamethoxam 30 FS), imidacloprid 17.8 SL and spinosad 45 EC were moderate toxic while quinalphos 25 EC was the most toxic for the same. Thus, thiamethoxam, imidacloprid or their combinations as seed treatment and spray, and spinosad can be used in cowpea ecosystem for better pest management as they are less toxic for natural enemies.

Nemade *et al* (2009) results revealed that imidacloprid seed treatments were found most safer for natural enemies of *Earias vittella* in okra field. Analogously, Khan *et al* (2015) showed that emamectin benzoate proved to be the best one with significantly least level of toxicity against egg, larva, pupa, and adult (26.67%, 20%, 20%, & 30%) mortality, respectively. Spinosad followed Emamectin benzoate in toxicity against different stages of *M. sexmaculatus* (46.67%, 50%, 40%, & 44%) mortality, respectively. The results further revealed that Neem oil was highly toxic by causing maximum egg and pupa (80% & 86.67%) mortality, respectively.

Thus, results show that there is a potential to use Emamectin benzoate in an IPM program. Nemade *et al* (2009), results revealed that imidacloprid seed treatments were found most safer for natural enemies of *Earias vittella* in okra field. Selvaraj *et al* (2017), concluded that, the new insecticide mixture Cholrantraniliprole 4.3% + Abamectin 1.7% SC @ 24 g a.i. ha^{-1} recorded safer to natural enemies (Spiders and Coccinellids) population in the tomato ecosystem. Potai *et al* (2018) concluded that Chlorantraniliprole 18.5% SC@25g.a.i./ha and Cypermethrin 10% EC@70g.a.i./ha along with a untreated control were field evaluated. Among the chemical treatments BAS 450 01 I 300 SC@12.5g.a.i./ha and BAS 450 01 I 300 SC@18.5g.a.i./ha found to be safer insecticides to natural enemies.

Table.4.9 : Effect of application of different insecticides on population of ladybird beetle (second spray)

Tr. No	Treatments	Dosage	Mean Population of ladybird beetle/ m row				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	7.75 (2.87)	8.50 (3.00)	8.75 (3.04)	8.00 (2.91)	7.25 (2.78)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	8.25 (2.96)	8.75 (3.04)	9.00 (3.08)	8.25 (2.96)	7.50 (2.83)
T3	Chlorantraniliprole-18.5 %SC	3 ml/10 *l*	5.75 (2.50)	5.25 (2.39)	5.00 (2.32)	4.25 (2.17)	5.25 (2.40)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	5.00 (2.34)	4.50 (2.22)	4.25 (2.17)	4.00 (2.10)	4.50 (2.23)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	5.50 (2.44)	5.00 (2.32)	4.75 (2.27)	4.50 (2.22)	5.00 (2.34)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	4.75 (2.28)	4.25 (2.18)	4.00 (2.10)	3.50 (2.00)	5.00 (2.34)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	5.25 (2.39)	5.00 (2.34)	4.50 (2.21)	4.25 (2.17)	4.75 (2.28)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	4.50 (2.22)	4.00 (2.10)	3.50 (2.00)	3.25 (1.93)	4.25 (2.18)
T9	Untreated (control)	-	8.75 (3.04)	9.25 (3.12)	9.75 (3.20)	8.75 (3.04)	7.75 (2.85)
	SE±		0.09	0.12	0.12	0.10	0.09
	CD 5 %		0.27	0.35	0.36	0.31	0.28
	CV %		7.22	9.60	10.18	8.90	7.91

Figures in the parenthesis are square root (x+0.5) transformed values.

4.1.6 Effect of application of different insecticides on population of spiders

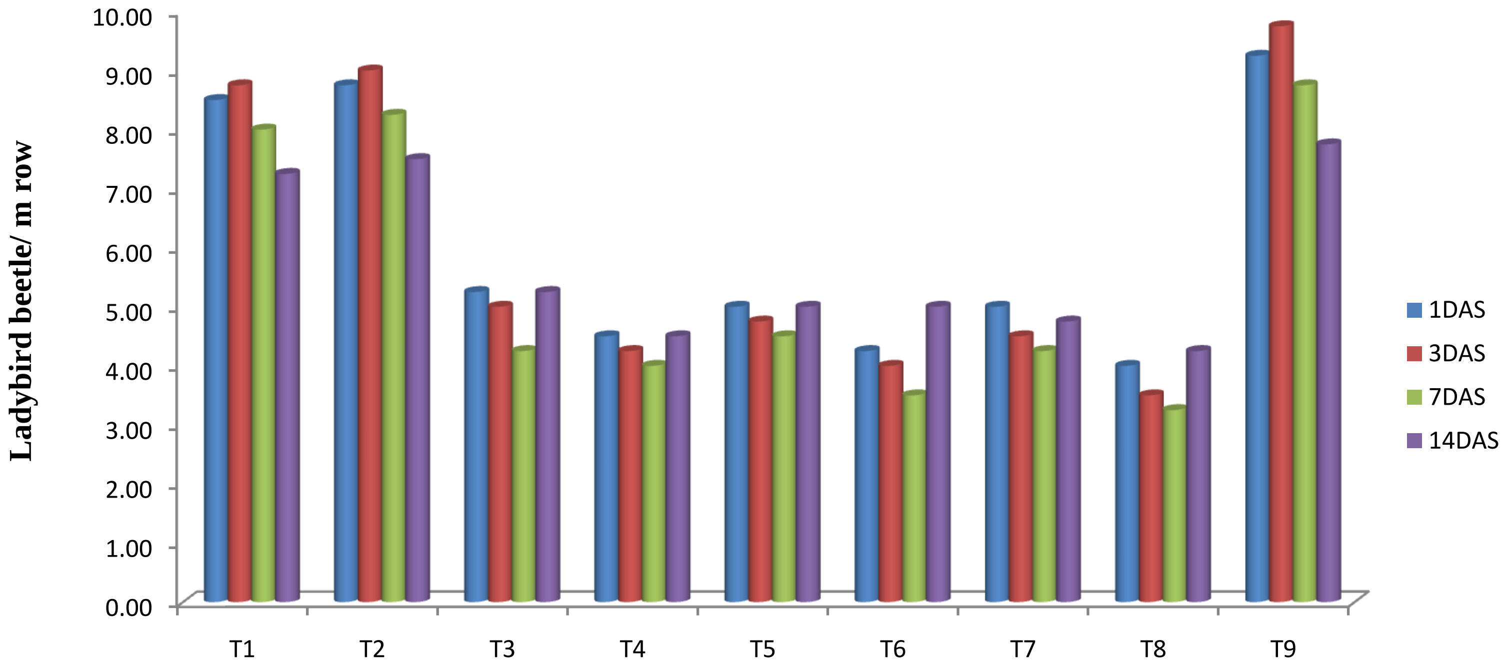
4.1.6.1 First spray

The observations on population of spiders were recorded on sorghum at different intervals after first spray and the data are presented in Table 4.10 and Fig.4.10.

One day after treatment, Imidacloprid 48%FS (seed treatment) plot was recorded highest population of spiders (3.50/m row). Among the treatment Untreated plot (3.25/m row) followed by Thiamethoxam 30FS (seed treatment) f.b. Chlorantraniliprole-18.5% SC 10ml/kg f.b 3ml/10 *l*(3.00/m row), Thiamethoxam 30FS seed treatment 10 ml/kg (2.75/m row), Imidacloprid 48% FS (seed treatment) f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.75/m row), Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.50/m row), Imidalcloprid 48%FS (seed treatment) f.b. Emamectin Benzoate 5% SG 5ml/kg (2.50/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.25/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.25/ m row).

At three days after treatment untreated control was recorded highest population of spiders (3.75/m row). Among the treatments, seed treatments with Imidalcloprid 48% FS seed treatment 5ml/kg (3.50/m row) followed by Thiamethoxam 30FS seed treatment 10ml/kg (3.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10*l* (2.50/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.50/m row), Chlorantraniliprole-18.5%SC 3ml/10 *l* (2.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.00/m row), Emamectin Benzoate 5% SG (1.75/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.75/ m row).

At 7 days treatment untreated control was recorded highest population of spiders (4.00/m row). Among the treatments, seed treatments with Imidacloprid 48% FS seed treatment 5ml/kg (3.75/m row) followed by Thiamethoxam 30FS seed treatment 10ml/kg (3.50/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.50/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.9: Effect of application of different insecticides on population of ladybird beetle (second spray).)

Table 4.10: Effect of application of different insecticides on population of spiders (first spray)

Tr.No	Treatments	Dosage	Mean Population of spider/ m row				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seedtreatment)	5ml/kg	3.25 (1.93)	3.50 (2.00)	3.50 (2.00)	3.75 (2.05)	4.25 (2.17)
T2	Thiamethoxam 30FS (seedtreatment)	10 ml/kg	2.50 (1.73)	2.75 (1.80)	3.25 (1.93)	3.50 (2.00)	3.75 (2.05)
T3	Chlorantraniliprole-18.5 %SC	3 ml/10 *l*	3.00 (1.86)	2.50 (1.72)	2.25 (1.65)	2.00 (1.58)	2.75 (1.80)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	2.50 (1.73)	2.25 (1.64)	1.75 (1.48)	1.75 (1.48)	2.50 (1.73)
T5	Imidalcloprid 48%FS (seedtreatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	3.25 (1.93)	2.75 (1.80)	2.50 (1.73)	2.25 (1.65)	3.00 (1.86)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	3.50 (2.00)	2.50 (1.73)	2.00 (1.56)	1.50 (1.40)	2.25 (1.65)
T7	Thiamethoxam 30FS (seedtreatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	3.75 (2.06)	3.00 (1.86)	2.50 (1.73)	2.50 (1.73)	3.25 (1.93)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	2.75 (1.80)	2.25 (1.65)	1.75 (1.48)	1.25 (1.27)	2.00 (1.58)
T9	Untreated (control)	-	3.00 (1.86)	3.25 (1.93)	3.75 (2.06)	4.00 (2.12)	4.50 (2.23)
	SE±		0.08	0.07	0.10	0.10	0.08
	CD 5 %		NS	0.22	0.31	0.29	0.24
	CV %		9.00	8.42	12.26	11.88	9.00

Figures in the parenthesis are square root (x+0.5) transformed values.

3ml/10 *l* (2.25/m row), Chlorantraniliprole-18.5% SC seed treatment 3ml/10*l* (2.00/m row), Emamectin Benzoate 5% SG 4g/10 *l* (1.75/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.50 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.25/ m row).

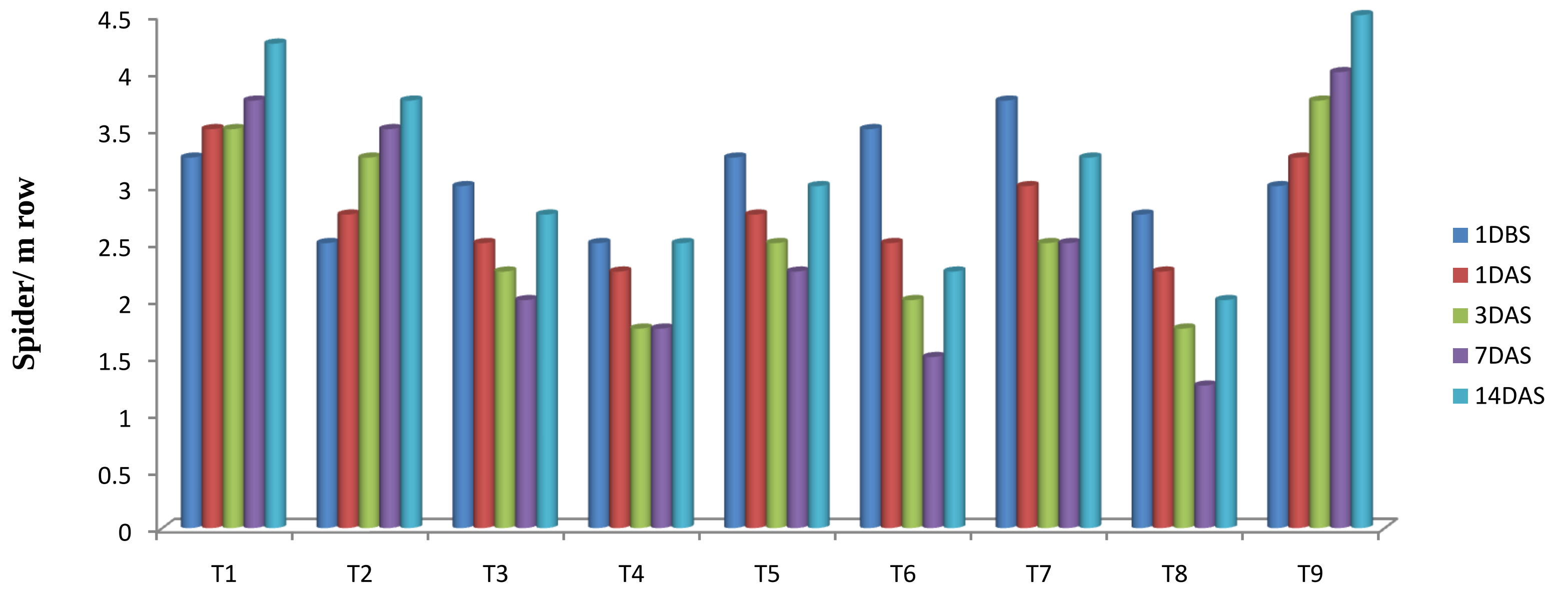
At 14 days after treatment untreated control was recorded highest population of spiders (4.50/m row). Among the treatments, seed treatments with Imidacloprid 48% FS seed treatment 5ml/kg (4.25/m row) followed by Thiamethoxam 30FS seed treatment 10ml/kg (3.75/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.25/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (3.00/m row), Chlorantraniliprole-18.5% SC seed treatment 3ml/10*l* (2.75/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.50/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.25 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.00/ m row).

4.1.6.1 Second spray

The observations on population of spiders were recorded on sorghum at different intervals after first spray and the data are presented in Table 4.11 and Fig.4.11.

One day after second spray, untreated control plot was recorded highest population of spiders (4.75/m row). Among the treatment Thiamethoxam 30FS seed treatment 10ml/kg (4.25/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg(4.00/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.75/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (2.75/m row), Chlorantraniliprole-18.5% SC seed treatment 3ml/10*l* (2.50/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.25/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.00 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.75/ m row).

At three days after second spray treatment untreated control was recorded highest population of spiders (5.25/m row). Amongst the treatments, seed treatments with Imidalcloprid 48% FS seed treatment 5ml/kg(4.75/m row) followed



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.10: Effect of application of different insecticides on population of spiders (first spray).

Table 4.11: Effect of application of different insecticides on population of spiders (second spray)

Tr. No	Treatments	Dosage	Mean Population of spider/ m row				
			1DBS	1DAS	3DAS	7DAS	14DAS
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	4.25 (2.17)	4.00 (2.11)	4.75 (2.28)	4.25 (2.18)	3.75 (2.05)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	3.75 (2.05)	4.25 (2.17)	4.50 (2.23)	5.00 (2.34)	4.50 (2.23)
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	2.75 (1.80)	2.50 (1.72)	2.25 (1.65)	3.25 (1.93)	3.25 (1.93)
T4	Emamectin Benzoate 5% SG	4g/10 *l*	2.50 (1.73)	2.25 (1.64)	2.00 (1.58)	2.50 (1.73)	2.75 (1.80)
T5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3ml/10 *l*	3.00 (1.86)	2.75 (1.80)	2.25 (1.64)	2.75 (1.80)	3.50 (1.98)
T6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	2.25 (1.65)	2.00 (1.56)	1.75 (1.48)	2.25 (1.65)	2.50 (1.73)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3ml/10 *l*	3.25 (1.93)	2.75 (1.80)	2.50 (1.73)	3.00 (1.86)	3.00 (1.86)
T8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	2.00 (1.58)	1.75 (1.48)	1.75 (1.49)	2.00 (1.58)	2.75 (1.80)
T9	Untreated (control)	-	4.50 (2.23)	4.75 (2.29)	5.25 (2.40)	4.75 (2.29)	4.00 (2.12)
	SE±		0.08	0.11	0.10	0.07	0.09
	CD 5 %		0.24	0.34	0.31	0.22	0.28
	CV %		9.00	12.73	11.66	7.97	10.07

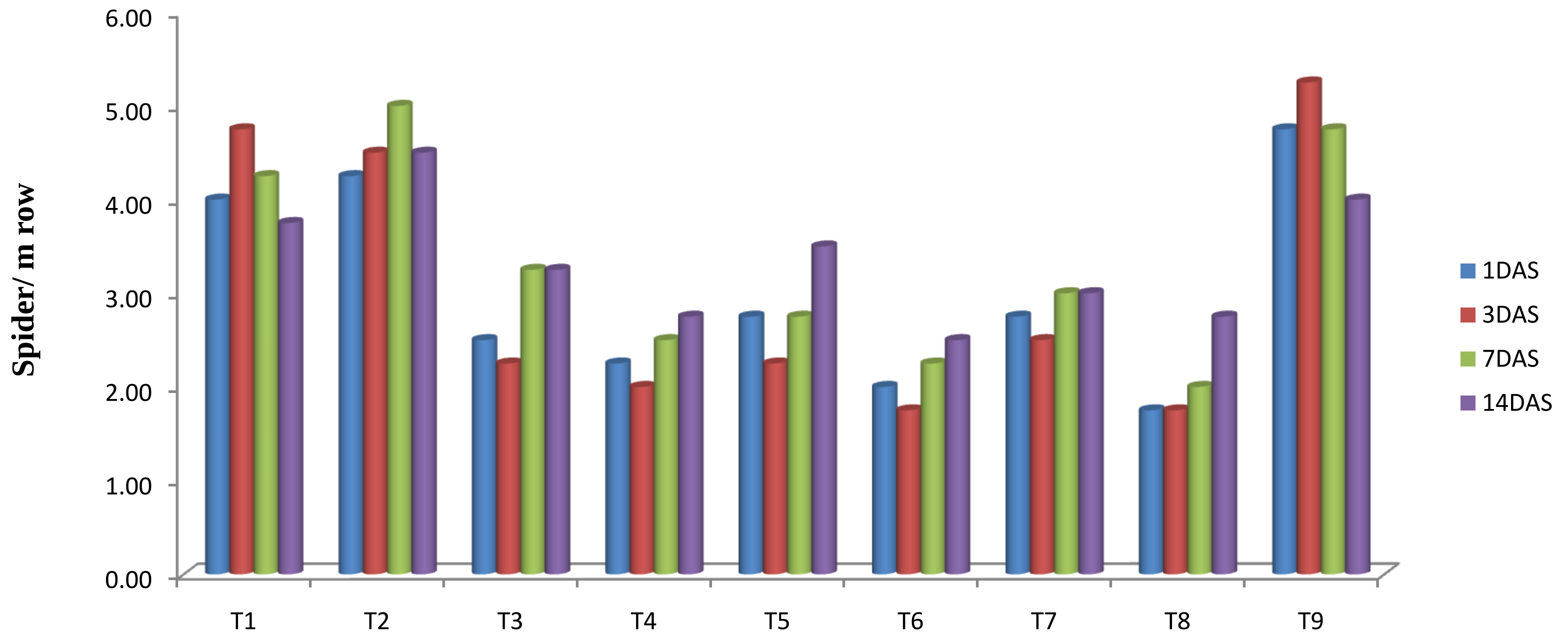
Figures in the parenthesis are square root (x+0.5) transformed values.

by Thiamethoxam 30FS seed treatment 10ml/kg (4.50/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (2.50/m row), Imidalcloprid 48% FS seed treatment 5ml/kg(4.75/m row),Chlorantraniliprole-18.5 %SC 3ml/10 *l* (2.25/m row), Chlorantraniliprole-18.5%SC 3ml/10 *l* (2.25/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.00/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.75 /m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (1.75/ m row).

At 7 days after second spray treatment Thiamethoxam 30 FS (seed treatment) was recorded highest population of spiders (5.00/m row). Among the treatments, untreated control was recorded (4.75/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg (4.25/m row), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (3.25/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.00/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (2.75/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.50/m row), Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.25/m row) and Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.00/ m row).

At 14 days after second spray treatment Thiamethoxam 30 FS (seed treatment) was recorded highest population of spiders (4.50/m row). Among the treatments, untreated control was recorded (4.00/m row) followed by Imidalcloprid 48% FS seed treatment 5ml/kg (3.75/m row), Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (3.50/m row), Chlorantraniliprole-18.5% SC 3ml/10 *l* (3.25/m row), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 % SC 3ml/10 *l* (3.00/m row), Emamectin Benzoate 5% SG 4g/10 *l* (2.75/m row), Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.75/ m row) and Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (2.50/m row).

The present findings are in close agreement with the earlier reports of Narayan *et al.* (2019) revealed that control plot contains more number of natural enemies and proved significantly superior overall treated plots followed by chlorantraniliprole 18.5% SC and cyantraniliprole 10% OD. Likewise, cartap hydrochloride 75% SG also better than emamectin benzoate 5% SG and flubendiamide 39.36% SC found less toxic to natural enemies. Analogously, results



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.11: Effect of application of different insecticides on population of spiders (second spray).

revealed that flubendiamide 20%WG @ 25 g a.i./ ha was the least toxic, allowing maximum occurrence of spiders (excluding untreated control). Thus, it can be considered in IPM for the best control of insect pests. Similarly, chlorantraniliprole 18.5%SC @ 30 g a.i./ ha followed by fipronil 5%SC @ 50 g a.i./ha were also found safe to spiders. Shyamrao *et al* (2021).

The results observed in present studies are more or less similar with the findings of Singh *et al* (2020) who noticed minimum population of spiders was found in treatment Quinalphos 20EC @ 2.0 ml per of water plants water with 0.50 spiders per five plants. the maximum adults population of spiders was recorded with Bacillus thuringiensis @ 2.0 gm per liter of water, neem oil (1500 ppm) @ 5.0 ml per litre of water, Emamectin benzoate 5% SG @ 0.5 gm per liter of water, Indoxacarb 14.5 SC@ 1.0 ml per liter of water, spinosad 45% SC @ 0.3 ml per liter of water, Profenophos 50EC @ 2.0ml per liter of water, Lambda- cyhalothrin @ 1.0 per liter of water and Quinalphos 20EC @ 2.0 ml per of water plants, respectively.

These observations are similar to that of Mishra (2008) with rynaxpyr 20EC at 40 g a.i./ ha and flubendiamide 480SC at 30 g a.i./ ha as safer to predators of rice pests. The results of Shanwei *et al* (2009) on chlorantraniliprole 20SC at 40 g a.i./ ha as highly safe to beneficial arthropods corroborate with this study; Jafar *et al*. (2013) observed that indoxacarb 15.8EC at 30 g a.i./ ha, chlorantraniliprole 18.5%SC at 30 g a.i./ ha, cartap hydrochloride 50%SP at 500 g a.i./ ha and fipronil 5%SC 625 ml/ ha are safer to rice natural enemies. Javaregowda and Naik (2005) with flubendiamide at 12.5, 25 and 50 g a.i./ ha observed 23.42, 23.82 and 24.33 spiders/ 10 hills, respectively, on par with the untreated check (22.47/ 10 hills).

4.1.7 Effect of different insecticides on grain yield of *rabi* sorghum

The results in respect of effect of different insecticides on grain yield of sorghum are presented in Table.4.12 and Fig.4.12.

The data regarding grain yield of sorghum indicated that all the treatments were statistically significant in increasing grain yield over untreated control. The grain yield of sorghum due to different treatments varied from 18.08 to 32.19 q per ha. The significantly highest grain yield (32.19 q per ha) of sorghum was observed in Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* which was followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b.

Chlorantraniliprole-18.5%SC 3ml/10 *l* (31.01 q per ha), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (30.67 q per ha), Thiamethoxam 30FS seed treatment 10ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* (28.61 q per ha), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (26.29 q per ha), Emamectin Benzoate 5% SG 4g/10 *l* (25.71 q per ha), Thiamethoxam 30FS seed treatment 10ml/kg (23.17 q per ha) and Imidalcloprid 48% FS seed treatment 5ml/kg (22.68 q per ha). All these treatments proved equally effective in increasing sorghum yield. However, the lowest grain yield (18.08 q per ha) was registered in untreated control.

More or less similar results were achieved by Khaliq *et al*. (2022) who reported maximum yield (1.79, 1.73 t/h) in thiamethoxam @ 7.5g and 5g/kg seed in sorghum. however, it was at par with spinosad treated plots (1480 kg/ha). While, khan *et al*. (2020) noted maximum yield in Clothianidin+ Imidacloprid produced (12,375 kg/ha), followed by Imidacloprid (11,681kg/ha). However, Balikai and Bhagwat (2009) who reported highest grain yield of 32.1q/ha with thiamethoxam 70 WS @ 4 g/ kg seeds According to Rawat *et al* . (2011) all the treatments also revealed superiority of imidacloprid 600 FS @ 5ml/kg of seed amongst all the treatments as imidacloprid 600 FS @ 5ml/kg of seed proved to be the best treatment in reducing infestation of shoot fly and also resulted in increased mean grain yield (23.64 q/ha) and mean fodder yield (109.00 q/ha). It was followed by thiamethoxam 70 WS @ 2g/kg of seed with the mean grain yield of 22.12q/ha and mean fodder yield of 102.00 q/ha and remained at par with chloropyriphos 20 EC @ 5ml/kg of seed with the mean grain yield of 20.80 q/ha. Khandare *et al* (2017) indicated that the treatment with thiamethoxam 35 FS @ 5 ml/kg seed produced highest grain yield (3462 kg/ha). Shid *et al* (2022) recorded highest yield in seed treatment with Thiamethoxam 30 FS @ 10 ml/kg of seed (15.70 q/ha) which was superior to all other treatments. The next best grain yield was registered in the plot of seed treatment with Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed (14.00 q/ha) which was at par with the plot of seed treatment with Imidacloprid 17.8 SL @ 3 ml/kg of seed (13.87 q/ha). Jambagi *et al* (2022) recorded higher grain yield (32.22 and 31.27 q/ha) and straw yield (76.30 and 74.78 q/ha) was obtained in the plots characterised with seed treatment of thiamethoxam 30 FS (5 ml/kg seed) followed by a spray of cypermethrin 10 EC (0.5 ml/l). Sonalkar *et al* (2018) highest yield was recorded Seed treatment with imidacloprid 70 % WS @ 10 g/kg seed followed by quinalphos 25 % EC spray

@ 20 ml/10 lit water (36.23 q/ha) followed in seed treatment with imidacloprid 48 FS @ 12 g/kg seed followed by quinalphos 25 % EC spray @ 20 ml/10 lit water (34.17 q/ha).

Table 4.12: Effect of different insecticides on grain yield of *rabi* sorghum

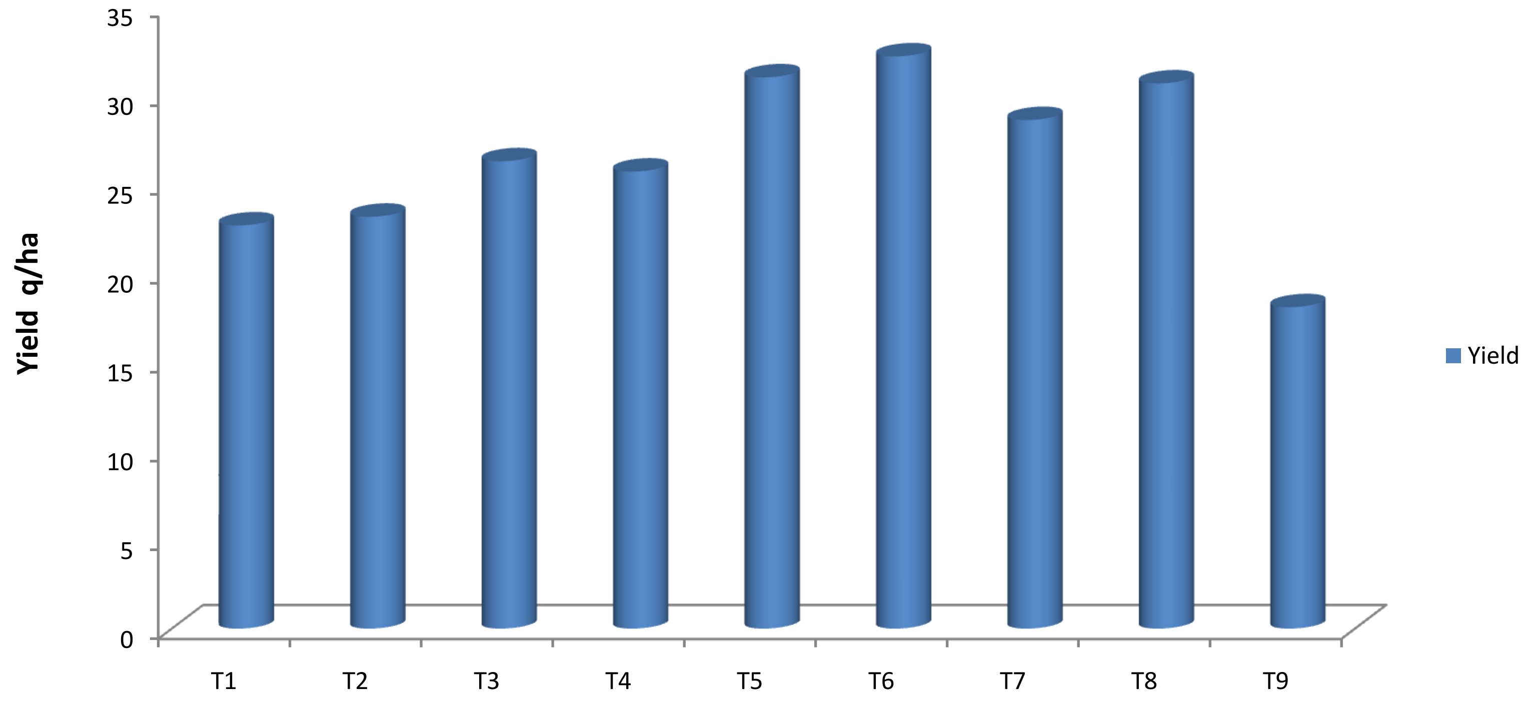
Tr. No.	Treatments	Dosage	Grain Yield (kg/ha)	Grain Yield (q/ha)	Increased yield over control
T1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	2268.52	22.68	4.60
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	2317.90	23.17	5.09
T3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	2629.63	26.29	8.21
T4	Emamectin Benzoate 5% SG	4g/10 *l*	2570.99	25.71	7.63
T5	Imidalcloprid 48%FS (seed treatment) f.b. Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3ml/10 *l*	3101.85	31.01	12.93
T6	Imidalcloprid 48%FS (seed treatment) f.b. Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	3219.14	32.19	14.11
T7	Thiamethoxam 30FS (seed treatment) f.b. Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3ml/10 *l*	2861.11	28.61	10.53
T8	Thiamethoxam 30FS (seed treatment) f.b. Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	3067.90	30.67	12.59
T9	Untreated (control)	-	1808.64	18.08	-
	SE±		80.82		
	CD 5 %		235.91		
	CV %		6.10		

4.1.8 Effect of different insecticides on incremental cost benefit ratio (ICBR).

The data generated on incremental cost benefit ratio of different insecticides applied against major insect-pests of sorghum are tabulated in Table 4.13 and depicted Fig.4.13.

Among all the treatments, highest incremental cost benefit ratio (1:25.1) was attained by Imidalcloprid 48%FS (seed treatment) which was followed by (1:24.3), Thiamethoxam 30FS (seed treatment), Imidalcloprid 48%FS (seed treatment) f.b. Emamectin Benzoate 5% SG (1:13.2), Thiamethoxam 30FS (seed treatment) f.b. Emamectin Benzoate 5% SG (1:11.3), Emamectin Benzoate 5% SG (1:7.0), Imidalcloprid 48%FS (seed treatment) f.b. Chlorantraniliprole-18.5%SC (1:4.8), Thiamethoxam 30FS (seed treatment) f.b. Chlorantraniliprole-18.5 %SC (1:3.7) and Chlorantraniliprole-18.5 %SC (1:2.8).

These results are in conformity to findings of Khandre *et al.* (2014), advocating, seed treatment with thiamethoxam 35 FS @ 5 ml/kg seed produced highest grain yield (3462 kg/ha). The maximum net monetary returns 1:56.25 (ICBR) were realized by the treatment thaimethoxam 35 FS @ 5 ml/kg seed. Kumar and Prabhuraj (2007), also observed that the efficacy of different seed treatment insecticides with respect to control of sorghum shoot fly; grain yield and green fodder yield and suggested thiamethoxam 70 WS at 2 g/kg recorded higher grain yield (31.93 q/ha) besides, higher fodder yield (56.92 q/ha). According to Shid *et al*. (2022) recorded maximum ICBR 1:43.80 was obtained in seed treatment with Imidacloprid 17.8 SL @ 3 ml/kg of seeds followed by Fipronil 5 SC @ 5 ml/kg of seed treatment (1:41.69) and Thiamethoxam 30 FS @ 10 ml/kg of seeds (1:37.43). It could be interpreted from the current results that although there was low net profit in seed treatment Imidacloprid 17.8 SL @ 3 ml/kg of seeds, the highest ICBR was observed because of low cost on plant protection measures. Similarly, Jambagi (2022) reported that the higher grain yield (32.22 and 31.27 q/ha) and straw yield (76.30 and 74.78 q/ha) was obtained in the plots characterised with seed treatment of thiamethoxam 30 FS (5 ml/kg seed) followed by a spray of cypermethrin 10 EC (0.5 ml/*l*) compared to other treatments. Sonalkar *et al*. (20118) noticed the incremental cost benefit raio was maximum i.e. 1:38.04 for imidacloprid 70 WS @ 10 g/kg seed fb quinalphos 25 % EC @ 20 ml/10 lit water thus the present findings are in line with these findings.



T1-Imidalcloprid 48 FS **T2-Thiamethoxam 30FS** **T3-Chlorantraniliprole 18.5 SC**
T4-Emamectin Benzoate 5 SG **T5- T1 f.b.T3** **T6- T1 f.b.T4**
T7- T2 f.b.T3 **T8- T2 f.b. T4** **T9- Control**

Fig. 4.12: Effect of different insecticides on grain yield of *rabi* sorghum.

Table 4.13: Incremental cost benefit ratio (ICBR) of different insecticides used against major insect-pests of *rabi* sorghum

Tr. No.	Treatment details	Dose (ml or kg/ha)	Yield (q/ha)	Increased yield over control (q/ha)	Additional income (Rs./ha)	Insecticide cost (Rs.)	Labour charges (Rs.)	Total costs (Rs.)	Incremental benefit	ICBR	Rank
1	Imidalcloprid 48%FS (seed treatment)	5ml/kg	22.68	4.60	12609	120	350	470	12139	1:25.8	1
2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	23.17	5.09	13961	200	350	550	13411	1:24.3	2
3	Chlorantraniliprole-18.5 %SC	3ml/10 *l*	26.29	8.21	22496	4500	1400	5900	16596	1:2.8	8
4	Emamectin Benzoate 5% SG	4g/10 *l*	25.71	7.63	20891	1200	1400	2600	18291	1:7.0	5
5	Imidalcloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	5ml/kg f.b. 3 ml/10 *l*	31.01	12.93	35426	4620	1400	6020	29406	1:4.8	6
6	Imidalcloprid 48%FS (seed treatment) followed by Emamectin Benzoate 5% SG	5ml/kg f.b. 4g/10 *l*	32.19	14.11	38637	1320	1400	2720	35917	1:13.2	3
7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5 %SC	10 ml/kg f.b. 3 ml/10 *l*	28.61	10.53	28834	4700	1400	6100	22734	1:3.7	7
8	Thiamethoxam 30FS (seed treatment) followed by Emamectin Benzoate 5% SG	10 ml/kg f.b. 4g/10 *l*	30.67	12.59	34496	1400	1400	2800	31696	1:11.3	4
9	Untreated (control)	-	18.08	-						-	

4.2 Residual toxicity of different insecticides against major insect pests of *rabi* sorghum

The residual toxicity resulting from application of insecticides could be of significance in indicating an effective duration over which an insecticide could persist in biologically active stage under the field condition. The duration of effectiveness was evaluated on the basis of PT values denoting persistent toxicity and LT_{50} values. Sarup *et al.* (1970) have advocated the importance of PT and LT_{50} values in the determination of relative residual toxicity of insecticides. They have stated that the PT value based on the percentage mortality has its own importance because it takes into account the duration of effectiveness of a particular insecticide over the entire period until it shows negligible mortality. It is very easy to calculate and thus can serve as ready recknor for quick selection of persistent pesticides. But an exact idea of the relative residual toxicity of different insecticides can be obtained only by calculating LT_{50} values.

4.2.1 Residual toxicity of different insecticides against Aphids, *Melanaphis sacchari*

4.2.1.1 First spray

The data on the average percentage mortality of aphids on sorghum leaves receiving first spray recorded at 1, 3, 7 and 14 days intervals are presented in Table 4.14 and depicted in Fig.4.14.

It is evident from Table 4.14 that Dimethoate 0.009 per cent and Quinalphos 0.007 per cent concentration showed comparatively high percentage mortality of aphids (34.48 and 31.03 per cent) at 14 days after spraying. On the basis of PT values the descending order of persistent toxicity was Dimethoate 0.009 per cent (898.69) > Quinalphos 0.007 per cent (802.86) > Chlorantraniliprole 0.005 per cent (756.28) > Emamectin benzoate 0.002 per cent (637.14) > Neem oil (563.22).

The data pertaining to LT_{50} values of insecticides against aphids of sorghum are presented in Table 4.15 and depicted in Fig. 4.15.

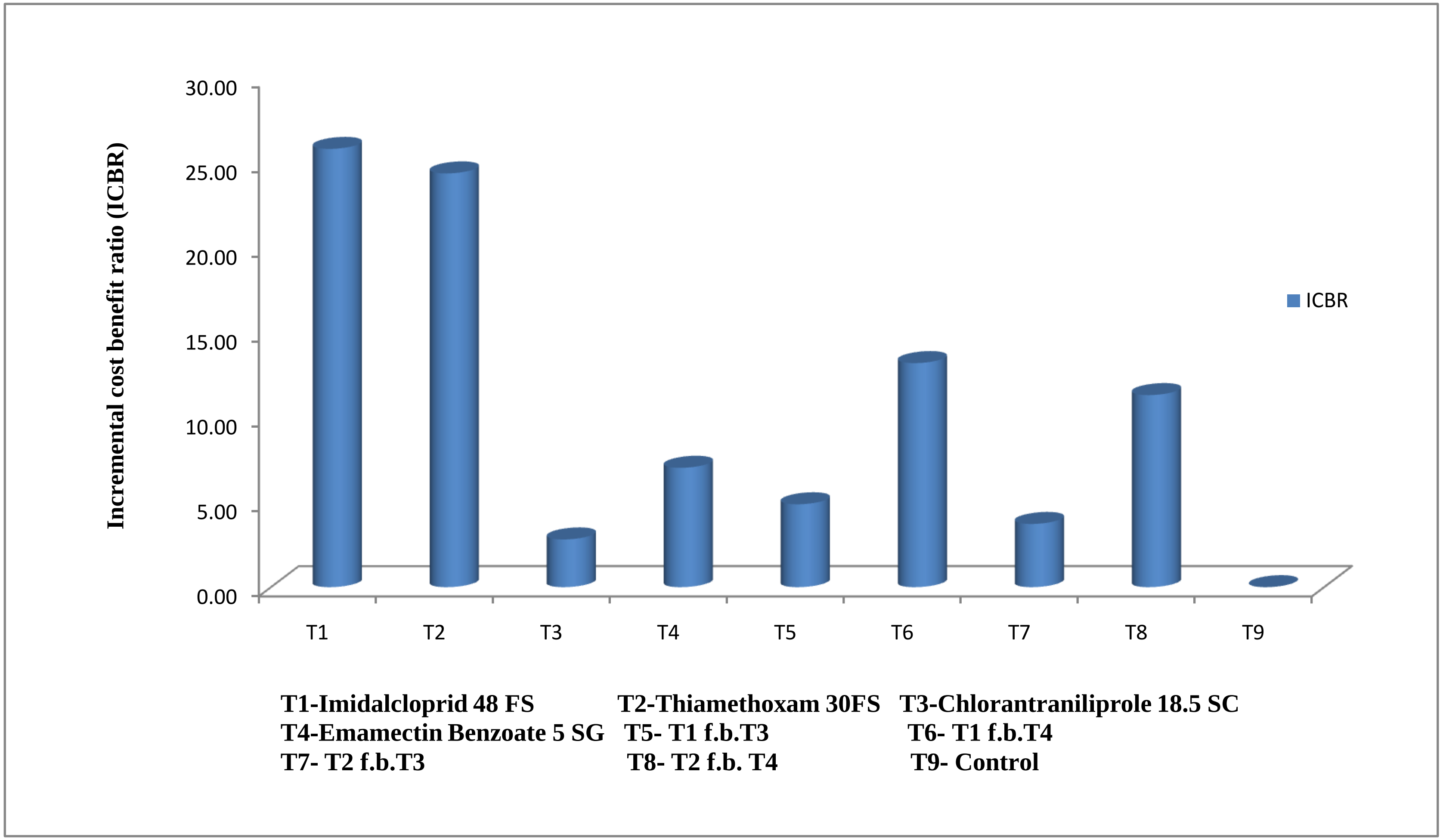


Fig. 4.13: Incremental cost benefit ratio (ICBR) of different insecticides used against major insect-pests of sorghum.

It is evident from Table 4.15 that Dimethoate 0.009 per cent showed highest LT50 value (8.32 days) against the aphids of sorghum receiving first application of insecticides. The descending relative order of efficacy of insecticides in days was found to be Dimethoate 0.009 per cent (8.32) > Quinalphos 0.007 per cent (6.57) > Chlorantraniliprole 0.005 per cent (5.33) > Emamectin benzoate 0.002 per cent (3.38) > Neem oil (2.47).

Thus, it indicates that Dimethoate 0.009 per cent followed by Quinalphos 0.007 per cent evidenced higher residual toxicity to aphids as compared to other insecticides. This could be due to their chemical nature.

4.2.1.2 Second spray

The data on the average percentage mortality of aphids of sorghum leaves receiving second spray recorded at 1, 3, 7 and 14 days intervals are presented in Table 4.16 and depicted in Fig 4.16.

It is evident from Table 4.16 Dimethoate 0.009 per cent and Quinalphos 0.007 per cent concentration showed comparatively high percentage mortality of aphids (27.58 and 24.13 per cent) at 14 days after spraying. On the basis of PT values the descending order of persistent toxicity was Dimethoate 0.009 per cent (828.41) > Quinalphos 0.007 per cent (766.75) > Chlorantraniliprole 0.005 per cent (735.67) > Emamectin benzoate 0.002 per cent (671.54) > Neem oil (527.45).

The data pertaining to LT50 values of insecticides against aphids of sorghum leaves receiving second spray are presented in Table 4.16 and depicted in Fig. 4.16.

The data presented in Table 4.17 indicated that the relative efficacy of insecticides in days was found to be Dimethoate 0.009 per cent (6.73) > Quinalphos 0.007 per cent (5.54) > Chlorantraniliprole 0.005 per cent (4.93) > Emamectin benzoate 0.002 per cent (3.99) > Neem oil (2.13).

It is evident from present investigation on residual toxicity of insecticides against Dimethoate 0.009 per cent followed by Quinalphos 0.007 per cent showed higher residual toxicity to aphids as compared to rest of the insecticides under investigation.

These results are in close conformity with those obtained by Patil *et al* (2018) showed that highest persistence was shown by the imidacloprid (19 and 20 days) followed by acetamiprid (15 and 16 days) > dimethoate (13 and 14 days) > thiamethoxam (11 and 19 days) > diafenthiuron, spiromesifen and chlorfenapyr (9 days each and 10 days each) at 24 and 48 hours of exposure, respectively. The PT (product of toxicity) of test insecticides were in the order: Imidacloprid, acetamiprid, dimethoate, thiamethoxam, diafenthiuron, spiromesifen and chlorfenapyr at 24 and 48 hours, respectively, which indicated that imidacloprid was more persistent followed by acetamiprid and dimethoate than the remaining insecticides against cowpea aphid *A. craccivora*. Zorempuii and Kumar (2019) showed the Maximum population reduction per cent of aphids (*Lipaphis erysimi*) was recorded in Malathion 50 Ec (86.10%) at 2nd spray followed by Dimethoate 30 Ec (84.04%), MECH333 (82.11), NSKE 5% (77.60%), Neem oil 0.03% (75.95%), Tobacco leaf extract (71.32%) and Lantana leaf extract (67.15%). Bhamare *et al* (2021) results on residual toxicity of different insecticides against *E. kerri* infesting soybean indicated that profenophos 0.100 per cent and quinalphos 0.050 per cent illustrated highest persistent toxicity index (PT) (864.67 and 873.18 and; 815.74 and 822.85, respectively) and LT50 values (6.80 and 7.02 and; 5.91 and 6.11 days, respectively) against *E. kerri* after first and second sprays as compared to other insecticides.

Similarly Dake and Bhamare (2019) reported residual toxicity of seven label recommended insecticides *viz.*, Imidacloprid 0.003 per cent, spinosad 0.007 per cent, indoxacarb 0.05 per cent, chlorantraniliprole 0.005 per cent, emamectin benzoate 0.002 per cent, fenpropathrin 0.01 per cent and flubendiamide 0.007 per cen was evaluated against jassids infesting sunflower. Imidacloprid 0.003 per cent revealed the highest persistent toxicity index (PT) value of (804.3 and 843.08) and LT50 values 5.75 and 5.91 days against jassids after first and second spray, respectively as compared to the other insecticides. Preetha *et al.* (2009) who observed longest persistence of higher dose of imidacloprid up to 27 days for *Aphis gossypii* on bhendi crop. Similarly, Shinde *et al.* (2011) reported highest persistent toxicity to first and third instar nymphs of *A. gossypii* in terms of FT values due to the application of imidacloprid 0.004 per cent. On the basis of LT_{50} values imidacloprid 0.004 per cent persisted longer in biologically active stage against 1st and 3rd instar nymphs of *A. gossypii*. According to Abd-Ella (2013) the LT_{50} values for acetamiprid, imidacloprid, thiamethoxam and dinotefuran were 5.8, 6.2, 6.95 and 4.2 days, respectively against cowpea aphids and also indicated that neonicotinoid insecticides were highly effective against cowpea aphids under field and laboratory conditions. While, Awasthi *et al* (2013) showed the order of relative toxicity of insecticides over spinosad against cotton aphid *Aphis gossypii* was acetamiprid > acephate > imidacloprid > emamectin benzoate > indoxacarb, with their relative toxicity values being 82.28, 23.04, 16.18, 1.57 and 1.45, respectively. However, Rouhani *et al* (2013) revealed highest sensitivity of *A. punicae* to imidacloprid followed by thiacloprid, flonicamid and thiamethoxam. Thus the observations recorded in the present investigation are in close agreement with the findings of above workers.

Table 4.14: Persistence of different insecticides in/on leaves of sorghum applied as first spray against aphids

Insecticides	Corrected percentage mortality after different intervals (days)				P	T	PT	R.E.	ORE
	1	3	7	14					
Chlorantraniliprole 0.005per cent	83.01	62.07	50.00	21.00	54.02	14	756.28	1.34	3
Emamectin benzoate 0.002 per cent	69.10	51.75	37.05	24.14	45.51	14	637.14	1.13	4
Dimethoate 0.009 per cent	93.10	75.86	53.33	34.48	64.19	14	898.69	1.59	1
Quinalphos 0.007 per cent	82.75	65.61	50.00	31.03	57.34	14	802.86	1.42	2
Neem oil 10000 ppm	62.07	48.28	33.33	17.24	40.23	14	563.22	1.00	5

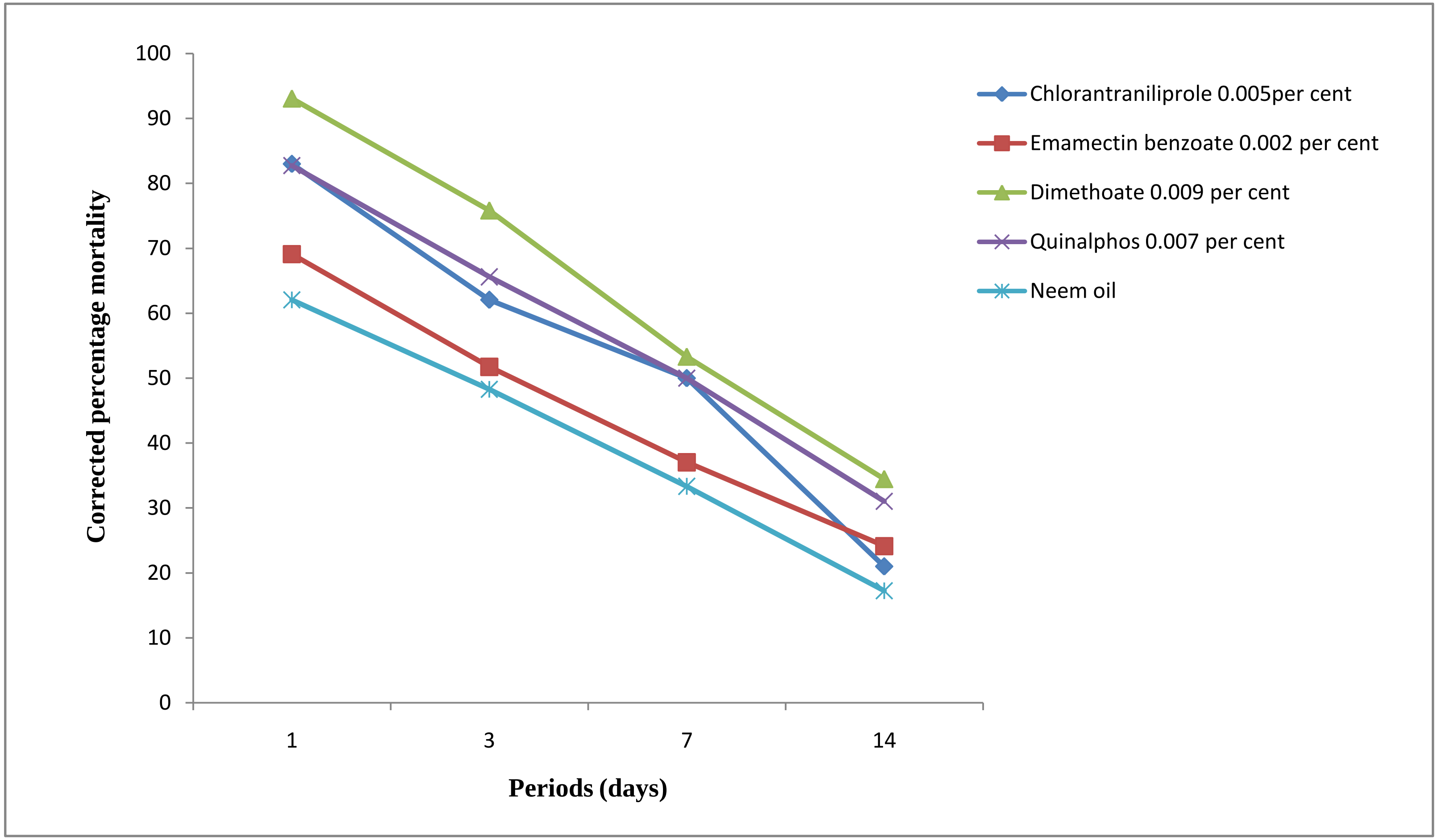


Fig.4.14: Effect of different insecticides on mortality of *M. sacchari*.on sorghum leaves at different intervals (first spray).

Table 4.15: Relative efficacy of different insecticides against aphids on sorghum applied as first spray

Insecticides	Heterogeneity		Log LT_{50} ± S.Em	LT_{50} (days)	Fiducial Limit (days)	R.E.	O.R.E.
	d.f.	χ^2					
Chlorantraniliprole 0.005per cent	2	0.87	0.7267±0.234	5.33	2.25 12.64	2.15	3
Emamectin benzoate 0.002 per cent	2	0.028	0.5289±0.210	3.38	1.06 10.77	1.36	4
Dimethoate 0.009 per cent	2	0.042	0.9201±0.277	8.32	3.80 18.19	3.36	1
Quinalphos 0.007 per cent	2	0.053	0.8175±0.232	6.57	2.44 17.67	2.65	2
Neem oil 10000 ppm	2	0.302	0.3926±0.207	2.47	0.77 7.88	1.00	5

Table 4.16: Persistence of different insecticides in/on leaves of sorghum applied as second spray against aphids

Insecticides	Corrected percentage mortality after different intervals (days)				P	T	PT	R.E.	ORE
	1	3	7	14					
Chlorantraniliprole 0.005per cent	82.80	59.02	47.67	20.70	52.54	14	735.66	1.39	3
Emamectin benzoate 0.002 per cent	76.13	55.17	43.33	17.24	47.96	14	671.54	1.27	4
Dimethoate 0.009 per cent	89.65	66.13	53.33	27.58	59.17	14	828.41	1.57	1
Quinalphos 0.007 per cent	86.20	62.06	46.68	24.13	54.76	14	766.74	1.45	2
Neem oil 10000 ppm	59.20	44.83	36.33	10.34	37.67	14	527.45	1.00	5

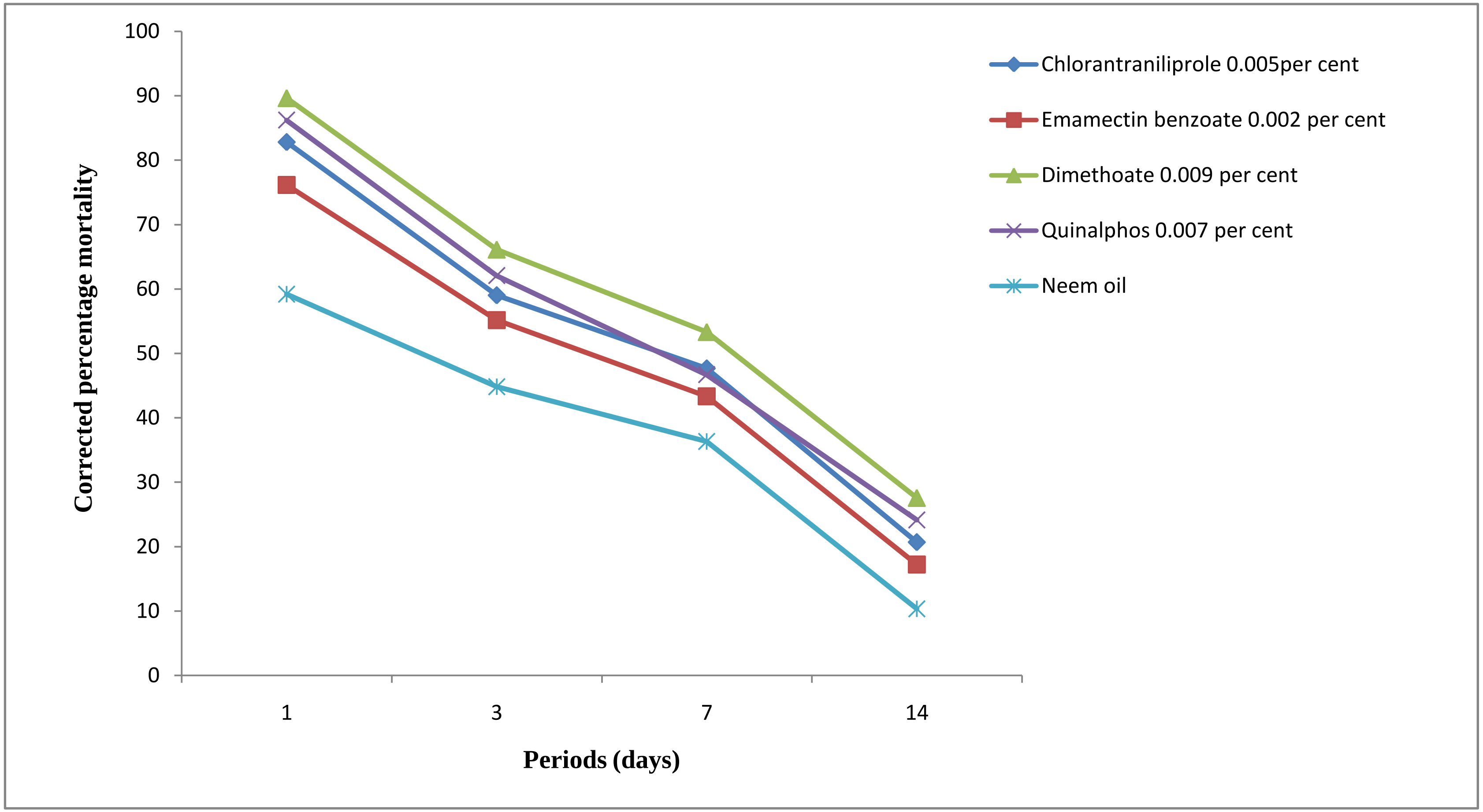


Fig.4.15: Effect of different insecticides on mortality of *M. sacchari*.on sorghum leaves at different intervals (second spray).

Table 4.17: Relative efficacy of different insecticides against aphids on sorghum applied as second spray

Insecticides	Heterogeneity		Log $LT_{50} \pm$ S.Em	LT_{50} (days)	Fiducial Limit (days)	R.E.	O.R.E.
	d.f.	χ^2					
Chlorantraniliprole 0.005per cent	2	0.501	0.6928±0.231	4.93	2.08 11.64	2.31	3
Emamectin benzoate 0.002 per cent	2	0.726	0.6009±0.220	3.99	1.58 10.08	1.87	4
Dimethoate 0.009 per cent	2	0.447	0.8280±0.251	6.73	2.95 15.30	3.15	1
Quinalphos 0.007 per cent	2	0.150	0.7435±0.239	5.54	2.41 12.71	2.60	2
Neem oil 10000 ppm	2	1.76	0.3283±0.206	2.13	0.68 6.63	1.00	5

CHAPTER-V

SUMMARY AND CONCLUSIONS

CHAPTER -V

SUMMARY AND CONCLUSION

Investigations were carried out to study the bio-efficacy and residual toxicity of different insecticides against major insect-pests of *rabi* sorghum at Department of Agricultural Entomology, College of Agriculture, Latur (Maharashtra) during *rabi 2*021. Bio-efficacy studies were carried out under field conditions using randomized block design. While, residual toxicity studies were conducted under laboratory conditions. Four label claimed insecticides at recommended doses were evaluated in comparison with untreated control for their bio-efficacy. In residual toxicity four label claimed insecticides at recommended doses were evaluated in comparison with untreated control. The results obtained during the course of investigation are summarized below.

5.1 Bio-efficacy of different insecticides against major insect-pests of sorghum.

Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded significantly minimum population of deadheart, to the extent of 9.01%, 11.01% 13.90%, and 17.99% per m row after first spray and 18.04%, 19.94%, 21.18% and 25.02% per m row after second spray at 1, 3, 7 and 14 days, respectively. Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* evidenced next best treatment in suppressing population of deadheart to the extent of 9.55%, 12.69%, 14.10% and 18.39% per m row after first spray and 18.78%, 19.07%, 20.26% and 24.78% per m row after second spray at 1, 3, 7, and 14 days, respectively. Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* observed subsequently effective treatment in suppressing deadheart population to the extent of 9.66%, 12.13%, 14.37% and 18.89% per m row after first spray and 19.31% ,19.72, 20.22% and 24.24% per m row after second spray at 1, 3, 7, and 14 days, respectively.

The incidence of fall armyworm *S.frugiperda* on sorghum plant was observed to be significantly decreased in the plots sprayed with Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* to the tune of 3.50, 3.00, 2.25 and 3.75 larvae per m row after first spray and 2.75, 2.00, 1.75 and 3.75 larvae per m row after second spray at 1,3,7 and 14 days, respectively. Imidalcloprid

48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded next best treatment in suppressing larval population of *S.frugiperda* to the tune of 4.00, 3.25, 2.75 and 4.00 larvae per m row after first spray and 3.25, 2.75, 2.25 and 4.75 larvae per m row after second spray at 1, 3, 7, and 14 days, respectively. Emamectin Benzoate 5% SG 4g/10 *l* evidenced subsequently effective treatment in suppressing larval population of *S.frugiperda* to the extent of 4.75, 4.00, 3.25 and 4.75 larvae per m row after first spray and 3.75, 3.00, 2.75 and 5.00 larvae per m row after second spray at 1,3,7, and 14 days, respectively.

The incidence of leafhopper, on sorghum plant was observed to be significantly decreased in the plots treated with Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* to the tune of 5.50, 4.75, 3.75 and 3.00 leafhopper per five plants after first spray and 2.75, 2.50, 2.25 and 3.75 leafhopper per five plant after second spray at 1,3,7, and 14 days, respectively. Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* recorded next best treatment in suppressing leafhopper population to tune of 5.75, 5.25, 5.00 and 3.75 leafhopper per five plants after first spray and 3.25, 3.00, 2.75 and 4.00 leafhopper per five plant after second spray at 1,3,7, and 14 days, respectively. Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* evidenced subsequently effective treatment in suppressing leafhopper population to tune of 7.25, 5.75, 5.25 and 5.00 after first spray and 4.25, 4.00, 3.50 and 4.75 leafhopper per five plant after second spray at 1,3,7, and 14 days, respectively.

5.2 Effect of application of different insecticides on population of ladybird beetle.

The lowest population of ladybird beetle to the extent of 4.75, 4.25, 3.50 and 4.50 per m row and 4.00, 3.50, 3.25 and 4.25 per m row was recorded at 1, 3, 7 and 14 days after first and second spray in the plots treated with Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l*. Whereas, highest population of ladybird beetle was evidenced in Chlorantraniliprole-18.5 %SC 3ml/10 *l* to tune of 6.00, 5.50, 5.25 and 5.75 per m row after first spray and 5.25, 5.00, 4.25 and 5.25 after second spray at 1,3,7, and 14 days, respectively. Imidalcloprid 48% FS seed treatment 5ml/kg tune of 6.25, 6.75, 7.25 and 7.75 per m row after first spray and 8.50, 8.75 ,8.00 and 7.27 after second spray at 1,3,7, and 14 days respectively. Thiamethoxam 30FS seed treatment 10ml/kg to tune of 7.25, 7.50, 8.00 and 8.25 per m row after first spray and 8.75, 9.00,8.25 and 7.50 after second spray at 1,3,7, and 14 days respectively both treatment also found highest population of ladybird beetle.

5.3 Effect of application of different insecticides on population of spiders.

The lowest population of spiders to the extent of 2.25, 1.75, 1.25 and 2.00 per m row and 1.75, 1.75, 2.00 and 2.75 per m row was recorded at 1, 3, 7 and 14 days after first and second spray in the plots treated with Thiamethoxam 30 FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l.* Whereas, highest population of ladybird beetle was evidenced in Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* to tune of 2.75, 2.50, 2.25 and 3.00 per m row after first spray and 2.75, 2.25, 2.75 and 3.50 after second spray at 1,3,7, and 14 days, respectively. Thiamethoxam 30FS seed treatment 10ml/kg to tune of 2.75, 3.25, 3.50 and 3.75 per m row after first spray and 4.25, 4.50, 5.00 and 4.50 after second spray at 1,3,7, and 14 days respectively. Imidalcloprid 48% FS seed treatment 5ml/kg tune of 3.50, 3.50, 3.75 and 4.25 per m row after first spray and 4.00, 4.75, 4.25 and 3.75 after second spray at 1,3,7, and 14 days respectively both treatment also found highest population of spiders.

5.4 Effect of different insecticides on grain yield of sorghum.

On the basis of grain yield of sorghum the order of effectiveness of different insecticides was Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* highest grain yield (32.19 q per ha) of sorghum followed by Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* (31.01 q per ha), Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* (30.67 q per ha), Thiamethoxam 30FS seed treatment 10ml/kg f.b. Chlorantraniliprole-18.5 %SC 3ml/10 *l* (28.61 q per ha), Chlorantraniliprole-18.5 %SC 3ml/10 *l* (26.29 q per ha), Emamectin Benzoate 5% SG 4g/10 *l* (25.71 q per ha), Thiamethoxam 30FS seed treatment 10ml/kg (23.17 q per ha) and Imidalcloprid 48% FS seed treatment 5ml/kg (22.68 q per ha). All these treatments proved equally effective in increasing sorghum yield. However, the lowest grain yield (18.08 q per ha) was registered in untreated control.

5.5 Effect of different insecticides on incremental cost benefit ratio (ICBR).

The highest incremental cost benefit ratio (1:25.1) was attained by Imidalcloprid 48%FS (seed treatment) which was followed by (1:24.3), Thiamethoxam 30FS (seed treatment), Imidalcloprid 48%FS (seed treatment) f.b. Emamectin Benzoate 5% SG (1:13.2), Thiamethoxam 30FS (seed treatment) f.b. Emamectin Benzoate 5% SG (1:11.3), Emamectin Benzoate 5% SG (1:7.0), Imidalcloprid 48%FS (seed treatment) f.b. Chlorantraniliprole-18.5%SC (1:4.8), Thiamethoxam 30FS (seed treatment) f.b. Chlorantraniliprole-18.5 %SC (1:3.7) and Chlorantraniliprole-18.5 %SC (1:2.8).

5.6 Residual toxicity of different insecticides against major insect pests of sorghum.

The highest persistent toxicity of sorghum aphids, *Melanaphis sacchari* in terms of PT values to the extent of 898.69 and 828.41 were observed due to the application of Dimethoate 0.009 per cent after first and second sprays, respectively. It was followed by Quinalphos 0.007 per cent (802.86 and 766.75) and Chlorantraniliprole 0.005per cent (756.28 and 735.66) after application of first and second sprays, respectively against *Melanaphis sacchari*. On the basis of LT_{50} values Dimethoate 0.009 per cent persisted in biologically active stage to the highest extent of 8.32 and 6.73 days against *Melanaphis sacchari* after first and second sprays, respectively. It was also followed by Quinalphos 0.007 per cent (6.57and 5.54 days) and Chlorantraniliprole 0.005 per cent (5.33 and 4.93 days) after first and second sprays, respectively against *Melanaphis sacchari.*

CONCLUSION

The present study brought out the significant difference among the insecticides against sorghum deadheart, fall armyworm, leafhopper. Among different insecticides, Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* and Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* exhibited highest efficacy against per cent deadheart, whereas, Thiamethoxam 30FS seed treatment 10 ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* and Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* performed better against fall armyworm and proved best option for management. Imidalcloprid 48% FS seed treatment 5ml/kg f.b. Chlorantraniliprole-18.5%SC 3ml/10 *l* and Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* were observed to lowest population of leafhopper. Thiamethoxam 30FS seed treatment 10ml/kg and Imidalcloprid 48% FS seed treatment 5ml/kg safer to natural enemies.The present investigation exhibited better response of Imidalcloprid 48%FS seed treatment 5ml/kg f.b. Emamectin Benzoate 5% SG 4g/10 *l* with higher grain yield of sorghum. The highest incremental cost benefit ratio (1:25.1) was attained by Imidalcloprid 48%FS (seed treatment). Residual toxicity and persistence studies of different insecticides against aphids showed highest PT and LT_{50} values in Dimethoate 0.009 per cent. Thus, the results of these studies may be used as a basis for selection of label claimed insecticides for successful control of sorghum aphids.

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APPENDICES

APPENDIX - I

Meteorological data recorded at Meteorological Observatory, Oilseeds Research Station, Latur (MS).

Year	:	2021-22	Latitude	:	18^0 24'N
State	:	Maharashtra	Longitude	:	76^0 36'
District	:	Latur	Altitude	:	633.85 m.
Zone	:	Deccan plateau Zone	Soil type	:	Vertisol

Sr. No.	SMW	**Period**	**Temperature (^{0}C)**		**Humidity (%)**	
			Max.	**Min.**	**AM**	**PM**
1	44	29-04 Nov	29.00	19.57	91	62
2	45	5-11 Nov	28.64	19.57	92	70
3	46	12-18Nov	29.07	20.21	91	79
4	47	19-25Nov	29.07	19.86	89	76
5	48	26-02 Dec	27.64	19.71	84	75
6	49	03-09 Dec	27.71	16.36	84	55
7	50	10-16 Dec	27.29	15.86	83	35
8	51	17-23Dec	27.73	16.43	83	56
9	52	24-31 Dec	27.13	14.44	88	72
10	1	1-7 Jan	28.14	13.64	79	58
11	2	8-14Jan	28.86	15.36	81	60
12	3	15-21Jan	30.14	14.43	67	44
13	4	22-28 Jan	28.93	13.93	78	55
14	5	29-4 Feb	28.21	14.43	90	24
15	6	5-11Feb	30.21	10.86	60	37
16	7	12-18 Feb	29.93	13.50	64	35

APPENDIX - II

Cost of insecticides and other details

a) Cost of insecticides	**(Rs)**
i) Imidalcloprid	120/-
ii) Thiamethoxam	200/-
iii) Chlorantraniliprole	4500/-
iv) Emamectin Benzoate	1200/-
v) Dimethoate	130/-
vi) Quinalphos	220/-
vii) Neem oil	350/-
b) Labour charges	350 Rs /day

c) Quantity of water required / ha

i. 1[st] spray - 500 liters

ii. 2[nd] spray - 500 liters

e) Selling rate of grains Rs. 2738 per quintal

CURRICULUM VITAE

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Full name of the candidate	:	**YASHWANT SHUBHAM BABUSHA**
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Title of the thesis	:	**Management of major insect pest of *rabi* sorghum.**

Academic qualifications

Course/ Degree	Name of college/ institute	University/ Board	Year of passing	Percentage (%)/ CGPA	Class/ Grade
SSC	S.B.V. Phondshiras	Pune Divisional Board	2014	81.00	First
HSC	M.R.S.V.& Jr.college Phaltan	Kolhapur Division Board	2016	67.29	Second
B.Sc. (Agri)	Sharad college of agriculture jainapur dist-kolhapur	MPKV, Rahuri	2020	80.70	First

Place: Latur
Date : 30 / 11/ 2022

(SHUBHAM BABUSHA YASHWANT)