Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]

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Thesis

Submitted to the
Swami Keshwanand Rajasthan Agricultural University,
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(Entomology)

By

Suresh Kumar Yadav

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Swami Keshwanand Rajasthan Agricultural University, Bikaner
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CERTIFICATE-I

Dated: /   /2014

This is to certify that **Mr. Suresh Kumar Yadav** had successfully completed the comprehensive examination held on **07-06-2013** as required under the regulation for the degree of **Master of Science in Agriculture (Entomology).**

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Dated: /   /2014

This is to certify that the thesis entitled **"Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]"** submitted for the degree of **Master of Science in Agriculture** in the subject of **Entomology** embodies bonafide research work carried out by **Mr. Suresh kumar Yadav** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on **12-07-2013**.

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Place: Bikaner
Date: **(SURESH KUMAR YADAV)**

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1. INTRODUCTION

Cluster bean [*Cyamopsis tetragonoloba* (L) Taub.] commonly known as guar is an important drought hardy leguminous crop cultivated mostly in the arid and semi-arid areas. Guar grown well in medium textured sandy soil and hot & dry climate. Cluster bean is grown for different purposes such as vegetables, green fodder, green manure and seed production. Its seeds contain 28-33% gum. Guar is the main raw material for gum industries. Gum is one of the important product, which has made the crop useful commercially and for export. The use of guar gum has increased tremendously, as it is a natural absorbent. It has diversified uses covering major industrial sectors like textile, printing, cosmetics, mining, explosive, pharmaceutical, oil and toiletry products.

Being a leguminous annual crop its primary use is in soil health enrichment through atmospheric nitrogen fixation , on average basis it has been estimated that it may fix nearly 30 kg N/ha. Furthermore, due to complete shedding of leaves up to maturity, the organic carbon may be added to the soil which would elevate organic carbon level that is the major concern under the arid areas. From the ancient time, cluster bean is being used as a source of food, fodder and feed under harsh environment. Young pods are a source of delicious vegetables from the late summer to the mid of rainy season which contain vitamin A, calcium, iron, phosphorous and ascorbic acid. Cluster bean provides very palatable and nutritious fodder and *guar* meal (feed) to the animals. It is a rich source of protein but low in TDN values. On dry matter basis cluster bean fodder contains about 16-20 per cent crude protein, 46 per cent TDN, 11-13 per cent DCP and more than 70 per cent digestibility. The dry matter intake is quite high *i.e.* 2.5 to 3.55 kg/100 body weight. Nutritional value of fodder varies with the stage of harvesting.

India accounts about 80% of the world guar production. Guar is mainly grown in India (Rajasthan, Haryana, Gujarat and Punjab), Pakistan, Sudan and USA. In India, Rajasthan and Haryana state contribute about 85% of the total production. India is the foremost country in the world with regards to area and production of cluster bean. Total area under the crop in India was around 34.02 lakh hectares with an annual production of 19.17 lakh tones (Anonymous, 2011a).

Rajasthan alone contribute 83.83 per cent of total guar production covering an area of 30.94 lakh hectares with an annual production of 18.46 lakh tones (Anonymous, 2011b) having a productivity of 597 kg ha^{-1} which is far below its potential yield of 1400 kg $ha^{-1.}$

Insect-pests are the major constrainst in the productivity of cluster bean. Among them Leaf hopper, *Empoasca motti* Pruthi.; whitefly, *Bemisia tabaci* Genn.; *Acaudaleyrodes rachipora* Singh.; aphid, *Aphis craccivora* Koch.; pod borer, *Helicoverpa armigera* Hub.; leaf perforator, *Dichomeris inthes* Meyr.; *Maruca testulalis* Geyer.*; Protaetia terrosa* G. & P. are important infesting cluster bean (Muralidharan *et al.,* 1999; Reddy and Rao, 2001; Arora and Kashyap, 2002; Khan *et al.,* 2002 and Singh, 2004).

Among various pests, sucking pests like whitefly, jassid and aphid cause considerable losses in the yield of cluster bean crop by sucking the sap from the ventral surface of leaves. As a result of their feeding, the affected parts become yellowish, the leaves wrinkle and curl downwards and are ultimately shed. Besides the feeding, these insects exude honey dew which favours the development of sooty mould which hinders the photosynthesis of the plant resulting in stunting growth. Not only seed yield is considerably reduced but the quality of the fodder also deteriorates, if the crop is grown for fodder purpose.

As a result of being high remunerative crop due to increasing demand by the gum producing industries, the area under the same has increased dramatically in the recent past. The availability of short duration cultivars are also responsible for tremendous increase in area under this crop, as the long duration cultivars have no promise due to erratic nature of monsoon. Since certain varieties are more preferred by a pest as compared to other or some may bear the losses caused by the pest, the study of the population of major sucking pests on different varieties of cluster bean would be done with a view to find out the least susceptible varieties against cluster bean sucking pests.

For the management of major insect-pests, chemical control has been recommended by some workers to combat with insect pests of cluster bean (Noor, 2002, Dodia *et. al.,* 2003, Patel, 2009 and Yadav *et.al*., 2011) but due to one or the other reasons could not become panacea in the protection of this crop.

Various insecticides and botanicals have been entered into market for controlling various sucking insect pests, but their efficacy is needed to be checked in clusterbean crop.

The available literature indicated that a meager work has been done on the population dynamics and management of major sucking pests of cluster bean under the hyper arid climatic conditions of Rajasthan. The present study was undertaken with the following objectives.

1. To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and their correlation with abiotic factors.
2. Screening of cluster bean varieties/genotypes against major sucking pests.
3. Bio-efficacy of various insecticides/botanicals against major sucking pests of cluster bean.

2. REVIEW OF LITERATURE

A perusal of the available literature revealed that a little work has been done on the **"Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]".** Therefore, the important and pertinent work done on other related crops has also been reviewed here:-

2.1 To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and their correlation with abiotic factors.

Faleiro *et al.* (1990) noted positive correlation (0.191 & 0.067) with maximum & minimum temperature and jassid, *E. kerri* on cowpea, whereas relative humidity (-0.062), wind speed (-0.007) and sunshine hrs. (-0.330) were found to be negatively correlated with leafhopper population. Rainfall and leafhopper population had a significant positive (0.421) association.

Pal and Dhuri (1991) studied the incidence of different species of insect pests at different crop stages of cowpea during October to November in Maharastra and found major pests as aphid, *Aphis craccivora* Koch; jassid, *Empoasca kerri* Pruthi with peak population in second week of November and *Bemisia tabaci* (Genn.) with peak population in fourth week of October.

Sahoo and Patnaik (1994) recorded *Madurasia obscurella* Jacoby, *Luperodes sp., A. craccivora* Koch, *B. tabaci* Genn., *Megalurothrips distalis, Caliothrips indicus, Cydia ptychora* Meyr. (*Leguminivora ptychora*), *Maruca testulalis* Geyer (*M. vitrata*) and *Helicoverpa armigera* Hub. on green gram.

Devesthali and Saran (1998) studied reaction of 20 green gram cultivars to insect pests in Malwa region of Madhya Pradesh, India and observed eight species of insect pests infesting the crop. There were three major pests, *viz.,* pea thrips (*C. indicus*), bean aphid (*A. craccivora*) and jassid (*Amrasca kerri*); three minor, *viz.,* green semilooper (*Plusia signata,* blue beetle (*Raphidopalpa intermedia,* Jacoby) and mung bug (*Chauliops fallax* Scott) and two negligible pests, green hopper and cotton grey weevil (*Myllocerus maculosus* Desbr.). Six pests, *viz.,* thrips, blue beetle, bean aphid, green jassid, green semilooper and mung bug appeared simultaneously at the early stage of the plant growth (crop age 13 days) followed by paddy grasshopper in the fourth week of August (crop age 34 days). Cotton grey weevil appeared in the last week of August (crop age 41 days). Most of the pests reached peak in the fourth and fifth week of August when the average weekly maximum and minimum temperatures and relative humidity were around 28^0C, 23^0C and 89.5 per cent, respectively.

Patel (2000) observed that the population of leafhopper (*E. kerri*) had significant positive correlation with bright sunshine hours, temperature (maximum and mean) and vapour pressure deficit (morning, evening and mean), whereas relative humidity and wind speed was found to be significantly negatively correlated with leafhopper population in cowpea.

Dar *et al.* (2002) studied insect pests of summer crop of mung bean (*Vigna radiata*) and urd bean (*V. mungo*) in Aligarh district, Uttar Pradesh and recorded 31 species of insect pests, of which 20 were of regular and 11 were sporadic in appearance. The crops were mainly infested by *B. tabaci, E. kerri, A. craccivora, Ophiomyia, Nezara viridula* Linnaeus and *Phytomyza horticola (*Goureau*) (Chromatomyia horticola). B. tabaci,* the most important among these pests was observed from the 16^{th} to 26^{th} week (from vegetative to pod formation stage) on mung bean and from 16^{th} to 25^{th} week on urd bean. Its population peaked at the 25^{th} and 26^{th} weeks on urd bean and mung bean, respectively. However, *B. tabaci* showed preference for both hosts, whereas, the bugs showed greater preference for mung bean. The pooled population of bugs peaked on the 21^{st} week (46 and 18 insects/ plant on mung bean and urd bean, respectively).

Das *et al.* (2003) studied the seasonal activity of *A. biguttula biguttula* in cotton and observed that, the incidence of leafhopper commenced from 26^{th} standard week and reached peak intensity (69.6/ 25 leaves during 30^{th} standard week i. e., last week of July. Correlation studies revealed that minimum temperature exhibited a significant positive correlation, whereas maximum temperature exhibited a significant negative correlation. Temperature of 30 ^{0}C was found to be most favourable.

Kumar *et. al.* (2004) reported that the peak population of whitefly on mung bean and urd bean was recorded in first fortnight of May and second fortnight of September in *Zaid* and *Kharif* crops, respectively. Temperature and sunshine hours were favourable for whitefly population as they had positive correlation.

Sharma and Rishi (2004) studied that the appearance of whitefly, *B. tabaci* population on cotton from the first week of June to end of September being high between mid August and end of September . Amongst the abiotic factor, relative humidity and sun sine hours were positively and significantly correlation with adult count of the whitefly, while maximum temperature rainfall and wind velocity were negatively and non-significantly associated.

Patel (2005) reported that among the pests, okra crop was invaded first by leafhopper while, aphid and shoot infestation by *E. vittella* formed the second group. The third group of pests *i.e.,* whitefly and green semilooper colonized okra crop 5 WAS. The fourth group consisting of thrips, mite and *O. versicolor* entered okra crop 8 WAS, whereas, *Helicoverpa* was the last to enter at later stage of crop growth forming fifth group. Based on occurrence and infestation, leafhopper, *E. vittella*, aphid, whitefly, thrips, mite and *Helicoverpa* were designated as major pests, while green semilooper and *O. versicolor* were designated as minor pests in okra crop.

Yadav and Kumawat (2008) reported that the infestation of jassids, *E., motti* and whitefly, *B. tabaci* started in the second week of August and reached at peak in first week of September on cluster bean. The maximum temperature showed significant negative correlation, the relative humidity revealed significant positive correlation with jassids and whitefly population.

Nitharwal and Kumawat (2009) reported that the major sucking pests of green gram. The infestation gradually reached at peak (12.40 jassids and 10.80 whitefly/three leaves during *Kharif* 2006 and 13.2 jassids and 11.20 whitefly/three leaves during *Kharif* (2007) in the first week of September during year. A significant negative correlation of jassids and whitefly with maximum temperature (r=-0.61 and -0.56 in 2006 -0.78 and -0.52 in 2007, respectively) and a positive significant correlation of jassids and whitefly with relative humidity (r=0.62 and 0.63 in 2006 and 0.70 and 0.56 in 2007) was observed.

Meena *et al.* (2010) reported that incidence of jassids (2.0 and 2.4 jassids/plant) started in first week of August and was being active till harvesting in both the years, its population reached at maximum (15.2 and 16.4 jassids/plant) in fourth and third week of September in the year 2002 and 2003, respectively, and found a non significant correlation between maximum and minimum temperature, relative humidity and rainfall and jassid population on okra crop.

Sarangdevot *et al.* (2010) noted that the mean temperature and relative humidity during the peaks were 24.1^0C and 24.82^0C, 38.5 and 47.5 per cent in 2000-01 and 2001-02, respectively. They concluded that the whitefly population was positively correlated with mean temperature, negatively correlated with mean relative humidity during both the seasons.

Patel *et al.* (2010) determine the population dynamics of insect pests of cowpeas in relation to different environmental factors. Incidence of all the major insect pests was recorded at weekly intervals starting from 15 days after germination and continued till harvest. The *A. craccivora, E. kerri* and *B. tabaci,* populations were recorded. The effects of temperature, relative humidity, sunshine hours, wind speed and vapour pressure on the pest populations were also determined. Results showed that none of the parameters had a significant effect on the occurrence of leafhoppers, whiteflies, thrips and leaf miners, while temperature and sunshine hours exhibited significant negative effects on aphid incidence.

Pachundkar (2011) observed that leafhopper appeared first on clusterbean crop, whereas whitefly was noted as second group. Later, thrips colonized the clusterbean crop on 36^{th} standard week (2^{nd} week of September). Based on occurrence and infestation, leafhopper and whitefly were designated major pests, while thrips was designated as minor pest.

2.2 Screening of cluster bean varieties/genotypes against major sucking pests.

Singh *et al.* (1996) screened 60 genotypes of clusterbean against whitefly, *B. tabaci* and found five genotypes, CH 14-2, HG 75, HG 94, HG 258 and HGS 365 with lowest nymphal population and appeared to be least preferred to whitefly, while genotypes, RGC 1001 was observed to have highest nymphal population followed by GAUG 9005 and GAUG 9010.

Singh (2002a) screened 15 normal maturing and 9 early maturing cultivars of cluster bean for resistance against whitefly, *Acaudaleyrodes rechipora* in Jodhpur, Rajasthan during *rainy* season of 1999. It was higher (5- 5o %) in the normal maturity cultivar, (0-35%) in early maturity cultivar of cluster bean. The early maturity cultivar, RGC 1017 had less than 10 per pest incidence. In the normal maturity group, the promising cultivar, CZ 9820, showed no incidence of whitefly; however, RGC 1020, RGC 1023, RGM 111 and RGM 112 were also promising, recording less than 10 per cent pest incidence.

Singh (2003) studied the incidence and damage incurred by black weevil, *Cyrtozemia cognata* on cluster bean (15 normal and 10 early maturing cultivars) in Jodhpur, Rajasthan during the *rainy* season of 2001. Pest incidence did not significantly vary among the cluster bean cultivars. Among the early maturing cultivars, pest incidence ranged from 6.67 (RGM1-13) to 86.67 per cent (HGS--880, HGS-885, RGC-1025, HG-365 and RGC-936), whereas, damage varied from 33.33 (RGM-114) to 66.67 per cent (GAUG-012) on 8 August. On 24 August, pest incidence varied from 46.67 (HGS-880 and HG-365) to 80.00 per cent (CAZG-50, HGS-870 and RGM-114), whereas, damage ranged from 53.33 (HGS-885) to 80.00 per cent (GAUG-011 and GAUG-012). Among the normal maturing cultivars, pest incidence ranged from 60.00 (HGS-875 and RGC-1031) to 86.67 per cent (GAUG-014), whereas, the percentage of damaged plants varied from 26.67 (HGS-875, HGS-881, HGS-884 and RGC-1031) to 40.00 per cent (GAUG-014 and CAZG-90-2) on 8 August. On 24 August, *C. cognata* incidence ranged from 53.33 (CAZG-97), HG-75 and GG-1) to 73.33 per cent (GAUG-014 and

CAZG-90-2), whereas the extent of damage varied from 33.33 (HG-75) to 53.33 per cent (HGS-875, CAZG-97 and GG-1).

Verma and Henry (2003) screened fifteen normal maturity and 9 early maturity varieties of cluster bean, against the whiteflies, *Acaudaleyrodes rachipora* at CAZRI, Jodhpur. The incidence of the pest in clusterbean was more (5-50 %) in the early varieties than in normal maturity varieties (0-35 %). In the normal maturity group, CZ 9820 showed no incidence of whiteflies, whereas others showing promise (<10 % incidence) were RGC 1020, RGM 111 and RGM 112. The only promising cultivar in the early maturity group (showing <10% pest incidence) was RGC 1017.

Chaudhary*, et al.* (2007a) determine the performance of the promising guar genotypes RGC-1033 and RGC-1038. RGC-1033 and RGC-1038 have shown an increase of 23.04, 28.85, 27.15 and 9.60% and 21.98, 27.73, 26.05 and 8.65% seed yield over the controls RGC-986, HG-75, GG-1 and HGS-365, respectively. The performance of RGC-1033 and RGC-1038 showed an increase in seed yield by 42.55, 62.11 and 26.68 and 21.19, 31.77 and 23.82% over the controls RGC-986, GG-1 and HGS-365, respectively. The genotypes RGC-1033 and RGC-1038 showed tolerance against jassid population per leaf over the controls. RGC-1033 and RGC-1038 showed an increase in seed yield of 51.52 and 57.58% compared to the local cultivar during the 2005 and 2006 *kharif* season.

Chaudhary *et al.* (2007b) reported that RGC-1031 (Guar Kranti) a cluster bean cultivar shown an increase of 28.15 and 33.48% seed yield over the controls GG-1 and HG-75 during, *kharif* 1999; and 11.81 and 16.41% seed yield over the controls RGC-986 and GG-1 during *kharif* 2000. In the State Multilocational trials during *kharif* 2004 and 2005, Guar Kranti has shown an increase of 9.49, 7.09, 16.37, 18.12 and 6.35% seed yield over the controls RGC-936, RGC-1003, RGC-986, RGC-197 and RGC-1002, respectively. RGC-1031 was found promising in the coordinated varietal trials conducted during *kharif* 2001 by a margin of 6.20 and 9.18% over the controls GG-1 and HG-75, respectively. It has been promising in seed yield by a margin of 4.74 and 11.18% over the controls RGC-986 and GG-1 in the coordinated trials conducted during *kharif* 2002 at the national level, respectively. This cultivar has a high degree of tolerance to major insect pests in comparison to RGC-986, HG-75 and GG-1.

Yadav and Kumawat (2008) evaluated fifteen genotype of cluster bean against jassid and whitefly. The genotype, RGC-197, RGC-1031, RGC-1017, RGC-1055 were found least susceptible to jassid; genotypes, RGC-1077, RGC-1066 and RGC-1078 moderately susceptible and genotypes RGC-1038, RGC-1003, RGC-1002, and RGC-936 were highly susceptible. The genotypes, RGC-1017, HGS-365, RGC-986, RGC-197, RGC-1031 and RGC-1076 were least susceptible to whitefly; genotypes, RGC-1017, RGC-986, RGC-197, RGC-1031 and RGC-1076 were moderately susceptible; genotypes RGC-1038, RGC-1003, RGC-1002, RGC-1078, and RGC-936 were highly susceptible to whitefly.

Patel *et al.* (2009) evaluated fourteen genotypes of clusterbean against whitefly. The results revealed that whitefly population differed among all the varieties from 3.63 (GAUG-0308) to 5.00 (GAUG-0524) per leaf. Significantly minimum whitefly population was recorded in the genotype GAUG-0308(3.63/ leaf) and it was at par with that of GAUG-0013 (3.86 /leaf) and GAUG-0004 (3.88 /leaf). Variety GG-2 gave highest yield of clusterbean (454 kg/ ha).

Panwar and Patel (2011) tested 20 varieties/genotypes for their susceptibility /resistance, variety GG 2 showed the multiple resistances against leafhopper, whitefly and thrips. Similarly, the genotype GAUG 826 exhibited the multiple resistances against leafhopper and whitefly, while GRG 1007 was resistant against leafhopper and thrips. Among rest of the genotypes, HG 75 was resistant against leafhopper; GRG 1012, GRG 1014 and GRG 1010 were resistant against whitefly and GRG 1023 was resistant against thrips.

2.3 Bio-efficacy of various insecticides/botanicals against major sucking pests of cluster bean.

Horowitz *et al*. (1998) reported that the imidacloprid @ 25 ml a.i./ha at 2, 7 and 14 days after application resulting in adult mortality of 90, 93 and 96 per cent and 76, 84 and 76 per cent for acetamiprid, respectively. Foliar application of 210 g a.i./ha imidacloprid and 60 g a.i./ha acetamiprid were found effective against whitefly population up to ten days of application.

Sonalkar (1999) evaluated the efficacy of acetamiprid at four doses against the whitefly, *Bemisia tabaci* (Genn.) on okra, *Abelmoschus esculentus* (L.) Monench in a farm trial at Akola, Maharashtra. Among the doses, acetamiprid at 20 g a.i./ha reduced the pest population significantly (94.42%). However, at 15 g a.i./ha, the mortality was only 54.34% at par with acephate (52.69%) and oxy demeton methyl (50.82%).

Afzal *et al.* (2002) evaluated efficacy of four insecticides, *viz*., Imicon 25 WP (imidacloprid) at 200 g acre^{-1}, Pride 25 WP (buprofezin) at 600 g acre^{-1}, Digital 20 EC (fenpropathrin) at 250 ml acre^{-1}, and Taophos 25 EC (quinalphos) at 250 ml acre^{-1} in Faisalabad, Pakistan, against whitefly, *B. tabaci* and black thrips, *C. indicus* on mung bean cultivar, NM-92 and reported these insecticides to be effective against whitefly, however, some of them were effective against black thrips. A spray of Imicon 25 WP at 200 g acre^{-1} was found to be most effective both against whitefly and black thrips.

Chiranjeevi *et al.* (2002) evaluated some insecticides (imidacloprid, lambda cyhalothrin, monocrotophos and cypermethrin) against chilli sucking pests. Foliar spray by imidacloprid 17.8 SL was most effective to control the pests followed by lambda-cyhalothrin, monocrotophos and cypermethrin.

Misra (2002) evaluated the bio-efficacy of some newer insecticides, *viz*. thiamethoxam (Actara 25 WG), imidacloprid (Confider 200 SL) and profenophos + cypermethrin (Rocket 44 EC) in field along with conventional insecticides, *viz*. dimethoate (Rogor 30 EC), cypermethrin (Superkiller 10 EC), profenophos (Curacron 50 EC) and a plant product, azadirachtin (Neemarin 1500 ppm) against okra aphid and jassid and reported imidacloprid and thiamethoxam @ 25 ml a.i. ha^{-1} as significantly superior followed by dimethoate @ 300 ml a.i. ha^{-1} and cypermethrin @ 100 ml a.i ha^{-1}.

Noor (2002) studied the efficacy of chemical and plant based insecticides against insect pests of cluster bean and found spray of monocrotophos 0.04 per cent, endosulfan 0.03 per cent mixed with *neem* oil (neemark) @ 5ml l^{-1} water and carbosulfan seed treatment (20 g kg^{-1} seed) followed by dusting with methyl parathion @ 25 kg ha^{-1} most effective against jassid, whitefly and black weevil which resulted in higher grain yield and cost benefit ratio.

Singh (2002b) studied management approaches for major pests of cluster bean, namely, *A. craccivora*, *E. kerri, B. tabaci*, *H. armigera* and *M. testulalis* (*M. vitrata*). The approaches recommended were early sowing, use of tolerant cultivars and insecticides, such as endosulfan, malathion and dimethoate.

Subhadra Acharya *et al.* (2002) reported that acetamiprid @20 g.a.i/ ha and thiamethoxam and imidacloprid (both) @ 25 g. a.i./ ha proved effective against okra leafhopper followed by abamectin @ 20 g. a.i./ ha. Acetamiprid, thiamethxam and imidacloprid @ 20 and 25 g.a.i./ ha were the best insecticide in controlling okra leafhopper up to 3 weeks.

Prajapati *et al.* (2003) reported that monocrotophos @ 0.04% followed by neem seed kernel suspension (NSKS) @ 3% resulted in the highest leafhopper mortality (90.58%) at 48 hr and one week after application (97.47%). The treatments also hosted higher grain yield (1154 kg/ha) and cost : benefit ratio (1 : 12.20) on cowpea in Gujarat.

Singh (2003) suggested growing improved / tolerant varieties of cowpea (CS 88, HC 95-98) and clusterbean (HG 75, HG 94) and also spraying the crops with 0.03 per cent oxy demeton methyl or dimethoate gave good result against the pest.

Dodia *et al. (*2003) found monocrotophos 0.04 per cent was significantly superior in controlling jassid (*Empoasa flavascens)* and whitefly (*Acaudaleurodes citri)* in clusterbean 48 hrs after spray. Highest (703 kg/ha) seed yield was harvested from the plots treated with monocrotophos 0.04 per cent followed by phosphamidon 0.03 per cent (559 kg/ha).

Ganapathy and Karuppiah (2004) determined the efficacy of new insecticides against whitefly (*B. tabaci* in mung bean cultivar, CO-4. The treatments comprised of seed treatment with 5 g imidacloprid kg^{-1} seed, seed treatment with 5 g thiamethoxam kg^{-1} seed, 0.25 ml imidacloprid l^{-1} at 15 days after sowing (DAS), 0.2 g thiamethoxam l^{-1} at 15 DAS, 0.1 g acetamiprid l^{-1} at 15 DAS, 0.25 ml fipronil l^{-1} at 15 DAS, 2 ml dimethoate l^{-1} at 15 DAS, 0.5 ml cypermethrin l^{-1} at 15 DAS, 1 ml *Neem* oil l^{-1} at 15 DAS and water spray (control). The whitefly population was observed at 25, 35 and 50 DAS. The 0.2 g thiamethoxam l^{-1} at 15 DAS effectively decreased whitefly population and gave the highest yield (800 kg ha^{-1}).

Khattak *et al*. (2004) determined the efficacy of insecticides against whitefly, jassid and thrips on mungbean. The insecticides comprised of acetamiprid 20 SP, thiamethoxam 25 WG, diafenthiuron 500 EC, methamidophos 60 SL and imidacloprid 200 SL. All the insecticides reduced the mean per cent population of whiteflies even at 10 days after spraying. A similar trend of insecticidal efficacy was also observed against thrips except thiamethoxam, which was not effective at 10 days after spraying. However, against jassid, acetamiprid, diafenthiuron and imidacloprid at 5 and 10 days after spraying were completely ineffective.

Dhamania *et al.* (2005) Conducted experiment on bio-efficacy of insecticides against sucking pests of mothbean and found dimethoate 0.03% highly effective for the control of jassids and thrips followed by monocrotophos 0.036% while phosphamidon 0.03% was found highly effective against white fly followed by dimethoate 0.03%. The azadirachtin 5 ml lit-1 was found least effective for the control of jassids, white fly and thrips. The maximum yield was obtained in plots treated with dimethoate 0.03% (5.15 q ha^{-1}) while minimum yield was obtained from the plots treated with azadirachtin 0.03 EC (3.00 q ha^{-1}), which was at par with control (2.88 q ha^{-1})

Raghuraman and Gupta (2005) reported that the Acetamiprid 40 g a.i./ ha and imidacloprid 100 g. a. i. were the most effective treatments against *B. tabaci.* (48% and 45% increase in seed cotton yield over control, respectively). Result suggests that acetamiprid and imidacloprid are good substitute for conventional insecticides in vogue, which could use in formulating a successful management strategy for *B. tabaci.*

Gowdar *at al.* (2007) reported that the agrochemicals like acetamiprid, imidacloprid, triazophos and monocrotophos resulted significant reduction on YVMV incidence and mean whitefly population as compared to control treatment. Spray with the insecticides recorded higher C:B ratio by increase in fruit yield. Two sprays of acetamiprid 20 SP @ 40g a.i/ha. was effective in reducing the incidence of YVMV, whitefly population and simultaneously increased the yield of okra.

Patel *et al*. (2009) evaluated eight treatments for their efficacy on leafhopper and whitefly on cluster bean after 2, 4 days and one week after application. The treatment, imidacloprid 17.8 SL was significantly superior in reducing the leafhopper and whitefly population as compared to rest of insecticides. So far as yield is concerned, maximum yield was obtained in acephate 75 SP (315 kg/ ha) which was at par with that obtained from carbosulfan 25 EC.

Singh *et al*. (2010) evaluated the bio-efficacy of some insecticides and plant products against jassid, whitefly and thrips on mothbean crop revealed plant products against jassid, whitefly and thrips on mothbean crop revealed that dimethoate 30 EC (0.03%) proved to be the most effective followed by imidacloprid 17.8 SL (0.005%) and thiamethoxam 25 WG (0.025%). As far as efficacy against whitefly is concerned imidacloprid 17.8 SL (0.005%) was next to thiamethoxam 25 WG (0.025%) followed by profenophos+cypermethrin 44 EC (0.04%), lambda-cyhalothrin 5 EC (0.005%) and novaluron 10 EC (0.02%). However, the plant products, viz. azadirachtin (5 ml/l), neem seed kernel extract (5.0%) and karanj seed extract (5.0%) proved to be least effective.

Udikeri *et. al.* (2010) indicated that new formulations of imidacloprid (Confidor 350SC) @ 26.25 g ai/ha was superior in reducing the population of leafhopper from 3.09 to 0.83 per cent respectively, during 2003-04 and 2004-05 at three days after first application. Similarly, the population of thrips/leaf was reduced from 21.5 to 5.38 (2003-04) and 18.42 to 3.31 (2004-05). The reduction in the aphid population was 18.60 to 5.81 and 22.60 to 4.60 in respective years. Highest yield of 9.92 and 15.32 q/ha seed cotton was recorded with the application of new formulations of imidacloprid during both the years.

Panwar and Patel (2011) tested eleven treatments, imidacloprid 17.8 SL @ 0.005 per cent and acetamiprid 20 SP @ 0.004 per cent were found most effective against the leafhopper, while acetamiprid 20 SP @ 0.004 per cent, thiamethoxam 25 WG @ 0.0084 per cent and clothianidin 50 WDG @ 0.025 per cent showed higher efficacy against whitefly. Rest of the treatments were moderately effective. They recorded highest grain yield in the treatment of acetamiprid 20 SP @ 0.004 per cent (679.33 kg/ha) followed by clothianidin 50 WDG @ 0.025 per cent (574.67 kg/ha) and thiamethoxam 25 WG @ 0.0084 per cent (569.00 kg/ha).

Yadav *et. al.* (2011) conducted an experiment to determine the efficacy of various insecticides against sucking insect pests of cluster bean. Results showed that dimethoate, imidacloprid and thiamethoxam treatments were the most effective in reducing the jassid, *E. motti* and whitefly, *B. tabaci* populations. The highest seed yield was also found in the plots treated with dimethoate followed by imidacloprid and thiamethoxam.

Rohini *et al*. (2012) reported that the insecticides tested were superior to untreated check by recording lower population of sucking pests on cotton

Panwar and Patel (2011) reported that the avoidable losses due to insect pests varied from 7.26 to 56.96 per cent in different treatments in cluster bean crop. However, it was recorded lowest (7.26 per cent) in the treatment of clothanidin 50 WDG @ 0.025 per cent, while in dimethoate 30 EC @ 0.03 per cent, 56.96 per cent loss in grain yield was recorded. The highest per cent increase in yield over control was observed in plot treated with acetamiprid (159.16 %) followed by clothanidin (119.33%) and thiamethoxam (117.17 %)

The highest (1:97.58) return was obtained with the treatment of acetamiprid 20 SP @ 0.004 per cent followed by imidacloprid 17.8 SL @ 0.005 per cent (1:70.95) and acephate 75 SP @ 0.075 per cent (1: 66.89).

3. MATERIALS AND METHODS

Different field experiments to study the **“Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]”** were conducted at Research Farm, College of Agriculture, Bikaner, Rajasthan during *kharif* 2012. The details of experimental techniques and the methodology adopted on different aspects pertaining to treatments and the evaluation during the course of investigation are described in this chapter.

3.1 General details of the investigation

3.1.1 Experimental site and location

The present investigations were undertaken at Research Farm and Department of Entomology, College of Agriculture, Bikaner. It is located in North to Bikaner at 28.0^{o}N latitude and 73.22^{o}E longitude with an altitude of 234.70 meters above mean sea level. This region falls under agro climatic zone I C (Hyper arid partially irrigated western plain zone) of Rajasthan and agro climatic zone XIV (Western Dry Region) of India.

3.1.2 Climatic and weather conditions of the location

The climate of this region is typically arid characterized with low rainfall and wide range of temperature in summer and winter. The relative humidity varies between 10 to 85 per cent. The mean weekly weather parameters for crop duration were recorded at the meteorological observatory, Agriculture Research Station Beechwal, Bikaner.

Plate No. 1 General view of the experimental field

Jassid, *Empoasca motti*

Whitefly, *Bemesia tabaci*

Plate No. 2 Sucking pests of cluster bean

3.1.3 Preparation of land and manuring

The experimental plot was ploughed twice with a *Desi* plough and leveled with a heavy wooden plank (*Patta*). Fertilizers were applied @ 10 kg Nitrogen per hectare as a starter dose and 40 kg P_2O_5 per hectare in the soil before sowing.

3.1.4 Seed and method of sowing

The seed was used @ 20 kg ha^{-1} and before sowing it was treated with streptocyclin 100 ppm and bacterial culture *Rhizobium*. The seeds were sown in the already laid out simple randomized block design in the furrows opened with a manually operated hand driven plough at a row to row and plant to plant spacing of 30 and 10 cm, respectively.

3.1.5 Irrigation schedule and cultural practices

In total, four irrigations were applied at the interval of 20 days. First irrigation was applied just after sowing. Thinning was done 22 days after sowing to maintain the plant distance of 10 cm. The other recommended agronomical practices (weeding, hoeing etc.) were followed as per package of practices of the zone.

3.1.6 Harvesting

The crop was harvested when grains were fully matured. Harvested plants were sun dried and kept separately plot wise. The dried plants were manually threshed and the grains were separated cleaned & weighed plot wise.

3.1.7 Method of observation

The observations on absolute population of jassid and whitefly were recorded soon after their appearance. All the observations were recorded early in the morning. The methods used for recording the population of major insect pests, *viz*., jassid, *Empoasca motti* Pruthi and whitefly, *Bemisia tabaci* Genn. have been described below:

Jassid, *Empoasca motti* Pruthi

The population of jassid was recorded on each five randomly selected and tagged plants in each plot. Three leaves, *viz*., one each from top, middle and lower canopy of the plant were taken into account for recording the population. The population was recorded in the early morning hours.

Whitefly, *Bemesia tabaci* Genn.

The population of whitefly was recorded by counting the nymphs and adults on five randomly selected plants permanently tagged in each plot. Three leaves, *viz.*, one each from top, middle and lower canopy of plant were taken into account to record the population.

3.1.8 Meteorological data

Data on weather parameters *viz.,* atmospheric temperature, relative humidity and rainfall were obtained from the meteorological section of Agricultural Research Station, Beechwal, Bikaner. The meteorological data have been presented in table 3.1 and fig 3.1

3.1.9 Interpretation of data

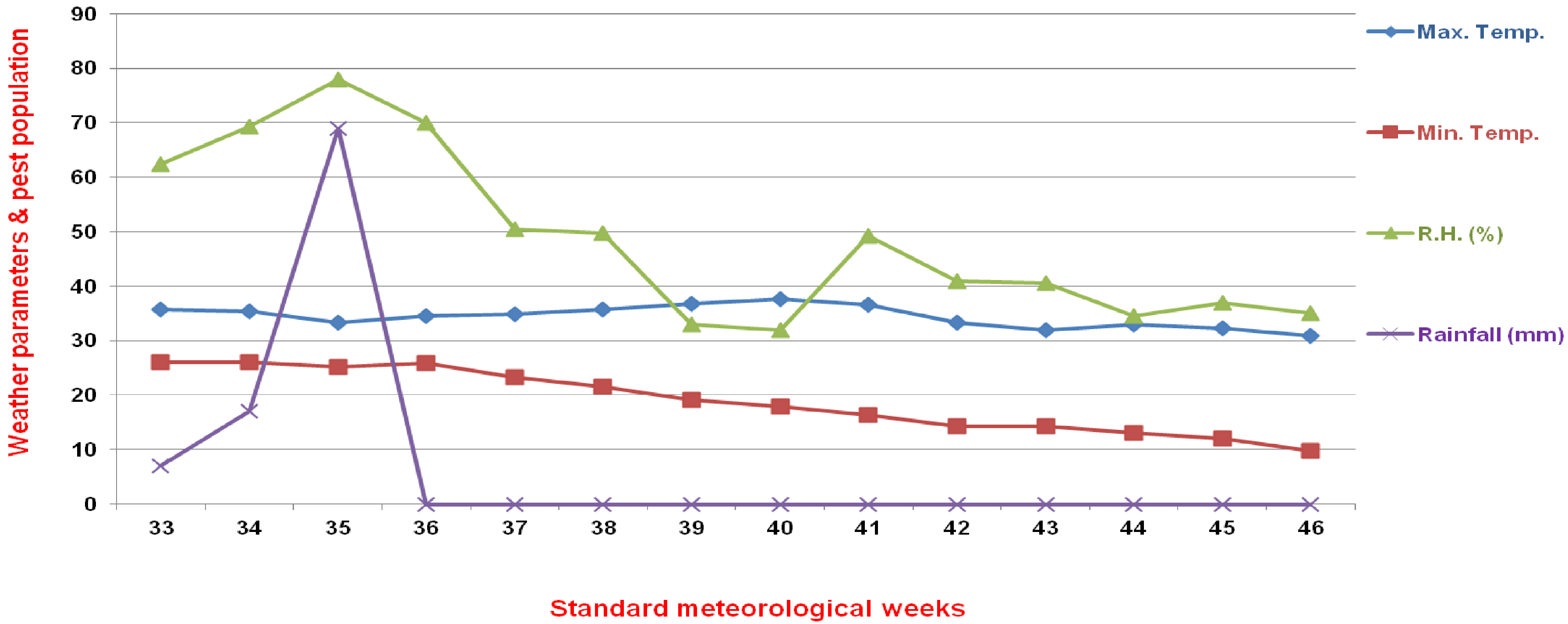
The data on jassid and whitefly population recorded from experimental plots were subjected to analysis of variance (Gomez and Gomez, 1976). The materials and methodologies used for individual experiment have been described below:

Table 3.1 Weekly mean meteorological observations recorded during *Kharif*, 2012.

SMW * No.	Period		Temperature (^0C)		Relative Humidity (%)	Rainfall (mm)
	From	To	Max.	Min.		
34	23.08.2012	29.08.2012	35.7	25.97	62.43	7
35	30.08.2012	05.09.2012	35.3	26.02	69.29	17
36	06.09.2012	12.09.2012	33.3	25.12	78.00	69
37	13.09.2012	19.09.2012	34.5	25.84	69.93	0
38	20.09.2012	26.09.2012	34.9	23.31	50.35	0
39	27.09.2012	02.10.2012	35.8	21.54	49.78	0
40	03.10.2012	09.10.2012	37.6	19.18	32.93	0
41	10.10.2012	16.10.2012	36.6	17.92	32.00	0
42	17.10.2012	23.10.2012	33.3	16.34	49.14	0
43	24.10.2012	30.10.2012	31.9	14.33	40.86	0
44	01.11.2012	07.11.2012	32.9	11.13	40.50	0
45	08.11.2012	14.11.2012	32.3	12.03	34.43	0
46	15.11.2012	22.11.2012	30.9	9.8	36.97	0

* Standard meteorological weeks.

Fig. 3.1 Weekly mean meteorological observation recorded during *kharif*, 2012.



3.2 Specific details of the experiments

3.2.1 Population dynamics of major sucking pests of cluster bean

3.2.1.1 Layout and design

To monitor the insect pests on cluster bean, variety RGC-1003 was shown on 3rd August 2012 in the plot of 10.0 x 10.0 m^2, keeping row to row and plant to plant distance of 30 and 10 cm, respectively.

3.2.1.2 Observations

For recording the observations, the crop was left for having the natural infestation. The observations on insect pest population were recorded from twenty five tagged plants at weekly interval from the appearance of insect pests till harvesting of the crop as mentioned vide supra 3.1.7.

3.2.1.3 Interpretation of data

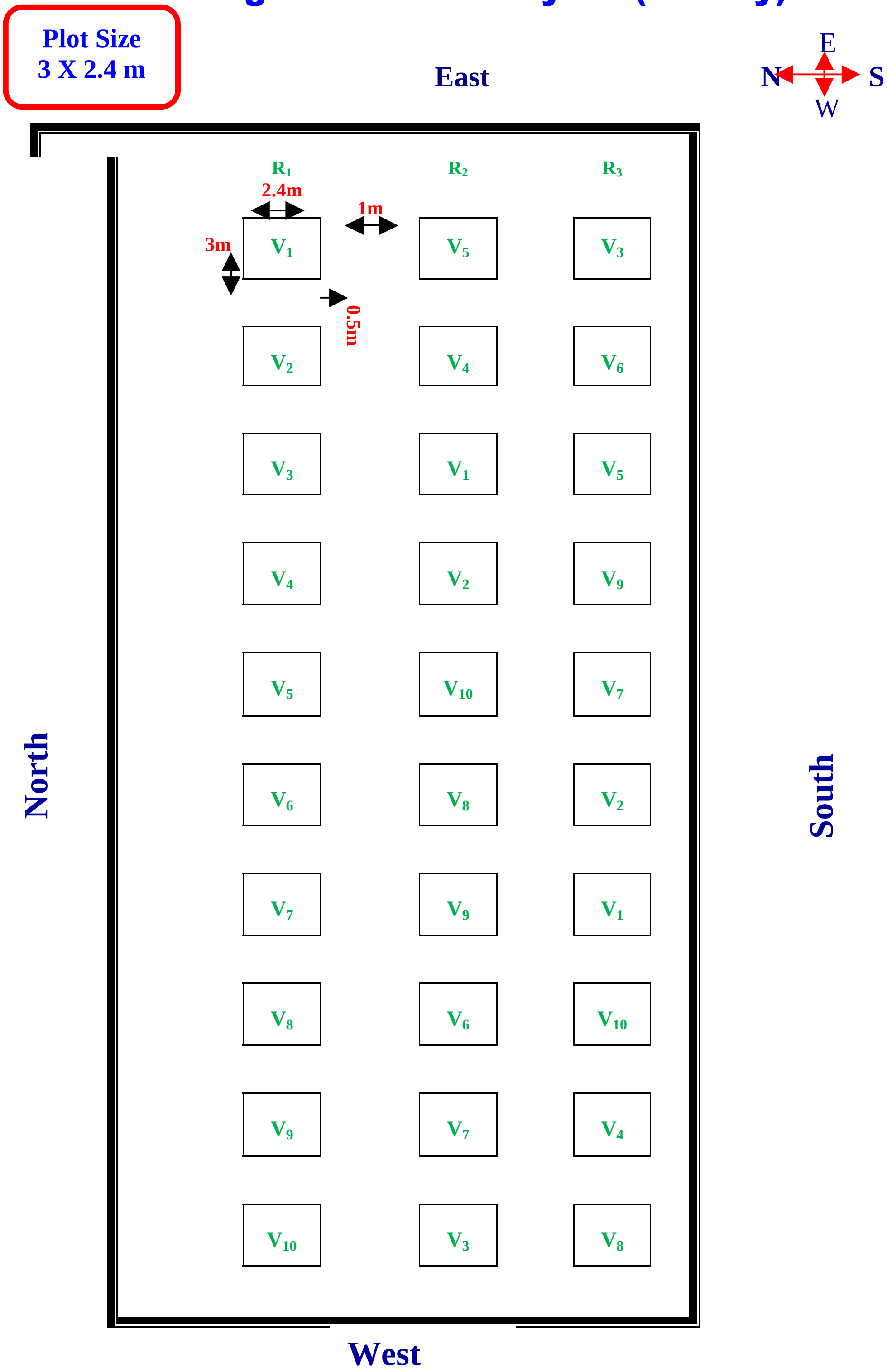
To interpret the results of population dynamics of major sucking insect pests on cluster bean, simple correlation was computed between pest population and abiotic factors, *i.e,.* the minimum and maximum temperature, relative humidity and rainfall.

3.2.2 Screening of cluster bean varieties against major sucking pests.

3.2.2.1 Layout and design

The experiment was laid out in simple randomized block design with three replications. The plot size kept was 3.0 x 2.4 m^2 with row to row and plant to plant distance of 30 and 10 cm, respectively. The crop was sown on 3rd August 2012.

Fig. 3.2 Plan of Layout (variety)



Name of variety					Design	RBD
V_1	RGC-986		V_6	RGC-1002		Replication	3
V_2	RGC-1017		V_7	RGC-1033			
V_3	RGC-1066		V_8	RGC-1003		Plot size	3 x 2.4 m^2
V_4	RGC-1055		V_9	RGC-197		Number of plots	30
V_5	RGC-1031		V_{10}	RGC-471			

3.2.2.2 Treatments

The cluster bean genotypes screened against insect pests were considered as treatments and there were ten such treatments. The genotypes screened and their source of supply has been presented in table 3.2.

Table 3.2 Details of Varieties of cluster bean and their source of supply -

S. No.	Varieties	Source of supply
1.	RGC-197	Rajasthan Agricultural Research Institute, Durgapura, Jaipur, (SKRAU, Bikaner)
2.	RGC-1017	”
3.	RGC-1031	”
4.	RGC-471	”
5.	RGC-1055	”
6.	RGC-1033	”
7.	RGC-1066	”
8.	RGC-986	”
9.	RGC-1003	Agriculture Research Station, Beechwal, Bikaner (SKRAU, Bikaner)
10.	RGC- 1002	”

3.2.2.3 Observations

The genotypes were allowed to have natural infestation. Weekly observations on population of jassid and whitefly were recorded soon after their appearance till harvesting of the crop. The method used for recording the population of major insect pests was same as mentioned vide supra 3.1.7

3.2.2.4 Interpretation of data

The data obtained on jassid and whitefly population recorded from the experimental field were transformed into $\sqrt{X + 0.5}$ (Gomez and Gomez, 1976) and subjected to analysis of variance. The peak population of jassid and whitefly on cluster bean genotypes recorded during the crop season was categorized on the basis of formula X $\pm$ σ (Yadav and Kumawat, 2008).

Where,
$\overline{X}$ = Mean of peak population, and
σ = Standard deviation

3.2.3 Bio-efficacy of various insecticides and botanicals against major sucking pests of cluster bean.

3.2.3.1 Layout and design

The experiment was laid out in simple randomized block design with ten treatments each replicated thrice. The seeds of cluster bean (variety, RGC-1003) were sown in the field on 3rd August in *Kharif,* 2012 in the plots measuring 3.0 x 2.4 m^2 keeping 30 and 10 cm row to row and plant to plant distance, respectively.

3.2.3.2 Application of Insecticides and botanicals.

The insecticides were applied when sufficient population of jassid and whitefly built up on the plants. The first spray was given on 15th September by using a foot sprayer and second application was made three weeks after first application. The re-build up of population was observed at this stage. The spray solution used for spraying the crop was 600 L ha^{-1}.

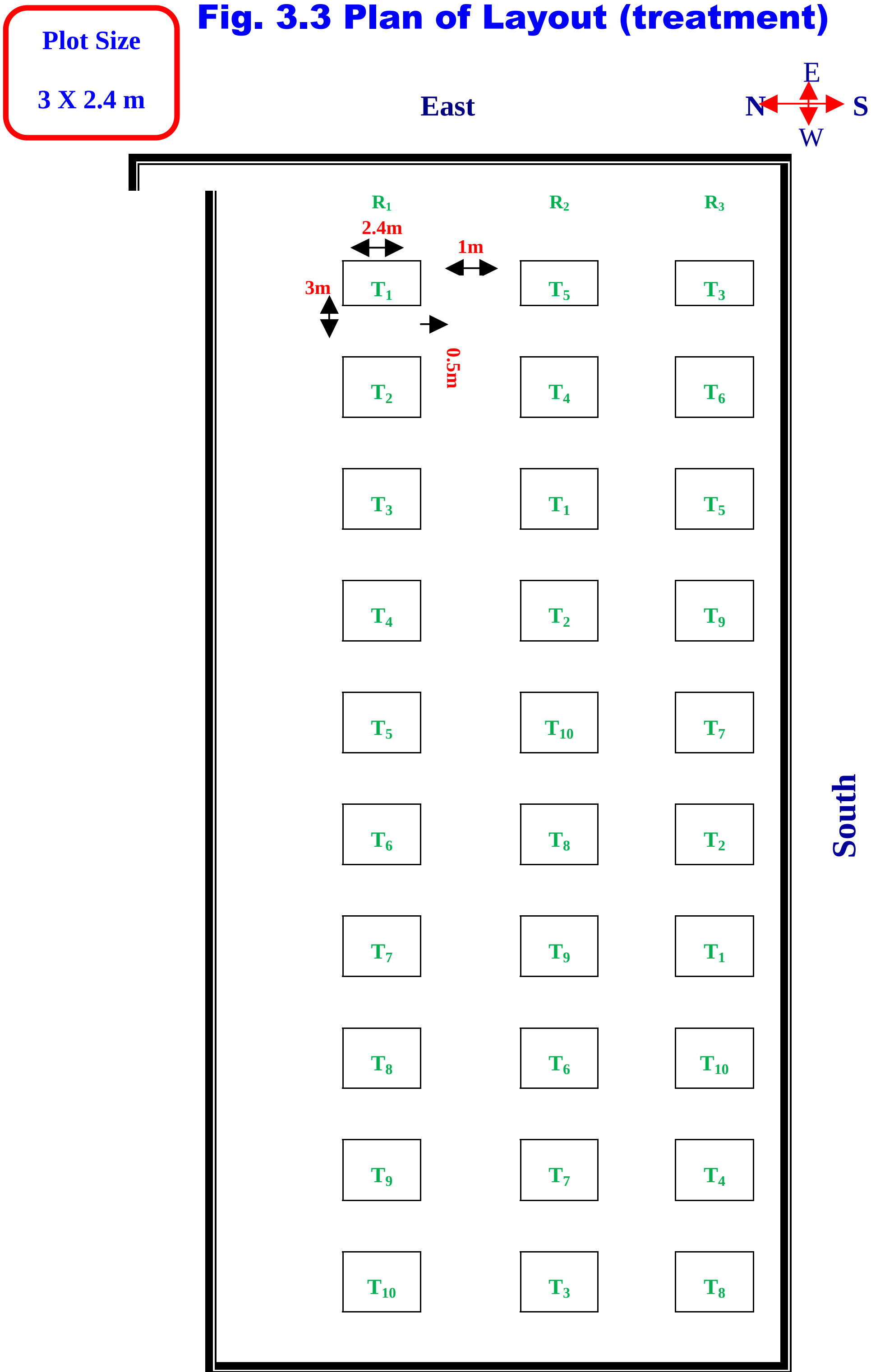
Table 3.4 Details of insecticides/botanicals used:-

S.No.	Insecticides / botanicals	Trade name	Formulations	Conc. (%)/ Dose
1	Imidacloprid	Confidor	17.8 SL	0.00
2	Thiamethoxam	Actara	25 WG	0.005
3	Acetamiprid	Pride	20 SP	0.004
4	Dimethoate	Rogor	30 EC	0.03
5	Profenophos	Tracer	50 EC	0.05
6	Acephate	Orthene	75 SP	0.05
7	Fipronil	Regent	5 SC	0.01
8	Azadirachatin	Azacel	0.03 EC	5 ml/l
9	NSKE	Lab Preparation	-	5
10	Control	-	-	

3.2.3.3 Observations

The observations on the jassid and whitefly populations were recorded as mentioned vide supra 3.1.7 one day before application (pre-treatment population) and one, three, seven and 10 days after application (post-treatment population) of insecticides. The second spray was done after rebuild up of pest population and again the observations were recorded at one day before and one, three, seven and 10 days after the application of treatments. The yield data were recorded after harvest of the crop and was computed per hectare.

Fig. 3.3 Plan of Layout (treatment)



Name of treatment						Design	RBD
T_1	Imidacloprid		T_6	Acephate		Replication	3
T_2	Thiamethoxam		T_7	Fipronil			
T_3	Acetamiprid		T_8	Azadirachtin		Plot size	3 x 2.4 m^2
T_4	Dimethoate		T_9	NSKE		Number of plots	30
T_5	Profenophos		T_{10}	Control			

3.2.4.4 Interpretation of data

The data obtained one day before and 1, 3, 7 and 10 days after spray were taken into consideration to calculate the reduction in the population which was done by applying a correction factor given by Henderson and Tilton (1955) referring it to be a modification of Abbott's formula (1925).

$$\text{Percentage reduction} = 100\left[1 - \frac{T_a \times C_b}{T_b \times C_a}\right]$$

Where,

Ta = Number of insects after treatment

Tb = Number of insects before treatment

C_a = Number of insects in untreated control after treatment and

C_b = Number of insects in untreated control before treatment

The statistical analysis (analysis of variance) of the data was carried out by transforming the percentage reduction data into angular transformation values (Gomez and Gomez, 1976). The avoidable loss and increase in yield of seed over control was calculated for each treatment by the following formula (Pradhan, 1964):

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot - Yield in the treatment}}{\text{Highest yield in treated plot}} X\,100$$

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treatment - Yield in control}}{\text{Yield in control}} X\,100$$

To determinate the most effective and economical treatment, the net profit and benefit cost ratio was worked out by taking the expenditure on individual insecticidal treatment and the corresponding yield into account.

The economics of various treatments was also worked out by computing the cost of insecticides as well as their cost of application. The gross income was worked out by multiplying the yield with the wholesale rate of cluster bean prevailing in the market at the time of threshing.

4. RESULTS

The results of studies undertaken during *Kharif* - 2012 on **"Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]"** are presented in following heads.

4.1 To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.)Taub.] and their correlation with abiotic factors.

4.1.1 Jassid, *Empoasca motti*

The population of major sucking pests of cluster bean, *Cyamopsis tetragonoloba* (Linn.) Taub. recorded during the monitoring has been presented in table 4.1 and fig. 4.1. The population of jassid appeared in the first week of September (33^{th} SMW) and increased up to the last week of September (36th SMW) and declined gradually till the crop was matured in last week of October. The population of jassid ranged from 0.96 to 12.72. The peak activity of jassid (12.72) was recorded in the 36th standard week, or last week of September.

The incidence of jassid started when maximum and minimum temperature was 33.2ºC and 24.92ºC however, relative humidity and rainfall were 74.36 per cent and 43 mm, respectively. The jassid population increased to its peak (12.72 jassid) at 33.3ºC maximum, 25.12ºC minimum, relative humidity 78 per cent and rainfall 69 mm. The data presented in table 4.2 showed the incidence of jassid resulted significant positive correlation (r=+0.56) at 5 per cent level and correlation (r=+0.36) at 1 per cent level with maximum and minimum temperature, respectively. The mean relative humidity had significant negative correlation (r=-0.48) at 1 per cent level and rainfall had significant positive correlation (r=+0.69) at 5 per cent level.

Table-4.1 Effect of abiotic factors on the population of jassid and whitefly of cluster bean.

*SMW	Date of observation	Mean jassid Population	Mean whitefly population	Meteorological parameters			
				Temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
				Maximum	Minimum		
33	03.09.2012	2.32	2.56	33.2	24.92	74.36	43
34	10.09.2012	6.00	6.60	35.7	25.97	62.43	7
35	17.09.2012	10.64	10.96	35.3	26.02	69.29	17
36	24.09.2012	12.72	13.16	33.3	25.12	78.00	69
37	01.10.2012	9.28	9.64	34.5	25.84	69.93	0
38	08.10.2012	4.68	4.88	34.9	23.31	50.35	0
39	15.10.2012	3.68	2.16	35.8	21.54	49.78	0
40	22.10.2012	0.96	0.80	37.6	19.18	32.93	0
Correlation coefficient with mean jassid population (r)				0.56	0.36	-0.48	0.69
Correlation coefficient with mean whitefly population (r)				0.57	0.43	-0.50	0.74

***SMW- Standard Meteorological Weeks.**

Fig 4.1 Effect of abiotic factors on the population of jassid and whitefly on cluster bean.

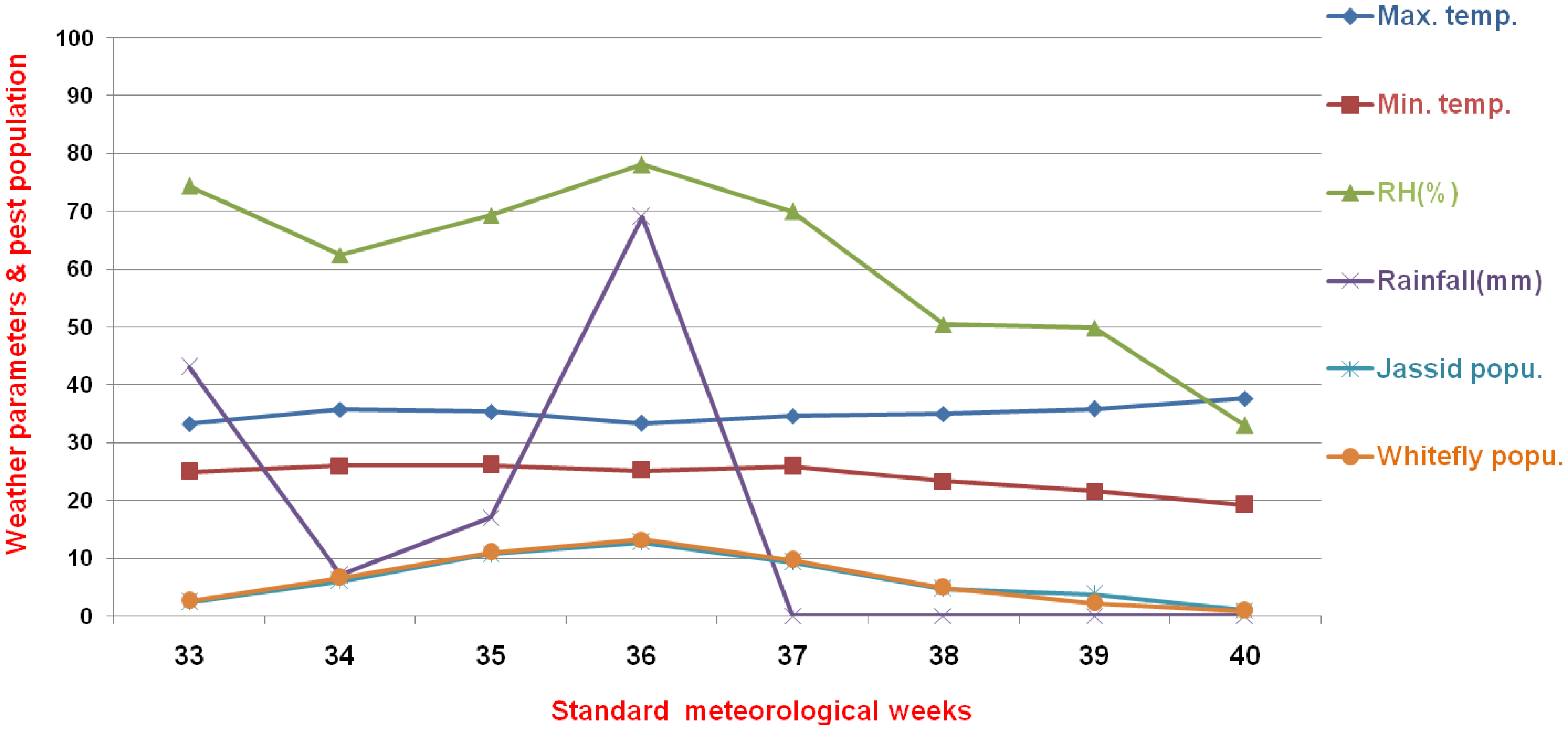


Table 4.2 Correlation co-efficient (r-value) between major sucking pests of cluster bean with abiotic factors.

Weather Parameters	Jassid	Whitefly
Maximum Temperature (°C)	+0.56*	+0.57*
Minimum Temperature (°C)	+0.36**	+0.43**
Relative Humidity (%)	-0.48**	-0.50**
Rainfall (mm)	+0.69*	+0.74*

*Significant at 5% level, **Significant at 1% level

4.1.1.2 Whitefly, *Bemesia tabaci*

The observations on *B. tabaci* population recorded during the *kharif*, 2012 (Table 4.1 and Fig. 4.1) showed that once the pest started activity on clusterbean was continued up to harvesting stage of the crop. The pest population (2.56 whitefly) commenced on 4 WAS coinciding with 1st week of September (33rd standard week). The whitefly activity gradually increased up to 8 WAS coinciding with 4st week of September (36th standard week) and reached a peak level (13.16 whitefly). The meteorological parameters like maximum and minimum temperature, relative humidity, and rainfall were recorded during the peak activity of pest as 33.3 ^{0}C, 25.12 ^{0}C, 78.00 per cent, and 69.0 mm, respectively (Table 1 and Fig. 1). The activity of this pest declined from 9 WAS coinciding with 1st week of October (37th standard week) and disappeared 12 WAS *i.e.* 4th week of October (40th standard week).

From the above results, it can be concluded that the *B.tabaci* remained active on cluster bean crop from 5 WAS to 10 WAS with a single peak during 8 WAS.

The maximum temperature showed significant positive correlation (r=+0.57) at 5 per cent level, the minimum temperature showed significant positive correlation (r=+0.43) at 1 per cent level and relative humidity revealed significantly negative correlation (r=-0.50) at 1 per cent level. The rainfall showed significantly positive correlation (r=+0.74) at 5 per cent level.

4.2 Screening of cluster bean varieties against major sucking pests.

Ten varieties of cluster bean were screened for relative susceptibility to jassids and whitefly during *Kharif,* 2012. The observation on jassid and whitefly population was recorded at weekly interval just after their appearance till disappearance of the pest. The data of comparative resistance are being presented below.

4.2.1 Jassid, *E. motti*

The data presented in table 4.3 and fig 4.2 revealed that none of the variety was found completely free from attack of jassid during the crop season. The infestation of jassid started 4 weeks after sowing in all the varieties screened. The mean data indicated that on initial stage of crop, jassid population ranged from 1.21 to 4.66. During this stage the minimum jassid was observed on variety RGC-197 (1.21 jassids) followed by RGC-1031 (1.91 jassids) which were found significantly superior over rest of the varieties. The maximum jassid population was observed on varieties RGC-1002 (4.66 jassid) followed by RGC-1003 (4.32 jassids) and RGC-1033 (4.27 jassids), however, these varieties were statically at par. The jassid population was 2.27, 2.31, 2.49, 2.89 and 3.46 on RGC-1017, RGC-986, RGC-1055, RGC-1066 and RGC-471, respectively, and all these varieties were statistically at par to each other.

The infestation of jassid increased gradually and reached to its peak in the last week of September (24^{th} September, 2012). At this stage the mean jassid population ranged from 8.34 to 13.86. The minimum jassid population were observed on varieties RGC-197 (8.34 jassids) followed by RGC-1031 (8.48 jassids) however, both varieties were statistically at par with each other. The maximum jassid population was observed on varieties RGC-1002 (13.86 jassids)

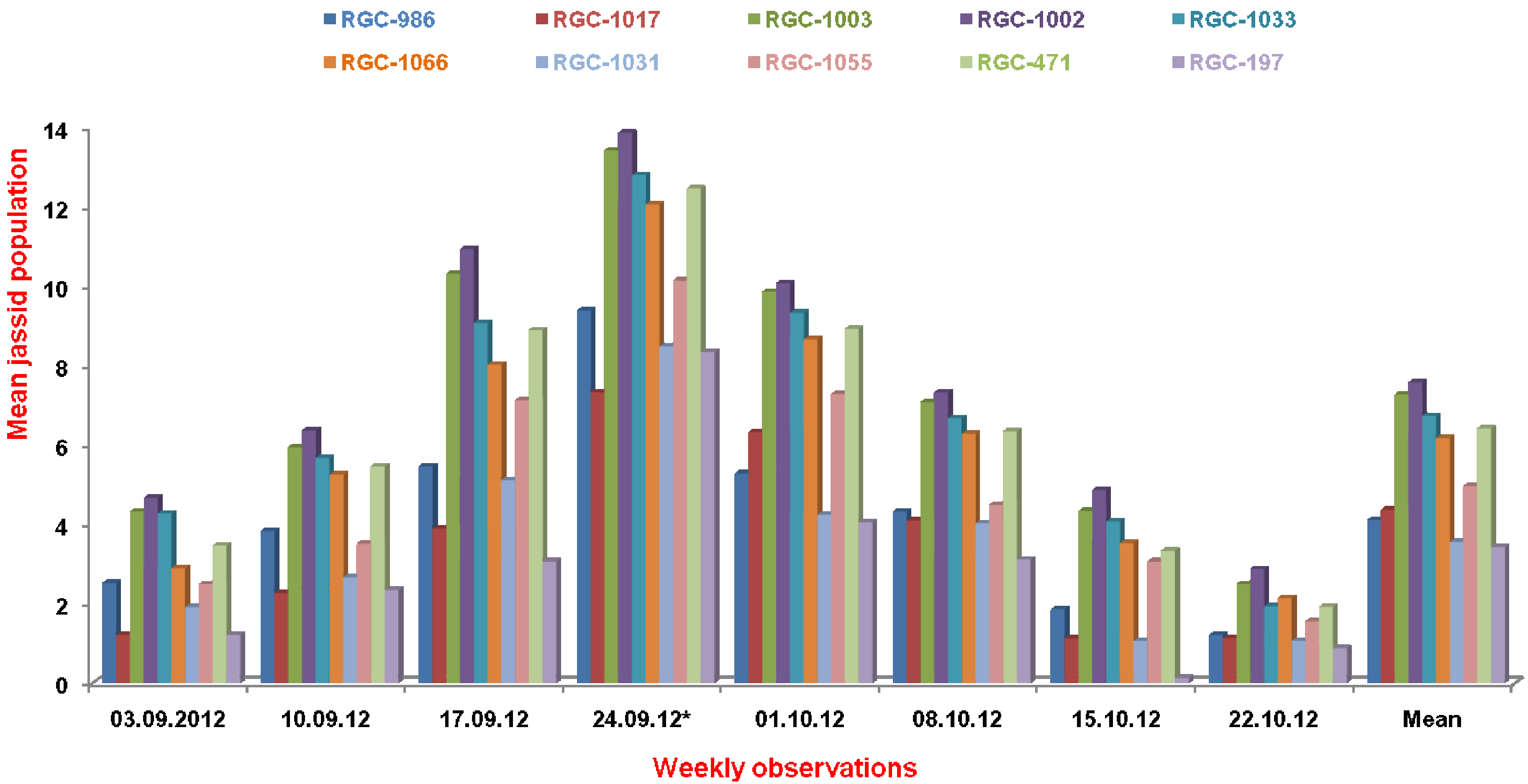
Table-4.3 Population of Jassid, *E. motti* Pruthi on different varieties of cluster bean.

S.No.	Varieties	Jassid population / plant								Mean
		03.09.2012	10.09.2012	17.09.2012	24.09.2012**	01.10.2012	08.10.2012	15.10.2012	22.10.2012	
1.	RGC-986	2.31 (1.68)*	3.86 (2.11)	6.02 (2.55)	9.88 (3.22)	6.31 (2.61)	4.23 (2.17)	1.86 (1.54)	1.21 (1.31)	4.33 (2.12)
2.	RGC-1017	2.27 (1.66)	3.08 (2.09)	6.31 (2.61)	9.58 (3.17)	6.32 (2.61)	4.09 (2.14)	1.12 (1.27)	1.13 (1.26)	4.36 (2.11)
3.	RGC-1003	4.32 (2.19)	5.94 (2.53)	10.31 (3.28)	13.42 (3.72)	9.86 (3.22)	7.07 (2.74)	4.33 (2.20)	2.49 (1.73)	7.27 (2.71)
4.	RGC-1002	4.66 (2.27)	6.36 (2.62)	10.93 (3.38)	13.86 (3.79)	10.07 (3.25)	7.32 (2.80)	4.86 (2.31)	2.87 (1.83)	7.57 (2.77)
5.	RGC-1033	4.27 (2.18)	5.67 (2.48)	9.07 (3.09)	12.80 (3.65)	9.33 (3.14)	6.67 (2.68)	4.07 (2.14)	1.93 (1.56)	6.73 (2.69)
6.	RGC-1066	2.89 (1.83)	5.25 (2.37)	8.02 (2.89)	12.06 (3.51)	8.66 (2.99)	6.28 (2.58)	3.52 (1.99)	2.14 (1.53)	6.17 (2.49)
7.	RGC- 1031	1.91 (1.55)	2.66 (1.78)	5.11 (2.37)	8.48 (2.68)	4.24 (2.18)	4.02 (2.13)	1.06 (1.25)	1.06 (1.25)	3.55 (1.93)
8.	RGC-1055	2.49 (1.70)	3.51 (2.14)	7.12 (2.88)	10.14 (3.17)	7.28 (2.72)	4.49 (2.18)	3.06 (1.85)	1.55 (1.41)	4.96 (2.21)
9.	RGC-471	3.46 (1.99)	5.46 (2.44)	8.89 (3.06)	12.46 (3.60)	8.92 (3.07)	6.34 (2.62)	3.83 (2.08)	1.92 (1.56)	6.41 (2.55)
10.	RGC-197	1.21 (1.31)	2.34 (1.68)	3.06 (1.92)	8.34 (2.97)	4.05 (2.13)	3.11 (1.90)	0.12 (0.95)	0.88 (1.03)	3.42 (1.88)
	S.Em +	0.11	0.14	0.19	0.23	0.18	0.15	0.11	0.09	0.15
	CD	0.32	0.40	0.55	0.58	0.54	0.35	0.33	0.27	0.44

* Figures in the parentheses are $\sqrt{x+0.5}$ values.

** Peak population of jassid during the crop season.

Fig.4.2 Population of jassid, *E. motti* Pruthi on different varieties/genotypes on cluster bean.



followed by RGC-1003 (12.80 jassids) and were found statistically at par with each other and significantly superior to rest of the varieties. The varieties *viz.,* RGC-1017 (9.58 jassids), RGC-986 (9.88 jassids), RGC-1055 (10.14 jassids), RGC-1066 (12.06 jassids) and RGC-471 (12.46 jassids) were statistically at par and ranked in middle order of infestation. After reaching peak, the population of jassid declined and persisted up to third week of October.

The mean jassid population at all the intervals (8 observations) ranged from 3.42 to 7.57. The minimum infestation was observed on varieties RGC-197 (3.42 jassids) followed by RGC-1031 (3.55 jassids) and were found statistically at par with each other. The maximum jassid population was observed on RGC-1002 (7.57 jassids) followed by RGC-1003 (7.27 jassids) and were statistically at par. Rest of varieties *viz.,* RGC-1017 (4.33 jassids), RGC-986 (4.27 jassids) and RGC-1055 (4.96 jassids) were ranked in middle order of infestation and were statistically at par to each other.

Based on peak jassid population and mean of all the observation taken during the crop season, the variability of susceptibility in cluster bean varieties order was RGC-197 < RGC-1031 < RGC-1017 < RGC-986 < RGC-1055 < RGC-1066 < RGC-471 < RGC-1033 < RGC-1003 < RGC-1002.

For the sake of convenience in expression, the cluster bean varieties were categorized on the basis of peak jassid population recorded on 24th September, 2012 using the formula:-

$$\bar{X} \pm \sigma$$

Where,

$\bar{X}$ = Mean of peak population

σ = Standard deviation

$\bar{X}$ = 10.75

σ = 2.24

So the categories were made as 10.75 $\pm$ 2.24

Mean jassid population	Categories
Below 8.51	Least susceptible
8.51 to 12.99	Moderately susceptible
Above 12.99	Highly susceptible

Taking the above criterion into consideration, the genotypes, RGC-197 and RGC-1031, were considered as least susceptible and RGC-986, RGC-1017, RGC-1055, RGC-1066 RGC-471 and RGC-1033 as moderately susceptible, whereas, RGC-1003 and RGC-1002 as highly susceptible against jassid.

4.2.2 Whitefly, *B. tabaci*

The perusal of data in table 4.4 and fig 4.3 revealed that none of the varieties was found free from the attack of whitefly. The infestation of whitefly started 4 weeks after sowing of cluster bean varieties. The data recorded on 3th September, 2012 revealed that the mean whitefly population ranged from 1.21 to 5.37. The minimum whitefly population was recorded on varieties RGC-1017 (1.21 whitefly) followed by RGC-1031 (2.00) and were statistically at par in their degree of infestation. The maximum whitefly population was recorded on varieties RGC-1002 (5.37 whitefly) followed by RGC-1003 (5.33 whitefly) and were found at par with each other. The varieties *viz*., RGC-197 (2.48 whitefly), RGC-986 (2.52 whitefly), RGC-1055 (2.79 whitefly), RGC-1066 (3.46 whitefly), RGC-1033 (3.47 whitefly) and RGC-471 (3.80 whitefly) were ranked in middle order of infestation.

The population of whitefly increased gradually and reached to its peak in the last week of September (24th September, 2012). The mean whitefly population ranged from 7.32 to 14.06. The minimum whitefly population was recorded on varieties RGC-1017 (7.32 whitefly) followed by RGC-1031 (8.68 whitefly) and these were statistically at par and significantly superior over rest of varieties with regard to their degree of infestation. The maximum whitefly population was recorded on varieties RGC-1002 (14.06 whitefly) followed by RGC-1003 (13.85 whitefly) and both were statistically at par and significantly inferior to rest of the

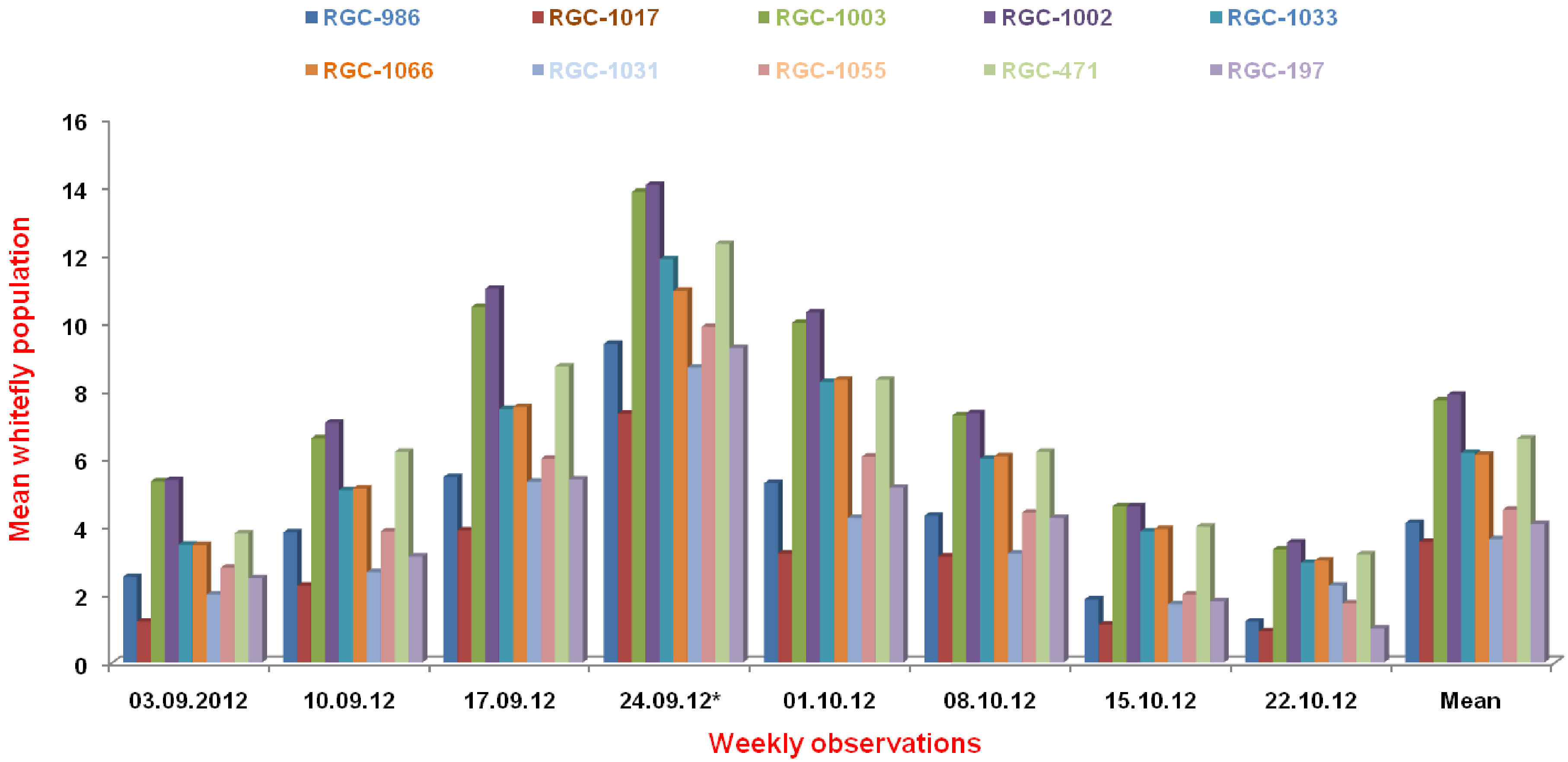
Table-4.4 Population of whitefly, *B. tabaci* Genn. on different varieties of cluster bean.

S.No.	Varieties	Population of white fly / plant								Mean
		03.09.2012	**10.09.12**	**17.09.12**	**24.09.12****	**01.10.12**	**08.10.12**	**15.10.12**	**22.10.12**	
1.	RGC-986	2.52 (1.74)*	3.83 (2.19)	5.46 (2.44)	9.38 (3.14)	5.28 (2.40)	4.32 (2.19)	1.86 (1.53)	1.21 (1.53)	4.11 (2.07)
2.	RGC-1017	1.21 (1.31)	2.26 (1.66)	3.89 (1.95)	7.32 (2.37)	3.21 (1.89)	3.12 (1.38)	1.12 (1.23)	0.92 (1.19)	3.55 (1.95)
3.	RGC-1003	5.33 (2.41)	6.60 (2.66)	10.46 (3.30)	13.85 (3.83)	10.00 (3.24)	7.27 (2.78)	4.60 (2.26)	3.33 (1.96)	7.71 (2.80)
4.	RGC-1002	5.37 (2.42)	7.06 (2.75)	11.00 (3.39)	14.06 (3.85)	10.31 (3.29)	7.34 (2.80)	4.60 (2.26)	3.53 (2.00)	7.88 (2.84)
5.	RGC-1033	3.47 (1.99)	5.07 (2.36)	7.46 (2.82)	11.87 (3.52)	8.26 (2.75)	6.00 (2.55)	3.86 (1.79)	2.93 (1.72)	6.17 (2.50)
6.	RGC-1066	3.46 (1.97)	5.12 (2.35)	7.52 (2.80)	10.94 (3.49)	8.32 (2.64)	6.07 (2.54)	3.93 (2.09)	3.00 (1.85)	6.12 (2.52)
7.	RGC-1031	2.00 (1.58)	2.66 (1.78)	5.32 (2.41)	8.68 (3.03)	4.26 (2.18)	3.21 (1.87)	1.72 (1.49)	2.26 (1.36)	3.65 (1.95)
8.	RGC-1055	2.79 (1.78)	3.86 (2.23)	6.00 (2.49)	9.88 (3.14)	6.06 (2.50)	4.41 (2.16)	2.00 (1.55)	1.74 (1.63)	4.50 (2.12)
9.	RGC-471	3.80 (2.07)	6.20 (2.59)	8.71 (3.03)	12.32 (3.58)	8.32 (2.87)	6.20 (2.59)	4.00 (2.12)	3.18 (1.92)	6.59 (2.61)
10.	RGC-197	2.48 (1.72)	3.12 (1.90)	5.39 (2.43)	9.26 (3.12)	5.14 (2.37)	4.26 (2.18)	1.80 (1.52)	1.00 (1.49)	4.08 (2.07)
	S.Em +	0.12	0.14	0.18	0.23	0.17	0.15	0.10	0.09	0.15
	CD	0.35	0.40	0.53	0.68	0.50	0.45	0.27	0.24	0.44

*Figures in the parentheses are $\sqrt{x+0.5}$ values.

**Peak population of whitefly during the crop season.

Fig. 4.3 Population of whitefly, *B. tabaci* Genn. on different/genotypes varieties of cluster bean.



varieties. The varieties *viz*., RGC-197 (9.26 whitefly), RGC-986 (9.38 whitefly), RGC-1055 (9.88 whitefly), RGC-1066 (10.94 whitefly), RGC-1033 (11.87 whitefly) and RGC-471 (12.32 whitefly) were statistically at par and ranked in middle order of infestation. After the peak period of infestation, the population of whitefly gradually declined and persisted up to first week of October.

The mean whitefly population at all the intervals (8 observations) ranged from 3.55 to 7.88. The minimum infestation was observed on varieties RGC-1017 (3.55 whitefly) followed by RGC-1031 (3.65 whitefly) and these were statistically at par. The maximum whitefly population was observed on varieties RGC-1002 (7.88 whitefly) followed by RGC-1003 (7.71 whitefly) and both were found statistically at par with each other. Rest of varieties *viz.,* RGC-197 (4.08 whitefly), RGC-986 (4.11 whitefly), RGC-1055 (4.50), RGC-1066 (6.12 whitefly), RGC-1033 (6.17 whitefly) and RGC-471 (6.59 whitefly) ranked in middle order of infestation.

Based on peak whitefly population and mean of all the observation taken during the crop season, the variability of susceptibility in cluster bean varieties order was RGC-1017 < RGC-1031 < RGC-197 < RGC-986 < RGC-1055 < RGC-1066 < RGC-1033 < RGC-471 < RGC-1003 < RGC-1002.

For the sake of convenience in expression, the cluster bean varieties were categorized on the basis of peak whitefly population recorded on 24th September, 2012 were categorized on the basis of formula:-

$$\bar{X} \pm \sigma$$

Where,

$\bar{X}$ = 11.10

σ = 2.05

So the categories were made as 11.10 $\pm$ 2.05

Mean whitefly population	Categories
Below 9.05	Least susceptible
9.05 to 13.15	Moderately susceptible
Above 13.15	Highly susceptible

Taking the above criterion into consideration, the varieties RGC-1017 and RGC-1031, were considered as least susceptible; RGC-986, RGC-197, RGC-1055, RGC-1066, RGC-471 and RGC-1033 as moderately susceptible and RGC-1003 and RGC-1002 as highly susceptible against whitefly.

Table 4.5 Categorization of different cluster bean varieties for their susceptibility to jassid and whitefly.

S. No.	Insects	Varieties	Category
	Jassid		
1.	Below 8.51	RGC-197, RGC-1031	Least susceptible
2.	8.51 to 12.99	RGC-986, RGC-1017, RGC-1055, RGC-1066, RGC-1033, RGC-471	Moderately susceptible
3.	Above 12.99	RGC-1003, RGC-1002	Highly susceptible
	Whitefly		
1.	Below 9.05	RGC-1017,RGC-1031,	Least susceptible
2.	9.05 to 13.15	RGC-986, RGC-197, RGC-1055 RGC-1066, RGC-471, RGC-1033	Moderately susceptible
3.	Above 13.15	RGC-1003, RGC-1002	Highly susceptible

4.3 Bio-efficacy of various insecticides/botanicals against major sucking pests of cluster bean.

The bio-efficacy of different treatments was determined on the basis of per cent reduction of jassid population and effect on seed yield.

4.3.1 First spray

4.3.1.1 Jassid*, E. motti*

One day after application of insecticides, it was observed that all the treatments were significantly superior over control (Table-4.6 and Fig. 4.4). The maximum jassid reduction of 78.63 per cent was recorded in the treatment of imidacloprid (0.005%) followed by acetamiprid (0.004%) and thiamethoxam (0.005%) which resulted in 75.75 and 70.81 per cent reduction, respectively, however, these treatment were at par with each other. The next effective treatments were fipronil (0.01%), acephate (0.05%), dimethoate (0.03%), and profenophos (0.05%) which resulted in 65.72, 63.86, 54.99 and 52.64 per cent reduction, respectively, however, these treatments were comparable to each other and found moderately effective in reducing the jassid population. The minimum jassid reduction of 41.67 per cent was recorded on the crop treated with NSKE (5%) followed by azadirachtin (5ml/l) resulted in 43.80 per cent reduction and proved significantly inferior over rest of the treatments.

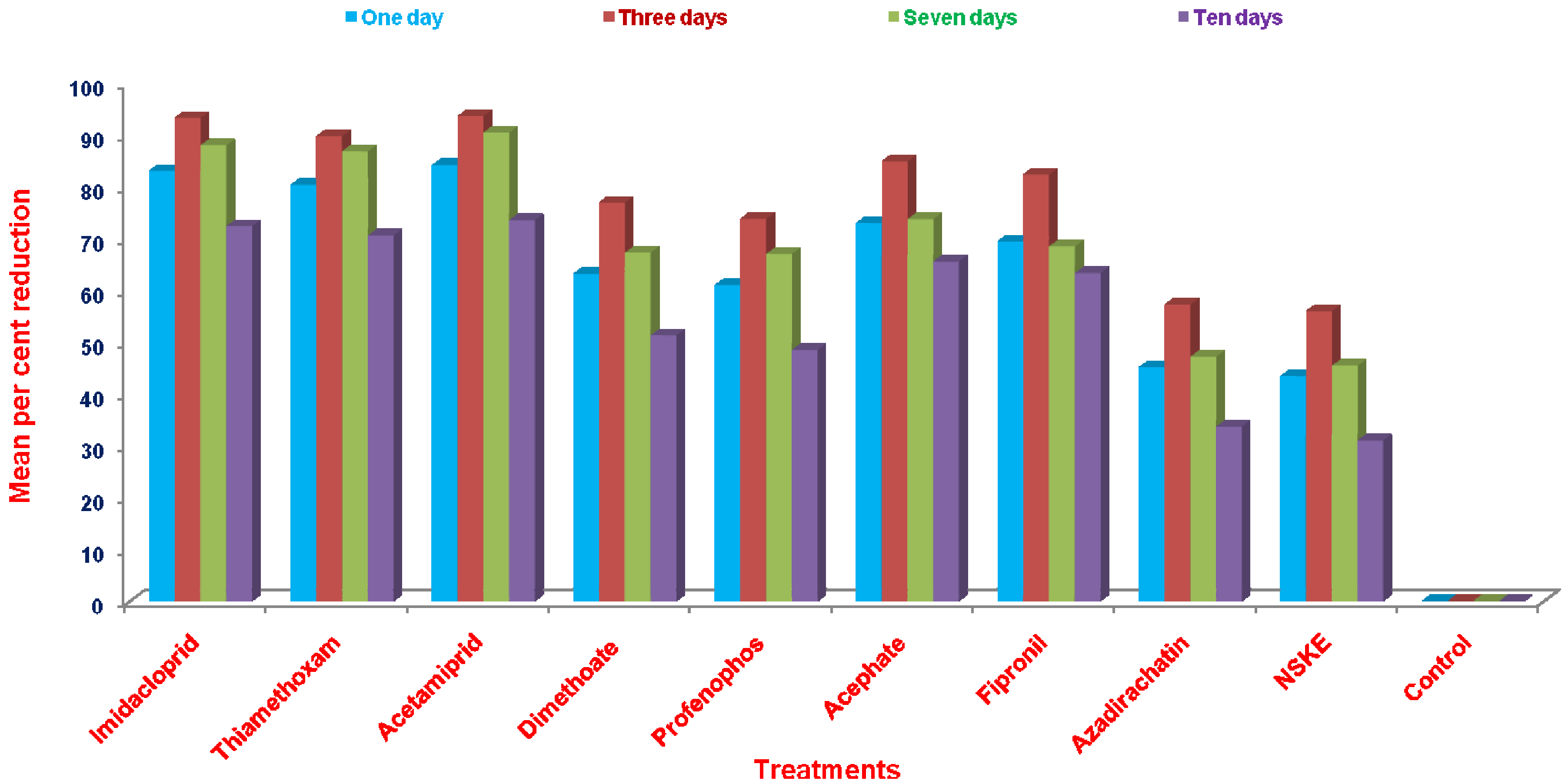
Three days after application of the treatments, the maximum jassid reduction of 91.84 per cent was recorded in imidacloprid followed by acetamiprid and thiamethoxam resulting in 90.86 and 88.56 per cent reduction, respectively, however, these were at par with each other. The next effective insecticides were fipronil, acephate, dimethoate and profenophos second best group of insecticides registered 83.06, 81.80, 77.55 and 75.82 per cent reduction, respectively, however, these treatments were comparable to each other. The minimum 59.64 per cent reduction was recorded in NSKE followed by azadirachtin which resulted in 60.55 per cent reduction of jassid population, significantly inferior over rest of the treatments.

Table- 4.6 Bio-efficacy of different insecticides/botanicals against jassid, *E. motti* Pruthi on cluster bean (First application).

S.No.	Treatments	Formulation	Conc.(%)/ dose	Mean per cent reduction after				Mean
				One day	Three days	Seven days	Ten days	
1.	Imidacloprid	17.8 SL	0.005	78.63 (62.49)*	91.84 (73.44)	84.79 (68.80)	71.76 (58.27)	81.76 (65.75)
2.	Thiamethoxam	25 WG	0.005	70.81 (57.31)	88.56 (70.47)	81.66 (64.77)	68.56 (56.15)	77.40 (62.18)
3.	Acetamiprid	20 SP	0.004	75.75 (60.52)	90.86 (72.97)	83.64 (66.46)	70.53 (57.20)	80.20 (64.29)
4.	Dimethoate	30 EC	0.03	54.99 (47.87)	75.82 (60.57)	64.69 (53.56)	51.49 (45.85)	61.67 (52.00)
5.	Profenophos	50 EC	0.05	50.64 (45.44)	77.55 (61.78)	62.69 (52.36)	53.79 (47.20)	61.25 (51.66)
6.	Acephate	75 SP	0.05	63.86 (53.06)	81.80 (64.75)	68.77 (56.25)	59.08 (50.30)	68.38 (56.09)
7.	Fipronil	5 SC	0.01	65.72 (54.37)	83.06 (65.97)	69.61 (56.56)	61.59 (51.71)	70.00 (57.15)
8.	Azadirachatin	0.03 EC	5 ml/l	43.80 (41.44)	60.55 (51.09)	48.75 (44.28)	34.79 (36.14)	46.97 (43.24)
9.	NSKE	-	5	41.67 (40.20)	59.64 (50.57)	46.50 (42.99)	32.70 (34.87)	45.13 (42.16)
10.	Control			0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	S.Em +			2.65	1.70	3.02	2.62	2.50
	CD			7.87	5.05	8.98	7.78	7.42

*Figures in the parentheses are angular transformation values.

Fig. 4.4 Bio-efficacy of different insecticides/botanicals against jassid, *E. motti* Pruthi on cluster bean (First application).



A similar trend of reduction in jassid population was also observed after **seven** days of treatment. The treatment of imidacloprid proved to be most effective in reducing the jassid population (84.79%) followed by acetamiprid and thiamethoxam which gave 83.64 and 81.66 per cent reduction, respectively, however, these treatments were at par with each other. The treatment of fipronil, acephate, dimethoate and profenophos formed next best group of insecticides resulted in 69.61, 68.77, 64.69 and 62.69 per cent reduction, respectively, and were comparable to each other. Among the neem based insecticides the treatment of NSKE reduced jassid population up to 46.50 per cent and found at par with azadirachtin where 48.75 per cent reduction was observed.

All the insecticidal treatments were found significantly superior over control after **ten** days of treatment. The maximum reduction of 71.76 per cent was observed in imidacloprid followed by acetamiprid (70.53), thiamethoxam (68.56) and fipronil (61.59) however; these treatments were at par with each other. The treatments of acephate, dimethoate and profenophos were next best group of insecticides resulted in 59.08, 53.79 and 51.49 per cent reduction, respectively, and comparable to each other. Among the neem based insecticides the treatment of NSKE reduced jassid population up to 32.70 per cent and found at par with azadirachtin where 34.79 per cent reduction was observed.

The order of effectiveness of insecticides/botanicals on the basis of per cent reduction in jassid population after first application was found to be imidacloprid (0.005%) > acetamiprid (0.004%) > thiamethoxam (0.005%) > fipronil (0.01%) > acephate (0.05%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5%).

4.3.1.2 Whitefly, *B. tabaci*

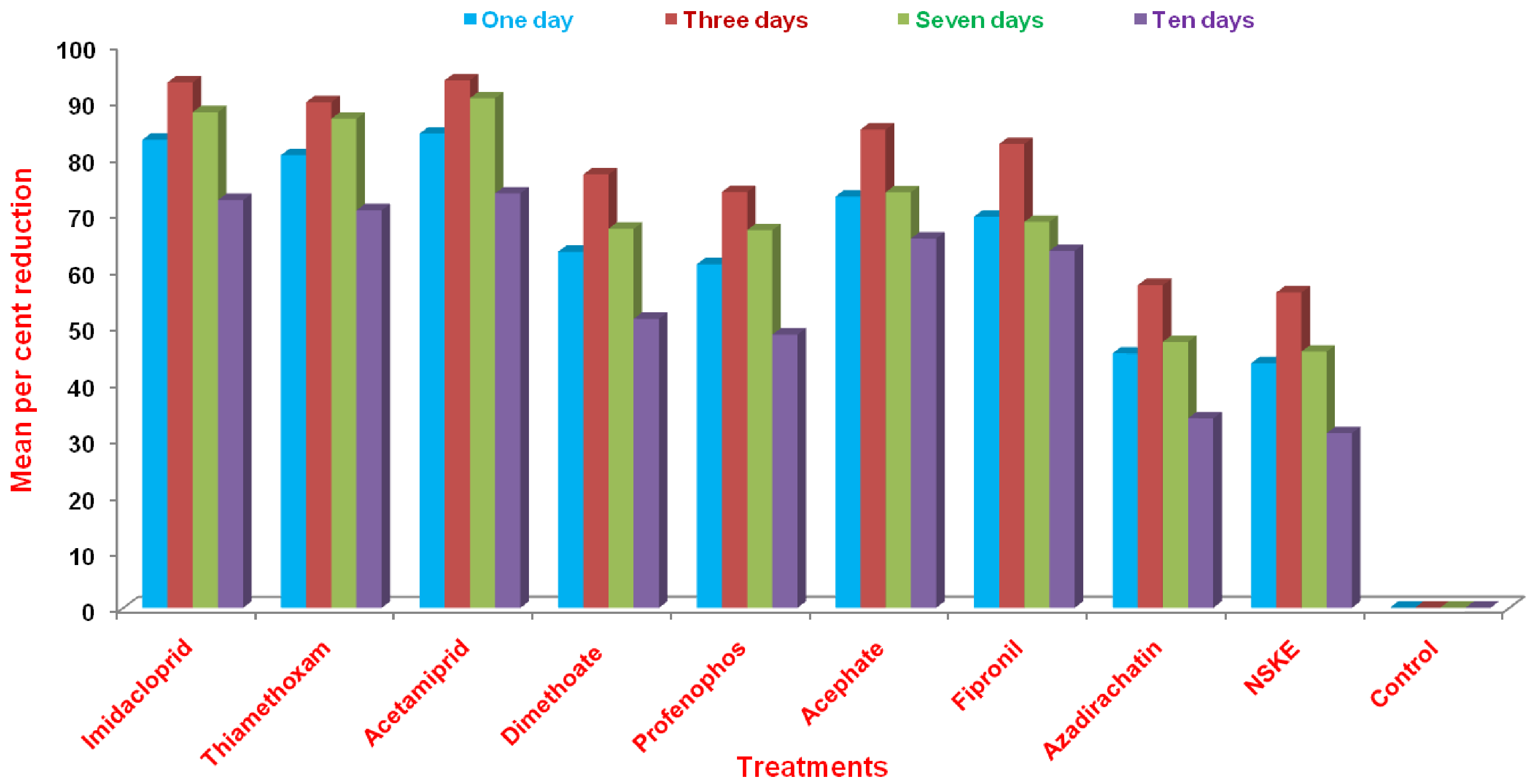
One day after application of insecticides, it was observed that all the treatments were found significantly superior over control (Table-4.7 and Fig. 4.5). The maximum whitefly reduction of 84.21 per cent was recorded in the treatment of acetamiprid (0.004%) followed by imidacloprid (0.005%) and thiamethoxam (0.005%) which resulted in 83.10 and 80.38 per cent reduction, respectively, however, these treatments were at par with each other. The next effective

Table 4.7 Bio-efficacy of different insecticides/botanicals against whitefly, *B. tabaci* Genn. on cluster bean. (First application)

S.No.	Treatments	Formulation	Conc.(%)/dose	Mean per cent reduction after				Mean
				One day	Three days	Seven days	Ten days	
1.	Imidacloprid	17.8 SL	0.005	83.10 (67.69)*	93.32 (76.25)	88.02 (73.10)	72.39 (58.70)	83.10 (67.69)
2.	Thiamethoxam	25 WG	0.005	80.38 (64.30)	89.79 (71.49)	86.84 (68.80)	70.59 (57.17)	80.38 (64.30)
3.	Acetamiprid	20 SP	0.004	84.21 (68.64)	93.68 (79.34)	90.49 (72.18)	73.59 (59.67)	84.21 (68.64)
4.	Dimethoate	30 EC	0.03	63.22 (52.87)	76.94 (61.36)	67.30 (55.14)	51.31 (45.75)	63.22 (52.87)
5.	Profenophos	50 EC	0.05	61.00 (51.51)	73.84 (59.26)	67.05 (54.98)	48.50 (44.14)	61.00 (51.51)
6.	Acephate	75 SP	0.05	73.01 (59.10)	84.92 (67.15)	73.79 (59.60)	65.56 (54.22)	73.01 (59.10)
7.	Fipronil	5 SC	0.01	69.44 (56.70)	82.36 (65.26)	68.50 (55.89)	63.37 (52.77)	69.44 (56.70)
8.	Azadirachatin	0.03 EC	5 ml/l	45.15 (42.17)	57.29 (49.19)	47.21 (43.40)	33.68 (35.47)	45.15 (42.17)
9.	NSKE	-	5	43.44 (41.17)	55.98 (48.44)	45.47 (42.40)	31.04 (33.85)	43.44 (41.17)
10.	Control			0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	S.Em +			2.83	3.04	3.38	2.83	2.83
	CD			8.41	9.02	10.03	8.40	8.41

*Figures in the parentheses are angular transformation values.

Fig. 4.5 Bio-efficacy of different insecticides/botanicals against whitefly, *B. tabaci* Genn. on cluster bean (First application).



treatments were acephate (0.05%), fipronil (0.01%), dimethoate (0.03%) and profenophos which resulted in 73.01, 69.44, 63.22 and 61.00 per cent reduction, respectively, however, these treatments were comparable. and found moderately effective in reducing the whitefly population. The minimum whitefly reduction of 43.44 per cent was recorded on the crop treated with NSKE (5%) followed by azadirachtin (5ml/l) resulted in 45.15 per cent reduction and proved significantly inferior over rest of the treatments

Three days of application of insecticides, the maximum whitefly reduction of 93.68 per cent was recorded in the treatment of acetamiprid followed by imidacloprid and thiamethoxam resulting in 93.32 and 89.79 per cent reduction, respectively, however, these were at par. The next effective insecticides were acephate, fipronil, dimethoate and profenophos ranked second best group of insecticides registered 84.92, 82.36, 76.94 and 73.84 per cent reduction, respectively, however, these treatment were comparable to each other. The neem product *viz*., NSKE and azadirachtin resulted in 48.44 and 49.19 per cent reduction of whitefly population, significantly inferior over rest of the treatments

A similar trend of reduction in whitefly population was also observed after **seven** days of treatment. The treatment of acetamiprid proved to be most effective in reducing the whitefly population (90.49%) followed by imidacloprid and thiamethoxam which gave 88.02 and 86.84 per cent reduction, respectively, however, these treatments were at par with each other. The treatment of acephate, fipronil, dimethoate and profenophos formed next best group of insecticides resulted in 73.79, 68.50, 67.30 and 67.05 per cent reduction, respectively, and were comparable to each other. Among the neem based insecticides the treatment of NSKE reduced whitefly population up to 45.47 per cent and found at par with azadirachtin where 47.21 per cent reduction was observed.

All the insecticidal treatments were found significantly superior over control after **ten** days of treatment. The maximum reduction of 73.59 per cent was observed in acetamiprid followed by imidacloprid (72.39), thiamethoxam (70.59) and acephate (65.56) however, these treatments were at par with each other. The treatments of fipronil, dimethoate and profenophos were next best group of insecticides resulted in 61.37, 51.31 and 48.50 per cent reduction, respectively, and comparable to each other. Among the neem based insecticides the treatment of NSKE reduced whitefly population up to 31.04 per cent and found at par with azadirachtin where 33.68 per cent reduction was observed.

The order of effectiveness of insecticides/botanicals on the basis of per cent reduction in whitefly population after first application was found to be acetamiprid (0.004%) > imidacloprid (0.005%) > thiamethoxam (0.005%) > acephate (0.05%) > fipronil (0.01%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5%).

4.4.2 Second spray

4.4.2.1 Jassid*, E. motti*

One day after application of insecticides, it was observed that all the treatments were significantly superior over control (Table-4.8 and Fig. 4.6). The maximum jassid reduction of 79.76 per cent was recorded in the treatment of imidacloprid (0.005%) followed by acetamiprid (0.004%) and thiamethoxam (0.005%) which resulted in 78.62 and 77.84 per cent reduction, respectively, however, these treatment were at par with each other. The next effective treatments were fipronil (0.01%), acephate (0.05%), dimethoate (0.03%), and profenophos (0.05%) which resulted in 69.71, 67.51, 66.74 and 63.83 per cent reduction, respectively, however, these treatments were comparable to each other and found moderately effective in reducing the jassid population. The minimum jassid reduction of 43.36 per cent was recorded on the crop treated with NSKE (5%) followed by azadirachtin (5ml/l) resulted in 45.61 per cent reduction and proved significantly inferior over rest of the treatments.

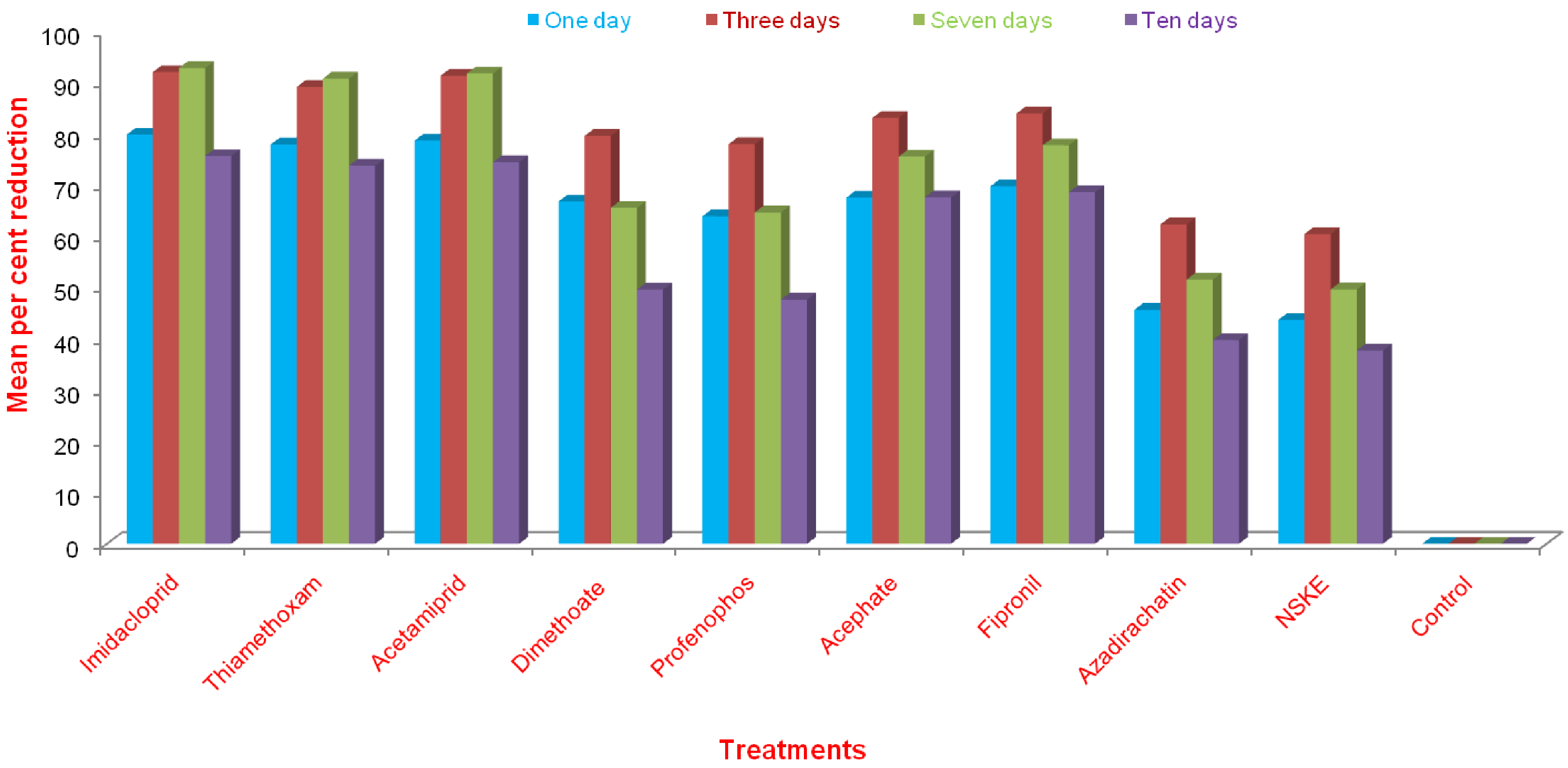
Three days after application of the treatments, the maximum jassid reduction of 91.97 per cent was recorded in imidacloprid followed by acetamiprid, thiamethoxam and fipronil resulting in 91.28, 89.09 and 83.07 per cent reduction, respectively, however, these were at par with each other. The next effective insecticides were acephate, dimethoate and profenophos formed second best group of insecticide registered 82.92, 79.59 and 77.93 per cent reduction,

Table 4.8 Bio-efficacy of different insecticides/botanicals against jassid, *E. motti* Pruthi on cluster bean (Second application).

S.No.	Treatments	Formulation	Conc.(%)dose	Mean per cent reduction after				Mean
				One day	Three days	Seven days	Ten days	
1.	Imidacloprid	17.8 SL	0.005	79.76 (63.27)*	91.97 (74.60)	92.77 (76.03)	75.62 (61.16)	85.03 (68.63)
2.	Thiamethoxam	25 WG	0.005	77.84 (62.00)	89.09 (71.10)	90.71 (72.80)	73.75 (59.23)	82.85 (66.28)
3.	Acetamiprid	20 SP	0.004	78.62 (63.26)	91.28 (74.06)	91.70 (74.45)	74.40 (60.10)	84.00 (68.10)
4.	Dimethoate	30 EC	0.03	66.74 (54.04)	79.55 (63.19)	65.51 (54.05)	49.58 (44.76)	63.35 (53.01)
5.	Profenophos	50 EC	0.05	63.87 (52.53)	77.93 (62.01)	64.61 (53.50)	47.61 (43.63)	62.01 (52.17)
6.	Acephate	75 SP	0.05	67.51 (55.44)	83.07 (67.23)	75.49 (60.81)	67.55 (55.47)	73.41 (59.74)
7.	Fipronil	5 SC	0.01	69.71 (56.62)	83.92 (66.41)	77.70 (61.84)	68.55 (55.90)	74.97 (60.19)
8.	Azadirachatin	0.03 EC	5 ml/l	45.61 (42.48)	62.29 (52.12)	51.51 (45.87)	39.73 (39.07)	49.79 (44.89)
9.	NSKE	-	5	43.66 (41.35)	60.39 (51.01)	49.60 (44.77)	37.68 (37.86)	47.83 (43.75)
10.	Control			0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	S.Em +			2.46	3.36	3.06	2.99	2.97
	CD			7.31	10.00	9.08	8.89	8.82

*Figures in the parentheses are angular transformation values.

Fig. 4.6 Bio-efficacy of different insecticides/botanicals against jassid, *E. motti* Pruthi on cluster bean (Second application).



respectively, however, these treatments were comparable to each other. The minimum 60.39 per cent reduction was recorded in NSKE followed by azadirachtin which resulted in 62.29 per cent reduction of jassid population, significantly inferior over rest of the treatments.

A similar trend of reduction in jassid population was also observed after **seven** days of treatment. The treatment of imidacloprid proved to be most effective in reducing the jassid population (92.77%) followed by acetamiprid and thiamethoxam which gave 91.70 and 90.71 per cent reduction, respectively, however, these treatments were at par with each other. The treatment of fipronil, acephate, dimethoate and profenophos formed next best group of insecticides resulted in 77.70, 75.49, 65.51 and 64.61 per cent reduction, respectively and comparable to each other. Among the neem based insecticides, the treatment of NSKE reduced jassid population up to 49.60 per cent and found at par with azadirachtin where 51.51 per cent reduction was observed.

All the insecticidal treatments were found significantly superior over control after **ten** days of treatment. The maximum reduction of 75.62 per cent was observed in imidacloprid followed by acetamiprid (74.40%), thiamethoxam (73.75%) and fipronil (68.65%) however, these treatments were at par with each other. The treatments of acephate, dimethoate and profenophos formed next best group of insecticides resulted in 64.55, 49.61 and 47.61 per cent reduction, respectively, and comparable to each other. Among the neem based insecticides, the treatment of NSKE reduced jassid population up to 37.86 per cent and found at par with azadirachtin where 39.73 per cent reduction was observed.

The order of effectiveness of insecticides/botanicals on the basis of per cent reduction in jassid population after second application was found to be imidacloprid (0.005%) > acetamiprid (0.004%) > thiamethoxam (0.005%) > fipronil (0.01%) > acephate (0.05%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5%).

4.4.2.2 Whitefly, *B. tabaci*

One day after application of insecticides, it was observed that all the treatments were found significantly superior over control (Table-4.9 and Fig. 4.7). The maximum whitefly reduction of 81.28 per cent was recorded in the treatment of acetamiprid (0.004%) followed by imidacloprid (0.005%) and thiamethoxam (0.005%) which resulted in 80.08 and 75.70 per cent reduction, respectively, however, these treatments were at par with each other. The next effective treatments were acephate (0.05%), fipronil (0.01%), dimethoate (0.03%) and profenophos (0.05%) which resulted in 68.28, 64.70, 62.57 and 60.59 per cent reduction, respectively, however, these treatments were comparable to each other and found moderately effective in reducing the whitefly population. The minimum whitefly reduction of 42.40 per cent was recorded on the crop treated with NSKE (5%) followed by azadirachtin (5ml/l) resulted in 43.53 per cent reduction and proved significantly inferior over rest of the treatments.

Three days of application of insecticides, the maximum whitefly reduction of 95.59 per cent was recorded in the treatment of acetamiprid followed by imidacloprid, thiamethoxam and acephate resulting in 95.14, 89.96 and 85.09 per cent reduction, respectively, however, these were at par. The next effective insecticides were fipronil, dimethoate and profenophos ranked second best group of insecticides registered 83.96, 76.96 and 74.94 per cent reduction, respectively, however, these treatment were comparable to each other. The neem product *viz*., NSKE and azadirachtin resulted in 57.29 and 60.68 per cent reduction of whitefly population, respectively and proved significantly inferior over rest of the treatments.

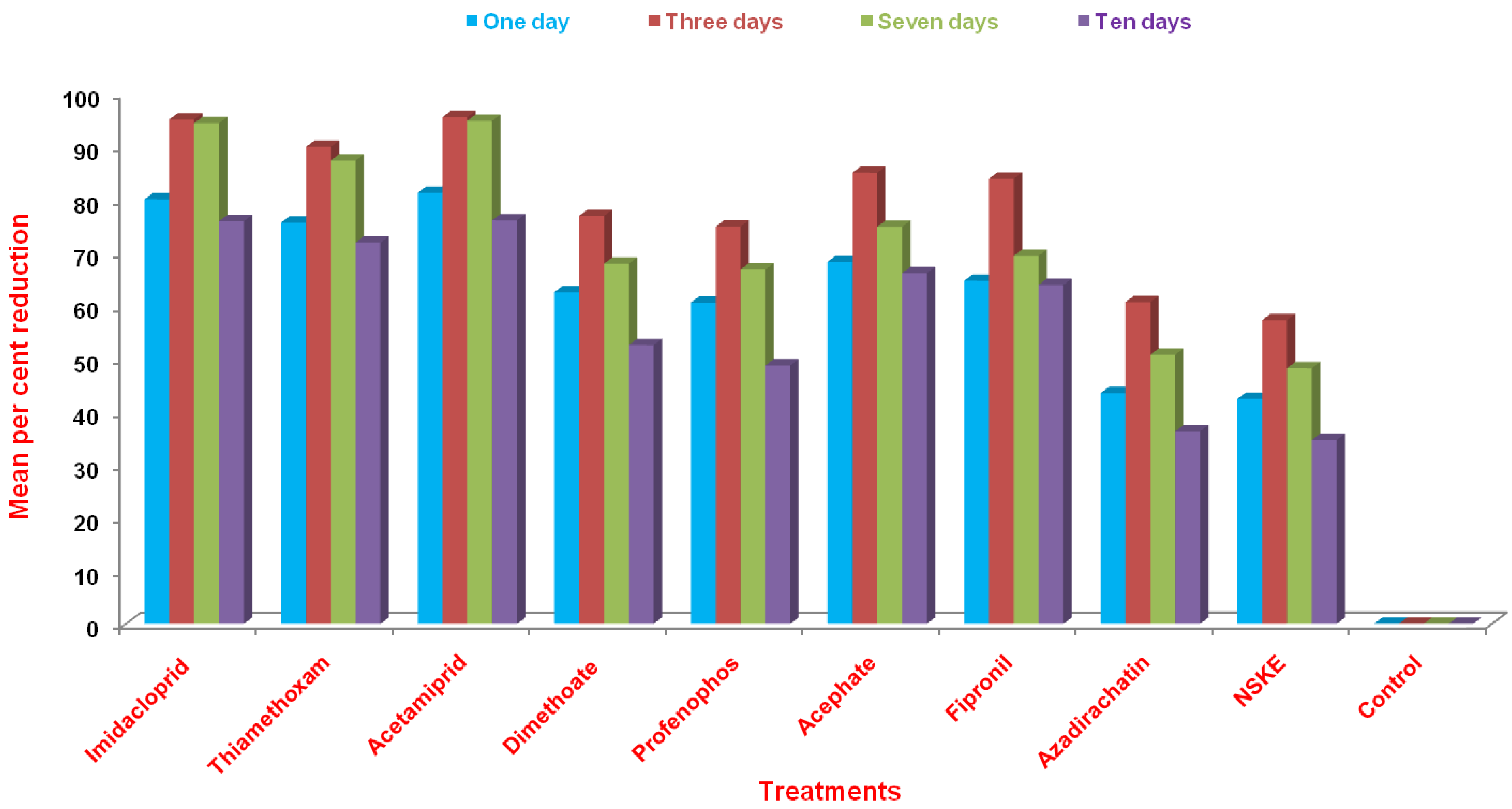
A similar trend of reduction in whitefly population was also observed after **seven** days of treatment. The treatment of acetamiprid proved to be most effective in reducing the whitefly population (94.89%) followed by imidacloprid and thiamethoxam which gave 94.43 and 87.40 per cent reduction, respectively, however, these treatments were at par with each other. The treatment of acephate, fipronil, dimethoate and profenophos formed next best group of insecticides resulted in 74.89, 69.92, 69.40 and 66.83 per cent reduction,

Table 4.9 Bio-efficacy of different insecticides/botanicals against whitefly, *B. tabaci* Genn. on cluster bean (Second application).

S.No.	Treatments	Formulation	Conc.(%)/dose	Mean per cent reduction after				Mean
				One day	**Three days**	**Seven days**	**Ten days**	
1.	Imidacloprid	17.8 SL	0.005	80.08 (63.50)*	95.14 (78.54)	94.43 (76.37)	75.95 (61.36)	86.40 (69.96)
2.	Thiamethoxam	25 WG	0.005	75.70 (60.48)	89.96 (71.55)	87.40 (69.29)	71.92 (58.01)	81.25 (64.83)
3.	Acetamiprid	20 SP	0.004	81.28 (64.37)	95.59 (79.56)	94.89 (76.96)	76.13 (61.41)	86.97 (70.56)
4.	Dimethoate	30 EC	0.03	62.57 (51.94)	76.96 (61.37)	67.92 (55.52)	52.56 (46.47)	64.00 (53.33)
5.	Profenophos	50 EC	0.05	60.59 (49.21)	74.94 (59.98)	66.83 (54.84)	48.74 (44.28)	61.53 (51.83)
6.	Acephate	75 SP	0.05	68.28 (55.93)	85.09 (70.01)	74.89 (59.93)	66.13 (54.58)	73.60 (60.11)
7.	Fipronil	5 SC	0.01	64.70 (53.57)	83.96 (67.44)	69.40 (56.45)	63.92 (53.10)	70.50 (57.64)
8.	Azadirachatin	0.03 EC	5 ml/l	43.53 (41.28)	60.68 (51.17)	50.76 (45.44)	36.30 (37.05)	47.82 (43.74)
9.	NSKE	-	5	42.40 (40.63)	57.29 (49.20)	48.21 (43.97)	34.68 (36.07)	45.65 (42.47)
10.	Control			0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	S.Em +			1.39	3.86	0.96	3.00	2.30
	CD			4.12	11.45	2.84	8.91	6.83

*Figures in the parentheses are angular transformation values.

Fig. 4.7 Bio-efficacy of different insecticides/botanicals against whitefly, *B. tabaci* Genn. on cluster bean (Second application).



respectively, and comparable to each other. Among the neem based insecticides, the treatment of NSKE reduced whitefly population up to 48.21 per cent and found at par with azadirachtin where 50.76 per cent reduction was observed.

All the insecticidal treatments were found significantly superior over control after **ten** days of treatment. The maximum reduction of 76.13 per cent was observed in acetamiprid followed by imidacloprid (75.97), thiamethoxam (71.92) and acephate (66.13) however, these treatments were at par with each other. The treatments of fipronil, dimethoate and profenophos were next best group of insecticides resulted in 63.92, 52.56 and 48.74 per cent reduction, respectively, and comparable to each other. Among the neem based insecticides, the treatment of NSKE reduced whitefly population up to 34.68 per cent and found at par with azadirachtin where 36.30 per cent reduction was observed.

The order of effectiveness of insecticides/botanicals on the basis of per cent reduction in whitefly population after second application was found to be acetamiprid (0.004%) > imidacloprid (0.005%) > thiamethoxam (0.005%) > acephate (0.05%) > fipronil (0.01%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5%).

4.4.3. Effect of insecticides/botanicals on Seed yield of cluster bean.

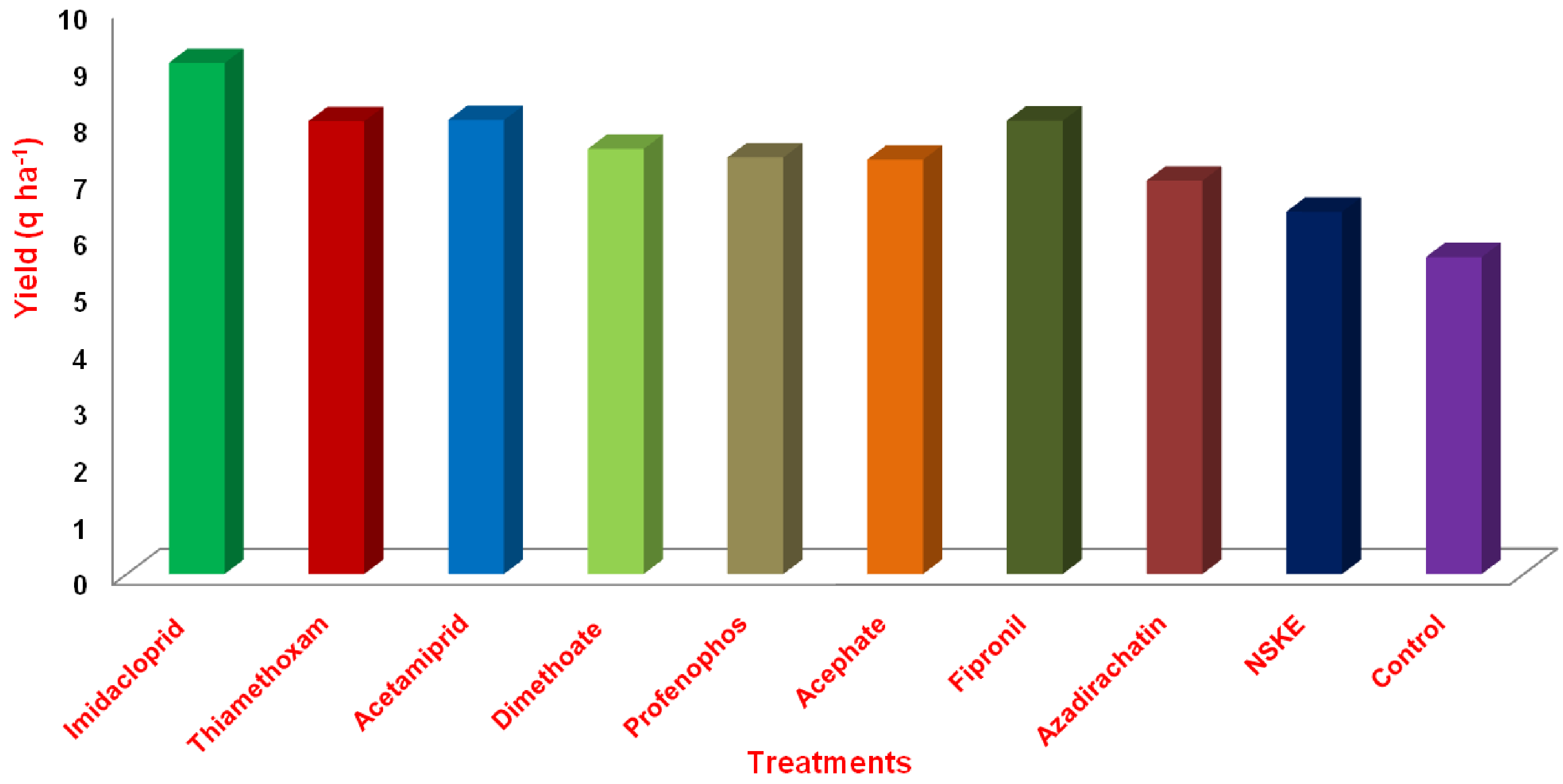
The data presented in table 4.10 and fig. 4.8 revealed that all the plots treated with insecticides gave significantly higher yield over control. The maximum seed yield was recorded in the plots treated with imidacloprid (0.005%) followed by acetamiprid (0.004), thiamethoxam (0.005%) and fipronil (0.01) which resulted in 9.03, 8.02, 8.00 and 8.01 q ha^{-1} seed yield, respectively. The next best treatments were dimethoate (0.03%), profenophos (0.05%), and acephate (0.05%) which gave a seed yield of 7.36, 7.51 and 7.32 q ha^{-1}, respectively, The minimum seed yield of 6.40 q ha^{-1} was obtained from the plots treated with NSKE (5%) followed by azadirachtin (5ml/l). which gave a seed yield of 6.95 q ha^{-1}.

The order of effectiveness of treatments on the basis of seed yield of cluster bean was imidacloprid (0.005%) > acetamiprid (0.004%) > thiamethoxam (0.005%) > fipronil (0.01%) > dimethoate (0.03%) > profenophos (0.05%) > acephate (0.05%) > azadirachtin (5ml/l) > NSKE (5.0%).

Table 4.10 Effect of insecticides/botanicals on seed yield yield of cluster bean.

S.No.	Treatments	Formulation	Conc.(%)/dose	yield (q ha^{-1})
1	Imidacloprid	17.8 SL	0.005	9.03
2	Thiamethoxam	25 WG	0.005	8.00
3	Acetamiprid	20 EC	0.004	8.02
4	Dimethoate	30 EC	0.03	7.51
5	Profenophos	50 EC	0.05	7.36
6	Acephate	75 SP	0.05	7.32
7	Fipronil	5 SC	0.01	8.01
8	Azadirachatin	0.03 EC	0.03	6.95
9	NSKE	Lab. Prep.	5.00	6.40
10	Control	-	-	5.60

Fig. 4.8 Effect of insecticides/botanicals on seed yield of Cluster bean.



4.4.4 Assessment of losses and increase in seed yield

During *kharif,* 2012 in the treatment of imidacloprid (0.005%), was found most effective in protecting the cluster bean crop as such avoidable losses in the treatment was taken zero (Table-4.11). Taking this plot as completely protected and untreated control as unprotected, the per cent loss was computed as 37.98. In the treatment of acetamiprid (0.005%), thiamethoxam (0.005%) and fipronil (0.01%) the total avoidable losses' were 1.01, 1.02 and 1.03 q ha^{-1} and 'per cent avoidable losses' were 11.18, 11.30 and 11.41 respectively. The treatment of dimethoate (0.03%), profenophos (0.05%) and acephate (0.05%) had total avoidable losses of 1.52, 1.67 and 1.71 q ha^{-1} and per cent avoidable losses of 16.83, 18.49 and 18.94, respectively. The maximum total avoidable losses were recorded from NSKE (5%) followed by azadirachtin (5ml/l) in which total avoidable losses were 2.63 and 2.08 q ha^{-1} and the per cent avoidable losses were 29.13 and 23.03 respectively.

The maximum increase in yield over control was recorded in the plots treated with imidacloprid (0.005%) in which total increase in yield over control was 3.43 q ha^{-1} and per cent increase in yield over control was 61.25 followed by acetamiprid (0.004%), thiamethoxam (0.005%) and fipronil (0.01%) where total increase in yield over control were 2.42, 2.41 and 2.40 q ha^{-1} and per cent increase in yield over control were 43.21, 43.04 and 42.86, respectively. The total increase in yield over control and per cent increase in yield over control in the treatments of dimethoate (0.03%), acephate (0.05%) and profenophos (0.05%) were 1.91, 1.76 and 1.72 q ha^{-1} and 34.11, 31.43 and 30.71, respectively. The minimum per cent increase in yield over control (14.29 and 24.11%) was recorded in NSKE (5%) and azadirachtin (5ml/l), respectively.

Table 4.11 Assessment of losses caused by sucking pests of cluster bean.

S.No.	Treatments	Formulation	Conc.(%)dose	yield (qha^{-1})	Total avoidable losses (qha^{-1})	Per cent avoidable losses	Total increase in yield over control (qha^{-1})	Per cent Increase in yield over control
1	Imidacloprid	17.8 SL	0.005	9.03	0.00	0.00	3.43	61.25
2	Thiamethoxam	25 WG	0.005	8.00	1.02	11.30	2.41	43.04
3	Acetamiprid	20 EC	0.004	8.02	1.01	11.18	2.42	43.21
4	Dimethoate	30 EC	0.03	7.51	1.52	16.83	1.91	34.11
5	Profenophos	50 EC	0.05	7.36	1.67	18.49	1.76	31.43
6	Acephate	75 SP	0.05	7.32	1.71	18.94	1.72	30.71
7	Fipronil	5 SC	0.01	8.01	1.03	11.41	2.40	42.86
8	Azadirachatin	0.03 EC	0.03	6.95	2.08	23.03	1.35	24.11
9	NSKE	Lab. Pre.	5.00	6.40	2.63	29.13	0.80	14.29
10	Control	-	-	5.60	3.43	37.98	0.00	0.00

4.4.5 Economics of insecticides/botanicals treatments

The data presented in table 4.12 revealed that the maximum profit was recorded from the plots treated with acetamiprid (0.004%) which gave incremental benefit cost ratio of 28.23, followed by imidacloprid (0.005%) and thiamethoxam (0.005%) where such ratio were 26.20 and 22.91, respectively. The next incremental benefit cost treatments were acephate (0.05%), dimethoate (0.03%) and profenophos which gave a ratio of 16.70, 15.08 and 14.36, respectively. The minimum incremental benefit cost ratio of 5.81 was recorded in fipronil (0.01%) followed by NSKE (5%) and azadirachtin (5ml/l) in which such ratio was 4.19 and 2.95, respectively.

Table 4.12 Comparative economics and incremental B:C ratio of different treatments.

S. No.	Treatments	Formulatios	Conc.(%)/dose	yield (qha^{-1})	Total increase in yield over control (qha^{-1})	Income of increased yield (Rs.)	Cost of insecti-cides (Rs.)	Total cost of protection (Rs.)	Net profit	Increm-ental B:C ratio
1	Imidacloprid	17.8 SL	0.005	9.03	3.43	34300.00	2120	1260.80	33039.20	26.20
2	Thiamethoxam	25 WG	0.005	8.00	2.40	24000.00	1932	1003.68	22996.32	22.91
3	Acetamiprid	20 EC	0.004	8.02	2.42	24200.00	1200	828.00	23372.00	28.23
4	Dimethoate	30 EC	0.03	7.51	1.91	19100.00	540	1188.00	17912.00	15.08
5	Profenophos	50 EC	0.05	7.36	1.76	17600.00	505	1146.00	16454.00	14.36
6	Acephate	75 SP	0.05	7.32	1.72	17200.00	540	972.00	16228.00	16.70
7	Fipronil	5 SC	0.01	8.01	2.41	24100.00	1250	3540.00	20560.00	5.81
8	Azadirachatin	0.03 EC	0.03	6.95	1.35	13500.00	480	3420.00	10080.00	2.95
9	NSKE	Lab. Prep.	5.00	6.40	0.80	8000.00	40	1540.00	6460.00	4.19
10	Control	-	—	5.60	0.00	0.00		0.00	0.00	0.00

* Cost of of cluster bean at current season was Rs. = 10000 per quintal

5. DISCUSSION

The investigations carried out during *kharif*, 2012 and results obtained are present in the chapter 4 are discussed under the following headings:

1. To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and their correlation with abiotic factors.
2. Screening of cluster bean varieties/genotypes against major sucking pests.
3. Bio-efficacy of various insecticides/botanicals against major sucking pests of cluster bean.

The management of major sucking pests of cluster bean was carried out by application of safe and economic insecticide/botanicals to reduce its population and resurgence of pest. It's only possible with the long persistence of pesticides. In arid region of Rajasthan cluster bean is one of the major crop which is sown as rainfed as well as irrigated. The increasing infestation of jassid and whitefly causes menaces to this crop. Apart from pest management by insecticide/botanicals to reduce its infestation, other methods were also tested i.e. studies on population dynamics as well as screening of cluster bean varieties to know any resistance against jassid and whitefly.

5.1 To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and their correlation with abiotic factors.

In the present investigation, the incidence of jassid and whitefly appeared in the first week of September (33th SMW) and increased up to the last week of September (36th SMW) and declined gradually till the crop was matured in last week of October. The population of jassid ranged from 0.96 to 12.72. The peak activity of jassid (12.72) was recorded in the 36th standard week, or last week of September. The whitefly population (2.56) commenced on 4 WAS coinciding with 1st week of September (33rd SMW). The whitefly activity gradually increased up to 8 WAS coinciding with 4th week of September (36th SMW) and reached a peak level (13.16 whitefly). The present findings are in accordance with that of

Pachundkar (2011) who reported that the leafhopper appeared in the first week of September on clusterbean crop, whereas whitefly was noted as second group. Later, whitefly colonized the clusterbean crop on 36th standard week (2nd week of September). Based on occurrence and infestation, leafhopper and whitefly were designated major pests. The present results are also in agreement with those of Kumar *et. al.* (2004) who observed the peak population of whitefly on mung bean and urd bean in the first fortnight of May and second fortnight of September in *Zaid* and *Kharif* crops, respectively. Contrary to present findings, Nitharwal and Kumawat (2009) reported the major sucking pests of green gram. The infestation reached at peak (12.40 jassids, 10.80 whitefly/three leaves during *Kharif* 2006 and 13.2 jassids, 11.20 whitefly and 9.87 thrips/three leaves during *Kharif* 2007 in the first week of September. However, Meena *et al.* (2010) reported the incidence of jassids (2.0 and 2.4 jassids/plant) in the first week of August and was being active till harvesting in both the years, its population reached at maximum (15.2 and 16.4 jassids/plant) in fourth and third week of September in the year 2002 and 2003.

The present results indicated that the incidence of jassid resulted significant positive correlation (r= 0.56) at 5 per cent level and correlation (r=0.36) at 1 per cent level with maximum and minimum temperature, respectively. The mean relative humidity had significant negative correlation (r=-0.48) at 1 per cent level and rainfall had significant positive correlation (r=0.69) at 5 per cent level.

The incidence of whitefly resulted significant positive correlation (r=0.57) at 5 per cent level and significant positive correlation (r=0.43) at 1 per cent level with maximum and minimum temperature, respectively. The mean relative humidity revealed significantly negative correlation (r=-0.50) at 1 per cent level. The rainfall showed significantly positive correlation (r=0.74) at 5 per cent level. These results corroborated the findings of Faleiro *et al.* (1990) who noted positive correlation (0.191 & 0.067) with maximum and minimum temperature and jassid, *E. kerri* on cowpea, whereas relative humidity (-0.062), wind speed (-0.007) and sunshine hrs. (-0.330) were found to be negatively correlated with leafhopper population. Rainfall and leafhopper population had a significant positive (0.421) association. Patel (2000) reported that the population of leafhopper, *E. kerri* had significant positive correlation with bright sunshine hours, temperature (maximum and mean) and vapour pressure deficit (morning, evening and mean), whereas relative humidity and wind speed was found to be significantly negatively correlated with leafhopper population in cowpea.

5.2 Screening of cluster bean varieties/genotypes against major sucking pests.

It is well known that certain varieties of crops are less attacked by a specific insect pest than others, because of natural resistance. In the cultural practices, currently applied to minimize the losses caused by insect pests, growing of resistant varieties against insect pests is the most important one in the pest management. This also provides insect pests management without extra cost.

In the present investigation, ten varieties/genotypes of cluster bean *viz*., RGC-197, RGC-1031, RGC-986, RGC-1017, RGC-1066, RGC-1055, RGC-471, RGC-1033, RGC-1003 and RGC-1002 were screened for their relative susceptibility to the jassid and whitefly infestation. The results on relative susceptibility of cluster bean revealed that none of the variety or genotypes was found completely free from jassid and whitefly attack. RGC-197 and RGC-1031 were considered as least susceptible whereas, RGC-986, RGC-1017, RGC-1055, RGC-1066, RGC-1033 and RGC-471 were considered as moderately susceptible. However, RGC-1003 and RGC-1002 were considered as highly susceptible.

The present findings are in agreement with that of Yadav and Kumawat (2008) who evaluated fifteen genotype of cluster bean against jassid. The genotype, RGC-197, RGC-1031, RGC-1017, RGC-1055 were found least susceptible to jassid; genotypes, RGC-1077, RGC-1066 and RGC-1078 as moderately susceptible and genotypes RGC-1038, RGC-1003, RGC-1002, and RGC-936 were highly susceptible.

The population of whitefly on cluster bean revealed that RGC-1017 and RGC-1031 were found less susceptible whereas, RGC-986, RGC-197, RGC-1055, RGC-1066, RGC-471 and RGC-1033 were existed moderately susceptible. However, RGC-1002 and RGC-1003 were found highly susceptible in the present investigation.

The present findings are in agreement with that of Singh *et al.,* (1996) who screened sixteen genotypes of cluster bean against whitefly, *B. tabaci* and among them five genotypes observed with low nymph population, HGS-365 was one. Singh (2002) reported that variety RGC-1017 of early maturing group showed less than 10 per cent whitefly incidence. Similar observation was made by Verma and Henry (2003) who screened fifteen normal maturity and 9 early maturity varieties of cluster bean, against the whiteflies, *Acaudaleyrodes rachipora*. The incidence of the pest in clusterbean was also more (5-50 %) in the early varieties than in normal maturity varieties (0-35 %). The only promising cultivar in the early maturity group (showing <10% pest incidence) was RGC 1017. Yadav and Kumawat (2008) reported, RGC-1017, HGS-365, RGC-986, RGC-197, RGC-1031 and RGC-1076 as least susceptible to whitefly. RGC-1017, RGC-986, RGC-197, RGC-1031 and RGC-1076 as moderately susceptible; RGC-1038, RGC-1003, RGC-1002, RGC-1078, and RGC-936 were highly susceptible to whitefly.

5.3 Bio-efficacy of different insecticides/botanicals against major sucking pests of cluster bean.

In the present investigation, the following criteria were taken in to consideration for evaluating the relative efficacy of insecticides against jassid and whitefly infesting cluster bean.

1. Effect of insecticidal/botanicals application on the reduction in jassid and whitefly population.

2. Effect of insecticidal/botanicals application on seed yield of cluster bean.

3. Assessment of losses caused by jassid and whitefly and economics of insecticidal/botanicals treatments.

5.3.1 Effect of insecticidal/botanicals application on the reduction in jassid and whitefly population.

5.3.1.1 Jassid, *E. motti*

In the present investigation, the treatments of imidacloprid (0.005%) was found to be most effective against jassid on cluster bean followed by acetamiprid (0.004%) and thiamethoxam (0.005%).The next effective treatments were fipronil (0.01%), acephate (0.05%), dimethoate (0.03%) and profenophos (0.05%). The treatment with NSKE (5%) and azadirachtin (5ml/l) was found less effective.

The present results are in accordance with that of Patel (2006) who recorded imidacloprid @ 0.005 per cent as the most effective insecticide in reducing the population of leafhopper in cowpea. Similarly Rohini *et. al*. (2012) observed Imidacloprid 17.8 SL @ 0.4 ml/l to be most promising against leafhopper in cotton. Patel *et al*.,(2009) evaluated eight treatments for their efficacy on leafhopper and whitefly after 2, 4 days and one week after application. The treatment, imidacloprid 17.8 SL was significantly superior in reducing the leafhopper population as compared to rest of insecticides. Udikeri *et. al.* (2010) indicated that new formulations of imidacloprid (Confidor 350SC) @ 26.25 g a.i./ha was superior in reducing the population of leafhopper from 3.09 to 0.83 per cent respectively, during 2003-04 and 2004-05 at three days after first application. Singh *et al*.(2010) and yadav *et al.* (2011) reported imidacloprid and thiamethoxam highly effective against jassid on mothbean and cluster bean, respectively. However, Kolhe *et al*. (2009) recorded imidacloprid, acetamiprid and thiamethoxam effective against jassid in cotton.

The treatments of fipronil, acephate, dimethoate and profenophos were found in the moderately effective group. These results are in agreement with that of Misra (2002) who reported profenophos (0.05%) as moderately effective for the control of jassid in green gram. However, Dhamaniya *et al.* (2005) reported dimethoate as highly effective against jassid on moth bean. However, Rohini *et. al*. (2012) observed fipronil 5 SC @ 2ml/l to be most promising against leafhopper in cotton.

The NSKE (5.0%) and Azadirachtin (5.0%) proved to be least effective in controlling the jassid. The present findings corroborates with those of Dhamaniya *et al.* (2005) who reported that although the neem based preparations had imposed jassid mortality but less effective in reducing the population. However, Prajapati *et.al*.(2003) reported neem seed kernel suspension @ 3% resulted in the highest leafhopper mortality on cowpea.

5.3.1.2 Whitefly, *B. tabaci*

The treatment of acetamiprid (0.004%) was found to be most effective against whitefly on cluster bean followed by imidacloprid (0.005%) and thiamethoxam (0.005%). The next effective treatments were acephate (0.05%), fipronil (0.01%), dimethoate (0.03%) and profenophos (0.05%). The treatments with NSKE (5%) and azadirachtin (5ml/l) were found less effective.

The present results are in accordance with that of Subhadra Acharya *et al.* (2002) reported that acetamiprid @ 20g.a.i/ ha and thiamethoxam and imidacloprid (both) @ 25 g. a.i./ ha proved effective against okra whitefly followed by abamectin @ 20 g. a.i./ ha. Acetamiprid, thiamethxam and imidacloprid @ 20 and 25 g.a.i./ ha were the best insecticide in controlling okra whitefly up to 3 weeks. Similarly, Rohini *et. al*. (2012) observed thiamethoxam 5 SG @ 0.2g/l as effective against whitefly in cotton. Raghuraman and Gupta (2005) reported that the acetamiprid 40 g a.i./ ha and imidacloprid 100 g. a.i. were the most effective treatments against *B. tabaci.* (48% and 45% increase in seed cotton yield over control, respectively). Result suggests that acetamiprid and imidacloprid are good substitute for conventional insecticides in vogue, which could use in formulating a successful management strategy for *B. tabaci.* Yadav *et.al*. (2011) reported dimethoate, imidacloprid and thiamethoxam as the most effective insecticide against jassid and whitefly in cluster bean.

The treatments of acephate 0.05 per cent, fipronil 0.01 per cent, dimethoate 0.03 per cent and profenophos 0.05 per cent were found in the moderately effective group and effective next to acetamiprid (0.004%) and imidacloprid (0.005). These results are in agreement with that of Misra (2002) who reported profenophos (0.05%) as moderately effective for the control of whitefly in green gram. Contrarary to the present finding, Singh *et al.* (2003) reported profenophos and profenophos + cypermethrin (Polytrin C) as most effective insecticides against whitefly in brinjal.

The NSKE (5.0%) and Azadirachtin (5.0%) proved to be least effective in controlling the whitefly. The present findings corroborates with that of Ganapathy and Karuppiah (2004) and Dhamaniya *et al.* (2005) who reported that although the neem based preparations imposed reduction in jassid and whitely population but to less extent.

5.3.2 Effect of insecticides/botanicals and on the seed yield of cluster bean.

The highest seed yield was found in the plots treated with imidacloprid (0.005%) followed by acetamiprid (0.004), thiamethoxam (0.005%) and fipronil (0.01) which resulted in 9.03, 8.02, 8.00 and 8.01 q ha^{-1} seed yield, respectively. The next best treatments were dimethoate (0.03%), profenophos (0.05%), and acephate (0.05%) which gave a seed yield of 7.36, 7.51 and 7.32 q ha^{-1}, respectively, The minimum seed yield of 6.40 q ha^{-1} was obtained from the plots treated with NSKE (5%) which was found at par with a seed yield of 6.95 q ha^{-1} obtained from the plots treated with azadirachtin (5ml/l).

The present findings corroborate with that of Panwar and Patel (2011) who obtained highest grain yield of cluster bean in the treatment of acetamiprid 20 SP @ 0.004 per cent. Yadav *et al.* (2011) recorded the highest seed yield from the plot treated with dimethoate followed by imidacloprid and thiamethoxam. However, Patel *et.al*. (2009) obtained maximum grain yield of cluster bean in the treatment of acephate75 SP which was at par with that of carbosulphan 25 EC.

5.4.3 Assessment of losses and economics of insecticides/botanicals.

In the present investigation, the treatment of imidacloprid (0.005%), was found most effective in protecting the cluster bean crop as such avoidable losses in the treatment was taken zero. Taking this plot as completely protected and untreated control as unprotected, the per cent loss was computed as 37.98. In the treatment of acetamiprid (0.005%), thiamethoxam (0.005%) and fipronil (0.01%) the total avoidable losses' were 1.01, 1.02 and 1.03 q ha^{-1} and 'per cent avoidable losses' were 11.18, 11.30 and 11.41 respectively. The treatment of dimethoate (0.03%), profenophos (0.05%) and acephate (0.05%) had total avoidable losses of 1.52, 1.67 and 1.71 q ha^{-1} and per cent avoidable losses of 16.83, 18.49 and 18.94, respectively. The maximum per cent avoidable losses were recorded from NSKE (5%) followed by azadirachtin (5ml/l) in which total avoidable losses were 2.63 and 2.08 q ha^{-1} and the per cent avoidable losses were 29.13 and 23.03 respectively. The present findings are in agreement with that of Yadav and Kumawat (2008) who reported 31.37 per cent avoidable losses due to attack of sucking pests in cluster bean crop. However, Panwar and Patel (2011) reported 56.96 per cent avoidable losses due to insect pests of cluster bean.

The maximum increase in yield over control was recorded in the plots treated with imidacloprid (0.005%) in which total increase in yield over control 3.43 q ha^{-1} and per cent increase in yield over control was 61.25 followed by acetamiprid (0.004%), thiamethoxam (0.005%) and fipronil (0.01%) where total increase in yield over control were 2.42, 2.41 and 2.40 q ha^{-1} and per cent increase in yield over control were 43.21, 43.04 and 42.86 per cent, respectively. The total increase in yield over control and per cent increase in yield over control in the treatments of dimethoate (0.03%), acephate (0.05%) and profenophos (0.05%) were 1.91, 1.76 and 1.72 q ha^{-1} and 34.11, 31.43 and 30.71, respectively. The minimum total increase in yield over control (24.11 and 14.29) was recorded in NSKE (5%) and azadirachtin (5ml/l), respectively. Yadav and Kumawat (2008) recorded maximum increase in yield over control in dimethoate (45.71%) followed by imidacloprid (43.57%) and thiamethoxam (42.86) partially support the present findings. However, Panwar and Patel (2011) observed highest increase in yield over control in plot treated with acetamiprid (159.16) followed by clothanidin (119.37%) and thiamethoxam (117.17).

In the present findings maximum profit was recorded from the plots treated with acetamiprid (0.004%) which gave incremental benefit cost ratio of 28.23, followed by imidacloprid (0.005%) and thiamethoxam (0.005%) where such ratio were 26.20 and 22.91, respectively. The next incremental benefit cost treatments were acephate (0.05%), dimethoate (0.03%) and profenophos which gave 16.70, 15.08 and 14.36, respectively. The minimum incremental benefit cost ratio of 5.81 was recorded in fipronil (0.01%) followed by NSKE (5%) and azadirachtin (5ml/l) with a benefit cost ratio of 4.19 and 2.95, respectively. Yadav and Kumawat (2008) recorded highest benefit cost ratio of 7.10 in dimethoate 30 EC @ 0.003% followed by imidacloprid 17.8 SL @ 0.005% (4.52). However, Panwar and Patel (2011) obtained highest return (97.58) with the treatment of acetamiprid 20 SP @ 0.004% followed by imidacloprid 17.8 SL @ 0.005% (70.95).

6. SUMMARY AND CONCLUSION

The present investigations entitled **"Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]"** was conducted with following objectives.

4. To study the population dynamics of major sucking pests of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and their correlation with abiotic factors.
5. Screening of cluster bean varieties/genotypes against major sucking pests.
6. Bio-efficacy of various insecticides/botanicals against major sucking pests of cluster bean.

The experiments were conducted during *Kharif*- 2012 at Research Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Campus Bikaner (Rajasthan).

The study on the population dynamics of major insect pests revealed that the population of jassid and whitefly appeared on cluster bean in the first week of September (33^{th} SMW) and increased up to the last week of September (36^{th} SMW) and declined gradually till the crop was matured in last week of October. The incidence of jassid and whitefly started when maximum and minimum temperature was 33.2^0C and 24.92^0C however, relative humidity and rainfall were 74.36 per cent and 43 mm, respectively. The jassid and whitefly population increased to its peak (12.72 jassid) and (13.16 whitefly) at 33.3^0C maximum, 25.12^0C minimum temperature, relative humidity 78 per cent and rainfall 69 mm.

To know the effect of abiotic factors on the incidence of jassid and whitefly on cluster bean, the correlation coefficient was worked out between mean jassid and whitefly population and weather parameters, *viz.,* maximum and minimum temperature, relative humidity and rainfall. The maximum and minimum temperature showed significantly positive correlation (r=0.56), (r=0.57) and (r=0.36), (r=0.43) whereas, the relative humidity revealed negative significant correlation (r=-0.48) and (r=-0.50) with jassid and whitefly population, respectively. The rainfall showed significantly positive correlation (r=0.69) and (r=0.74) with jassid and whitefly population on cluster bean, respectively.

Ten varieties of cluster bean were screened against jassid and whitefly. The data revealed that none of variety was found free from their attack. On the basis of peak jassid population, the varieties RGC-197 and RGC-1031 (below 8.51 jassid) were categorized as least susceptible, RGC-986, RGC-1017, RGC-1055, RGC-1066 RGC-471 and RGC-1033 (between 8.51 to 12.99 jassid) as moderately susceptible, whereas, RGC-1003 and RGC-1002 (above 12.99 jassid) as highly susceptible against jassid. Similarly, on the basis of peak population of whitefly RGC-1017 and RGC-1031 (below 9.05 whitefly) were considered as least susceptible, RGC-986, RGC-197,RGC-1055, RGC-1066, RGC-471 and RGC-1033 (between 9.05 to 13.15 whitefly) as moderately susceptible and RGC-1003 and RGC-1002 (above 13.15 whitefly) as highly susceptible against whitefly.

The relative efficacy of nine insecticides including botanicals was studied against jassid and whitefly at 1, 3, 7 and 10 days after insecticide application. The population of jassid was reduced significantly in all the insecticidal treatments. However, among all the insecticides tested, imidacloprid (0.005%) proved to be most effective followed by acetamiprid (0.004%) and thiamethoxam (0.005%). The treatments of fipronil (0.01%), acephate (0.05%), dimethoate (0.03%) and profenophos (0.05%) showed medium order of effectiveness, whereas, NSKE (5.0%) proved least effective followed by azadirachtin (5ml/l). The over all order of efficacy of insecticides on the basis of reduction in jassid population was imidacloprid (0.005%) > acetamiprid (0.004%) > thiamethoxam (0.005%) > fipronil (0.01%) > acephate (0.05%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5%). The population of whitefly was reduced significantly in all the insecticidal treatments. However, among all the insecticides tested, acetamiprid proved to be most effective followed by imidacloprid and thiamethoxam. The treatments of acephate, fipronil, dimethoate and profenophos showed middle order of effectiveness, whereas, NSKE proved least effective followed by azadirachtin. The over all order of efficacy of insecticides on the basis of reduction in whitefly population was found to be acetamiprid (0.004%) > imidacloprid (0.005%) > thiamethoxam (0.005%) > acephate (0.05%) > fipronil (0.01%) > dimethoate (0.03%) > profenophos (0.05%) > azadirachtin (5ml/l) > NSKE (5.0%).

The maximum seed yield of 9.03 q ha^{-1} was obtained from the plots treated with imidacloprid followed by acetamiprid, thiamethoxam and fipronil which resulted in 8.02, 8.00 and 8.01 q ha^{-1} seed yield, respectively. The minimum seed yield of 6.40 q ha^{-1} was obtained from the plots treated with NSKE followed by azadirachtin yielded 6.95 q ha^{1}. The yield in untreated control was 5.60 q ha^{-1}.

The ‘avoidable losses’ in seed yield of cluster bean due to attack of jassid and whitefly were maximum (3.43 q ha^{-1} and 37.98 per cent) in untreated plots followed by NSKE and azadirachtin. The total avoidable losses from the plots treated with imidacloprid were taken as zero. The per cent increase in yield over control was maximum (61.25%) in imidacloprid followed by acetamiprid (43.21%) and thiamethoxam (42.86%). Whereas, it was minimum (14.29%) in plots treated with NSKE followed by azadirachtin (24.11%).

The highest incremental cost-benefit ratio (28.23) was obtained from the plots treated with acetamiprid followed by imidacloprid and thiamethoxam which resulted in a cost benefit ratio of 26.20 and 22.91, respectively, however, these treatments were proved to be most economic. The lowest benefit cost ratio of 2.95 was obtained in azadirachtin followed by NSKE (4.19).

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Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]

Suresh Kumar Yadav* (Scholar)

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ABSTRACT

An investigation on **"Population Dynamics and Management of Major Sucking Pests of Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]"** was conducted at Research Farm, College of Agriculture, Bikaner during *kharif*, 2012.

The study on the population dynamics of major sucking pests of cluster bean revealed that the infestation of jassid and whitefly appeared in the first week of September and increased up to the last week of September and declined gradually till the crop was matured in last week of October. The maximum, minimum temperature and rainfall showed significantly positive correlation whereas, the relative humidity revealed significant negative correlation with jassid and whitefly population.

Ten varieties of cluster bean were screened for resistance against jassid and whitefly, none of variety was found free from their attack. On the basis of peak jassid population, the varieties RGC-197, RGC-1031 and RGC-1017, RGC-1031 were categorized as least susceptible against jassid and whitefly, respectively.

Seven chemical insecticides and two botanicals were evaluated against jassid and whitefly on cluster bean crop, revealed that imidacloprid (0.005%), acetamiprid (0.004%) and thiamethoxam (0.005%) were found highly effective against jassid whereas, acetamiprid (0.004%), imidacloprid (0.005%) and thiamethoxam (0.005%) were found highly effective against whitefly. The maximum seed yield (9.03 q ha^{-1}) was obtained in the treatment of imidacloprid followed by acetamiprid and thiamethoxam. The highest incremental benefit cost ratio of 28.23 was obtained from acetamiprid followed by imidacloprid.

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** Thesis submitted for partial fulfillment of the degree in Entomology under the supervision of **Dr. H. L. Deshwal**, Assoc. Professor, Department of Entomology, (Swami Keshwanand Rajasthan Agricultural University, Bikaner.)

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ग्वार *साइमोप्सिस टेट्रागोनोलोबा* (एल.) तॉब के मुख्य चूसने वाले कीटों की जनसंख्या गतिशीलता एवं प्रबन्धन के अध्ययन हेतु *खरीफ*, 2012 में अनुसंधान प्रक्षेत्र, कृषि महाविद्यालय, बीकानेर पर शोध किया गया।

ग्वार के मुख्य चूसने वाले कीटों की जनसंख्या गतिशीलता के अध्ययन से ज्ञात हुआ कि हरातेला और सफेदमक्खी का प्रकोप सितम्बर माह के प्रथम सप्ताह में शुरू हुआ, और इनकी संख्या में बढोतरी सितम्बर के अन्तिम सप्ताह तक हुई तथा उसके बाद अक्टूबर के अन्तिम सप्ताह में फसल के पकने तक धीरे–धीरे इनकी संख्या में कमी हुई। हरातेला और सफेद मक्खी का अधिकतम तथा न्यूनतम तापमान और वर्षा के साथ सकारात्मक सार्थक तथा सापेक्षित आर्द्रता के साथ नकारात्मक सार्थक सहसंबन्ध पाया गया।

हरातेला और सफेद मक्खी के प्रति ग्वार की दस प्रजातियों की पारस्परिक प्रतिरोधकता देखी गयी, जिसमें से कोई भी प्रजाति उनके प्रकोप से मुक्त नहीं पायी गयी। सर्वोच्च प्रकोप के आधार पर आर.जी.सी.–197 व आर.जी.सी–1031 हरातेला के प्रति जबकि आर.जी.सी.–1017 व आर.जी.सी.–1031 सफेद मक्खी के प्रति कम सुग्राह्य पाई गई।

ग्वार में हरातेला व सफेद मक्खी के लिए सात रासायनिक और दो पादपजनित कीटनाशी के उपचारों से ज्ञात हुआ कि इमिडाक्लोप्रिड (0.005%), एसिटामीप्रिड (0.004%) व थाएमेथोक्जाम (0.005%) के दो छिड़काव हरातेला के प्रति अत्यन्त प्रभावी पाये गये जबकि एसिटामिप्रिड (0.004%), इमिडाक्लोप्रिड (0.005%) व थाएमिथोक्जाम (0.005%) के दो छिड़काव सफेद मक्खी के प्रति अत्यन्त प्रभावी पाये गये। अधिकतम बीज उपज इमिडाक्लोप्रिड (9.03 क्विंटल/हैक्टेयर) के उपचार से पायी गई जिसका अनुसरण एमिटामिप्रिड व थाएमिथोक्जाम ने किया। अधिकतम लाभ लागत 28.23 एसिटामिप्रिड से उपचारित करने पर मिला, जिसका अनुसरण इमिडाक्लोप्रिड ने किया।

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** कृषि संकाय के कीट विज्ञान विषय में स्नातकोत्तर उपाधि की आंशिक आवश्यकता की सम्पूर्ति हेतु शोध ग्रंथ, Mk- ,p-,y- ns'koky, सह प्राध्यापक कीट विज्ञान विभाग (स्वामी केशवानन्द राजस्थान कृषि विश्वविद्यालय) बीकानेर के निर्देशन में पूर्ण किया गया।

Appendix –I

Expenditure of insecticidal/botanicals treatments

S. No.	Treatments	Formulations	Conc.(%)/dose	Quantity needed ha^{-1} in two applications (lit or kg)	Rate per liter or kg (Rs.)	Cost of insecticides (Rs.)	Cost of labour (Rs.)*	Total expenditure (Rs.)
1	Imidacloprid	17.8 SL	0.005	0.34	2120	720.80	540	1260.8
2	Thiamethoxam	25 WG	0.005	0.24	1932	463.60	540	1003.6
3	Acetamiprid	20 EC	0.004	0.24	1200	288	540	828
4	Dimethoate	30 EC	0.03	1.20	540	648	540	1188
5	Profenophos	50 EC	0.05	1.20	505	606	540	1146
6	Acephate	75 SP	0.05	0.80	540	432	540	972
7	Fipronil	5 SC	0.01	2.4	1250	3000	540	3540
8	Azadirachatin	0.03 EC	0.03	6	480	2880	540	3420
9	NSKE	Lab. Prep.	5.00	25	40/lit.	1000	540	1540
10	Control	-	-	-	-	-	-	-

*Labour charges: Number of man days/ha/spray /two sprays
Total number of man days/ha for two sprays= 4 Labour charges @ Rs.135/day/man.