BIOEFFICACY OF DIFFERENT INSECTICIDES AND BIOPESTICIDES AGAINST SORGHUM APHID, *Melanaphis sacchari* ZEHNTNER.

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI - 413 722, DIST- AHMEDNAGAR,
MAHARASHTRA, INDIA

for the award of the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

by

MR. VINOD KHANDU GHODEKAR
(Reg. No.15/160)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST-AHMEDNAGAR,
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A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
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in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

APPROVED BY

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2017

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part of
There of has not been submitted
by me or any other person to any
other University or Institute
for a Degree or
Diploma.

Place : MPKV, Rahuri (V. K. Ghodekar)
Date :

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Sorghum Entomologist,
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CERTIFICATE

This is to certify that the thesis entitled **"BIOEFFICACY OF DIFFERENT INSECTICIDES AND BIOPESTICIDES AGAINST SORGHUM APHID, *Melanaphis sacchari* ZEHNTNER"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist.-Ahmednagar, Maharashtra State, for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a *bona fide* research carried out by **MR. VINOD KHANDU GHODEKAR**, under my guidance and supervision and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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Maharashtra State (India)

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LIST OF ABBREVIATIONS

@	:	At the rate of
a.i.	:	Active ingredient
CD	:	Critical difference
CFU	:	Colony Forming Unit
cm	:	Centimeter
^{o}C	:	Celsius
DAS	:	Days after spraying
EC	:	Emulsifiable concentrate
et al.	:	Et alli (and others)
etc.	:	Et cetra
e.g.	:	(for example)
Fig.	:	Figure(s)
g	:	Gram(s)
ha	:	Hectare
hrs	:	Hours
i.e.	:	Id est (that is)
Kg	:	Kilogram(s)
LC_{50}	:	Lethal Concentrate
Ltd	:	Limited
Ltr	:	Liter
M	:	meter
Ml	:	milliliter
mm	:	milimeter
MW	:	Meteorological Week
NSKE	:	Neem Seed Kernel Extract
q	:	Quintal
q/ha	:	Quintal per hectare
r	:	Pearson's correlation coefficient value
Std	:	Standard
SC	:	Soluble Concentrate
SE	:	Standard Error
SL	:	Soluble Liquid
SP	:	Soluble Powder
spp	:	Species
t	:	Tonnes
viz.,	:	Vide licet (Namely)
WP	:	Wettable Powder
/	:	Per
%	:	Per cent

ABSTRACT

"BIOEFFICACY OF DIFFERENT INSECTICIDES AND BIOPESTICIDES AGAINST SORGHUM APHID, *Melanaphis sacchari* ZEHNTNER"

by

VINOD KHANDU GHODEKAR

A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

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Bioefficacy of different insecticides and biopesticides against sorghum aphid, *Melanaphis sacchari* Zehntner was studied during *rabi* season 2016-17 at All India Coordinated Sorghum Improvement Project, MPKV, Rahuri. Seasonal abundance studies revealed that the aphid abundance was started from 48^{th} standard meteorological week and increased gradually to reach its peak period in 3^{rd} standard meteorological week. Thereafter, it declined gradually and started disappearing from 7^{th} standard meteorological week. There was negative correlation with maximum temperature (r= -0.4834) where as significant and negative correlation with minimum temperature (r= -0.5750). There was negative correlation with morning humidity (r= -0.2480) evening humidity (r= -0.0776) and sunshine hrs (r= -0.1492). The correlation of aphid population and lady bird beetle (r= 0.9779) and green lace wing (r= 0.9816) were

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significant and positive.

The cumulative mean results revealed that all the treatments were significantly superior over untreated control in minimizing infestation of sorghum aphid, *M. sacchari*. The minimum aphid infestation was observed in plots treated with dimethoate 30 EC at 0.03 % (0.63 aphids/sq.cm of leaf). The next best chemical treatments were chlorpyriphos 20 EC at 0.02 % (1.05 aphids), acephate 75 SP at 0.0375 % (1.34 aphids), fipronil 5 SC at 0.0075 % @ (2.16 aphids), difenthiuron 50 WP at 0.05 % (2.90 aphids), buprofezin 25 SC at 0.025 % (4.97 aphids). Among the biopesticides, azadirachtin 10000 ppm @ 3 ml/l (4.34 aphids) was the most effective, however the next best biopesticides were *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (6.11 aphids), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (6.35 aphids) which were at par with each other.

Dimethoate 30 EC at 0.03 per cent was highly toxic to natural enemies of aphids followed by chlorpyriphos 20 EC at 0.02 per cent.Next treatments were acephate 75 SP at 0.0375 %, fipronil 5 SC at 0.0075 %. IGR's like buprofezin 25 SC at 0.025 % and difenthiuron 50 WP at 0.05 % were least toxic to natural enemies of aphid. Biopesticides were non toxic to natural enemies.

The dimethoate 30 EC proved to be the most promising treatment against sorghum aphid which recorded highest grain yield (26.10 q ha^{-1}) and highest fodder yield

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(57.70 q ha^{-1}) with highest ICBR (1: 4.82) and maximum net profit (Rs 11780/ha). It was followed by chlorpyriphos 20 EC grain yield (25.24 q ha^{-1}) and fodder yield (56.29 q ha^{-1}) with highest ICBR (1: 4.14) and net profit (Rs 9778/ha). Next best chemical treatment was acephate 75 SP with net profit (Rs. 6348/ha) and ICBR (1: 3.70). Among the biopesticides, *L. lecanii* was the best treatment with net profit (Rs. 3279/ha) and ICBR (1: 2.14). Yield recorded in other treatments were in order of acephate 75 SP > fipronil 5 SC > difenthiuron 50 WP > *L. lecanii* > azadirachtin 10000 ppm > *M. anisopliae* > buprofezin 25 WP. In the present investigation chemical treatment viz. dimethoate, chlorpyriphos and acephate recorded higher yields. In biopesticides, *L. lecanii* recorded better yield than azadirachtin and *M. anisopliae*.

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1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the major source of food and fodder for millions of people in the tropics and semi-arid tropics. Grain sorghum is the fifth most important cereal crop in the world. It is the principle food grain for more than 750 million people in semi-arid areas. Sweet sorghum is used for producing syrups and molasses and ethanol. Grass sorghum is used for pasture and hay. In the livestock market, sorghum is used in the poultry, beef, and dairy and pork industries. Stems and foliage are used for green chop, hay, silage and pasture. In the world, sorghum is grown over 43.75 million hectares accounts for production of 54.15 million tons of grains with an average yield of 1238 kg/ha. Nearly 80 per cent of the cultivated area lies in Asia and Africa. In world, India ranks third in area. India has the largest area representing 19 per cent under sorghum cultivation in the world. It is grown in arid and semi-arid tracts where fine cereals like wheat and rice can't be grown profitably. In India, Maharashtra stands first with an area and annual production. The major *kharif* growing districts are Nanded, Latur, Yavatmal, Buldhana, Jalgaon, Parbhani, Sangli, Amaravati. While Solapur, Ahmednagar, Pune, Aurangabad, Beed, Osmanabad, Satara, Sangli and Parbhani are *rabi* growing season.

Though, sorghum is known for its versatile use, hardiness dependability, stability of yield and adaptability over a wide range of cultures and climates, the adverse climatic conditions, pests and diseases prevailing in sorghum growing areas of the world limit the crop production. In sorghum, nearly 150 insect pests have been reported. Among these sorghum aphid (*Melanaphis sacchari* Zehntner) is becoming economically important in recent years. The genus *Melanaphis* has 20 species associated with Gramineae. The aphid, *M. sacchari* is distributed in Asia, Africa and the America. This insect multiplies by parthenogenesis. Each female gives birth to 60-100 nymphs in 13-20 days. The life cycle is completed in 7-8 days. Its abundance is high during post rainy season in India. It prefers to feed on the under surface of older leaves. The damage proceeds from lower to upper leaves. The nymph and adult suck sap from under surface of leaves, resulting in drying of leaves, stunted plant growth and plant mortality in severe infestation. It is a vector of three persistent viruses (millet red leaf, sugarcane yellow leaf, and sugarcane mosaic viruses). Sorghum responses to *M. sacchari* injury includes purple leaf discoloration of seedlings followed by chlorosis, necrosis, stunting, delay in flowering and grain filling including quality and quantity yield losses.

Population increase and peak during January, when the post-rainy sorghum crop was between flowering and milk stage declined thereafter till maturity. Dispersal occurs within 6–10 days at a temperature regime of 15.1 and 31.0 ^{0}C (Balikai, 2001), but the population died at 35 ^{0}C. Waghmare *et al.* (1995) reported that the highest rate of multiplication was found when the morning and evening relative humidity was 94 and 43 per cent respectively. Balikai and Lingappa (2002) observed that aphid incidence started from 2nd or 3rd week of December, and reached a peak during 3rd or 4th week of January and disappeared by 2nd week of February in Karnataka.

Nearly six species of aphids have been reported to attack the sorghum. However, only three of these have become abundant over a large area *Melanaphis sacchari* (Zehntner), *Rhaphalosiphum maidis* (Fitch) and *Schiaphis graminum* (Rondani). In these, *Melanaphis sacchari* (Zehntner) is major and important in recent years. After the attainment of peak population by the aphids during 3rd or 4th week of January, coccinellid attained peak during 1st week of February (Balikai and Lingappa, 2002). Balikai (2001) reported that, the syrphid and chrysoperla populations attained their peaks during 3rd and 4th weeks of January, respectively. Dimethoate, chlorpyriphos, alfamethrin, and malathion not only reduced aphid populations but promoted grain and fodder yields, besides increase in kernel weight (Balikai, 2001).

Among the sucking pests, in the recent past the sorghum aphid, *Melanaphis sacchari* Zehntner is becoming a production constraint in *rabi* tract. Both grain and fodder of *rabi* sorghum are considered to be equally important by the farming community. Since the grain and fodder quality are better during *rabi* compared to *kharif*. The aphid, not only affects the grain and fodder yield but also the fodder quality directly and indirectly (Balikai, 2007). In sorghum, the losses varied from 12-26 and 10-31 per cent with an overall loss of 16 and 15 per cent for grain yield and fodder yield, respectively (Balikai, 2001). Balikai and Lingappa (2002) reported 23-70 per cent grain loss and 20 per cent fodder yield loss. In addition, they also secrete honeydew on which black sooty mould develops, which hinders the photosynthetic activity of plants. The aphid infestation also spoils the crop's fodder quality. Narayana *et al.* (1982) and Mote (1983) observed deterioration of fodder quality.

In view of the growing need for the improvement in yield of sorghum and due to the fact that sorghum aphid is one of the factors in reducing the yield. Hence, it is the need of time to develop safer and cost effective strategy to manage these pests. The present investigation was undertaken with following objectives-

1. To study the seasonal abundance of sorghum aphid
2. To find out effective and economical insecticides and biopesticides against sorghum aphid
3. To study the effect of insecticides and biopesticides on natural enemies of aphid

2. REVIEW OF LITERATURE

While presenting the review of research work done on sorghum aphid, *Melanaphis sacchari* Zehntner an attempt has been made to provide a literature pertaining to seasonal incidence, distribution, losses, management, toxicity of different insecticides and biopesticides to the aphid and its natural enemies are presented here under.

2.1 Seasonal incidence of sorghum aphid and its natural enemies

Narayana (1982) studied that the incidence of aphid on sorghum and also observed aphid population throughout the crop period. The delayed in planting of sorghum was heavily infested with aphids (*Aphis sacchari*). The minimum (19.50 ^{0}C) and maximum (34.70 ^{0}C) temperatures at the time may have played a role in the rapid multiplication of the aphid.

Behura and Bohidar (1983) found that at the temperature of 35 ^{0}C the aphids did not survive in sorghum.

Mote (1983) observed that the causes of epidemic of aphid on sorghum, symptoms and stage of occurrence of aphid on sorghum. Cloudy weather coupled with a rise in temperature and humidity increased the density of aphid (*A. sacchari*). The under surface of all leaves was completely covered by colonies of aphids. Sorghum aphid density was more in irrigated crops than non-irrigated ones. They also caused sugary symptoms. However, the pest occurred at the late stage of the crop (milky stage), the grain yields were not severely affected, but fodder quality deteriorated.

Mote and Kadam (1984) studied that incidence of sorghum aphid increases as temperature and humidity increases and during cloudy weather particularly as the crop approaches maturity and plant characters were correlated to pest attack. Minimum temperature of 16 ^{0}C and maximum temperature of 29 ^{0}C played a significant role in the rapid multiplication of aphids.

Hijam and Singh (1989) showed that the aphid population was influenced more by density independent factors than by population of natural enemies on cowpea.

Mote and Jadhav (1993) observed that aphid population on sorghum appeared during 4th week of November when relative humidity was high and climate was cloudy. The aphid population continued with increasing number up to 2nd week of December and decline in aphid population is due to heavy rains.

Aheer *et al.* (1994) reported that abiotic factors severely affect the population build up of wheat aphids. Effect maximum and average temperature on aphids was significant and positive but minimum temperature showed negative and significant correlation with aphid density.

Waghmare *et al.* (1995) showed that the critical maximum temperature recorded at 14.30 hrs beyond which aphids did not survive was found to be 45^{o}C. The highest rate of pest multiplication was found to be at relative humidity of 94 per cent recorded at 7.30 hrs while it 43 per cent at relative humidity recorded at 14.30. The most critical temperature was at 7.30 hrs. Highest rapid multiplication was at 11.4^{o}C while it was 30^{o}C at 14.30 hrs. Further aphid population negatively correlated with depression of temperature recorded at 7.30 and 14.30 hrs and positively correlated with cumulative depression of RH-II (14.30hrs).

Patil and Sathe (2001) observed that *Menochilus sexmaculata* F. appeared from 2nd week of November and attained a peak in 2nd week of February in *rabi* season. In both season predator caused higher mortality of aphid, *R. maidis* in sorghum ecosystem.

Balikai and Lingappa (2002) revealed that the aphid appeared on the 48th or 49th standard week (2nd or 3rd week of December) and reached a peak in the 3rd or 4th standard week (3rd or 4th of January) and declined thereafter before disappearing in the 7th standard week and also studied the population of natural enemies, which was peak during 3rd or 4th standard week.

Patel and Purohit (2013) revealed that the incidence of aphid commenced during 1st week of December i.e. 49th std. week and continue until first week of January and third week of January during 2006-07 and 2007-08, respectively.

Patel and Purohit (2014) studied that the occurrence and population fluctuation of aphids and correlation with weather parameters was carried out for two consecutive years (*rabi* 2006-07 and 2007-08) on sorghum variety GJ 38. *M. sacchari* incidence on sorghum commenced with 2.05 aphids per leaf from 48th standard week (last week of November) and reached a peak level (19.20 aphids/leaf) on 51th std. week (third week of December).

Pawar *et al.* (2014) reported that the incidence of aphid started from 1st week of December, i.e. 90 days after sowing and further increased continuously up to last week of January and declined thereafter. The population was at its peak in the month of January i.e. 120 days after sowing. The correlation coefficient (r) of aphid incidence and weather parameters of the same week, one, two and three week prior to the date of observation indicated that the weather parameters of one and two week prior to the date of observation had significant correlation with the incidence of aphid and there was negative correlation with maximum (r= -0.640 and r= -0.863) and minimum temperature (r= -0.703 and r= -0.695). The favorable range of maximum temperature and minimum temperature during the peak infestation of aphid was from 29 to 30 and 9 to 11^{o}C, respectively.

2.2 Biofficacy of different insecticides and biopesticides against sorghum aphid

Bhatia *et al.* (1973) revealed that dimethoate, malathion, methyl demeton significantly reduced the aphid population as compare with the untreated control.

Ghorpade *et al.* (1982) reported that 0.02 per cent phenthoate (98.17 % control) followed by dimethoate (0.02 %), quinalphos (0.02 %) were most effective for controlling the corn leaf aphid.

Gandhale *et al.* (1986) evaluated the insecticides for the control of aphids and delphacids on jowar. The treatment with 0.03 per cent dimethoate, 0.02 per cent methyl demeton, 0.02 per cent formothion, 0.03 per cent quinalphos and 10 per cent carbaryl @ 20 kg/ha were at par and significantly superior over rest of the treatments in reducing the population of aphids.

Denmark (1988) recommended diazinon, dimethoate, malathion, Oxydemeton methyl, mevinphos and phorate for the control of aphids (*M. sacchari* and *S. flava*) on sugarcane in Florida.

Lampert and Godding (1990) reported that acephate at 0.56 kg a.i./ha reduced both aphid abundance and proportion of tobacco plants colonized by *Myzus nicotianae* Blackman.

John and Ragupathy (1992) found that the order of toxicity of the insecticides to the aphids on tobacco was monocrotophos > demeton methyl > methamidophos > acephate, while on chilli, it was methamidophos = monocrotophos > acephate > demeton methyl = dimethoate.

Upadhyay and Mishra (1999) revealed that oxydemeton methyl 0.025 per cent followed by methomyl 0.05 per cent and acephate 0.05 per cent had effectively controlled aphid infestation with higher seed yield and better avoidable loss.

Misra (2002) revealed that imidacloprid and thiomethoxam, both used @ 25 g a.i/ha proved significantly superior in controlling aphids and jassids on okra. Dimethoate @ 300 g a.i./ha followed the above two treatments. The plant product azadirachtin @ 3 g a.i/ha was effective against aphids but not against jassids of okra.

Balikai and Lingappa (2003) revealed that dimethoate shows 95.25 per cent reduction in sorghum aphid population at ten days after spraying chlorpyriphos 91.13 per cent and gave significantly high grain yield (27.37 q/ha) fodder yield (6.66 t/ha) and 1000 grain weight (31.88 g).

Wadnerkar *et al.* (2003) reported that fipronil 5 per cent SC at the rate of 400, 200 and 100 g a.i./ha were found to be effective in lowering insect pest population. However, fipronil 5 per cent SC @ 50-75 g a.i./ha was found optimum against aphids, jassids and thrips in cotton.

Balikai (2004) observed that one spray either of dimethoate 30 EC 0.05 per cent, monocrotophos 36 WSC @ 0.04 per cent or chlorpyriphos 20 EC @ 0.05 per cent effectively controlled the aphid (83.3, 80.2, 79.7 and 77.5 per cent reduction in sorghum aphid population, respectively) and recorded higher percentage of avoidable losses (12.8, 10.0 and 9.0 per cent, respectively) and also registered higher grain yield (28.9, 28.0 and 27.7 q /ha respectively) with higher benefit cost ratio of 13.5, 8.2 and 9.9, respectively.

Singh *et al.* (2004) revealed that the status of research of its geographical distribution, host range, nature of damage, extent of crop losses, and eco-biology in sorghum is summarized. Among the control tactics, cultural practices, natural enemies and chemical control together can prevent the sorghum aphid from reaching the economic threshold levels.

Bhamare and Tiwari (2006) reported that all the insecticidal treatments were found significantly superior in reducing sorghum aphid population and increasing grain and fodder yield. Amongst various insecticides, dimethoate 30 EC @ 0.03 per cent and imidacloprid 17.8 SC @ 0.009 per cent were recorded highly effective in reducing aphid population to 1.17 and 1.84 aphid/leaf/cm^2 respectively.

The dimethoate treated plots recorded highest grain yield (2205.75 kg/ha) and fodder yield (56.79 q/ha).

Balikai (2007) studied the population dynamics of aphid, its natural enemies and the losses caused by aphid. Screening methods and the efficacy of different plant products, insecticides and other methods are reviewed and discussed.

Booth *et al.* (2007) conducted a laboratory experiment for two insecticides on enzyme activity and mortality of an aphid and its lacewing predator. The study revealed that lacewings were less sensitive than aphids to both the insecticides, and dimethoate was more toxic than lamda-cyhalothrin.

Akashe *et al.* (2008) reported that the highest per cent decline in aphid population over control after two sprays were recorded with thiamethoxam (87.69 and 95.54 per cent) followed by acetamiprid (84.92 and 95.15 per cent), imidacloprid (80.74 and 91.69 per cent), dimethoate (76.50 and 86.06 per cent) and fipronil (46.36 and 74.13 per cent). The economics of the treatments showed that the treatment 0.005 per cent thiamethoxam recorded highest B: C ratio of 1.89 followed by 0.004 per cent acetamiprid (1.62), 0.03 per cent dimethoate (1.52) and 0.0045 per cent imidacloprid (1.46).

Harischhandra and Shekharappa (2009) revealed that in aphid management, oil based formulation of *V. lecanii* was best and recorded 7.75 aphids/3 leaves followed by *B. bassiana* oil based recorded the 9.75 aphids/3 leaves after second spray.

Daware *et al.* (2011) found that all insecticides thiamethoxam 25 WG, imidacloprid 17.8 SL, dimethoate 30 EC and biopesticides namely NSKE 5 per cent, nimark and karanj leaf extract 5 per cent, were significantly superior against sorghum aphid. The biopesticides were also significantly superior over control and at par with each other. The highest incremental cost benefit ratio was obtained in dimethoate (1:11.2) followed by imidacloprid (1:7.3), thiamethoxam (1:6.6) and NSKE 5 per cent (1:5.6).

Suresh *et al.* (2012) evaluated *Lecanicillium lecanii* under field condition at three different concentrations *viz.*, $1x10^7$, $1x10^8$, $1x10^9$ spores/ml against cowpea aphid. It was found that LL-3 showed higher per cent mortality of 73.99 and 57.73 of adult and nymphs of *Aphis craccivora*, respectively. Under field condition LL-3 @ $1x10^9$ spores/ml showed higher per cent mortality of aphids (71.62) compared to other two lower concentrations. This study indicates the scope of using *L. lecani* for the management of cowpea aphid under field condition.

Vaghasia *et al.* (2012) evaluated the bio-efficacy of *Verticillium lecanii* (Zimmerman) against aphid infesting coriander as alone and in combination with neo-nicotinoid insecticides. Considering the effectiveness of different treatments, *V. lecanii* @ 2.0 g/lit + dimethoate 0.015 per cent, *V. lecanii* @ 4.0 g/lit and *V. lecanii* @ 2.0 g/lit + imidacloprid 0.0025 per cent were found to be the most effective by reregistering 84.32, 82.31 and 81.15 per cent mortality of aphid at seven days after feeding.

Radha (2013) showed that among the pesticides, chlorpyriphos proved highly effective against aphids as compared to the rest of the pesticides. Furthermore, yield of cowpea was also higher in chlorpyriphos treatments. Thus, it is concluded that all the studied insecticides proved effective against the aphids but the toxicity studies of the insecticides was observed from maximum to minimum in the following order, chlorpyriphos > spinosad > neem seed kernel extract.

Bhati and Sharma (2014) revealed that acephate 75 SP @ 350 g a.i./ha was most effective to pest control as this resulted in more reduction in population of mustard aphid. Higher seed yield was obtained from fipronil 5 SC @ 50 g a.i./ha (15.56 q/ha) and higher return based on C:B ratio (1:6.8) with thiamethoxam 25 WG @ 25 g a.i./ha. However, imidacloprid 17.8 SL @ 20 g a.i./ha and clothianidin 50 WDP @ 15 g a.i./ha were moderately effective.

Ghelani *et al.* (2014) revealed that among the bio-pesticides, neem oil 1.0 per cent, *V. lecanii* @ 2.5 kg/ha and azadirachtin 0.009 per cent were found moderately effective against major sucking pests of *Bt* cotton. In case of toxicity of insecticides on predators (coccinellid and chrysoperla) of sucking pests, all the bio-pesticides were found safer to predators, while chemical pesticides were found moderate to higher toxic to predators on *Bt* cotton.

Khinchi and Kumawat (2014) studies the relative efficacy of eleven insecticides against the aphid, *Rhopalosiphum maidis* (Fitch) and revealed that dimethoate emulsion (0.03 %) was the most effective followed by imidacloprid (0.005 %), thiamethoxam (0.025 % dispersion) and acephate (0.037 % solution). *Metarhizium anisopliae* (1×108 spores L-1), *Beauveria bassiana* (1X108 spores L-1), karanj seed extract (5 ml L-1), and neem seed kernel extract (5 ml L-1) were the least effective. The maximum yield was recorded from the plots treated with dimethoate (7.79 q ha-1) followed by imidacloprid and thiamethoxam and the minimum from *M. anisopliae* (5.37 q ha-1). The highest benefit: cost ratio (39.51:1) was obtained in dimethoate treatment followed by acephate (36.92:1) and imidacloprid (24.84:1).

Mishra *et al.* (2015) revealed that *L. lecanii* which recorded 1.86 and 2.06 aphids/plant and 82.16 and 82.92% reduction of aphid population during *kharif* and summer, respectively. The other biopesticides in order of effectiveness were *M. anisopliae*, Neemazol and *B. bassiana* recording (3.02 and 3.10, 4.01 and 3.92, 3.96 and 4.08 aphids/plant) during *kharif* and summer, respectively.

Onur and Samet (2016) revealed that third instar nymphs of *M. coryli* were more susceptible to the entomopathogenic fungi at 25 °C than 18 °C. *M. anisopliae* was highly and statically equally effective against nymphs of *M. coryli* at 18, 22 and 25 °C (80.8, 93.8 and 100 per cent) after 10 days of conidial treatment. The other isolates, TR-05 and TR-78.07 weren't as effective as *M. anisopliae* on nymphs of *M. coryli* at 25 °C (67.8 and 62.6 per cent). This study showed that isolate of *M. anisopliae* has virulent and highly potential for biological control on nymphs of *Myzocallis coryli.*

Yadav and Singh (2016) evaluated the bio-efficacy and economics of some new insecticides against aphid on Indian mustard and reported that imidacloprid spray resulted into 97.88 per cent reduction in aphid population over control followed by thiamethoxam, dimethoate and fipronil with 97.27, 96.67 and 95.45 per cent reduction in aphid population over control respectively. The maximum seed yield of 1630 kg/ha was recorded in imidacloprid, which remained on par with thiamethoxam (1620 kg/ha) and dimethoate (1615 kg/ha).

2.3 Effect of insecticides and biopesticides on natural enemies of aphid

Dirimonov *et al.* (1974) reported that acephate, ethiofen and carbaryl were found slightly toxic to the *C. septempunctata*, two hours after treatment. Dimethoate and Omethoate were found more toxic to the predator two hours after treatment. Dimthoate and methomyl caused 20 to 40 per cent mortality after 24 hrs.

Hassan *et al.* (1985) reported that diflubenzuron, fenvalerate, dimethoate, methamidophos, chlorpyriphos and methidathion were harmful to *C. carnea.*

Dhoubi (1992) reported that among insecticides viz., buprofezin (12.5 g a.i. /ha), butacarboxin (500 g a.i./ha) and imidacloprid 200 SL (15 g a.i./ha) tested, except buprofezin all the other found to affect parasitoids.

Thayaalini and Raveendranath (1998) observed that longevity of aphid predator, *Cheilomenes sexmaculata* was significantly reduced by dimethoate compared to *Gardenia cramerii* Ait, a plant spp. has showed insecticidal action on cowpea aphids.

Gour and Pareek (2005) evaluated relative toxicity of some insecticides against grubs and adults of coccinellid, *Coccinella septumpunctata.* Cypermethrin was found to be the most toxic to grub and adults followed by dimethoate. Ethofenprox, malathion and imidacloprid existed in moderate group of toxicity to grubs and adults, whereas, cartap hydrochloride, acephate and neem extract as less toxic.

Nasreen *et al.* (2005) revealed that low and recommended concentrations of difenthiuron and buprofezin were found harmless while high concentration of both insecticides was found slightly harmful after 24 hours exposure to the coccinellid population present in field. All insecticides, at all concentrations were found toxic after 48 hours except buprofezin and thiodicarb. Pupation rates were lowest in the acetamiprid and highest in the buprofezin treatment.

Jalali *et al*. (2009) studied and evaluated the toxicity of some insecticides against two spotted ladybird, *Adalia bipunctata* in laboratory. Susceptibility of 4th instars and adults was assessed by measuring toxicity *viz.,* residual contact and ingestion through feeding on contaminated green peach aphids (*Myzus persicae*). Flonicamid and spinosad has no lethal effects on larvae and adults. Imidacloprid was highly toxic to the larval stage by residual and ingestion exposure but caused very low adult mortality when ingested through contaminated prey. The findings indicated that pest management program in agriculture using dimethoate, λ-cyhalothrin, imidacloprid (in lesser degree) are detrimental to

A. bipunctata, whereas pirimicarb, flonicamid and spinosad are more compatible with the use of this predator.

Meena and Kanwat (2010) studied the seasonal incidence and relative safety of pesticides to the coccinellid beetles, *Coccinella septumpunctata* L. and *Cheilomenes sexmaculata* (Fabricus) on okra under field conditions. Use of *Bt* (Dipel) 0.012 per cent was found to be least toxic to the coccinellid followed by NPV 0.10 per cent and azadirachtin (5ml/lit.). Monocrotophos 0.04 per cent prove to be highly toxic followed by acephate 0.037 per cent whereas imidacloprid 0.006 per cent and other were moderately toxic to coccinellid predators in okra agro-ecosystem.

Awasthi *et al.* (2013) evaluated the 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 predatory coccinellid. And reported that on the basis of LC_{50} values, acetamiprid was the most toxic whereas, spinosad was the least toxic insecticide to predatory coccinellid. 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.

Abbas and Farhan (2015) revealed that per cent mortality of beneficial fauna in descending order looks as follows- difenthiuron> spinotoram> acetamiprid> pyriproxyfen> spirotetramid> flonicamid > buprofezin . Hence buprofezin being last is safe to beneficial fauna and difenthiuron being the most harmful among the tested pesticides.

2.4 Estimation of yield loss due to aphid

Rensburg and Hamburg (1976) reported that an unchecked aphid population resulted in 77 per cent loss in grain yield.

Narayana *et al.* (1982) reported that delayed planting of sorghum in late November during post rainy season resulted in heavy incidence of *A. sacchari*. Since, the crop all ready reached maturity, there was likely little loss in grain yields, but the feeding value of the fodder deteriorated considerably.

Mote (1983) reported that the aphid occurred at the last stage of the crop (milky) and therefore grain yields not severely affected but fodder quality deteriorated.

Balikai and Lingappa (2002) reported 23-70 per cent grain loss and 20 per cent fodder yield loss.

3. MATERIAL AND METHODS

The studies on objectives set out in the introductory chapter were carried out during *rabi* 2016-17 at the All India Coordinated Sorghum Improvement Project, MPKV, Rahuri. Field experiments were carried out on medium black soils. Material and methods followed during the course of investigation have been described below.

3.1 Seasonal incidence of sorghum aphid and its natural enemies

With a view to study the seasonal incidence of sorghum aphid and its natural enemies, sorghum seeds of variety Phule Vasudha sown on 20th October 2016 in a plot size of 10 X 10 m.

The sorghum crop was raised with a spacing of 45 X 15 cm. All recommended package of practices for raising a good crop were followed except plant protection measures. This trial was conducted during *rabi* season 2016-17. Aphid population present on 1 sq.cm leaf area was recorded from top, middle and bottom leaves of each plant. Similarly, the population of natural enemies present on each plant was recorded at weekly interval. These observations were recorded on randomly selected 25 plants at weekly interval. The mean population of aphid and its natural enemies was then correlated with the weather parameters like temperature relative humidity, rainfall and bright sunshine hours. Simple correlation and multiple regression equations were worked out between aphid population, natural enemy and weather parameters.

Table 1. Details of treatments

Sr. No.	Insecticide/ Bio- pesticides	Trade Name	Manufacturing company	Conc. (%)	Dose (g a.i./ha)	Dose (per lit)
1	Dimethoate 30 EC	Rogor	Cheminova, Bandra (Mumbai)	0.03	300	1 ml/l
2	Acephate 75 SP	Asataf	TATA Rallis, (Mumbai)	0.037	375	0.5 g/l
3	Difenthiuron 50 WP	Pegasus	Syngenta, Baner (Pune)	0.05	500	1g/l
4	Fipronil 5 SC	Regent	Bayer Crop Science, (Mumbai)	0.0075	75	1.5 ml/l
5	Chlorpyriphos 20 EC	Dursban	Dow Agro Sciences, (Mumbai)	0.02	200	1 ml/l
6	Buprofezin 25 SC	Applaud	Biostadt, (Mumbai)	0.025	250	1 ml/l
7	*Metarhizium anisopliae*	Phule Metarhizium	MPKV, Rahuri	0.4	-	4 g/l
8	*Lecanicillium lecanii*	Phule Verticillium	MPKV, Rahuri	0.4	-	4 g/l
9	Azadirachtin 10000 ppm	Neemazol	T. Stans & Co. Ltd	0.3	-	3 ml/l
10	Untreated control	-	-	-	-	-

3.2 Bioefficacy of different insecticides and biopesticides against sorghum aphid

The experiment was laid out at All India Co-ordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri to test the bioefficacy of nine insecticides and biopesticides against sorghum aphid. It was conducted during post rainy season of 2016-17 by using randomized block design with three replications. The plot size was 3.60 X 4.00 m and spacing followed was 45 X 15 cm between row to row and plant to plant. All the package of practices except plant protection measures were recommended for raising the crop. The widely grown variety Phule Vasudha was selected for the experiment and it was sown on 20th October, 2016 with application of post sowing irrigation.

The emergence count of sorghum plant was recorded 7 days after sowing by keeping single plant at each hill. There were 10 treatments consisting of 6 chemical insecticides, 2 biopesticides, 1 botanical insecticide for foliar sprays and one untreated control. The insecticides were used dimethoate 30 EC at 0.03 per cent, acephate 75 SP at 0.037 per cent, difenthiuron 50 WP at 0.05 per cent, fipronil 5 SC at 0.0075 per cent, chlorpyriphos 20 EC at 0.02 per cent, buprofezin 25 SC at 0.025 per cent, *Lecanicillium lecanii.* 1X10^{8} CFU @ 4 g/l, *Metarhizium anisopliae* 1X10^{8} CFU 4 g/l and azadirachtin 10000 ppm @ 3 ml/l. For the different insecticide treatments a required solution of given concentration of insecticides and biopesticides was made with water for spraying three replications of each treatments. The recommended cultural practices were followed.

3.2.1 Method of preparation of spray solution

All the chemicals were applied through spray. The amount of spray solution required was estimated at each time by spraying water on with untreated control. The amount of insecticide required for preparing spray solution was calculated by using following formula:

$$Q \times a.i. = C \times V$$

Where, Q = Quantity of insecticide required.

a.i. = Active ingredient in product.

C = Required concentration.

V = Volume of spray solution required.

The known quantity of insecticide was mixed with little quantity of water and then the solution was poured in the bucket containing desired quantity of water. It was thoroughly stirred with the help of wooden stick and applied to Sorghum crop. Application of insecticides and biopesticides was done when 90 to 100 per cent of the total plant population was infested with aphid.

3.2.2 Method of recording observations

The efficacy of insecticides at given doses against the pest was assessed, on the basis of surviving population of aphids in each treatment after the spray (two spray). Observations on the number of aphids were counted on the same plants which observed for recording the aphid number before one day and after three, five and ten days of the application of insecticides. The incidence of sorghum aphids were recorded on number of aphids per sq.cm per leaf from three leaves (top, middle and bottom canopy of plant) of five tagged plants selected at random one day before and 3, 5 and 10 days after each spraying (DAS). Data were collected on the number of aphids per square cm and suitable conversions were made. Then individual treatment plots were harvested and threshed separately. Further the observations on grain yield per plot, fodder yield per plot were recorded separately and necessary conversions were made. The data were analyzed statistically.

3.3 Evaluation of insecticidal effect on natural enemies of aphid

To study the toxicity of different insecticides, five plants were randomly selected and tagged for recording the population of natural enemies of aphid. The observations were recorded on different predators (grubs + adults) present on these plants. These observations were recorded one day before and seven days after the application of each spray (two spray). The mycosis of biopesticides observed in the field as well as in the laboratory. Thus, the data obtained were analyzed after necessary transformation.

3.4 Analysis of experimental data

The data on average survival population of sorghum aphid translated into square root transformation ($\sqrt{n + 0.5}$) subjected to statistical analysis as suggested by Panse and Sukhatma (1985). The standard error (S.E.) and critical difference (C.D.) at 5% level of probability were calculated. The yield data was subjected to statistical analysis. Finally, an incremental cost benefit of each treatment was worked out.

4. RESULTS AND DISCUSSION

During the present investigations, a field trial was undertaken to evaluate the bioefficacy of insecticides and biopesticides against sorghum aphid, their impact on natural enemies and on yield. The results obtained during the course of this investigation are described under the following heads-

4.1 Seasonal abundance of aphid

4.2 Effect of insecticides and biopesticides for the control of Sorghum aphid

4.3 Impact of insecticides and biopesticides on natural enemies.

4.1 Seasonal abundance of sorghum aphid and its natural enemies

Seasonal abundance of sorghum aphid and its natural enemies was studied on Phule Vasudha variety in *rabi* season at Rahuri. Data in respect of aphid population were recorded on 1 cm^2 leaf area at weekly interval, during the middle period of every standard meteorological week and presented in Table 2 and Fig. 2. The abundance of aphid was started from 48th standard meteorological week and increased gradually to reach its peak period in 3rd standard meteorological week. Thereafter, it declined gradually and started disappearing from 7th standard meteorological week.

The total number of *Coccinella septumpunctata* and *Chrysoperla carnea* (adults and grubs) recorded weekly interval are presented in Table 2. Predatory beetles started appearing along with aphid and attained their peak during 3rd standard meteorological week and declined gradually and decline gradually and disappeared by 7th standard meteorological week.

4.1.1 Effect of environmental factors on abundance of sorghum aphid and its natural predators

The abundance of the sorghum aphid was largely influenced by prevailing environmental weather parameters viz. thermal (maximum and minimum temperature ^{O}C), hydrological (rainfall cm), per cent relative humidity (a.m. and p.m.) and solar energy (bright sunshine hours).

The correlation coefficient (r) of aphid abundance and weather parameters of the two week prior to the date of observation indicated that the weather parameters of two weeks prior to the date of observation had significant correlation with the abundance of sorghum aphid and there was negative correlation with maximum (r= -0.4834) and significant negative correlation with minimum temperature (r= -0.5750). Minimum temperature had significant role in increase of aphid population. There was negative correlation with morning humidity (r= -0.2480) and evening humidity (r= -0.0776). There was negative correlation with sunshine hrs. (r= -0.1492) found. The r value of lady bird beetle and green lace wing were significant and positive r= 0.9779, r= 0.9816, respectively. It indicated that there was increase in population of these natural predators with increase in aphid population.

In nutshell, the establishment of relationship of weather parameters with population counts of insect would help in predict the probable levels of insect counts, their intensities with reference to their economical thresholds (ETL) and planning appropriate control measures for their effective management within economic viabilities.

Table 2. Seasonal abundance of sorghum aphid and its natural enemies and their correlation with weather parameters

MW	Dt. of obs.	Aphid/sq.cm	Correlation coefficient of aphid population with weather parameters and natural enemies							
			Max. Temp.	Min. Temp.	Morn. H	Eve. H	RF	S. Shine	Coccinellids/plant	chrysoperla/pl.
46	15.11.16	0	30.0#	14.9#	51.0#	42.0#	0.00#	9.20#	0	0
47	22.11.16	0	29.8	12.4	52.0	26.0	0.00	9.70	0	0
48	29.11.16	0	30.0	14.9	78.0	47.0	0.00	8.30	0	0
49	06.12.16	2	29.0	9.9	55.0	29.0	0.00	10.40	0	0
50	13.12.16	11.7	32.4	10.4	63.0	27.0	0.00	9.40	1.33	0.56
51	20.12.16	15.23	29.6	11.4	64.0	30.0	0.00	8.50	3.2	1.4
52	27.12.16	20.36	29.8	9.9	56.0	25.0	0.00	9.70	7.24	2.5
1	03.01.17	27.2	28.4	9.5	52.0	33.0	0.00	9.30	8.56	3.6
2	10.01.17	35.55	27.6	7.9	51.0	29.0	0.00	9.50	10.66	3.9
3	17.01.17	47.25	29.0	8.9	47.0	41.0	0.00	9.80	11.66	4.6
4	24.01.17	44.25	28.4	9.4	52.0	22.0	0.00	9.70	11.26	4.9
5	31.01.17	33.56	29.6	14.9	77.0	37.0	0.00	5.60	9.66	3.4
6	06.02.17	19.23	32.4	13.9	61.0	32.0	0.00	9.10	6	2.6
7	13.02.17	11.36	32.4	12.4	57.0	22.0	0.00	10.20	2	1.2
8	20.02.17	3.45	32.0	13.5	70.0	34.0	0.00	9.10	0	0
9	27.02.17	0	30.6	13.5	54.0	28.0	0.00	9.50	0	0
‘r’ values			**-0.483**	**-0.575***	**-0.248**	**-0.078**	**-**	**-0.149**	**0.979****	**0.982****

Data of two weeks prior to the date of observation. * Significant at 0.05 % & 0.01 % = 0.497 & 0.623, respectively

In the present study, aphid abundance started from 1st week of December and reached a peak in 3rd week of January and declined there after gradually disappearing in 3rd week of February. Balikai and Lingappa (2002) revealed that the sorghum aphid appeared on the 48th or 49th standard week (1st or 2nd week of December) and reached a peak in the 3rd or 4th standard week (3rd or 4th of January) and declined thereafter before disappearing in the 7th standard week and also studied the population of natural enemies, which was peak during 3rd or 4th standard week.

The temperature during period of sorghum aphid abundance in the present study ranged from 7.9 to 32.4°C very close to ranges (11.4 to 34.7°C) recorded by Waghmare *et al.* (1995), Mote and Kadam (1984) and Narayana *et al.* (1982). Our findings are in accordance Behura and Bohidar (1983) found that at the temperature of 35°C the aphids did not survive.

Pawar *et al.* (2014) reported that the abundance of sorghum aphid started from 1st week of December, i.e. 90 days after sowing and further increased continuously up to last week of January and declined thereafter. The population was at its peak in the month of January i.e. 120 days after sowing. The correlation coefficient (r) of aphid abundance and weather parameters of the two week prior to the date of observation indicated that the weather parameters of two week prior to the date of observation had significant correlation with the abundance of aphid and there was negative correlation with maximum ($r= -0.640$ and $r= -0.863$) and minimum temperature ($r= -0.703$ and $r= -0.695$). The favorable range of maximum temperature and minimum temperature during the peak infestation of aphid was from 29 to 30°C and 9 to 11°C respectively.

Patil and Sathe (2001) observed that *Menochilus sexmaculata* F. appeared from 2nd week of November and attained a peak in 2nd week of February with respect to the level of pest population, respectively. In both season predator caused higher mortality of aphid, *R. maidis* in sorghum ecosystem.

After the attainment of peak population by the sorghum aphid during 3rd week of January, simultaneously lady bird beetle and chrysoperla population also attained their peak during 3rd Week of January.

4.2 Effect of insecticides and biopesticides for the control of sorghum aphid

4.2.1 One day before 1st spray

It was observed that in whole experimental plots the differences in the initial population of sorghum aphid were statistically non significant, indicating that pest spread was uniform over entire experimental plots (Table 3).

4.2.2 Three days after 1st spray

The data presented in Table 3 and Fig. 2 revealed that there were significant differences in respect of aphid population after three days of spraying. Almost all the insecticidal treatments were significantly superior over untreated control. Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (0.77 aphid/sq.cm of leaf). Chlorpyriphos 20 EC at 0.02 per cent (1.29 aphids) and acephate 75 SP 0.0375 at per cent (1.60 aphids) were at par

Table 3: Efficacy of different treatments against sorghum aphid

Sr. No.	Treatments	Aphid population at 1st spray					
		Dose per lit.	**Pre-count**	**3 DAS**	**5 DAS**	**10 DAS**	**Mean**
1	Dimethoate 30 EC at 0.03 %	1 ml/l	14.01 (3.80)*	0.77 (1.12)	0.40 (0.94)	1.17 (1.29)	0.73 (1.12)
2	Acephate 75 SP at 0.037 %	0.5g/l	13.75 (3.77)	1.60 (1.44)	1.14 (1.28)	2.35 (1.69)	1.54 (1.47)
3	Difenthiuron 50 WP at 0.05 %	1g/l	13.19 (3.69)	4.39 (2.21)	3.13 (1.90)	3.28 (1.94)	3.57 (2.02)
4	Fipronil 5 SC at 0.0075 %	1.5ml/l	13.35 (3.72)	2.72 (1.79)	2.33 (1.68)	2.95 (1.85)	2.69 (1.77)
5	Chlorpyriphos 20 EC at 0.02 %	1 ml/l	14.24 (3.84)	1.29 (1.33)	0.82 (1.15)	1.85 (1.53)	1.20 (1.34)
6	Buprofezin 25 SC at 0.025 %	1 ml/l	13.77 (3.77)	7.06 (2.75)	5.44 (2.43)	4.45 (2.22)	5.65 (2.47)
7	*Lecanicillium lecanii* 1x10^8CFU	4 g/l	14.77 (3.90)	11.36 (3.44)	6.08 (2.56)	3.53 (2.00)	7.18 (2.67)
8	*Metarhizium anisopliae* 1x10^8 CFU	4 g/l	13.41 (3.73)	11.44 (3.45)	6.11 (2.57)	3.90 (2.09)	7.41 (2.70)
9	Azadirachtin 10000 ppm	3 ml/l	14.22 (3.83)	4.73 (2.29)	5.05 (2.35)	5.11 (2.36)	4.98 (2.34)
10	Untreated control		13.15 (3.69)	13.24 (3.71)	13.70 (3.77)	15.91 (4.05)	14.14 (3.84)
SE ±			0.84 (0.11)	0.27 (0.06)	0.29 (0.06)	0.48 (0.07)	0.95 (0.19)
C.D. at 5 %			NS (NS)	0.80 (0.18)	0.85 (0.18)	1.44 (0.20)	2.81 (0.57)

DAS : Days after spray

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

with each other. The next effective chemical treatments were fipronil 5 SC at 0.0075 per cent (2.72 aphids), difenthiuron 50 WP at 0.05 per cent (4.39 aphids), buprofezin 25 SC at 0.025 per cent (7.06 aphids). The biopesticides viz. azadirachtin 10000 ppm @ 3 ml/l (4.73 aphids *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (11.36 aphids), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (11.44 aphids) were moderately effective as compare to chemical pesticides. However, *L. lecanii* and *M. anisopliae* were at par with each other.

4.2.3 Five days after 1st spray

The data presented in Table 3 and Fig. 2 regarding the aphid population after five days of spraying revealed that there were significant differences in respect of aphid population after five days of spraying. Almost all the insecticidal treatments were significantly superior over untreated control. Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (0.40 aphid/sq.cm of leaf). However, chlorpyriphos 20 EC at 0.02 per cent (0.82 aphids) and acephate 75 SP at 0.0375 per cent (1.14 aphids) were at par with each other. The next effective treatments were fipronil 5 SC at 0.0075 per cent (2.33 aphids), difenthiuron 50 WP at 0.05 per cent (3.13 aphids), buprofezin 25 SC at 0.025 per cent (5.44 aphids). The biopesticides viz. azadirachtin 10000 ppm @ 3 ml/l (5.05 aphids), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (6.08 aphids), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (6.11 aphids) were moderately effective as compare to chemical pesticides. However, *L. lecanii* and *M. anisopliae* were at par with each other.

4.2.4 Ten days after 1st spray

It is revealed from the data presented in Table 3 and Fig. 2 that there were significant differences among the different insecticidal treatments regarding aphid population after ten days of spraying.

Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (1.77 aphid/sq.cm of leaf). Chlorpyriphos 20 EC at 0.02 per cent (1.85 aphids) and acephate 75 SP at 0.0375 per cent (2.35 aphids) were at par with each other. The next effective treatments were fipronil 5 SC at 0.0075 per cent (2.95 aphids), difenthiuron 50 WP at 0.05 per cent (3.28 aphids) were at par with each other and buprofezin 25 SC at 0.025 per cent (4.45 aphids) less effective in chemical pesticides. Among the biopesticides, *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (3.53 aphids), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (3.90 aphids) showed best results than azadirachtin 10000 ppm @ 3 ml/l (5.11 aphids). They were moderately effective as compared to chemical pesticides. However, acephate and fipronil, *L. lecanii* and *M. anisopliae* were at par with each other.

Overall results revealed that dimethoate 30 EC at 0.03 per cent was found superior over all treatments which recorded lowest aphid population (0.73 aphid/leaf/sq.cm) followed by chlorpyriphos 20 EC at 0.02 per cent (1.20 aphids). The next effective treatments were acephate 75 SP at 0.0375 per cent (1.54 aphids), fipronil 5 SC at 0.0075 per cent (2.69 aphids), difenthiuron 50 WP at 0.05 per cent (3.57 aphids), buprofezin 25 WP at 0.025 per cent (5.65 aphids). Among the biopesticides, azadirachtin 10000 ppm @ 3 ml/l

(4.98 aphids) is effective than *Lecanicillium lecanii* $1x10^8$ CFU @ 4 g/l (7.18 aphids), *Metarhizium anisopliae* $1x10^8$ CFU @ 4 g/l (7.41 aphids). However, the biopesticides were moderately effective as compared to chemical pesticides. While chlorpyriphos and acephate, *L. lecanii* and *M. anisopliae* were at par with each other. All the insecticidal treatments were significantly superior over untreated control.

4.2.5 One day before 2nd spray

It was observed that in whole experimental plots the differences in the initial population of aphid were statistically non significant, indicating that pest spread was uniform over entire experimental plots (Table 4).

4.2.6 Three days after 2nd spray

The data presented in Table 4 and Fig. 3 revealed that there were significant differences in respect of aphid population after three days of spraying. Almost all the insecticidal treatments were significantly superior over untreated control. Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (0.58 aphid/ sq.cm of leaf). Chlorpyriphos 20 EC at 0.02 per cent (1.13 aphids) and acephate 75 SP at 0.0375 per cent (1.24 aphids) were at par with each other. The next effective chemical treatments were fipronil 5 SC 0.0075 per cent (2.03 aphids/plant), difenthiuron 50 WP at 0.05 per cent (2.88 aphids), buprofezin 25 SC at 0.025 per cent (5.15 aphids). In biopesticides, azadirachtin 10000 ppm @3 ml/l (3.95 aphids) was effective than *Lecanicillium lecanii* $1x10^8$ CFU @ 4 g/l (9.51 aphids) and *Metarhizium anisopliae* $1x10^8$ CFU @ 4 g/l (9.82 aphids) and they were moderately effective as compared to chemical pesticides. However, *L. lecanii* and *M. anisopliae* were at par with each other.

Table 4: Efficacy of different treatments against sorghum aphid

Sr. No.	Treatments	Aphid population at 2nd spray					
		Dose per lit.	Pre-count	3 DAS	5 DAS	10 DAS	Mean
1	Dimethoate 30 EC at 0.03 %	1 ml/l	9.85 (3.22)*	0.58 (1.03)	0.32 (1.03)	0.57 (1.03)	0.49 (0.99)
2	Acephate 75 SP at 0.037 %	0.5 g/l	10.08 (3.25)	1.24 (1.32)	0.87 (1.32)	1.30 (1.33)	1.14 (1.27)
3	Difenthiuron 50 WP at 0.05 %	1 g/l	10.86 (3.37)	2.88 (1.84)	1.88 (1.84)	1.88 (1.54)	2.21 (1.64)
4	Fipronil 5 SC at 0.0075 %	1.5 ml/l	10.78 (3.36)	2.03 (1.59)	1.24 (1.59)	1.62 (1.45)	1.63 (1.45)
5	Chlorpyriphos 20 EC at 0.02 %	1 ml/l	10.24 (3.27)	1.13 (1.27)	0.70 (1.27)	0.86 (1.16)	0.90 (1.17)
6	Buprofezin 25 SC at 0.025 %	1 ml/l	11.10 (3.40)	5.15 (2.37)	4.59 (2.37)	3.13 (1.90)	4.29 (2.17)
7	*Lecanicillium lecanii* 1x10^8 CFU	4 g/l	11.44 (3.45)	9.51 (3.16)	3.75 (3.16)	1.85 (1.53)	5.04 (2.25)
8	*Metarhizium anisopliae* 1x10^8 CFU	4 g/l	11.75 (3.50)	9.82 (3.21)	4.03 (3.21)	2.01 (1.58)	5.29 (2.31)
9	Azadirachtin 10000 ppm	3 ml/l	11.22 (3.410)	3.95 (2.11)	4.23 (2.11)	2.92 (1.85)	3.70 (2.04)
10	Untreated control		14.15 (3.82)	16.33 (4.10)	15.46 (3.99)	9.57 (3.17)	13.79 (3.75)
SE ±			0.77 (0.12)	0.34 (0.07)	0.24 (0.06)	0.32 (0.08)	1.05 (0.20)
C.D. at 5 %			NS (NS)	1.00 (0.22)	0.71 (0.18)	0.94 (0.25)	3.12 (0.58)

DAS : Days after spray

*The values in parentheses indicates $\sqrt{n+0.5}$ values

4.2.7 Five days after 2nd spray

The data presented in Table 4 and Fig. 3 regarding the aphid population after five days of spraying revealed that there were significant differences in respect of aphid population after three days of spraying. Almost all the insecticidal treatments were significantly superior over untreated control.

Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (0.32 aphid/sq.cm of leaf). Chlorpyriphos 20 EC at 0.02 per cent (0.70 aphids) and acephate 75 SP at 0.0375 per cent (0.87 aphids) were at par with each other. The next effective chemical treatments were fipronil 5 SC at 0.0075 per cent (1.24 aphids), difenthiuron 50 WP at 0.05 per cent (1.88 aphids), Buprofezin 25 SC at 0.025 per cent (4.59 aphids/plant). However, acephate and fipronil were at par with each other. In biopesticides, *Lecanicillium lecanii* $1x10^8$ CFU @ 4 g/l (3.75 aphids) was effective than *Metarhizium anisopliae* $1x10^8$ CFU @ 4 g/l (4.03 aphids) and azadirachtin 10000 ppm @ 3 ml/l (4.23 aphids). These three treatments were at par with each other. They were moderately effective as compare to chemical pesticides.

4.2.8 Ten days after 2nd spray

It is revealed from the data presented in Table 4 and Fig. 3 that there were significant differences among the different insecticidal treatments regarding aphid population after ten days of spraying.

Dimethoate 30 EC at 0.03 per cent recorded lowest population of aphids (0.57 aphid/ sq.cm of leaf), chlorpyriphos 20 EC at 0.02 per cent (0.86 aphids) and acephate 75 SP at

0.0375 per cent (1.30 aphids) were at par with each other. The next effective chemical treatments were fipronil 5 SC at 0.0075 per cent (1.62 aphids), difenthiuron 50 WP at 0.05 per cent (1.88 aphids) were at par with each other and buprofezin 25 SC at 0.025 per cent (3.13 aphids) at last. Among the biopesticides, *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (1.85 aphids) was effective than *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (2.01 aphids) and azadirachtin 10000 ppm @ 3 ml/l (2.92 aphids). However, *L. lecanii*, *M. anisopliae and* azadirachtin were at par with each other and they were moderately effective as compared to chemical pesticides.

Overall results revealed that dimethoate 30 EC at 0.03 per cent was found superior over all treatments which recorded lowest aphid population (0.49 aphids/ sq.cm of leaf) followed by chlorpyriphos 20 EC at 0.02 per cent (0.90 aphids). The next effective chemical treatments were acephate 75 SP at 0.0375 per cent (1.14 aphids), fipronil 5 SC at 0.0075 per cent (1.63 aphids), difenthiuron 50 WP at 0.05 per cent (2.21 aphids), buprofezin 25 SC at 0.025 per cent (4.29 aphids). Among the biopesticides, azadirachtin 10000 ppm @ 3 ml/l (3.70 aphids/plant) was better than *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (5.04 aphids) and *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (5.29 aphids). While *L. lecanii* and *M. anisopliae* were at par with each other and were moderately effective as compared to chemical pesticides. All the insecticidal treatments were significantly superior over untreated control.

4.2.9 Cumulative mean of two spray

The cumulative mean results revealed that all the treatments were significantly superior over untreated

Table 9: Efficacy of different treatments against sorghum aphid (Cumulative mean of two spray)

Sr. No.	Treatments	Aphid population (Cumulative mean of two spray)			Average
		R I	R II	R III	
1	Dimethoate 30 EC at 0.03 %	0.69 (1.09)*	0.60 (1.04)	0.61 (1.04)	0.63 (1.06)
2	Acephate 75 SP at 0.037 %	1.42 (1.46)	1.33 (1.34)	1.28 (1.32)	1.34 (1.37)
3	Difenthiuron 50 WP at 0.05 %	2.46 (1.71)	3.25 (1.92)	2.98 (1.86)	2.90 (1.83)
4	Fipronil 5 SC at 0.0075 %	1.95 (1.54)	2.41 (1.69)	2.12 (1.61)	2.16 (1.61)
5	Chlorpyriphos 20 EC at 0.02 %	0.89 (1.25)	1.16 (1.27)	1.10 (1.25)	1.05 (1.26)
6	Buprofezin 25 SC at 0.025 %	4.5 (2.22)	5.09 (2.35)	5.32 (2.40)	4.97 (2.32)
7	*Lecanicillium lecanii* $1x10^8$ CFU	5.73 (2.36)	6.09 (2.47)	6.52 (2.55)	6.11 (2.46)
8	*Metarhizium anisopliae* $1x10^8$ CFU	6.71 (2.52)	6.15 (2.50)	6.19 (2.50)	6.35 (2.51)
9	Azadirachtin	4.03 (2.11)	4.76 (2.28)	4.24 (2.17)	4.34 (2.19)
10	Untreated control	13.87 (3.81)	13.99 (3.79)	14.02 (3.79)	13.96 (3.80)
SE $\pm$		0.53 (0.07)	0.34 (0.07)	0.30 (0.05)	0.15 (0.04)
C.D. at 5 %		1.70 (0.24)	1.08 (0.22)	0.96 (0.17)	0.46 (0.11)

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

control in minimizing infestation of sorghum aphid, *M. sacchari* Zehntner. The minimum aphid infestation was observed in plots treated with dimethoate 30 EC at 0.03 % (0.63 aphids/ sq.cm of leaf). The next best treatment were chlorpyriphos 20 EC at 0.02 % (1.05 aphids), acephate 75 SP at 0.0375 % (1.34 aphids). The other effective chemical treatments were fipronil 5 SC at 0.0075 % @ (2.16 aphids), difenthiuron 50 WP at 0.05 % (2.90 aphids) and buprofezin 25 SC at 0.025 % (4.97 aphids). Among the biopesticides, azadirachtin 10000 ppm @ 3 ml/l (4.34 aphids) was the most effective. However, *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (6.11 aphids) and *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (6.35 aphids) were at par with each other. The biopesticides were moderately effective as compared to chemical pesticides. The effectiveness of dimethoate against aphid on sorghum was supported by the research of following workers. In that two application of foliar sprays of dimethoate effectively reduced the sorghum aphid population and increased yields by 14-17 per cent in Northern India. (Bhatia *et al.* 1973). Dimethoate 30 EC was most effective treatment against sorghum aphid in Maharashtra during 1980 (Gandhale *et al.* 1983). Dimethoate 30 EC showed 95.25 per cent reduction in aphid population 10 days after spraying in sorghum (Balikai and Lingappa 2003). Similarly, Balikai (2004) observed that, one spray either of dimethoate 30 EC 0.05 per cent, monocrotophos 36 WSC at 0.04 per cent or chlorpyriphos 20 EC at 0.05 cent effectively controlled the aphid (83.3, 80.2, 77.5 per cent reduction in aphid population of sorghum. Dimethoate 30 EC at 0.03 per cent and imidacloprid 17.8 SC at 0.009 per cent were recorded highly effective in reducing sorghum aphid population to 1.17 and 1.84 aphid/leaf/cm^2 respectively (Bhamare and Tiwari 2006). Similarly, the effectiveness of chlorpyriphos 20 EC at 0.05% which was second effective treatment in the present study was also reported by Balikai (2004).

Wadnerkar *et al.* (2003) reported that fipronil 5 per cent SC at 50-75 g a.i./ha was found optimum against aphids, jassids and thrips in cotton.

Daware *et al.* (2011) suggested that when bioefficacy and yield are concerned for sorghum aphid it was found that all insecticides thiamethoxam 25 WG, imidacloprid 17.8 SL, dimethoate 30 EC and biopesticides namely NSKE 5 per cent, nimark and karanj leaf extract 5 per cent were significantly superior. The biopesticides were also significantly superior over untreated control and at par with each other.

Very few literature on effectiveness of *L. lecanii, M. anisoplae* and *B. bassiana* against sorghum aphid is available. However, Mishra *et al.* (2015) revealed that *L. lecanii* which recorded 1.86 and 2.06 aphids/plant and 82.16 and 82.92 per cent reduction of aphid population in okra during *kharif* and *summer*, respectively. The other biopesticides in order of effectiveness were *M. anisopliae*, Neemazol and *B. bassiana* recording (3.02 and 3.10, 4.01 and 3.92, 3.96 and 4.08 aphids/plant) during *kharif* and *summer*, respectively. During the present investigation, the biopesticides viz. *L. lecanii* and *M. anisopliae* were next best effective treatments besides the chemicals treatments.

4.3 Effect of insecticides and biopesticides on the natural enemies of aphid

4.3.1 Effect of insecticides and biopesticides on natural enemies seven day after 1st spray

4.3.1.1 Effect of insecticides and biopesticides on coccinellid grub

Data presented in Table 6 regarding the effect of insecticides and biopesticides on coccinellid grub revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be most toxic recording lowest population of 1.00 coccinellid grubs per plant followed by chlorpyriphos 20 EC at 0.02 per cent (1.19 coccinellid grub), acephate 75 SP at 0.0375 per cent (1.33 coccinellid grub) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.66 coccinellid grub). Difenthiuron 50 WP at 0.05 per cent (4.66 coccinellid grub) and buprofezin 25 SC at 0.025 per cent (5.33 coccinellid grub) comparatively less toxic to coccinellid grub and at par to each other. Azadirachtin 10000 ppm @ 3 ml/l (8.33 coccinellid grub), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (9.67 coccinellid grub), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (9.67 coccinellid grub) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.1.2 Effect of insecticides and biopesticides on coccinellid adult

Data presented in Table 6 regarding the effect of insecticides and biopesticides on coccinellid adult revealed the significant differences. The treatment with dimethoate 30 EC

Table 5: Effect of different treatments on predators of sorghum aphid (one day before 1st spray)

Sr. No.	Treatments	Lady bird beetle		Chrysoperla	
		Grub	Adult	Larvae	Adult
1	Dimethoate 30 EC at 0.03 %	7.33 (2.79)*	2.00 (1.56)	3.33 (1.95)	1.67 (1.46)
2	Acephate 75 SP at 0.037 %	8.00 (2.91)	1.67 (1.46)	3.33 (1.94)	2.00 (1.58)
3	Difenthiuron 50 WP at 0.05%	7.00 (2.73)	1.67 (1.46)	3.67 (2.02)	1.00 (1.22)
4	Fipronil 5 SC at 0.0075 %	7.67 (2.85)	1.67 (1.44)	4.67 (2.27)	1.67 (1.46)
5	Chlorpyriphos 20 EC at 0.02 %	7.00 (2.73)	1.33 (1.34)	3.67 (2.02)	2.00 (1.58)
6	Buprofezin 25 SC at 0.025 %	7.00 (2.73)	1.33 (1.34)	4.67 (2.27)	1.67 (1.46)
7	*Lecanicillium lecanii* $1x10^8$ CFU	7.33 (2.80)	1.67 (1.46)	4.67 (2.27)	1.33 (1.29)
8	*Metarhizium anisopliae* $1x10^8$ CFU	8.33 (2.97)	2.67 (1.77)	4.33 (2.20)	2.00 (1.58)
9	Azadirachtin 10000 ppm	8.33 (2.96)	2.33 (1.68)	4.67 (2.27)	2.00 (1.58)
10	Untreated control	8.67 (3.02)	2.00 (1.58)	4.33 (2.20)	1.67 (1.46)
SE ±		0.13	0.13	0.13	0.12
C.D. at 5 %		NS	NS	NS	NS

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

Table 6: Effect of different treatments on predators of sorghum aphid (seven days after 1st spray)

Sr.	Treatments	Lady bird beetle		Chrysoperla	
		Grub	Adult	Larvae	Adult
1	Dimethoate 30 EC at 0.03 %	1.00 (1.22)*	0.33 (0.88)	0.47 (0.98)	0.27 (0.85)
2	Acephate 75 SP at 0.037 %	1.33 (1.35)	0.47 (0.96)	0.67 (1.05)	0.47 (0.96)
3	Difenthiuron 50 WP at 0.05 %	4.67 (2.27)	1.11 (1.27)	1.67 (1.46)	0.83 (1.15)
4	Fipronil 5 SC at 0.0075 %	1.66 (1.47)	1.00 (1.22)	1.00 (1.22)	0.67 (1.05)
5	Chlorpyriphos 20 EC at 0.02 %	1.19 (1.30)	0.40 (0.92)	0.58 (1.03)	0.44 (0.95)
6	Buprofezin 25 SC at 0.025 %	5.33 (2.41)	1.00 (1.22)	2.11 (1.61)	1.33 (1.34)
7	*Lecanicillium lecanii* 1x10^8 CFU	9.67 (3.19)	1.67 (1.46)	4.00 (2.12)	1.33 (1.34)
8	*Metarhizium anisopliae* 1x10^8 CFU	9.67 (3.19)	2.00 (1.58)	4.33 (2.20)	1.67 (1.46)
9	Azadirachtin 10000 ppm	8.33 (2.96)	2.00 (1.58)	3.67 (2.04)	1.67 (1.46)
10	Untreated control	11.67 (3.48)	2.11 (1.61)	4.33 (2.20)	2.00 (1.58)
SE ±		0.08	0.09	0.09	0.09
C.D. at 5 %		0.24	0.26	0.28	0.26

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

at 0.03 per cent found to be most toxic recording lowest population of 0.33 coccinellid adult per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.40 coccinellid adult), acephate 75 SP at 0.0375 per cent (0.47 coccinellid adult) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.00 coccinellid adult). Chlorpyriphos, acephate and fipronil were at par with each other. Difenthiuron 50 WP at 0.05 per cent (1.11 coccinellid adult) and buprofezin 25 SC at 0.025 per cent (1.00 coccinellid adult) comparatively less toxic to coccinellid adult. Azadirachtin 10000 ppm @ 3 ml/l (2.00 coccinellid adult), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (1.67 coccinellid adult), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (2.00 coccinellid adult) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.1.3 Effect of insecticides and biopesticides on chrysoperla larvae

Data presented in Table 6 regarding the effect of insecticides and biopesticides on chrysoperla larvae revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be highlly toxic recording lowest population of 0.47 chrysoperla larvae per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.58 chrysoperla larvae), acephate 75 SP at 0.0375 per cent (0.67 chrysoperla larvae). The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.00 chrysoperla larvae). Dimethoate, chlorpyriphos, acephate, fipronil these four treatments were at par with each other in toxicity to chrysoperla larvae. Difenthiuron 50 WP at

0.05 per cent (1.67 chrysoperla larvae) and buprofezin 25 SC at 0.025 per cent (2.11 chrysoperla larvae) comparatively less toxic to chrysoperla larvae. Azadirachtin 10000 ppm @ 3 ml/l (3.67 chrysoperla larvae), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (4.00 chrysoperla larvae), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (4.33 chrysoperla larvae) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.1.4 Effect of insecticides and biopesticides on chrysoperla adult

Data presented in Table 6 regarding the effect of insecticides and biopesticides on chrysoperla adult revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be most toxic recording lowest population of 0.27 chrysoperla adult per plant followed by chlorpyriphos 20 at EC at 0.02 per cent (0.44 chrysoperla adult), acephate 75 SP at 0.0375 per cent (0.47 chrysoperla adult) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (0.67 chrysoperla adult). Difenthiuron 50 WP 0.05 per cent (0.83 chrysoperla adult) and buprofezin 25 SC at 0.025 per cent (1.33 chrysoperla adult) comparatively less toxic to chrysoperla adult and at par with each other. Azadirachtin 10000 ppm @ 3 ml/l (1.67 chrysoperla adult), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (1.33 chrysoperla adult), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (1.67 chrysoperla adult) were least toxic among all the insecticides tested. Buprofezin, *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.2 Effect of insecticides and biopesticides on natural enemies seven day after 2nd spray

4.3.2.1 Effect of insecticides and biopesticieds on coccinellid grub

Data presented in Table 8 regarding the effect of insecticides and biopesticides on coccinellid grub revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be most toxic recording lowest population of 0.67 coccinellid grubs per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.79 coccinellid grub), acephate 75 SP at 0.0375 per cent (1.00 coccinellid grub) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.33 coccinellid grub). Difenthiuron 50 WP at 0.05 per cent (3.11 coccinellid grub) and buprofezin 25 SC at 0.025 per cent (4.18 coccinellid grub) comparatively less toxic to coccinellid grub and at par to each other. Azadirachtin 10000 ppm @ 3 ml/l (7.33 coccinellid grub), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (7.67 coccinellid grub), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (7.33 coccinellid grub) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

Table 7: Effect of different treatments on predators of sorghum aphid (one day before 2nd spray)

Sr. No.	Treatments	Lady bird beetle		Chrysoperla	
		Grub	Adult	Larvae	Adult
1	Dimethoate 30 EC at 0.03 %	6.67 (2.67)*	2.00 (1.58)	3.33 (1.95)	1.67 (1.46)
2	Acephate 75 SP at 0.037 %	6.33 (2.61)	1.33 (1.34)	2.67 (1.77)	2.00 (1.58)
3	Difenthiuron 50 WP at 0.05 %	5.67 (2.47)	1.67 (1.46)	3.67 (2.04)	1.33 (1.34)
4	Fipronil 5 SC at 0.0075 %	6.67 (2.65)	1.67 (1.44)	3.67 (2.03)	1.67 (1.46)
5	Chlorpyriphos 20 EC at 0.02 %	7.00 (2.73)	1.33 (1.34)	3.33 (1.95)	2.00 (1.58)
6	Buprofezin 25 SC at 0.025 %	6.33 (2.61)	1.67 (1.46)	3.67 (2.04)	1.67 (1.46)
7	*Lecanicillium lecanii* 1x10^8 CFU	8.33 (2.97)	2.00 (1.58)	4.00 (2.11)	1.67 (1.46)
8	*Metarhizium anisopliae* 1x10^8 CFU	7.67 (2.86)	2.33 (1.68)	4.33 (2.19)	2.00 (1.58)
9	Azadirachtin 10000 ppm	8.00 (2.91)	2.00 (1.56)	3.67 (2.04)	1.67 (1.46)
10	Untreated control	7.33 (2.80)	2.33 (1.68)	4.33 (2.20)	2.33 (1.68)
SE $\pm$		0.12	0.12	0.08	0.10
C.D. at 5 %		NS	NS	NS	NS

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

Table 8: Effect of different treatments on predators of sorghum aphid (seven days after 2nd spray)

Sr. No.	Treatments	Lady bird beetle		Chrysoperla	
		Grub	Adult	Larvae	Adult
1	Dimethoate 30 EC at 0.03 %	0.67 (1.08)*	0.33 (0.89)	0.40 (0.94)	0.29 (0.89)
2	Acephate 75 SP at 0.037 %	1.00 (1.22)	0.53 (0.99)	0.67 (1.05)	0.51 (0.98)
3	Difenthiuron 50 WP at 0.05 %	3.11 (1.90)	1.22 (1.31)	2.00 (1.58)	1.00 (1.22)
4	Fipronil 5 SC at 0.0075 %	1.33 (1.35)	1.00 (1.22)	1.00 (1.22)	0.67 (1.05)
5	Chlorpyriphos 20 EC at 0.02 %	0.79 (1.14)	0.40 (0.92)	0.60 (1.04)	0.47 (0.96)
6	Buprofezin 25 SC at 0.025 %	4.18 (2.16)	1.33 (1.34)	2.33 (1.68)	1.00 (1.22)
7	*Lecanicillium lecanii* 1x10^8 CFU	7.67 (2.86)	2.00 (1.58)	3.33 (1.95)	1.67 (1.46)
8	*Metarhizium anisopliae* 1x10^8 CFU	7.33 (2.80)	2.00 (1.58)	3.67 (2.04)	1.67 (1.460
9	Azadirachtin 10000 ppm	7.33 (2.80)	1.70 (1.48)	2.67 (1.77)	1.11 (1.27)
10	Untreated control	8.33 (2.97)	2.33 (1.68)	4.00 (2.12)	2.11 (1.61)
SE ±		0.05	0.10	0.09	0.11
C.D. at 5 %		0.14	0.29	0.26	0.31

*The values in parentheses indicates $\sqrt{n + 0.5}$ values

4.3.2.2 Effect of insecticides and biopesticides on coccinellid adult

Data presented in Table 8 regarding the effect of insecticides and biopesticides on coccinellid adult revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be most toxic recording lowest population of 0.33 coccinellid adult per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.40 coccinellid adult), acephate 75 SP at 0.0375 per cent (0.53 coccinellid adult) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.00 coccinellid adult). Chlorpyriphos, acephate and fipronil were at par with each other. Difenthiuron 50 WP at 0.05 per cent (1.22 coccinellid adult), buprofezin 25 SC at 0.025 per cent (1.33 coccinellid adult) comparatively less toxic to coccinellid adult. Azadirachtin 10000 ppm @ 3 ml/l (1.70 coccinellid adult), *Lecanicillium lecanii* $1x10^8$ CFU @ 4 g/l (2.00 coccinellid adult), *Metarhizium anisopliae* $1x10^8$ CFU @ 4 g/l (2.00 coccinellid adult) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.2.3 Effect of insecticides and biopesticides on chrysoperla larvae

Data presented in Table 8 regarding the effect of insecticides and biopesticides on chrysoperla larvae revealed the significant differences. The treatment with dimethoate 30 EC at 0.03 per cent found to be most toxic recording lowest population of 0.40 chrysoperla larvae per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.60 chrysoperla larvae), acephate 75 SP at 0.0375 per cent (0.67 chrysoperla larvae). The next toxic treatment was fipronil 5 SC at 0.0075 per cent (1.00 chrysoperla larvae). Dimethoate, chlorpyriphos, acephate, fipronil these four treatments were at par with each other in toxicity to chrysoperla larvae. Difenthiuron 50 WP at 0.05 per cent (2.00 chrysoperla larvae), buprofezin 25 SC at 0.025 per cent (2.33 chrysoperla larvae) comparatively less toxic to chrysoperla larvae. Azadirachtin 10000 ppm @ 3 ml/l (2.67 chrysoperla larvae), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (3.33 chrysoperla larvae), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (3.67 chrysoperla larvae) were least toxic among all the insecticides tested. *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

4.3.2.4 Effect of insecticides and biopesticides on chrysoperla adult

Data presented in Table 8 regarding the effect of insecticides and biopesticides on chrysoperla adult revealed the significant differences. The treatment with dimethoate 30 EC at0.03 per cent found to be most toxic recording lowest population of 0.29 chrysoperla adult per plant followed by chlorpyriphos 20 EC at 0.02 per cent (0.47 chrysoperla adult), acephate 75 SP at 0.0375 per cent (0.51 chrysoperla adult) were at par with each other. The next toxic treatment was fipronil 5 SC at 0.0075 per cent (0.67 chrysoperla adult). Difenthiuron 50 WP at 0.05 per cent (1.00 chrysoperla adult) and buprofezin 25 SC at 0.025 per cent (1.00 chrysoperla adult) comparatively less toxic to chrysoperla adult and at par with each other. Azadirachtin 10000 ppm @ 3 ml/l (1.11 chrysoperla adult), *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l

(1.67 chrysoperla adult), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (1.67 chrysoperla adult) were least toxic among all the insecticides tested. Buprofezin, *L. lecanii*, *M. anisopliae* and azadirachtin were at par with each other.

All the results of present study corroborate with the results of following workers.

Dirimonov *et al.* (1974) reported that acephate, ethiofen and carbaryl were found slightly toxic to the *C. septumpunctata*, two hours after treatment. Dimethoate and Omethoate were found more toxic to the predator two hours after treatment.

Hassan *et al. (1985)* reported that dimethoate and fenvelerate were harmful to *C. carnea.*

Thayaalini and Ravindranath (1988) reported that dimethoate had detrimental effect on *C. sexmaculata.*

Dhoubi (1992) reported that among insecticides viz., buprofezin 25 SC (12.5 g a.i. /ha), butacarboxin (500 g a.i./ha) and imidacloprid 200 SL (15 g a.i./ha) tested, except buprofezin all the other found to affect predators.

Awasthi *et al.* (2013) evaluated the order of relative toxicity of insecticides over spinosad was acetamiprid > acephate > imidacloprid > emamectin benzoate > indoxacarb to predatory coccinellid.

4.4 Grain yield of sorghum in insecticides and biopesticides treatments

The observations on grain yield presented in Table 9 revealed that the insecticides treated plots gave significantly higher grain yield over untreated control.

The highest grain yield of 26.10 q/ha was obtained with dimethoate 30 EC at 0.03 per cent followed by chlorpyriphos 20 EC at 0.02 per cent 25.24 q/ha. The next promising treatments were acephate 75 SP at 0.0375 per cent (24.79 q/ha), fipronil 5 SC at 0.0075 per cent (23.89 q/ha), difenthiuron 50 WP at 0.05 per cent (24.08 q/ha), Buprofezin 25 SC at 0.025 per cent (22.44 q/ha). The biopesticides treatments viz. *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (23.59 q/ha), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (23.40 q/ha) and azadirachtin 10000 ppm @ 3 ml/l (23.44 q/ha) recorded moderately effective yield as compare to chemical pesticides treatment.

4.5 Fodder yield of sorghum in insecticides and biopesticides treatments

Data given in Table 9 regarding effect of newer insecticides on fodder yield of sorghum revealed significant differences. The highest fodder yield of 57.70 q/ha was obtained with dimethoate 30 EC at 0.03 per cent followed by chlorpyriphos 20 EC at 0.02 per cent 56.29 q/ha. The next promising treatments were acephate 75 SP at 0.0375 per cent (55.39 q/ha), fipronil 5 SC at 0.0075 per cent (54.66 q/ha), difenthiuron 50 WP at 0.05 per cent (54.80 q/ha), Buprofezin 25 SC at 0.025 per cent (52.16 q/ha). The biopesticides treatments viz. *Lecanicillium lecanii* 1x10^8 CFU @ 4 g/l (54.57 q/ha), *Metarhizium anisopliae* 1x10^8 CFU @ 4 g/l (54.31 q/ha) and azadirachtin 10000 ppm @ 3 ml/l (54.32 q/ha) recorded moderately effective yield as compare to chemical pesticides treatment.

Table 10: Economics of treatments used against sorghum aphid

Sr. No.	Treatments	Grain Yield (q/ha)	Increased gain yield over control (q/ha)	Income of increased grain yield (Rs/ha)	Fodder yield (qha^{-1})	Increased fodder yield over control (q/ha)	Income of increased fodder yield (Rs/ha)	Total income of increased yield (Grain + fodder)	Cost of treatments for two sprays (Rs/ha)	Net Profit (Rs/ha)	ICBR
T1	Dimethoate 30 EC at 0.03 %	26.10	4.95	9900	57.70	9.4	1880	11780	2440	9340	1 : 4.82
T2	Acephate 75 SP at 0.037 %	24.79	3.64	7280	55.39	7.09	1418	8698	2350	6348	1 : 3.70
T3	Difenthiuron 50 WP at 0.05%	24.08	2.93	5860	54.80	6.5	1300	7160	5760	1400	1 : 1.24
T4	Fipronil 5 SC at 0.0075 %	23.89	2.74	5480	54.66	6.36	1272	6752	4100	2652	1 : 1.64
T5	Chlorpyriphos 20EC at 0.02 %	25.24	4.09	8180	56.29	7.99	1598	9778	2360	7418	1 : 4.14
T6	Buprofezin 25SC at 0.025 %	22.44	1.29	2580	52.16	3.86	772	3352	3260	92	1 : 1.02
T7	*Lecanicillium lecanii* $1x10^8$ CFU	23.59	2.44	4880	54.57	6.27	1254	6154	2875	3279	1 : 2.14
T8	*Metarhizium anisopliae* $1x10^8$ CFU	23.40	2.25	4500	54.31	6.01	1202	5702	2875	2827	1 : 1.98
T9	Azadirachtin 10000 ppm	23.44	2.29	4580	54.32	6.02	1204	5784	5720	64	1 : 1.01
T10	Untreated control	21.15			48.30						
	SE ±	0.60			1.49						
	C.D. at 5%	1.78			4.42						

Cost of inputs: 1) labour-: 250 Rs./labour/day (4 labours/ha/day) 2) Milk for biopesticides spray-: 30 Rs/l (2.5 l/ha/spray)

3) Rate of insecticides-:
1.Dimethoate 30 EC at 440 Rs/l,
2. Acephate 75 SP at 700 Rs./kg,
3. Difenthiuron 50 WP at 960 Rs/kg,
4. Fipronil 5 SC at 1400 Rs/l,
5.Chlorpyriphos 20 EC at 360 Rs/l,
6. Buprofezin 25 SC at 1260 Rs/l,
7. *L. lecanii* & *M.anisopliae* at 150 Rs/kg,
8. Azadirachtin 10000 ppm at 1240 Rs/l.

4)Sorghum grain price-: 20 Rs./kg, Fodder price-: 2000 Rs./t

4.3.3 Economics of treatment used against sorghum aphid

The treatment dimethoate 30 EC at 0.03 per cent showed highest net profit (Rs 9340/ha) over the control and had highest ICBR ratio (1: 4.82) followed by chlorpyriphos 20 EC at 0.02 Net profit (Rs 7418 /ha) and ICBR ratio (1: 4.14). The net profit and ICBR ratio of remaining treatments acephate 75 SP at 0.0375 per cent (Rs 6348/ha, 1 : 3.70), fipronil 5 SC at 0.0075 per cent (Rs 2652 /ha, 1 : 1.64), difenthiuron 50 WP at 0.05 per cent (Rs 1400/ha, 1 : 3.70), buprofezin 25 SC at 0.025 per cent (Rs 92/ha, 1 : 1.02), *Lecanicillium lecanii* 1x10^8 CFU (Rs 3259 /ha, 1 : 2.14), *Metarhizium anisopliae* 1x10^8 CFU (Rs 2307/ha, 1 : 1.98) and azadirachtin 10000 ppm @ 3 ml/l (Rs 64/ha, 1:1.01), respectively.

Bhatia *et al.* (1973) reported that dimethoate treatment increased the yield of 14-17 per cent in case of barley.

Gandhale *et al.* (1986) reported the increased yield due to dimethoate compared with untreated control in sorghum.

5. SUMMARY AND CONCLUSIONS

Detailed studies on sorghum aphid, *Melanaphis sacchari* Zehntner were undertaken on *rabi* sorghum during 2016-17 at the All India Coordinated Sorghum Improvement Project, MPKV, Rahuri. Studies were carried out setting the objectives like i) To study the seasonal abundance of sorghum aphid. ii) To find out effective and economical insecticides and biopesticides against sorghum aphid. iii) To study the effect of chemicals and biopesticides on natural enemies of aphid.

5.1 Summary

The findings of present investigations are summarized and concluded in this chapter.

5.1.1 Seasonal abundance of sorghum aphid and its natural enemies

Sorghum aphid abundance appeared in the 48th standard meteorological week i.e. (1st week of December) and reached a peak in the 2nd standard meteorological week (3rd week of January) and thereafter declined gradually before disappearing in 7th standard meteorological week. During the period of aphid activity the temperatures were within favorable range from 7.9 to 32.4^{o}C. Natural predators appeared in the 49th standard meteorological week i.e. (2nd week of December) and reached a peak in the 3rd standard meteorological week (3rd week of January). Among weather parameters, relative humidity (p.m.) and sunshine hours correlated negatively, while maximum and minimum temperature, morning relative humidity and rainfall correlated negatively with population of aphids as well as natural predators. Minimum temperature played significant role to increase aphid population.

5.1.2 Effect of different insecticides and biopesticides against sorghum aphid

Dimethoate 30 EC at 0.03 per cent offered best control of sorghum aphid and reduced the population to the lowest level at all times of observations. Chlorpyriphos 20 EC at 0.02 per cent was also much effective in suppressing the aphid population to the lowest level in all observations. Effectiveness of other treatments was acephate 75 SP, fipronil 5 SC, difenthiuron 50 WP, buprofezin 25 SC. In biopesticides, azadirachtin 10000 ppm, *L. Lecanii* $1x10^8$, and *M. anisopliae* $1x10^8$ respectively. Chlorpyriphos and acephate, *L. lecanii* and *M. anisopliae* were at par with each other. In biopesticides, *L. lecanii* showed better result than *M. anisopliae.*

5.1.3 Effect of insecticides and biopesticides on natural enemies of aphid

The insecticides which were used for controlling the sorghum aphid were also studied for their toxic effect on coccinellids grub and adult, chrysoperla larvae and adults under field condition. Dimethoate 30 EC at 0.03 per cent was highly toxic to natural enemies of aphids followed by chlorpyriphos 20 EC at 0.02 per cent. Next toxic treatments were acephate 75 SP at 0.037 per cent, fipronil 5 SC at 0.0075 per cent. IGR’s like buprofezin 25 SC at 0.025 per cent and difenthiuron 50 WP at 0.02 per cent were least toxic to natural enemies of aphid. Biopesticides were non toxic to natural enemies.

5.1.4 Effect of treatments on yield and ICBR of sorghum

Dimethoate 30 EC at 0.03 per cent offered complete protection of sorghum plant from sorghum aphid and hence figured the enhanced grain yield, fodder yield over rest of the treatments. The highest grain yield of 26.10 q/ha was obtained with dimethoate 30 EC at 0.03 per cent followed by chlorpyriphos 20 EC at 0.02 per cent 25.24 q/ha. The remaining treatments which showed their effectiveness were acephate 75 SP > fipronil 5 SC > difenthiuron 50 WP > *L. lecanii* $1x10^8$ > azadirachtin 10000 ppm > *M. anisopliae* $1x10^8$ > buprofezin 25 SC.

5.2 Conclusion

- Two applications of dimethoate 30 EC at 0.03 per cent at 15 days interval was found most effective for the control of sorghum aphid. Next best treatments were chlorpyriphos 20 EC at 0.02 per cent and acephate 75 SP at 0.037 per cent.
- Difenthiuron 50 WP at 0.02 per cent and buprofezin 25 SC at 0.025 per cent were moderately control controlled the sorghum aphid and they were least toxic to natural enemies of aphid.
- Though, dimethoate 30 EC at 0.03 per cent, chlorpyriphos 20 EC at 0.02 per cent and acephate 75 SP at 0.037 per cent were best treatments for sorghum aphid but they were highly toxic to its natural enemies also.

- In the biopesticides, azadirachtin 10000 ppm, *L. lecanii* 1x10^8 and *M. anisopliae* 1x10^8 respectively, showed better result. Also biopesticides were non toxic to natural enemies of aphid.
- The dimethoate 30 EC at 0.03 per cent proved to be the most promising results against sorghum aphid which recorded highest grain yield (26.10 q ha^{-1}) and highest fodder yield (57.70 q ha^{-1}) with highest ICBR (1: 4.82) and maximum net profit (Rs 11780/ha).
- In the biopesticides, *L. lecanii* recorded highest grain yield (23.59 q ha^{-1}) and highest fodder yield (54.57 q ha^{-1}) with highest ICBR (1: 2.14) and maximum net profit (Rs 3279/ha).

5.3 Future line of work

- As this pest is increasing in an alarming proportion an integrated low cost, less complex and easily adaptable management strategy needs to develop based on present investigation.

- Assessment of role of natural enemies in suppressing the population of aphids and possibilities of their mass rearing and multiplication for future use in IPM.

6. LITERATURE CITED

Abbas, G. and Farhan M. 2015. Efficacy of the new chemistry pesticides on nymph and adult population of whitefly *Bemisia tabaci* Genn. and their effect on naturally existing beneficial fauna of Cotton in Punjab, Pakistan. *Int. J. Sci. and Res.* 4: 10.

Aheer, G. M., Ahmad, K. J., Ali, A. 1994. Role of weather in fluctuating aphid density in wheat crop. *J. Agric. Res.,* 32 (3): 295–301.

Akashe, V. B., Gud, M. A., Shinde, S. K. and Deshpande A. N. 2008. Bio-efficacy of some newer insecticides against *Uroleucon compositae* (Theobald) infesting safflower, *Carthamus tinctorius* Linnaeus. *7th Int. Safflower Conf.*

Awasthi, N. S., Bharkhade, U. P., Patil, S. R. and Lande, G. K. 2013. Comparative toxicity of some commonly used insecticides to cotton aphid and their safety to predatory coccinellid. *The Bioscan.,* 8 (3): 1007-1010.

Balikai, R. A. 2001. Bioecology and management of the sorghum aphid, *Melanaphis sacchari* Zehntner. Ph.D. Thesis. University of Agricultural Sciences, Dharwad. Karnataka. India, 203 pp.

Balikai, R. A. and Lingappa S. 2002. Population dynamics studies of sorghum aphid, *Melanaphis sacchari* (Zehntner) (Homoptera: Aphidae) and its natural enemies. *J. Aphidology.*, 16: 27-34.

Balikai, R. A. and Lingappa, S. 2003. Chemical control of *Melanaphis sacchari* (Zehntner) in *rabi* sorghum. *J. Ent. Res.,* 27: 121-126.

Balikai, R. A. 2004. Chemical control of sorghum aphid, *Melanaphis sacchari* (Zehntner) on *rabi* sorghum. *Agric. Sci. Digest.*, 24 (2): 142-144.

Balikai, R. A. 2007. Eco-biology and management of sorghum aphid, *Melanaphis sacchari* (Zehntner) in *rabi* sorghum. *Agric. Rev.,* 28 (1): 18-25.

Behura, B. K. and Bohidar, K. 1983. Effect of temperature on the fecundity of five species of aphids. *Pranikee.,* 4: 23-27.

Bhamare, V. K. and Tiwari, R. B. 2006. Bioefficacy of different insecticides against sorghum aphid, *Melanaphis sacchari* (Zehntner). *Int. J. Pl. Sci.,* 1 (1): 113-115.

Bhati, R. and Sharma, R. C. 2014. Efficacy of newer chemicals against mustard aphid. *Biolife J.,* 2 (4): 1165-1169.

Bhatia, S. K., Young, W. R. and Shrivastavsa, A. N. 1973. Control of corn leaf aphid on barley in India. *J. Econ. Ent.,* 66 : 463-467.

Booth, L. H., Wratten, S. D. and Kebrli, P. 2007. Effect of reduced rates of two insecticides on enzyme activity and mortality of aphid and its lace wing predator. *J. Econ. Ent.,* 100(1): 11-19.

Daware, D. G., Ambilwade, P. P., Kamble, R. J. and Bhosle, B. B. 2011. Bioefficacy of insecticides and biopesticides against sorghum aphid, *Melanaphis sacchari (*Zehntner*). Indian J. Ent.,* 73 (2) : 97-99.

*Denmark, H. A. 1988. Sugarcane aphids in Florida (Homoptera: Aphididae). *Ent. Circular,* Division of Plant Industry, Florida Department of Agriculture 1: 302.

Dhoubi, M. H. 1992. Efficacy of certain chemical products with regard to the whiteflies *Aleurethrixus floccosus* Mask and *Parabemisia myricae* Kuw (Homoptera: Aleurodidae) and their impact on the beneficial *Cales noacki* Holward and *Encarsia transvena* Timberlake (Hymenoptera: Aphelinidae). *Mededelingen-van-de-faculteit-Landhou-eten-Schappen -Universiteit-Gent.,* 57 : 493-503.

*Dirimonov, M., Stefanove, D. and Dimitrov, D. 1974. The effect of certain insecticides on the more important species of useful insects on tobacco. *Rastiteina Zaschita.,* 22: 18-20.

Gandhale, D. N., Patil, A. S., Awate, B. G., Jadhav, D. B. and Naik, L. M. 1986. Evaluation of insecticides for the control of aphids and delphacids on Jowar. *Pestic.,* 20 (2) : 17-18.

Ghelani, M. K., Kabaria, B. B. and Chhodavadia, S. K. 2014. Field efficacy of various insecticides against major sucking pests of *Bt* cotton. *J. Biopest.,* 7 : 27-32.

Ghorpade, S. A., Patil, P. T. and Ambekar, J. S. 1982. Studies on the bio-efficacy of some newer insecticides against aphid, *Rhopalosiphum maidis* on wheat. Pestic., 16: 15-16.

Gour, I. S. and Pareek, B. L. 2005. Relative toxicity of some insecticides to coccinellids, *Coccinella septempunctata* Linn. and Indian honey bee, *Apis cerana indica. Indian J. Agril. Res.,* 39 (4): 299-302.

Harischandra P. R. and Shekharappa. 2009. Field evaluation of different entomopathogenic fungal formulations against sucking pests of okra. *Karnataka J. Agric. Sci.,* 22 (3): 575-578.

Hassan, S. A., Klingauf, F. and Shahin, F. 1985. Role of *Chrysoperla carnea* Stephens, as an aphid predator on sugarbeet and the effect of pesticides on it. *Zeitschrift for Angewandte Ent.*, 100 (2): 163-174.

Hijam, B. S. and Singh, T. K. 1989. Seasonal incidence of *Aphis craccivora* Koch. on cowpea *Vigna uniguiculata* (L.) Walp. in Manipur. *J. Aphidology.,* 3 (1-2): 68-72.

Jalali, M. A., Leumen, T. V., Tirry, L. and De Clerc, P. 2009. Toxicity of selected insecticides to the two spotted lady bird beetle, *Adalia bipunctata. Phytoparasitica.*, 37: 323-326.

John, A. H. and Ragupathy, A. 1992. Influence of host plant on the susceptibility of *Myzus persicae* (Sulz.) to certain insecticides. *Insect Sci. and its Applic.,* 13 (1): 79-86.

Khinchi, S. K. and Kumawat, K. C. 2014. Newer synthetic and biorational insecticides against aphid, *Rhapalosiphum maidis* (Fitch) on *Plantago ovata* Forsk. *Pestic. Res. J.,* 26 (1): 30-34.

*Lampert, E. P. and Godding, G. V. 1990. Effect of acephate and lamda cyhalothrin on aphid abundance and potato virus Y incidence in flue cured tobacco. *Tobacco Int.,* 192 (14): 45-49.

Meena, N. K. and Kanwat, P. M. 2010. Studies on seasonal incidence and relative safety of pesticides against coccinellids beetles in okra ecosystem. *J. Biological Control.,* 24(2): 116-122.

Mishra, B. K., Mishra, I. and Mohanisha, J. 2015. Evaluation of different biopesticides against the aphid in okra at Bhubaneshwar. *Middle-East J. Sci. Res.,* 23 (3): 421-425.

Misra, H. P. 2002. Field evaluation of some newer insecticides against aphid (*Aphis gossypii*) and jassids (*Amrasca biguttula biguttula*) on okra. *Indian J. Ent.,* 64 (1): 80-84.

Mote, U. N. 1983. Epidemic of delphacids and aphids on winter sorghum. *Sorghum News.*, 26 : 76.

Mote, U. N., and Kadam, J. R. 1984. Incidence of (*Aphis sacchari* Zehntner) in relation to sorghum plant characters. *Sorghum News.*, 27 : 86.

Mote, U. N., and Jadhav, S. S. 1993. Seasonal occurrence of flea beetles, delphacids, leaf sugary exudation and aphids on *rabi* sorghum. *J. Maharashtra Agric. Univ.*, 18 (1): 133-134.

Narayana, D., Sahib, K. H., Rao, B. S. and Rao, M. R. 1982. Studies on the incidence of an aphid (*Aphis sacchari*) in sorghum. *Sorghum News.*, 25 : 72.

Nasreen, A., Ghulam, M. and Muhammad, A. 2005. Mortality of *Chrysoperla carnea* (stephens) (Neuroptera: Chrysopidae) after exposure to some insecticides. *South Pacific Studies.,* 26 : 1.

Onur, S. and Samet H. A. 2016. Entomopathogenicity of *Metarhizium anisopliae* and some fungi toward the filbert aphid, *Myzocallis coryli* Goetze (Hemiptera: Aphididae). *Int. J. Fauna and Biological Studies.,* 3 (5): 32-37.

*Panse, V. G. and Sukhatme, P. V. 1985. Statistical method for agricultural workers. 4th Edn. ICAR, New Delhi. Pp. 145-165.

Patel, D. R. and Purohit, M. S. 2013. Spatial distribution of sorghum aphid, *Melanaphis sacchari* Zehntner. *Indian J. Ent.*, 75 (4).

Patel, D. R. and Purohit, M. S. 2014. Occurrence of aphids *Melanaphis sacchari* Zehntner on *rabi* sorghum. *Indian J. Ent.*, 76 (2).

Patil, V. J. and Sathe, T. V. 2001. Seasonal abundance of *Cheilomenes sexmaculatus* (Feb.), a predator of Jowar aphid, *Rhopalosiphum maidis* (Fitch.) in Sangli district Maharashtra. *Trends in Environmental and Evolutionary Biology*, Karnataka University, Dharwad. pp. 3.

Pawar, D. B., Bhoge, R. S., Gadakh, S. R. and Andhale, R. P. 2014. Correlation of incidence of aphid (*Melanaphis sacchari* Zehntner) on *rabi* sorghum with abiotic factors. *J. Agric. Res. Tech.,* 39 (1): 175-177.

Radha R., 2013. Comparative studies on the effectiveness of pesticides for aphid control in cowpea. *Res. J. Agri. and Forestry Sci.* 1 (6): 1-7.

*Rensburg, N. J. and Hamberg, H. V., 1976. Grain sorghum pests: an integrated control approach. *Progress Report 1976,* Plant Protection research Institute Pretoria. South Africa. pp. 151-162.

Singh, B. U., Padmaja, P. G. and Seetharma, N. 2004. Biology and management of the sorghum aphid, *Melanaphis sacchari* (*Zehntner*) (Homoptera: Aphididae), in sorghum: a review. *Crop Prot.,* 23: 739-755.

Suresh, B. C., Khander Khan, H. and Prasanna, P. M. 2012. Efficacy of different entomopathoginc fungi against cowpea aphid, *Aphis craccivora* Koch under laboratory and field condition. *Int. J. Pl. Prot.* 5 (1): 68-71.

Thayaalini, S. and Raveendranath, S. 1998. Effect of *Gardenia cramerii* Ait and dimethoate on the aphid predator, *Cheilomenes sexmaculata* Fabr. (Coleoptera-Coccinellidae). *Pest Management in Hortil. Ecosyst.*, 4 : 49-50.

Upadhyay, S. and Mishra, R. C. 1999. Efficacy and economics of insecticides and neem (*Azadirachta indica*)-based products on incidence of aphid (*Aphis gossypii*) on isabgol (*Plantago ovata*). *Indian J. Agril. Sci.,* 69 (2): 161-2.

Vaghasia, P. R., Kabaria, B. B., Acharya, M. F., Khanpara, A. V. and Dabhi, M. V. 2012. Bio-efficacy of biopesticide, *Verticillium lecanii* (Zimmerman) against aphid in coriander. *AGRIES- An int. e - j.,* 26: 163-167.

Wadnerkar, D. W., Kathekar, B. R. and Zanwar, P. R. 2003. Evaluation of fipronil 5 SC against cotton insect pests. *Pestic.,* 27 (9) : 15-18.

Waghmare, A. G., Varshneya, M. C., Khandge, S. V., Thakur, S. S., and Jadhav, A. S. 1995. Effect of Meteorological parameters on the incidence of aphids on sorghum. *J. Maharashtra Agric. Univ.,* 20 (2): 307-308.

Yadav, S. and Singh, S. P. 2016. Bio-efficacy of some new insecticides against mustard aphid, *Lipaphis erysimi* Kalt on Indian mustard. *The Bioscan.*, 11(1): 23-26.

***Originals not seen**.

8. VITA

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of
MASTER OF SCIENCE (AGRICULTURE)
in
AGRICULTURAL ENTOMOLOGY
2017

Title of Thesis : "Bioefficacy of different insecticides and biopesticides against sorghum aphid, *Melanaphis sacchari* Zehntner"

Major Field : Agricultural Entomology.

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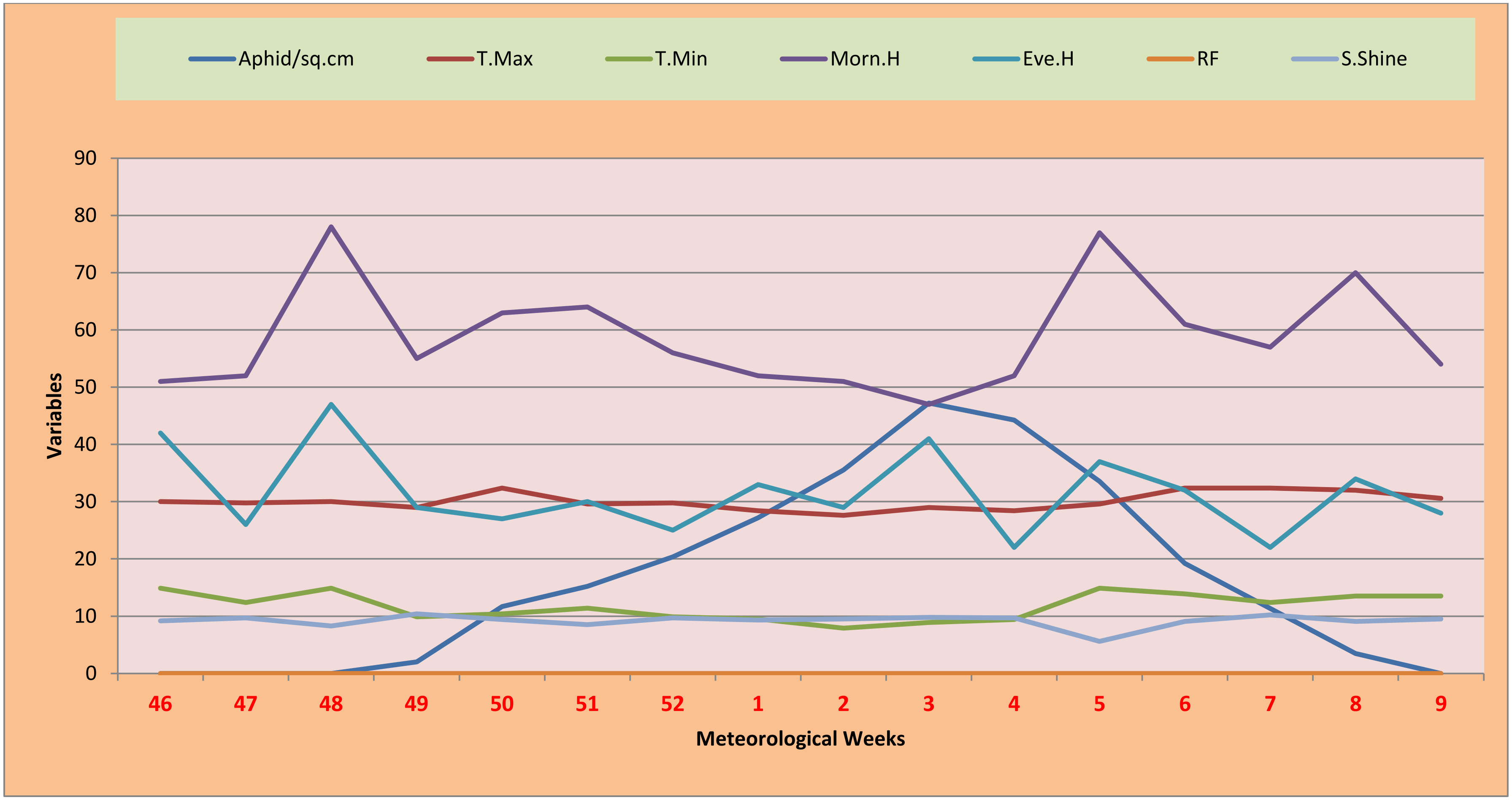


Fig 2 Seasonal abundance of sorghum aphid and its natural enemies

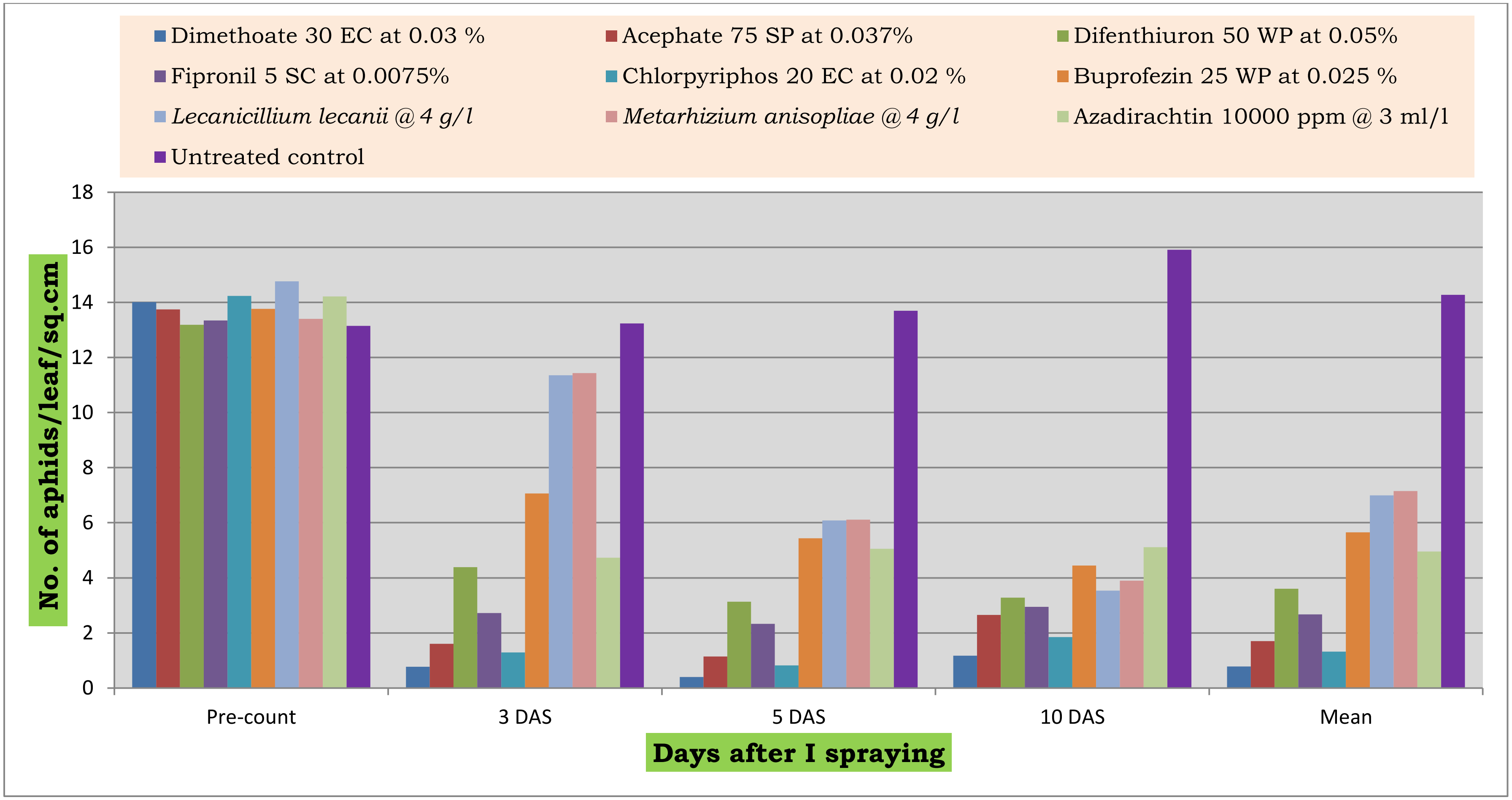


Fig 3 Efficacy of different treatments against sorghum aphid at 1st spray

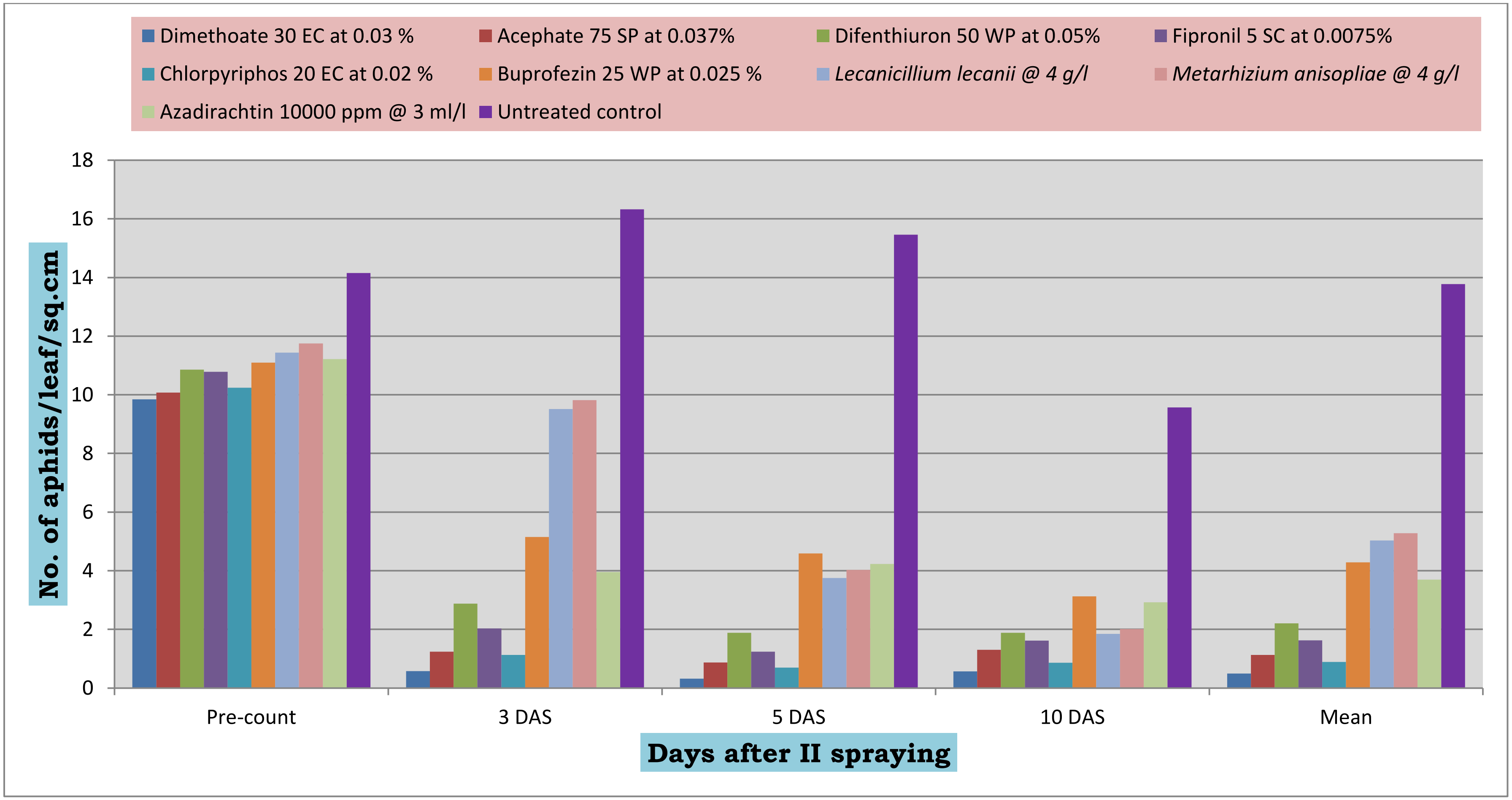


Fig. 4 Efficacy of different treatments against sorghum aphid at 2nd spray

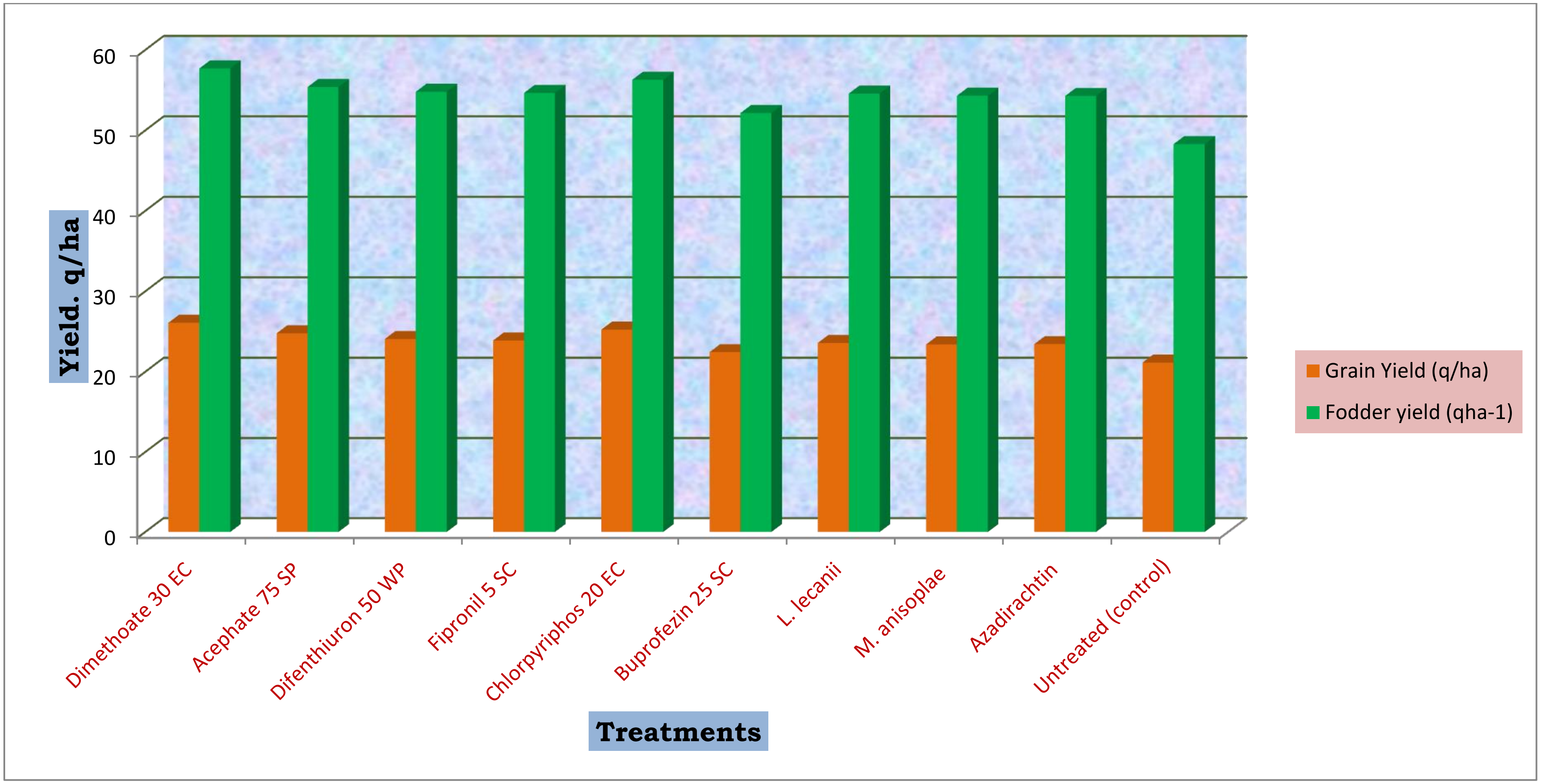


Fig. 5 Sorghum grain and fodder yield due to different treatments

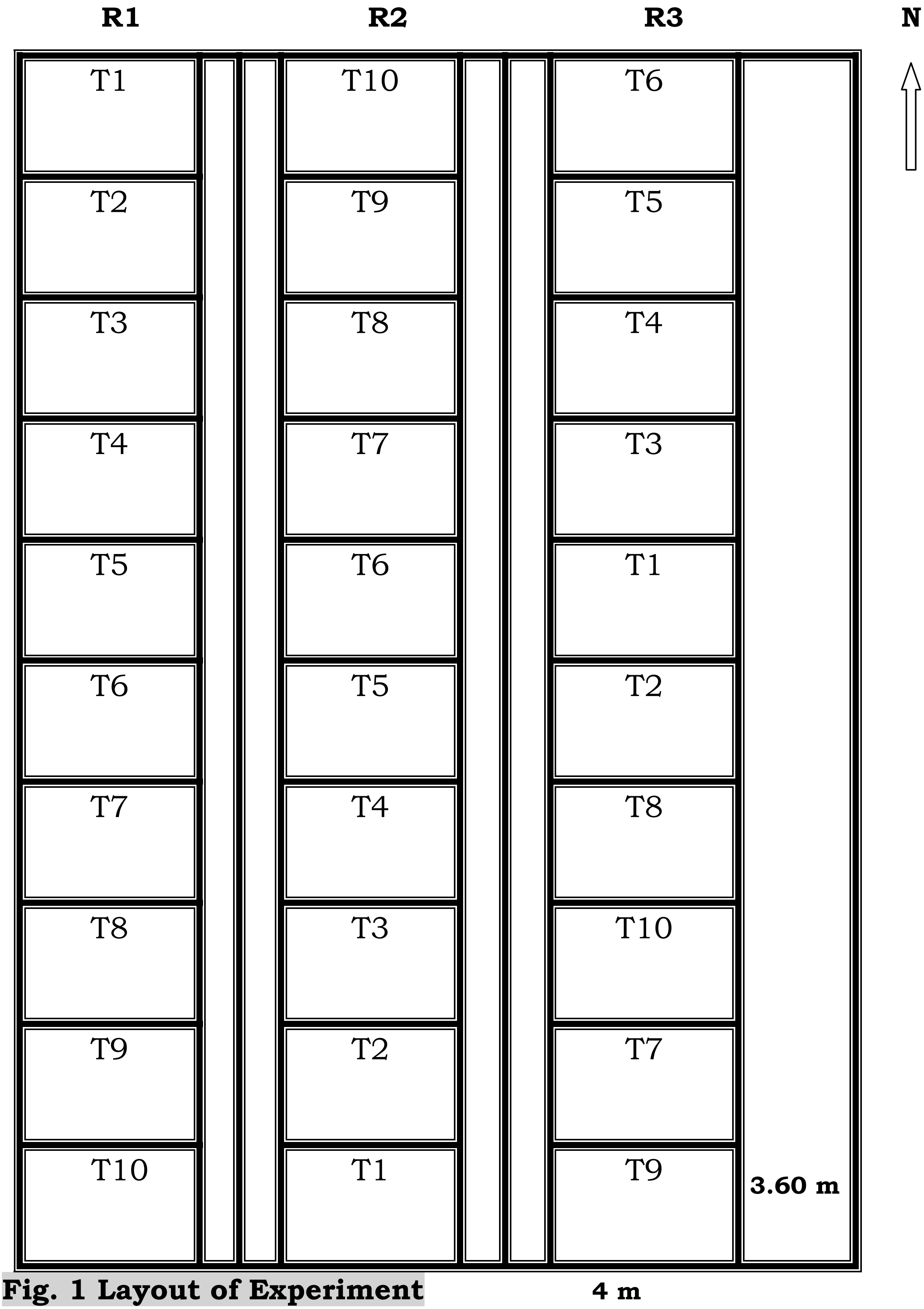
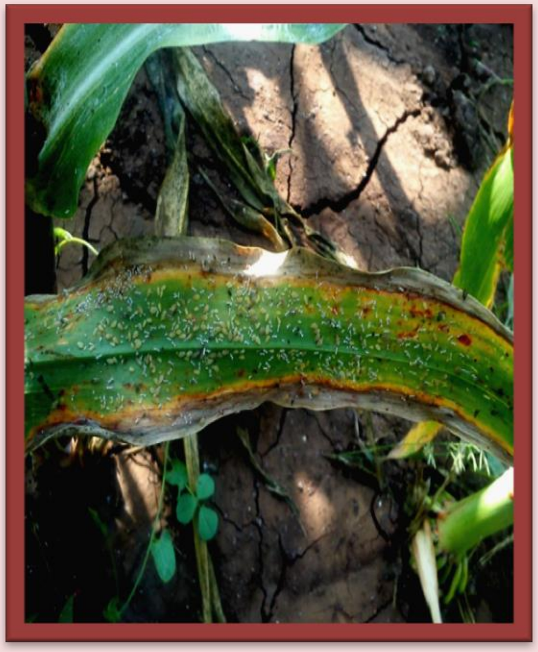


Fig. 1 Layout of Experiment

Plate 1: Experimental field

Plate 2: Sorghum aphid infestation

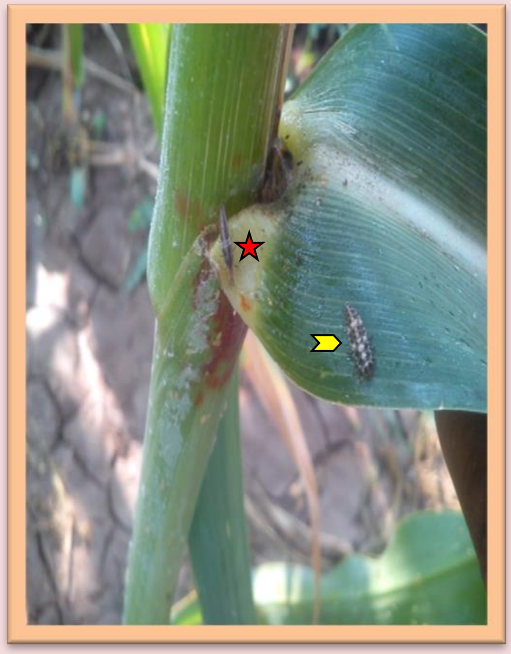


A B

C D

Plate 3: Nature of damage due to sorghum aphid

A. Eggs of *Chrysoperla carnea*



B. Larva of *Chrysoperla spp.* ★ and grub of *Coccinella septumpuntata*

C. Adults of *Chrysoperla carnea*

D. Adults of *Cheilomenes sexmaculata*

Plate 4: *Coccinellids* and *Chrysoperla*- Natural predators of aphid

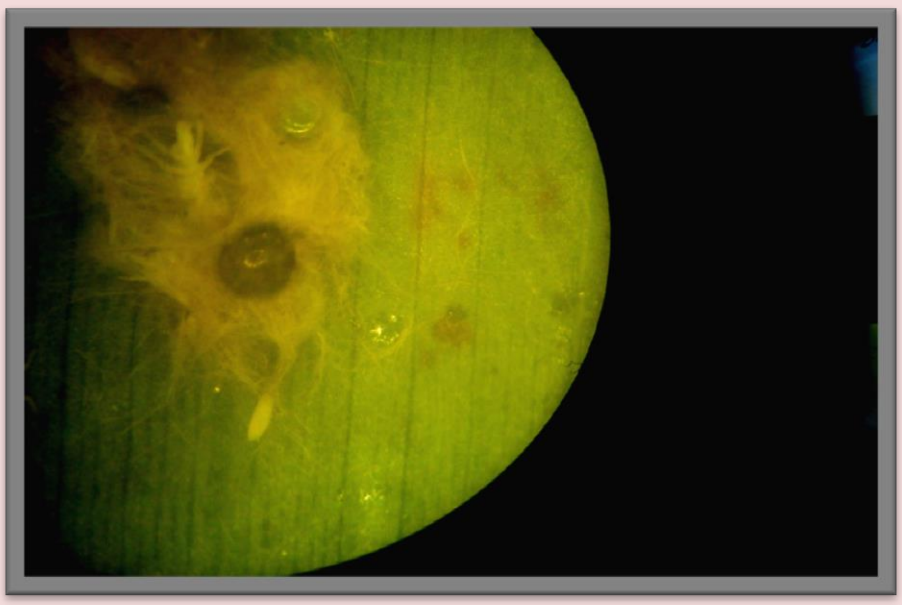
Plate 5: Spraying of insecticides and biopesticides

A

B

Plate 6: Effect of insecticides after spray

A. Infected sorghum aphid by *M. anisopliae*



B. Infected sorghum aphid by *L. lecanii*

Plate 7: Infection to sorghum aphid due to *M. anisoplae* and *L. lecanii*