Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan

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Narendra Singh

THESIS

Master of Science in Agriculture

(Entomology)

2015

Department of Entomology
COLLEGE OF AGRICULTURE

SWAMI KESHWANAND RAJASTHAN
AGRICULTURAL UNIVERSITY BIKANER 334006

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Thesis

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By

Narendra Singh

2015

SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
COLLEGE OF AGRICULTURE, BIKANER

CERTIFICATE-I

Dated:...........

This is to certify that **Mr. Narendra Singh** had successfully completed the comprehensive examination held on **24-06-2014** as required under the regulation for the degree of **Master of Science in Agriculture (Entomology).**

(**Veer Singh**)
HEAD
Department of Entomology
College of Agriculture

Swami Keshwanand Rajasthan
Agricultural UniversityBikaner

SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
COLLEGE OF AGRICULTURE, BIKANER

CERTIFICATE-II

Dated:...........

This is to certify that the thesis entitled "**Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan.”** submitted for the degree of **Master of Science in Agriculture** in the subject of **Entomology** embodies bonafide research work carried out by **Mr. Narendra Singh** 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 11.11.2014.

(Veer Singh)
HEAD
Department of Entomology

(A. R. Naqvi)
Major Advisor

(I. J. Gulati)
DEAN
College of Agriculture
Bikaner

SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
COLLEGE OF AGRICULTURE, BIKANER
CERTIFICATE-III

Dated:..........

This is to certify that the thesis entitled "**Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan."** submitted by **Mr. Narendra Singh** to the Rajasthan Agricultural University, Bikaner in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the subject of **Entomology,** after recommendation by the external examiner, was defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory. We therefore, recommend that the thesis be approved.

(A. R. Naqvi)
Major Advisor

(H. L. Deshwal)
Advisor

(S. L. Godara)
Advisor

(D. K. Garg)
Dean PGS Nominee

(Veer Singh)
HEAD
Department of Entomology

(I. J. Gulati)
DEAN
College of Agriculture
Bikaner

Approved

(S. Gangopadhya)
DEAN
Post Graduate Studies,
Swami Keshwanand Rajasthan
Agricultural University,Bikaner

SWAMI KESHWANANDRAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
COLLEGE OF AGRICULTURE, BIKANER

CERTIFICATE-IV

Dated:...........

This is to certify that **Mr. Narendra Singh** of the Department of Entomology, College of Agriculture, Bikaner (Rajasthan) has made all corrections/modifications in the thesis entitled "**Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan."** Which were suggested by the external examiner and the advisory committee in the oral examination held on...............2015. The final copies of the thesis duly bound corrected were submitted on ....2015 and forwarded herewith for approval.

(A. R. Naqvi)
Major Advisor

(Veer Singh)
HEAD
Department of Entomology

Approved

(I. J. Gulati)
Dean
College of Agriculture Bikaner

(S. Gangopadhya)
Dean
Post Graduate Studies,
Swami Keshwanand Rajasthan
Agricultural University,Bikaner

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Place: Bikaner

Date: **(Narendra Singh)**

1. INTRODUCTION

Tomato, *Lycopersicon esculentum* Mill. belongs to family Solanaceae. It is one of the most popular and widely grown vegetable throughout the world ranking second in importance after potato in India. Tomato is cultivated on 879.63 thousand hectares in India with an annual production and average productivity as 18226.64 thoustand MT and 20.72 MT ha^{-1}, respectively. Whereas, in Rajasthan, the annual production of tomato is 73.57 thousand MT from 15.51 thousand hectares area with the average productivity of 4.74 MT ha^{-1} (Anonymous, 2012-13).

Tomato fruits are eaten raw, cooked or used to prepare soup, juice, ketchup, puree, paste, powder *etc*. Tomato fruits are good source of carbohydrates, proteins, fats, vitamins and minerals along with roughages, which are essential constituents of balanced diet. Tomato is also popular because of its high content of vitamin A and B. It also provides colour and flavor to the food. Moreover, tomato has got medicinal properties, the pulp and juice of fruit is digestible, promoter of gastric secretion and blood purifier. It is one of the richest vegetables which keep our stomach and intestine in good condition. Tomato seeds contain 24 per cent oil, which is used in canning industry.

Various factors have been attributed for low yield of tomato like poor quality seeds, incidence of pests and adverse climate. Among all the known factors, insect pests are of prime importance which affect not only its yield but also spoil the quality.

Butani (1977) has listed as many as 16 species of insect and non-insect pests infesting tomato crop right from germination to harvesting. Among the insect pests, tomato fruit borer, *Helicoverpa armigera* (Hub.), jassid, *Amrasca biguttula biguttula* (Ishida) and *Empoasca punjabensis* (Pruthi), tobacco caterpillar, *Spodoptera litura* (Fab.), thrips, *Thrips tabaci* (Linn.), aphids, *Aphis gossypii* (Glover), *Lipaphis erysimi* (Kalt.) and *Myzus persicae* (Sulzer), whitefly, *Bemisia tabaci* (Genn.) and epilachna beetle, *Epilachna dodecastigma* (Wiedemann) etc. occur regularly during the cropping season.

The tomato fruit borer or gram pod borer or american bollworm, *Helicoverpa armigera* (Hub.) is the most important insect pest infesting tomato fruits. This is a key pest as it attacks the cashable part of the plant *i.e.* fruits and makes them unfit for human consumption causing considerable crop loss leading up to 55 per cent (Selvanarayanan, 2000). It has been estimated that the crops worth Rs.1000 crore are lost annually by this pest (Jayraj *et al.,*1994). In order to prevent the loss caused by this insect and produce a quality crop, it is essential to manage the pest population at appropriate time with suitable methods. A thorough knowledge of seasonal activity of tomato fruit borer determines the predisposing climatic factors affecting their population dynamics. Chemical insecticides are generally preferred for the control of pest due to their easy availability and applicability, but their excessive and indiscriminate use has resulted in plethora of problems e.g. resurgence of minor insect pests, insecticidal resistance in insects, mortality of natural enemies and non target species and pesticide residue in harvested produce leading to various health hazards, besides the increased cost of cultivation per unit area. To overcome these problems, it has now become imperative to select safer insecticides that should protect the crop and keep the pest population below injury level.

In Rajasthan, the tomato crop is grown during winter, summer and kharif season but winter season crop is grown predominantly. Zone I C is Hyper Arid agro climatic part of Rajasthan and with the commencement of irrigation facilities through Indira Gandhi Nahar Pariyojana (IGNP) and tubewells, area under vegetable cultivation is increasing continuously. This needs a safer, economical and effective insect pest management system. As such no systematic study on insect pest management in tomato has been conducted in this zone. Keeping this in view, the present studies were taken up with the following objectives:

1. To study the seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato in relation to weather parameters.
2. To study the management of tomato fruit borer by incorporating newer and biorational insecticides.
3. To study the assessment of crop losses due to tomato fruit borer in tomato.

2. REVIEW OF LITERATURE

The pertinent review on the present investigation "Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan." have been reviewed and presented under following sub heads:

2.1 Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato, in relation to weather parameters.

2.2 Management of the tomato fruit borer by incorporating newer and bio-rational insecticides.

2.3 Assessment of crop losses due to tomato fruit borer in tomato.

2.1 Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato, in relation to weather parameters

Tomato fruit borer, *H. armigera* is a well known polyphagous insect. The larvae feed on the leaves and bore into fruits, thereby causing severe damage to the crop and significant losses in yield. Besides tomato, it is a regular pest of chickpea and cotton.

Parihar *et al.* (1986) reported low larval population of *H. armigera* upto the first week of February and population increased rapidly thereafter, reaching a peak in the last week of March. In the last week of April, the population declined to 4 larvae/10 plants. Percentage fruit infestation was low up to the end of February, while, in the 2nd week of April 33.04 to 50.08 per cent of fruits were infested. Thereafter, fruit infestation decreased reaching to a level of 1.44 to 2.84 per cent in the second week of May.

Prasad *et al*. (1989) recorded low larval population of *H. armigera* during the month of December when the minimum temperature was only 7.5^{0}C. The higher population of *H. armigera* was recorded during first week of March in chickpea which was sown on 22nd October as compared to 12th October sown crop.

Ravi and Verma (1997) observed that incidence of *H. armigera* initiated by first week of January and reached its peak by March.

Patel and Koshiya (1997) observed that pest was active during November to January-February, with a peak during December. Similarly, Patel and Koshiya (1999) observed that *H. armigera* is active from the third week of November to February with a peak in third week of December. Maximum and minimum temperature showed decreasing trends which contribute to population fluctuation of the pest during the study period.

Krishna *et al.* (2004) observed that the number of trap catches of *H. armigera* increased with the advancement of crop stage and increase in temperature. Trap catches increase by 3 to 6 fold per week between 7th to 10th standard weeks. The flowering and podding or pod maturation stages of the crop coincided with the increase in moth population.

Reddy and Kumar (2004) studied the correlation between abiotic factors and incidence of tomato fruit borer. They reported that the pest attained a peak in March-April and the population declined during October-November. The numbers of eggs per plant were highest in March, but the numbers of larvae per plant were highest in April. Highly significant positive correlations were found between egg and larval populations with the maximum and minimum temperature.

Kakati *et al.* (2005) reported that tomato fruit borer population increased from the first week of November and reached to its peak during the first week of December. Temperature, relative humidity, rainfall and bright sunshine hours was found to the associated with fluctuation in population.

Prasad *et al.* (2006) reported that moth catches of *H. armigera* were maximum with a mean of 3 to 22 moths per traps during September-October and 54-86 moths per traps during January-February. Humidity and rainfall were found to exhibit positive correlation in the pest population.

Sharma *et al.* (2006) found that the larvae of tomato fruit borer, *H. armigera* appeared on the crop by the end of May (21^{st}-22^{nd} SW), increased steadily and attained a peak by second fortnight of June (25^{th}-26^{th} SW), followed by a sharp decline till end July. The correlation between pest population and weather factors during the study period was inconsistent and statistically non-significant except during 2005 season when the correlation coefficient with maximum temperature was positive and significant.

Mohapatra *et al.* (2007) reported that relatively higher number of moths were trapped during March-April. Peak of moth population was recorded during third and fourth week of April 2004 and 2005, respectively. After attaining the peak, the moths possibly migrate to other areas of crop which attained susceptible stage.

Reddy *et al.* (2009) found that the incidence of the pod borer, *H. armigera* in chick pea commenced from secondweek of February *i.e.* in the early part of 1^{st} fortnight of February, with 0.05 mean larval population/plant. The larval population started increasing and reached its maximum of 12.97 mean larval population/plant during 4^{th} week of March (12^{th} standard week). The population had significantly positive correlation with both minimum and maximum temperature and the correlation coefficient being 0.71 and 0.82, respectively. The correlation coefficient of morning and afternoon relative humidity was -0.66. The rainfall and larval population showed positive correlation coefficient (0.03) but it was non-significant. The wind velocity and the sunshine hours showed positive non significant correlation with larval population.

Umbarkar *et al.* (2010) reported that the pest appeared with population density of 0.34 larvae per plant during 4^{th} week after sowing (31^{st} standard week) and reached to a peak of 3.42 larvae per plant in 37^{th} standard week (10^{th} week after sowing). Among the weather parameters, minimum temperature (r=-0.557) and evening relative humidity (r=-0.583) exhibited highly significant negative correlation with the gram pod borer population. Rest of the weather parameters had non-significant effect on pest population.

Chakraborty *et al.* (2011) observed that the maximum temperature, minimum temperature and temperature gradient showed a significant positive correlation with larval population. The correlation of average relative humidity on larval incidence was positive. Whereas, correlation of sunshine hours, rainfall and number of rainy days on pest incidence was negative.

Singh *et al.* (2011) observed the occurrence of *H. armigera* larvae in 50th standard week during 2005-06 and in 52nd standard week in 2006-07. The initial population was noticed to a low *ebb i.e*. 0.12 and 0.10 larvae per meter row length in 2005-06 and 2006-07, respectively. During both the years of experimentation pest population was lower from December to February and remained confined on vegetative growth. The pest attained its peak *i.e.* 3.81 and 4.20 larvae per meter row length in 15th standard week (second week of April) during both the years of investigation. After second week of April, the population went on declining till last picking of the crop.

Pandey *et al.* (2012) recorded highest larval population in the 4th week of March 2012 (12th standard week) with 15.3 mean larval population/plant. The population had significant positive correlation with both minimum and maximum temperature and the correlation coefficient was 0.62 and 0.64, respectively. The correlation coefficient of morning and afternoon relative humidity was negative (-0.76 and -0.73). The rainfall and larval population showed negative non significant correlation coefficient (-0.09).

Raghuwanshi and Garg (2013) reported that the maximum number of moth catches was observed during 10th SMW (5.15 moth/week). The activity declined and ended in 13rd SMW with 0.80 moth/week. The population of male moths showed a non-significant positive correlation with maximum and minimum temperature as well as relative humidity and rainfall.

Sharma *et al.* (2013) reported that the tomato fruit borer population was first initiated in the 14th standard week (2.50 borer/plant) with a population peak of 13.70 borer/ plant during the 21st standard week. The borer population exhibited significant positive correlation with the temperature (maximum, minimum) (r=0.921, 0.626), whereas, it was positive and non-significant with sunshine hours (r =0.246). A significant negative correlation between borer population and maximum and minimum relative humidity (r =-0.700, -0.641) and non-significant negative with rainfall (r =-0.420) was observed during the study.

Waluniba and Ao (2014) reported that the incidence of tomato fruit borer had a positive significant effect with maximum temperature and minimum relative humidity at 19th November and 19th December planting crop.

2.2 Management of the tomato fruit borer by incorporating newer and biorational insecticides

Ganguli and Dubey (1998) found NPV (250 LE/ha) + endosulfan (0.07%) as the most effective against *H. armigera* resulting in 47.96 per cent increase yield of tomato. Whereas, significantly decreased larval count of *H. armigera* and increased fruit yield of tomato was reported with the spray of same insecticidal combination by Gopalakrishnan and Ashokan (1998).

Pokharkar *et al.* (1998) reported that application of HaNPV with increasing number of sprays from 1 to 6 by reducing intervals from 15 to 5 days proportionately reduced the larval population and fruit damage and increased the yield of tomato fruits. Six sprays of HaNPV at 5 days interval, resulted in complete reduction of larval population, 8.08 per cent mean fruit damage, 271.45 q ha^{-1} mean total yield and 253.95 q ha^{-1} mean marketable yield. However, it was at par with 5 sprays of HaNPV at

7 days interval, 4 sprays of HaNPV at 10 days interval and 2 sprays of endosulfan at 15 days interval.

Wanjari *et al.* (1998) found that HaNPV, Dipel, Neem seed extract and endosulfan either alone or in a combination of two products were effective in reducing larval population of *H.armigera* and produced greater yield as compared to the untreated control.

Chandrakar *et al.* (1999) studied on the efficacy of HaNPV, Dipel (*Bacillus thuringiensis* subsp. *Kurstaki*) and/or endosulfan at 0.035 and 0.07 per cent. HaNPV + 0.07 per cent endosulfan (15 days after spraying; DAS), HaNPV + 0.035 per cent endosulfan (7 DAS), HaNPV + 0.07 per cent endosulfan (7 DAS) and two sprays of 0.07 per cent endosulfan at 15 days interval proved to be the best treatments as they recorded the lowest per cent fruit damage and the highest yields (465.78, 454.06, 435.03 and 432.43 q ha^{-1}, respectively). Dipel was ineffective.

Mehta *et al.* (2000) tested the bio-efficacy of different biopesticides against *H. armigera* on tomato for three seasons. Among the biopesticides tested, *B. thuringiensis* treated plots had lowest fruit infestation (10.68%) followed by HaNPV (11.95%) and azadirachtin (14.68%).

Chiranjeevi *et al.* (2002) studied on the efficacy of beta-cyfluthrin @ 2.5 or 8.5g a.i./ha. Rimon @ 50 or 75g a.i./ha, NPV @ 300 POB/ml, NPV + endosulfan @ 700g a.i./ha against the tomato fruit borer, *H. armigera.* All the treatments resulted in higher fruit yield as compared to the control.

Mahalingam *et al.* (2003) evaluated the efficacy of HaNPV individually and in combination with the recommended insecticides against the tomato fruit borer, *H. armigera.* They reported that larval mortality was higher in treatments with endosulfan at 1250 ml ha^{-1} (84.88 %) and monocrotophos at 750 ml ha^{-1} (83.12 %). These two treatments were followed by HaNPV at 250 LE ha^{-1} + monocrotophos at 375 ml ha^{-1} (49.85 %) and HaNPV at 250 LE ha^{-1} + endosulfan at 625 ml ha^{-1} (46.26 %). The larval mortality was 24.93 per cent in HaNPV at 250LE ha^{-1}

alone. The same trend was noticed on analysis of fruit damage. However, all the treatments were superior to the untreated control.

Ramasubramanian and Regupathy (2004) reported corrected percentage mortality of *H. armigera* as 76.9 to 80.0 per cent at recommended dose of spinosad.

Tripathi and Singh (2004) studied the toxicity of *B. thuringiensis* variety *kurstaki* and endosulfan. They reported that *B. thuringiensis kurstaki* and endosulfan alone were found significantly inferior than combination of both these insecticides.

Mani *et al*. (2005) observed that sprays of nuclear polyhedrosis virus (NPV) were highly effective for the control of *H. armigera* in tomato.

Murray *et al.* (2005) reported that indoxacarb and spinosad were consistently superior to other tested insecticides against *H. armigera.*

Singh *et al.* (2005) evaluated different insecticides against tomato fruit borer on tomato. They reported that acephate 75 SP at 2 kg ha^{-1}, had minimum fruit damage (7.44%), and highest yield (756.45 q ha^{-1}) along with maximum net return of Rs 75645/ha, which was at par with indoxacarb 14.5% SC at 500 ml ha^{-1} (fruit damage 8.93% and yield 602.78 q ha^{-1}). In untreated control, the fruit damage and yield were 43.68 per cent and 329.72 q ha^{-1}, respectively.

Siddegowda *et al.* (2006) tested the efficacy of spinosed 45 SC, indoxacarb 14.5 SC, profenofos 50 EC and chlorpyrifos 20 EC against *H. armigera.* Spinosad @ 22.5 g a.i./ha and indoxacarb @ 21.75 g a.i./ha recorded significantly lower pod damage (6.68 and 7.74%) as compared to other chemicals.

Patil *et al.* (2007) reported that indoxacarb @ 75 g a.i./ha and spinosad @ 50 g a.i./ha were found equally effective against bollworms by registering significantly lowest larval population of 1.55 and 1.59 larvae/plant, respectively followed by profenophos 50 EC @ 1000 g a.i./ha (1.84 larvae/plant) and quinalphos 25 EC 500 g a.i./ha (2.07 larvae/plant). The lowest damage to fruiting body was also noticed in spinosad and indoxacarb which gaves higher yield of 18.37 and 18.31 q ha^{-1}, respectively.

Kuttalam *et al*. (2008) tested the efficacy of different doses of flubendiamide 480 SC at 24, 36 and 48 g a.i./ha, indoxacarb 14.5 SC at 75 g a.i./ha and spinosad 2.5 SC at 75 g a.i./ha against fruit borer *H. armigera* in tomato. They observed that flubendiamide, indoxacarb and spinosad were significantly superior to untreated control in reducing *H. armigera*, population and mean fruit damage in tomato. While flubendiamide 480 SC at 48 g a.i./ha recorded lowest population of *H. armigera* than other remaining treatments.

Ravi *et al.* (2008) worked on the efficacy of different sequential application of microbials *viz., Ha*NPV @ $1.5x10^{12}$ POB/ha, *Bacillus thuringiensis* var. *kurstaki*, spinosad 45 SC @ 75 g a.i./ha and neem (neemazol 1.2 EC @ 1000 ml/ha) against *H. armigera* in comparison with sequential application of synthetic insecticides and untreated control on tomato. They found that different sequential application of microbials and neeml were equally effective as that of sequential application of synthetic chemical insecticides *viz.,* endosulfan 35 EC @ 350 g a.i./ha, quinalphos 25 EC @ 250 g a.i./ha and indoxacarb 14.5 SC @ 75 g a.i./ha in reducing *H. armigera* larval population and fruit damage.

Patel *et al.* (2009) evaluated the bio-efficacy of new molecule emmamectin benzoate 5 per cent SG (3 doses) in comparison to other insecticides (chlorpyriphos, quinalphos and endosulfan). They reported that all the insecticidal treatments were significantly effective as compared to control after 7 and 14 days of spray.

Ghosh *et al.* (2010) studied on bio-efficacy of spinosad against tomato fruit borer. They reported that spinosad was effective against *H. armigera* on tomato at 73 to 84 gm a.i./ha than quinalphos, lambda cyhalothrin and cypermethrin.

Dhaka *et al*. (2010) carried out field efficacy of sequential application of some noval insecticides *viz.,* novaluron 10 EC, indoxacarb

14.5 SC, bifenthrin 10 EC, λ cyhalothrin 5 EC, and bio pesticides *viz.,* HaNPV, *B. thuringiensis* var. *kurstaki* and neemarin, against *H. armigera* in comparision to sequential application of conventional insecticide, *i.e.* endosulfan 35 EC and untreated control on tomato hybrid Pusa Ruby. They reported that among different sequential application of insecticides, the lowest fruit infestation of 2.53 and 2.83 and highest yield of 39.45 and 35.85 q ha^{-1} with indoxacarb were recorded during both the season. While among the bio pesticides, neemarin followed by *B. thuringiensis* and NPV with mean fruit yield of 30.27 and 29.60, 28.17 and 27.16, and 26.70 and 26.11 q ha^{-1} were obtained in two seasons, respectively.

Ram and Singh (2011) evaluated the botanical, microbial and chemical insecticide against fruit borer damage in tomato. They recorded lowest fruit damage with *B. thuringiensis* var *kurstaki* (1g/l) + endosulfan (1ml/l) as 8.50 per cent and 7.98 per cent in w/w and n/n, respectively and as highest yield (231.03 q ha^{-1}) followed by endosulfan 35 EC (2ml/l) as 8.83 per cent and 8.13 per cent in w/w and n/n, respectively with mean yield 229.24 q ha^{-1}, while, *B. thuringiensis* var *kurstaki* (*Btk*) was recorded 10.37 and 9.10 per cent fruit damage with 224.25 q ha^{-1} mean marketable yield as compared to control with 31.09 and 31.03 per cent damage w/w and n/n with 196.97 q ha^{-1} mean marketable yield.

Ghosal *et al.* (2012) tested the efficacy of spinosad, rynaxypyr, indoxacarb, flubendiamide for the management of *H. armigera* on tomato under field conditions. They observed that rynaxypyr 18.5 SC @ 40 g a.i. ha^{-1} was superior over other treatments against tomato fruit borer, with 98.04 per cent reduction, closely followed by spinosad 45 SC @ 60 g a.i. ha^{-1} (88.03%), flubendiamide 20 WG @ 30 g a.i. ha^{-1} (87.96%), rynaxypyr 18.5 SC @ 20 g a.i. ha^{-1} (85.84%) and indoxacarb 14.5 SC @ 75 g g a.i. ha^{-1} (80.21%). The same trend was followed in case of yield also rynaxypyr @ 40 g a.i. ha^{-1} recorded the highest fruit yield of 34.74 q ha^{-1}.

Jat and Ameta (2013) evaluated the relative efficacy of biopesticides and newer insecticides against *H. armigera* (Hub.) on tomato in field conditions. They reported that three applications of flubendiamide 480 SC at 200 ml ha^{-1} was found significantly most effective, which caused highest mean reduction of population of tomato fruit borer larvae and fruit damage, 89.94 and 3.10 per cent. It was followed by spinosad 45 SC at 200 ml ha^{-1} and HaNPV at 250 LE/ha with 74.67 and 74.10 per cent mean reduction, respectively and were at par with each other and the spinosad observed 4.86 per cent fruit damage followed by HaNPV, *B. thuringiensis* @1.5 kg ha^{-1} and beta-cyfluthrin 2.5 SC were found moderately effective treatment being 8.16, 10.14 and 6.68 per cent fruit damage, respectively. The highest marketable yield of 265.68 q ha^{-1} was recorded in case of flubendiamide 480 SC @ 200 ml/ha with highest C: B ratio of 1:2.075. It was followed by spinosad (251.29 q ha^{-1}) and beta-cyfluthrin (238.38 q ha^{-1}).

Saini *et al.* (2013) evaluated bioefficacy of foliar application of novaluron @ 18.75, 37.5 and 75 g a.i./ha against *H. armigera.* They found that after 10 days of spray, novaluron at different doses was significantly superior to the standard check, quinalphos (525 g a.i./ha) with respect to pod damage and grain yield. It was concluded that novaluron even at the lowest dose (18.75 g a.i./ha) proved comparable/superior to the standard check, quinalphos and was significantly superior at higher dose (37.5 g a.i./ha) in reducing larval population and pod damage, and thus increasing grain yield of chickpea.

Katroju *et al.* (2014) evaluated the efficacy of insecticides *viz*., emamectin benzoate 5 SG @11 g a.i. and 22 g a.i. ha^{-1}, profenophos 50 EC @ 500 g a.i. and @1000 g a.i. ha^{-1}, spinosad 45 SC @ 100 g a.i. ha^{-1}, bifenthrin 10 EC @ 100 g a.i. ha^{-1} and *B. thuringiensis* @ 25 g a.i. ha^{-1} against tomato fruit borer *H. armigera*. Among all the insecticides, profenophos (1000 g a.i. ha^{-1}) was found to be the most effective one with a maximum reduction in fruit borer population (65.20%), minimum per cent of fruit damage (28.80%) and maximum yield (26.43 kg/20 m^2) followed by bifenthrin with reduced larval population of 64.51 per cent and damaged fruits 32.60 per cent.

Rahman *et al.* (2014) observed that the lowest tomato fruit infestation, both in number and weight, was obtained from treatment of HaNPV and *B. thuringiensis* alternate spraying (11.78%, 9.64%), followed by *B. thuringiensis* (13.25%, 10.85%) and HaNPV (17.67%, 13.11%). The highest fruit yield (16.92 t ha^{-1}) was obtained from HaNPV and *B. thuringiensis* alternate spraying plots followed by *B. thuringiensis* (16.65 t ha^{-1}) and HaNPV (14.73 t ha^{-1}). In case of MBCR, the highest MBCR was obtained from HaNPV and *B. thuringiensis* alternate spraying (5.30) followed by HaNPV (4.46) and *B. thuringiensis* (3.37).

2.3 Assessment of crop losses due to tomato fruit borer in tomato

Aheer *et al.* (1998) assessed the quantitative losses in tomato fruits caused by *H. armigera.* They found that fruit borer infestation in sprayed plots was 3.23 and 3.10 per cent as against 35.32 and 35.06 per cent in the unsprayed plot during 1991 and 1992, respectively. The yield of marketable fruits in 4 pickings was 188.9 and 330.9 quintals/ha in protected plots, as against 52.5 and 73.6 q ha^{-1} in the unsprayed plots. Yield loss was 72.19 and 77.76 per cent during 1991 and 1992, respectively.

Brar *et al.* (1999) reported less than 15 per cent to more than 31 per cent fruit damage in different varieties of tomoto caused by tomato fruit borer.

Kumar *et al*. (1999) found that in crop transplanted in the first week of April yield loss to the extent of 105.29, 76.02 and 57.02 per cent could be avoided by giving three sprays of acephate (0.05%), fenvalerate (0.01%) and endosulfan (0.05%), respectively. In crop transplanted in the first week of May yield loss of 32.64, 28.04 and 18.50 per cent could be avoided as a result of sprays of respective insecticides. Whereas in June-transplanted crop, 2 sprays each of acephate, fenvalerate and endosulfan helped in avoiding 25.03, 13.91 and 11.76 per cent yield loss, respectively. Irrespective of dates of transplanting, the average yield loss to the extent of 49.27, 36.54 and 26.59 per cent could be avoided by sprays of acephate, fenvalerate and endosulfan. The average net return per rupee invested worked out to be Rs 14 for acephate, Rs 13.18 for fenvalerate and Rs 7.80 for endosulfan sprays.

Chaudhuri *et al.* (2001) reported that in the winter, untreated and treated crops yielded 82.95 and 90.53 t ha^{-1}, respectively, in Abinash-II and 48.65 and 52.59 t ha^{-1}, respectively, in Pusa Ruby; in the spring-summer crop these treatments yielded 53.18 and 58.16 t ha^{-1}, respectively, in Abinash-II and 20.05 and 22.09 t ha^{-1}, respectively, in Pusa Ruby.

Shivaramu and Kulkarni (2008) assessed the yield losses in chilli due to the fruit borer *H. armigera* on plants in green house and field conditions. Under green house conditionin potted plants, the observed percentage fruit damage was 0, 13.46, 21.30, 31.18, 40.00, 46.65 and 49.30 with 0, 1, 2, 3, 4, 5 and 6 larvae per plant respectively. Yield reduction due to individual larva was 2.5 q ha^{-1}. Further, it was evident that 2, 3, 4, 5 and 6 larvae resulted in yield reductions of 4.26, 6.23, 7.77, 9.07 and 9.99 q ha^{-1}. In field experiment, it was revealed that the fruit damages were 0, 11.68, 18.84, 25.00, 31.25, 40.27 and 50.00 at 0, 1, 2, 3, 4, 5 and 6 larval loads per plant respectively. The yield reduction for 1, 2, 3, 4, 5 & 6 larvae per plant was 0, 2.49, 3.61, 4.72, 6.94, 8.05 and 11.11 q ha^{-1}, respectively. Based on regression equation, for every increase in larval number per plant the increase in damage to fruits was 7.87 per cent, while, yield decreased by 171 q ha^{-1}. The regression equation based on the cost of plant protection measures against the pest and market price of the produce projected that the economic threshold of *H. armigera* in chilli was 1.46 larvae / plant.

Kurl and Kumar (2011) worked on economic evaluation of *H. armigera* on tomato crop. They reported that on an average the fruit damage 24.2 per cent and 11.0 per cent by number and 34.8 per cent and

15.9 per cent by weight was recorded in Dev and Pusa Ruby, respectively.

Sinha and Nath (2011) reported that in various treatments, per cent damage on weight basis varied from 7.3-14.0 while it was 23.7 per cent in control. However, on number basis, infestation in different treatments ranged from 6.2-16.8 per cent while it was 23.4 per cent in untreated check.

Arora *et al.* (2012) reported 70–80 per cent fruit borer damage control as compared to check plots, resulting in enhanced fruit yield of 35 t ha^{-1} as compared to 15 t ha^{-1} in the check plots.

Kumar and Devi (2014) worked on the field efficacy, net profit and cost benefit ratio of certain insecticides against fruit borer, *H. armigera* in tomato. They reported that all the insecticidal treatments significantly recorded lower fruit yield losses as compared to control (50.85 %). Maximum fruit yield was registered by treatment of endosulfan (69.50 q ha^{-1}) which was followed by cypermethrin (64 q ha^{-1}) and fenvalerate (61.33 q ha^{-1}) and lowest in control (20.33 q ha^{-1}).

3. MATERIALS AND METHODS

The materials used and methodology adopted for conducting the experiment on "Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan." was envisaged in the plan of present work have been described in this chapter.

3.1 Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato, in relation to weather parameters

The experiment was conducted at the farm of Agricultural Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi,* 2013-14.

3.1.1 Layout of experiment, preparation of nursery and transplanting

To study the seasonal incidence of tomato fruit borer a block of 10×10 m^2 was laid out. The seed of tomato (variety RS-2) were sown in raised nursery beds in last week of October. The seedlings were transplanted in the experimental block after they attained a height of 15 cm with 8-10 leaves in the last week of November keeping row to row 60 cm and plant to plant distance of 40 cm. All recommended agronomical practices were followed from time to time to raise the crop successfully, as per Package and Practices Booklet of the region.

3.1.2 Population estimation

The pest population was recorded on 5 randomly selected and tagged plants in early hours when insects have minimum activity. The crop was kept under constant observation for appearance of pest after one week of transplanting. The observations were recorded at weekly intervals right from appearance of the pest till harvesting by direct visual counting of larvae on each plant.

3.1.3 Meteorological data

Weekly data of atmosphere temperature (maximum & minimum), relative humidity and total rainfall were obtained from meteorological observatory, Agricultural Research Station, Bikaner have been presented in Table 3.1 and Fig 3.1.

3.1.4 Statistical Analysis

Population data of *H. armigera* thus obtained were subjected to statistical analysis to find out the coefficient of correlation with maximum & minimum temperature, relative humidity and rainfall. A simple correlation was worked out between the population of *H. armigera* and abiotic environmental factor using the following formula.

$$r_{xy} = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{n}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{n}\right]}}$$

Where,

r_{xy} = Simple correlation coefficient

X = Variable *i.e.* abiotic component. (Maximum & minimum temperature, relative humidity and rainfall)

Y = Variable *i.e.* mean number of insect pests

n = Number of paired observations

Table 3.1: Mean weekly weather data for *rabi*, 2013 (November, 2013 to April, 2014) at Bikaner

SMW	Period	Temperature (°C)		Average relative humidity (%)		Total Rainfall (mm)
		Max.	Min.	Max.	Min.	
47	24-30 Nov	29.5	9.5	53.8	26.8	0.0
48	01-07 Dec.	30.1	11.3	57.4	20.2	0.0
49	08-14 Dec.	27.8	12.4	64.5	25.8	0.0
50	15-21 Dec.	27.8	11.0	60.0	28.4	0.0
51	22-28 Dec.	20.5	8.4	75.4	43.8	0.0
52	29-05 Jan.	20.1	10.6	61.0	25.7	0.0
1	06-12 Jan.	19.7	3.9	66.0	25.0	0.0
2	13-19 Jan.	18.7	3.5	70.0	38.0	0.0
3	20-26 Jan.	18.8	4.0	69.7	45.5	0.0
4	27-02 Feb.	20.6	5.8	77.5	48.5	0.0
5	03-09 Feb.	26.1	8.6	71.5	25.8	0.0
6	10-16 Feb.	23.0	9.2	69.2	25.4	0.0
7	17-23 Feb.	23.2	8.4	64.0	35.5	0.0
8	24-01 Feb.	26.0	9.1	58.2	35.7	0.0
9	02-08 March	25.9	11.3	53.8	38.2	0.0
10	09-15 March	27.8	14.6	55.8	33.4	0.0
11	16-22 March	30.1	11.4	68.7	40.0	0.0
12	23-29 March	32.7	16.4	78.7	42.0	0.0
13	30-05 April	31.8	18.1	72.1	43.3	0.0
14	06-12 April	36.2	18.4	63.5	18.4	5.4

Figure 3.1 Meteorological observations during the course of study period, 2013-14

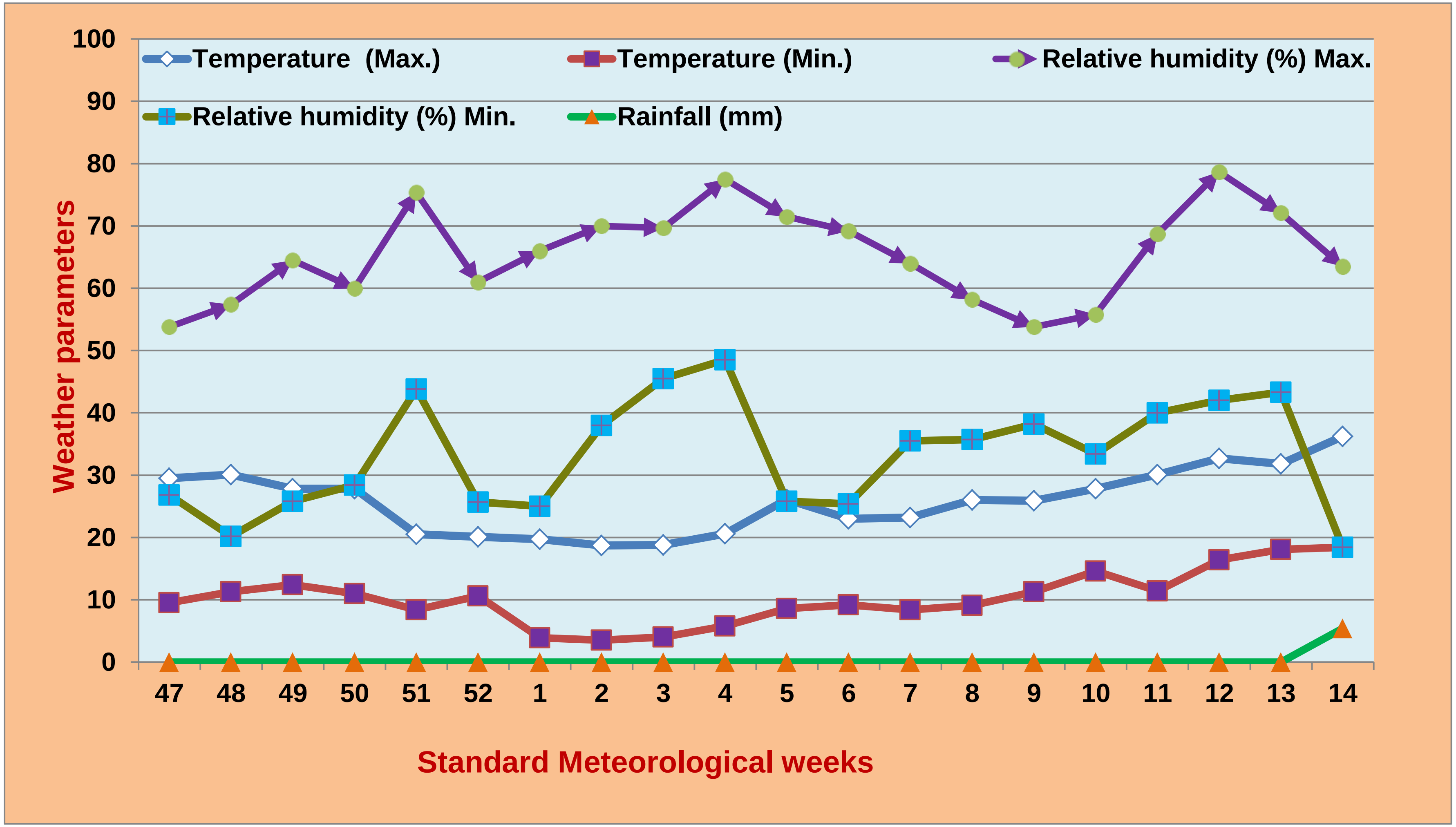
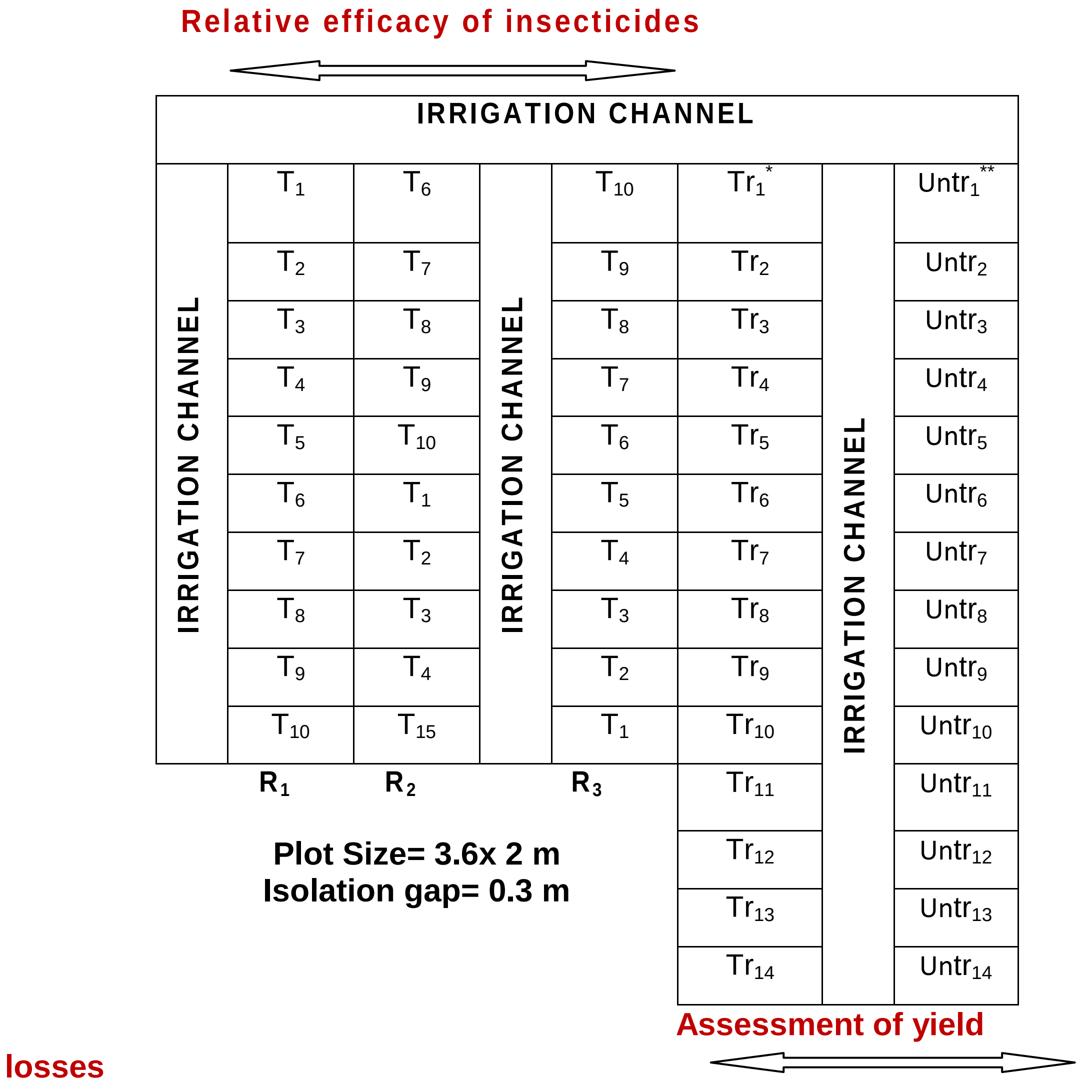


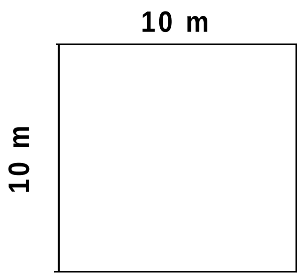
Plate 1: General view of Experimental Field

Fig. 3.2 Layout of Experiment



*Treated plot, **Untreated plot

For Seasonal Incidence



3.2 Management of the tomato fruit borer by incorporating newer and biorational insecticides

The experiment was laid out in a Randomized Block Design with three replications. Each plot size was $3.6 \times 2.0 \ m^2$. The seed of tomato (Variety "RS-2") were sown in raised nursery beds in last week of October. The seedlings were transplanted in the experimental block after they attained a height of 15 cm with 8-10 leaves in the last week of November keeping row to row 60 cm and plant to plant distance 40 cm. All recommended agronomical practices were followed from time to time to raise the crop successfully, as per Package and Practices Booklet of the region.

3.2.1 Insecticides and their application

The details of nine insecticides have been given in Table 3.2. Pre calibrated knapsack sprayer was used for spraying the insecticides on the crop. Care was taken to check the drift of insecticides, by putting polythene sheet screen around each plot at the time of spraying.

First spray was given after 9 weeks of transplanting of seedling and thereafter, repeated at 15 days intervals, in all two sprays were applied consecutively.

3.2.2 Observations

The population of tomato fruit borer was recorded 3, 6, 9, 12 and 15 day after spray. In case of fruit borer damage, the observation recorded on per cent infestation of fruits on number basis at 3, 6, 9, 12 and 15 day after spray. The yield data was recorded at each picking and the mean fruit yield was computed on the basis of cumulative data of all picking. The economics of the treatments was worked out.

Table 3.2: Details of insecticides/bio-pesticides used

S. No.	Chemical name	Trade name	Formulations	Concentration (%) Dosages
1.	Acephate	Orthene	75 SP	0.037
2.	Quinalphos	Ekalux	25EC	0.02
3.	*Bacillus thuringiensis*	Dipel	8L	0.012
4.	Chlorantraniliprole	Coragen	18.5 SC	0.02
5.	Abamectin	Emamectin benzoate	5 SG	0.01
6.	HaNPV	Elcar	250 LE/ha	_
7.	Indoxacarb	Avaunt	14.5 SC	0.01
8.	Novaluron	Counter	10 EC	0.01
9.	Spinosad	Success	2.5 SC	0.01
10.	Control	_	_	_

3.2.3 Statistical Analysis

The population data of *H. armigera* obtained was subjected for the conversion into per cent reduction using Henderson and Tilton (1952) formula as under:

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

Where,

T_a = Number of insects after treatment

T_b = Number of insects before treatment

C_a = Number of insects in untreated check after treatment

C_b = Number of insects in untreated check before treatment.

The reduction percentage figures were transferred into arc sine values and subjected to analysis of variance.

The data on percentage infestation of tomato fruits by borer was calculated at each picking by counting damage and healthy fruits in each spray application. The mean per cent fruit damage was calculated using formula:

$$Mean\ fruit\ damage\ (\%) = \frac{Number\ of\ damaged\ fruits}{Total\ number\ of\ fruits} \text{x}100$$

3.2.4 Economics and incremental cost benefit ratio

The economics of different treatments was calculated by taking into consideration the cost of application of different treatments and prevailing market price of tomato. The total marketable fruit yields obtained from all plots were computed on hectare basis. The increase in fruit yield was calculated as yield increase in treated plots compared to untreated plots as follows:

$$Per\ cent\ increased\ yield = \frac{Increase\ yield\ \text{in}\ treated\ plot}{Yield\ in\ untreated\ plot} \times 100$$

Incremental cost benefit ratio was calculated by deducting the cost of insecticidal treatments from price of increased yield over control by using following formula:

$$\text{B:C ratio over control} = \frac{\text{Returns in treatment (Rs./ha)}}{\text{Returns in control (Rs./ha)} + \text{Cost of insecticides and labour (Rs./ha)}}$$

3.3 Assessment of crop losses due to tomato fruit borer in tomato

3.3.1 Experimental details

1.	Season	-	*rabi,* 2013-14
2.	Experimental design	-	Paired plot (Paired t-test)
3.	Test crop	-	Tomato
4.	Treatments	-	2 (Treated and untreated)
5.	Replications	-	14
6.	Date of transplanting	-	November , 2013
7.	Plot size	-	3.6 m X 2 m = 7.2 m^2
8.	Row to Row distance	-	60 cm
9.	Plant to plant distance	-	40 cm
10.	Manures and Fertilizers	-	As per the Package and Practices of zone I C

3.3.2 Method of Observations

One set of plot referred, here as protected was provided complete protection by spraying with acephate 75 SP and quinalphos 25 EC alternatively at weekly interval. In another set of plots (unprotected plots) no insecticide was sprayed on the crop and was exposed to natural infestation. The infestation & fruit yield of treated and untreated plots was recorded at each picking.

To know the avoidable losses due to *H. armigera,* 10 plants were selected from each replication in both protected and unprotected set of plots and observation pertaining to various plant characters related to the plant yield *viz.,* height of plants, number of leaves, and weight of fruits was subjected to ‘t’ test and significance was tested. Finally loss in yield due to fruit borer was calculated by following formula (Leclerg, 1971).

$$s = \sqrt{\frac{Sum\ of\ square\ of\ the\ deviation\ of\ difference}{Number\ of\ paired\ plots - 1}}$$

$$sd = \frac{s}{\sqrt{n}}$$

$$t = \frac{\mathrm{X1 - X2}}{sd}$$

Where,

X_1 = yield in protected plots

X_2 = yield in unprotected plots

4. RESULTS

The results of studies undertaken during *rabi*, 2013-14 on "Eco-friendly management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan" are presented in the following heads :

4.1 Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato, in relation to weather parameters

The larval population of *H. armigera* was recorded at weekly interval during entire crop season of tomato. The data presented in Table 4.1 revealed that the incidence of *H. armigera* on tomato initiated in the last week of December (52nd SMW). Initial mean population of larvae on tomato variety RS-2 was 1.40 per five plants. The population lowered down upto 3rd SMW and thereafter, population increased but fluctuating trend (1.21 to 2.10 larvae/five plants) was recorded upto 9th SMW. The larval population increased and reached to peak in 12th SMW (4.45 larvae/five plants). Thereafter, it's population decreased gradually and negligible population was recorded upto 14th SMW.

4.1.1 Correlation between tomato fruit borer and abiotic factors

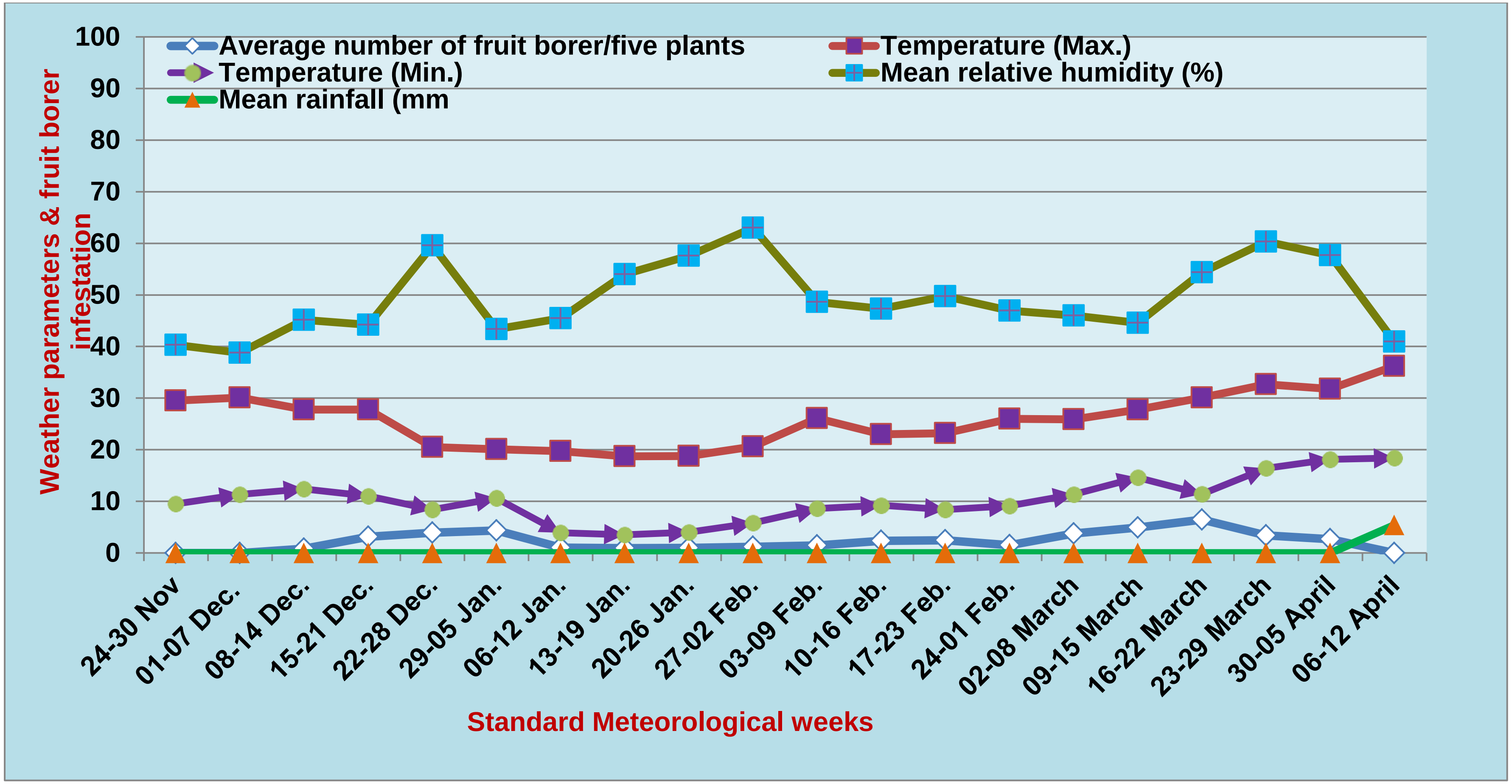
The incidence of fruit borer started at 20.1 **°C** maximum and 10.6 **°C** minimum temperature and 43.35 per cent relative humidity. The fruit borer population reached to its maximum (4.45 larvae/five plants) at 32.7 **°C** maximum, 16.4 **°C** minimum temperature and 60.35 per cent relative humidity.

A significant positive correlation was observed between pest population and maximum(r=0.600) and minimum temperature (r=0.562), whereas, it was non-significant positive with average relative humidity (r=0.291). A non-significant negative correlation was computed between pest population and total rainfall (r=-0.236).

Table 4.1: Seasonal incidence of *H. armigera* (Hub.) on tomato in relation to abiotic factors during *rabi*, 2013-14

SMW	Period of observation	Average number of fruit borer/five plants	Temperature (°C)		Average relative humidity (%)	Total rainfall (mm)
			Max.	Min.		
52	29-05 Jan.	1.40	20.1	10.6	43.35	0.0
1	06-12 Jan.	0.72	19.7	3.9	45.50	0.0
2	13-19 Jan.	0.92	18.7	3.5	54.00	0.0
3	20-26 Jan.	0.95	18.8	4.0	57.60	0.0
4	27-02 Feb.	1.21	20.6	5.8	63.00	0.0
5	03-09 Feb.	2.10	26.1	8.6	48.65	0.0
6	10-16 Feb.	1.48	23.0	9.2	47.30	0.0
7	17-23 Feb.	1.74	23.2	8.4	49.75	0.0
8	24-01 Feb.	2.05	26.0	9.1	46.95	0.0
9	02-08 March	1.97	25.9	11.3	46.00	0.0
10	09-15 March	2.63	27.8	14.6	44.60	0.0
11	16-22 March	3.20	30.1	11.4	54.35	0.0
12	23-29 March	4.45	32.7	16.4	60.35	0.0
13	30-05 April	2.17	31.8	18.1	57.70	0.0
14	06-12 April	1.02	36.2	18.4	40.95	5.4
Correlation coefficient			0.600*	0.562*	0.291NS	-0.236NS

Figure 4.1 Seasonal incidence of *H. armigera* (Hub.) on tomato in relation to abiotic factors during *rabi*, 2013-14



4.2 Relative efficacy of newer and biorational insecticides

Field trial was conducted during *rabi,* 2013-14 to evaluate the efficacy of nine insecticides against tomato fruit borer. The trends of effectiveness of different insecticides have been presented below:

4.2.1 Mean larval reduction

4.2.1.1 First spray

4.2.1.1.1 Three days after spray

The data recorded on mean reduction of fruit borer larvae revealed that all the treatments were significantly superior over control (33.75%) at three day after spraying (Table 4.2). Application of indoxacarb 14.5 SC was found most effective with 68.65 per cent mean reduction in population of fruit borer larvae. It was followed by novaluron 10 EC and acephate 75 SP which caused 66.97 and 64.53 per cent mean reduction, respectively. These treatments were statistically at par to each other. Application of chlorantraniliprole 18.5 SC, abamectin 5 SG, spinosad 2.5 SC and quinalphos 25 EC were found moderately effective registering 62.37, 61.45, 59.71 and 58.05 per cent mean reduction in population of fruit borer larvae, respectively. These treatments were statistically at par to each other. However, treatments of chlorantraniliprole, abamectin and spinosad were statistically at par to the treatment of acephate. While, *Bacillus thuringiensis* 8L and HaNPV were found as least effective treatments which caused 45.87 and 45.85 per cent mean reduction, respectively. These treatments were at par to each other and significantly inferior to all other treatments.

On the basis of mean data of all the nine insecticides, the descending order of efficacy of insecticides after three days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

4.2.1.1.2 Six days after spray

The data presented in Table 4.2 revealed that all the insecticides lowered down the population of fruit borer in comparison to control (33.25%). Application of indoxacarb was found most effective with 72.44 per cent mean reduction in population of fruit borer larvae. It was followed by novaluron and acephate which caused 72.10 and 69.52 per cent mean reduction, respectively. These treatments were statistically at par to each other. Application of chlorantraniliprole, abamectin, spinosad and quinalphos were found moderately effective with 65.08, 64.52, 62.00 and 59.68 per cent mean reduction in population of fruit borer larvae, respectively. The treatments of HaNPV and *B. thuringiensis* were proved to be the least effective insecticides causing 59.30 and 57.36 per cent mean reduction, respectively and were at par with quinalphos.

On the basis of mean data of all the nine insecticides, the descending order of efficacy of insecticides after six days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.1.3 Nine days after spray

All the insecticides lowered down the population of fruit borer in comparison to control (31.97%). The data presented in Table 4.2 indicated that indoxacarb was found most effective with 68.41 per cent mean reduction in population of fruit borer larvae followed by novaluron (65.14%) and acephate (63.74%). These three treatments were comparable to each other. Application of chlorantraniliprole, abamectin, spinosad, quinalphos and HaNPV were existed in middle order of their efficacy registered 61.11, 60.74, 57.55, 56.45 and 55.66 per cent mean reduction in population of fruit borer larvae, respectively. These treatments were statistically at par to each other. The treatment of *B. thuringiensis* (48.58%) was proved as least effective insecticide and comparable to the treatment of HaNPV only.

On the basis of mean data of all the nine insecticides, the descending order of efficacy of insecticides after nine days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.1.4 Twelve days after spray

Perusal to the data in the Table 4.2 revealed that indoxacarb was found most effective insecticides with 63.15 per cent mean reduction in population of fruit borer larvae. It was followed by novaluron, acephate and chlorantraniliprole which caused 62.56, 61.41 and 60.09 per cent mean reduction, respectively. These treatments were statistically at par to each other. Application of abamectin (48.59%), spinosad (46.04%) and quinalphos (45.16%) were found moderately effective. These three treatments were statistically at par to each other. The minimum larval population reduction was observed in the treatment of *B. thuringiensis* (40.32%) and HaNPV (32.11%) and categorized as least effective insecticides. The treatment *B. thuringiensis* was also at par with treatment of quinalphos.

On the basis of mean data of all the twelve insecticides, the descending order of efficacy of insecticides after three days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

4.2.1.1.5 Fifteen days after spray

It is evident from the Table 4.2 that per cent larval population reduction was higher in all the insecticides tested in comparison to control (19.95%). Maximum larval reduction was recorded in indoxacarb (56.26%) which was followed by novaluron, acephate and chlorantraniliprole caused 55.23, 54.13 and 52.92 per cent mean reduction, respectively. These treatments were statistically at par to each other and significantly superior to all other treatments. Treatments of *B. thuringiensis* (32.46%) and HaNPV (30.35%) proved least effective insecticide and statistically at par to the treatments of abamectin (38.71%), spinosad (37.20%) and quinalphos (35.81%).

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after fifteen days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

The overall efficacy of insecticides evaluated against fruit borer in respect of population reduction after first spray revealed that the insecticides indoxacarb (65.78%) was found most effective followed by novaluron (64.40%) and acephate (62.67%) whereas, chlorantraniliprole (60.31%), abamectin (54.80%), spinosad (52.50%) and quinalphos (51.03) ranked in middle order of efficacy. *B. thuringiensis* (44.92%) and HaNPV (44.65%) were found least effective treatments. The insecticides chlorantraniliprole was at par with abamectin and spinosad, whereas, the treatment *B. thuringiensis* was comparable to the treatment of quinalphos and spinosad.

The overall efficacy of insecticides at all the intervals pooled mean of first spray, the descending order of efficacy was: indoxacarb> novaluaran> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

4.2.1.2 Second spray

4.2.1.2.1 Three days after spray

The data presented in Table 4.3 revealed that all the treatments significantly lowered down the population of fruit borer larvae in comparison to control (29.55%) at three days after spray. Application of indoxacarb proved most effective with 68.78 per cent mean reduction in population of fruit borer larvae followed by novaluron and acephate which caused 65.52 and 62.28 per cent reduction, respectively. The treatments of novaluron and acephate were statistically at par to the chlorantraniliprole (60.03%) and abamectin (59.36%). While, spinosad,

Table 4.2: Reduction in larval population of *H. armigera* in tomato after 1st spray of insecticides/bio-pesticides

S. No.	Treatments	Reduction in larval population (%)					Mean
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS	
1	Acephate 75 SP @ 0.037%	64.53	69.52	63.74	61.41	54.13	62.67
		(53.45)*	(56.50)	(52.98)	(51.60)	(47.39)	(52.38)
2	Quinalphos 25 EC @ 0.02%	58.05	59.68	56.45	45.16	35.81	51.03
		(49.64)	(50.58)	(48.72)	(42.22)	(36.74)	(45.58)
3	*Bacillus thuringiensis* 8L @ 0.012%	45.87	57.36	48.58	40.32	32.46	44.92
		(42.63)	(49.23)	(44.19)	(39.42)	(34.73)	(42.04)
4	Chlorantraniliprole 18.5 SC @ 0.02%	62.37	65.08	61.11	60.09	52.92	60.31
		(52.17)	(53.79)	(51.51)	(50.90)	(46.70)	(51.01)
5	Abamectin 5 SG @ 0.01%	61.45	64.52	60.74	48.59	38.71	54.80
		(51.62)	(53.45)	(51.21)	(44.19)	(38.44)	(47.78)
6	HaNPV @ 250 LE/ha	45.85	59.30	55.66	32.11	30.35	44.65
		(42.61)	(50.39)	(48.25)	(34.48)	(33.39)	(41.82)
7	Indoxacarb 14.5 SC @ 0.01%	68.65	72.44	68.41	63.15	56.26	65.78
		(55.97)	(58.36)	(55.81)	(52.63)	(48.60)	(54.27)
8	Novaluron 10 EC @ 0.01%	66.97	72.10	65.14	62.56	55.23	64.40
		(54.93)	(58.15)	(53.82)	(52.28)	(48.00)	(53.44)
9	Spinosad 2.5 SC @ 0.01%	59.71	62.00	57.55	46.04	37.20	52.50
		(50.60)	(51.96)	(49.35)	(42.73)	(37.58)	(46.44)
10	Control	33.75	33.25	31.97	25.58	19.95	28.90
		(35.47)	(35.16)	(34.43)	(30.38)	(26.53)	(32.39)
	S.Em ±	1.08	1.31	1.38	1.48	1.742	1.40
	CD at 5%	3.22	3.88	4.10	4.40	5.176	4.15

*Figure in parentheses are angular transformed values, **Days after spray.

quinalphos, HaNPV and *B. thuringiensis* were found as least effective treatments which caused 53.46, 51.57, 51.26 and 50.54 per cent mean reduction, respectively and were at par with each other.

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after three days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.2.2 Six days after spray

The data presented in Table 4.3 indicated that significant difference existed in the larval population reduction by different insecticides tested and were significantly superior to that of control. The data of population reduction indicated that insecticide indoxacarb proved most effective and registered maximum population reduction (75.83%) followed by novaluron (72.16%) and acephate (71.21%). However, all these insecticides were statistically at par and significantly superior to rest of the treatments. The larval population reduction in chlorantraniliprole (65.40%) was comparable with that of abamectin (63.09%) and spinosad (60.85%). The insecticide *B. thuringiensis* (52.40%) proved least effective followed by HaNPV (54.79%) and quinalphos (55.03%). However, all these insecticides were comparable to each other and significantly superior to that of control (31.45%) and significantly inferior than rest of the insecticides.

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after six days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis.*

4.2.1.2.3 Nine days after spray

It is evident from the Table 4.3 that the per cent larval reduction in all the insecticides was significantly high in comparison to control (29.33%). Application of indoxacarb was found most effective with 69.84 per cent mean reduction in population of fruit borer larvae. It was followed by novaluron and acephate which caused 67.89 and 63.73 per cent mean reduction, respectively. These three treatments were statistically at par to each other. Application of chlorantraniliprole, abamectin, spinosad and quinalphos were found moderately effective with 60.74, 58.75, 54.39 and 53.27 per cent mean reduction in population of fruit borer larvae, respectively and were statistically at par to each other. However, chlorantraniliprole was comparable to novaluron and acephate. While, HaNPV and *B. thuringiensis* were found as least effective treatments which caused 51.15 and 50.48 per cent mean larval population reduction.

On the basis of mean data of all the nine insecticides, the descending order of efficacy of insecticides after nine days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos > HaNPV> *B. thuringiensis*.

4.2.1.2.4 Twelve days after spray

The data presented in Table 4.3 revealed that all the insecticides lowered down the population of fruit borer in comparison to control (22.00%). Application of indoxacarb was observed most effective with 52.38 per cent mean reduction in population of fruit borer larvae. It was followed by novaluron and acephate which caused 50.92 and 47.79 per cent mean reduction, respectively. These treatments were statistically at par to each other. Application of chlorantraniliprole and abamectin were found moderately effective with 45.55 and 45.20 per cent mean reduction in population of fruit borer larvae, respectively. These treatments were statistically at par to each other. However, abamectin was comparable to novaluron, acephate and chlorantraniliprole. While spinosad (40.79%), quinalphos (38.15%), *B. thuringiensis* (37.86%) and HaNPV (36.35%) were found as least effective treatments. Spinosad was statistically at par with abamectin and chlorantraniliprole also.

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after twelve days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

4.2.1.2.5 Fifteen days after spray

The data depicted in Table 4.3 revealed that all the insecticides lowered down the population of fruit borer in comparison to control (18.03%). The population mean data indicated that indoxacarb was found most effective with 41.96 per cent mean reduction in population of fruit borer larvae followed by novaluron and acephate which caused 39.97 and 37.99 per cent mean reduction, respectively. These three treatments were statistically at par to each other. Application of chlorantraniliprole and abamectin existed in middle order of efficacy registered 36.62 and 36.21 per cent mean reduction in population of fruit borer larvae, respectively. These treatments were statistically at par to each other. While, spinosad, quinalphos, HaNPV and *B. thuringiensis* were found as least effective treatments which caused 32.61, 31.46, 31.27 and 30.83 per cent mean reduction, respectively and were at par with each other. However, spinosad was comparable to that of chlorantraniliprole and abamectin.

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after fifteen days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos >HaNPV>*B. thuringiensis*.

The overall efficacy of insecticides evaluated against fruit borer in respect of population reduction after second spray revealed that insecticides indoxacarb (61.76%) was found most effective followed by novaluron (59.29%) and acephate (56.60%). Whereas, the insecticides chlorantraniliprole (53.67%), abamectin (52.52%) and spinosad (48.42%) ranked in middle order of efficacy. Quinalphos (45.90%), HaNPV (44.96%) and *B. thuringiensis* (44.42%) were found least effective.

The overall efficacy of insecticides at all the intervals of second spray, the descending order of efficacy was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis.*

Table 4.3: Reduction in larval population of *H. armigera* in tomato after 2nd spray of insecticides/bio-pesticides

S. No.	Treatments	Reduction in larval population (%)					Mean
		3 DAS**	**6 DAS**	**9 DAS**	**12 DAS**	**15 DAS**	
1	Acephate 75 SP @ 0.037%	62.28	71.21	63.73	47.79	37.99	56.60
		(52.11)*	(57.58)	(52.97)	(43.73)	(38.05)	(48.89)
2	Quinalphos 25 EC @ 0.02%	51.57	55.03	53.27	38.15	31.46	45.90
		(45.90)	(47.89)	(46.88)	(38.14)	(34.11)	(42.58)
3	*Bacillus thuringiensis* 8L @ 0.012%	50.54	52.40	50.48	37.86	30.83	44.42
		(45.31)	(46.38)	(45.28)	(37.97)	(33.73)	(41.73)
4	Chlorantraniliprole 18.5 SC @ 0.02%	60.03	65.40	60.74	45.55	36.62	53.67
		(50.79)	(53.98)	(51.21)	(42.45)	(37.24)	(47.13)
5	Abamectin 5 SG @ 0.01%	59.36	63.09	58.75	45.20	36.21	52.52
		(50.40)	(52.60)	(50.04)	(42.24)	(36.99)	(46.45)
6	HaNPV @ 250 LE/ha	51.26	54.79	51.15	36.35	31.27	44.96
		(45.72)	(47.76)	(45.66)	(37.08)	(34.00)	(42.04)
7	Indoxacarb 14.5 SC @ 0.01%	68.78	75.83	69.84	52.38	41.96	61.76
		(56.04)	(60.69)	(56.70)	(46.37)	(40.37)	(52.03)
8	Novaluron 10 EC @ 0.01%	65.52	72.16	67.89	50.92	39.97	59.29
		(54.24)	(58.19)	(55.75)	(45.52)	(39.16)	(50.57)
9	Spinosad 2.5 SC @ 0.01%	53.46	60.85	54.39	40.79	32.61	48.42
		(46.99)	(51.28)	(47.52)	(39.69)	(34.82)	(44.06)
10	Control	29.55	31.45	29.33	22.00	18.03	26.07
		(32.93)	(34.11)	(32.79)	(27.97)	(25.12)	(30.58)
	S.Em ±	1.59	1.44	1.66	1.18	0.96	1.37
	CD at 5%	4.71	4.28	4.94	3.52	2.86	4.06

*Figure in parentheses are angular transformed values, **Days after spray.

4.2.1.3 Overall efficacy of newer insecticides/bio-pesticides after two sprays on larval population reduction

4.2.1.3.1 Three days after spray

The data on cumulative effectiveness of different treatments presented in Table 4.4 revealed that after the two applications, indoxacarb proved to be most effective in reducing the larval population of fruit borer up to 68.72 per cent. It was closely followed by novaluron and acephate which exhibited 66.25 and 63.41 per cent population reduction, respectively. Chlorantraniliprole, abamectin and spinosad were the next in order of effectiveness which caused reduction of 61.20, 60.40 and 56.59 per cent, respectively. However, chlorantraniliprole was comparable to novaluron and acephate. Quinalphos and HaNPV exhibited 54.81 and 48.56 per cent reduction and at par to each other. *B. thuringiensis* (48.21%) was least effective and comparable with HaNPV.

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after third day of both sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.3.2 Six days after spray

After studying the average of both sprays at six days of spraying, it was found that all the insecticides significantly lowered down the pest population as compared to control (32.35%). Indoxacarb proved most effective in reducing the larval population of fruit borer (74.13%) followed by novaluron and acephate which exhibited 72.13 and 70.37 per cent reduction, respectively. Chlorantraniliprole, abamectin and spinosad proved in middle order of efficacy registered population reduction of 65.24, 63.80 and 61.43 per cent, respectively. *B. thuringiensis* (54.88%) observed least effective insecticide and statistically at par with quinalphos (57.35%) and HaNPV (57.05%).

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after six days of two spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin > spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.3.3 Nine days after spray

After nine days of spraying, it was found that indoxacarb (69.12%) proved most effective in reducing the larval population of fruit borer followed by novaluron and acephate which exhibited 66.51 and 63.73 per cent reduction, respectively. Quinalphos, HaNPV and *B. thuringiensis* exhibited 54.86, 53.40 and 49.53 per cent reduction and prooved least effective insecticides. Chlorantraniliprole and abamectin were in the moderate group of insecticidal efficacy which caused 60.93, 59.74 per cent population reduction, respectively and statistically at par to each other. The treatment spinosad indicated 55.97 per cent reduction in larval population of fruit borer. However, spinosad was comparable to chlorantraniliprole, abamectin and quinalphos.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after nine days of two sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.1.3.4 Twelve days after spray

Twelve days after spraying, indoxacarb (57.77%) proved as the most effective in reducing the larval population of fruit borer. It was followed by novaluron (56.74%) and acephate (54.60%). Chlorantraniliprole, abamectin and spinosad were the next in order of efficacy which caused population reduction of 52.82, 46.89 and 43.42 per cent, respectively. HaNPV (34.23%) proved as least effective insecticide and comparable to quinalphos (41.66%) and *B. thuringiensis* (39.09%).

On the basis of mean data of all the nine treatments, the descending order of efficacy of insecticides after twelve days of two sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

4.2.1.3.5 Fifteen days after spray

After computing the average of both two sprays at fifteen days of spraying, it was found that indoxacarb proved most effective in reducing the larval population of fruit borer upto 49.11 per cent. It was closely followed by novaluron, acephate and chlorantraniliprole which exhibited 47.60, 46.06 and 44.77 per cent reduction, respectively. Abamectin, spinosad and quinalphos were the next in order of effectiveness which caused overall reduction of, 37.46, 34.91 and 33.63 per cent, respectively. *B. thuringiensis* and HaNPV exhibited 31.65 and 30.81 per cent reduction and were least effective. However, these two insecticides are statistically at par with spinosad and quinalphos at fifteen day of spray.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after fifteen days of two spray was: ind oxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

The overall efficacy of insecticide evaluated against fruit borer in respect of population reduction after two sprays revealed that indoxacarb (63.37%) proved most effective insecticide followed novaluron (61.85%), acephate (59.65%) and chlorantraniliprole (56.99%). Whereas, abamectin, spinosad and quinalphos registered 53.66, 50.46 and 48.46 per cent population reduction, respectively ranked in middle order of their efficacy. HaNPV (44.81%) and *B. thuringiensis* (44.67%) proved as least effective insecticides and both are comparable to the quinalphos.

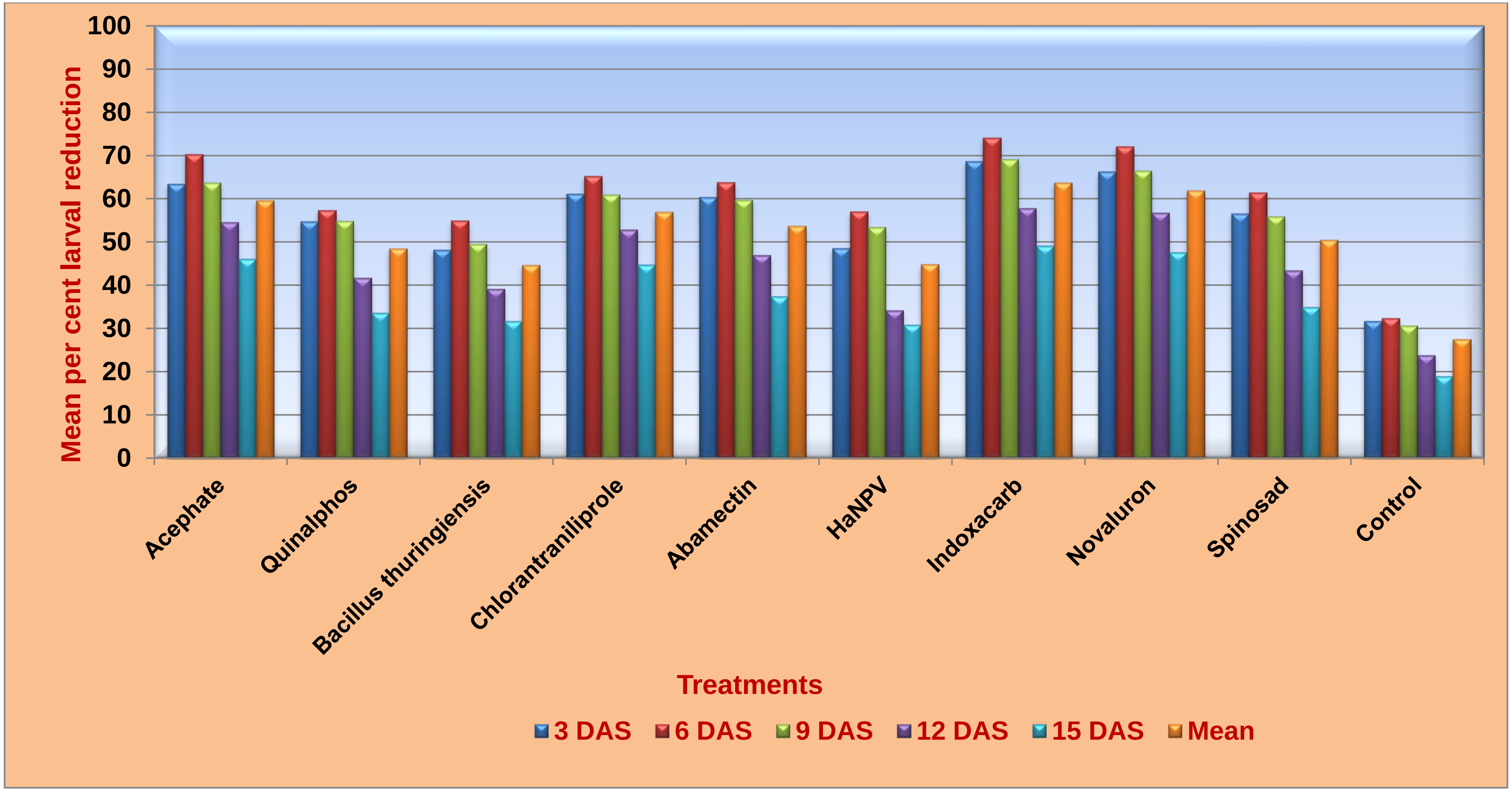
The overall efficacy of insecticides at all intervals after two sprays, the descending order of efficacy was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> *B. thuringiensis*> HaNPV.

Table 4.4: Overall efficacy of insecticides/bio-pesticides on the larval reduction of *H. armigera* infesting tomato after two sprays

S. No.	Treatments	Reduction in larval population (%)					Mean
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS	
1	Acephate 75 SP @ 0.037%	63.41	70.37	63.73	54.60	46.06	59.63
		(52.78)*	(57.03)	(52.98)	(47.64)	(42.73)	(50.63)
2	Quinalphos 25 EC @ 0.02%	54.81	57.35	54.86	41.66	33.63	48.46
		(47.76)	(49.23)	(47.79)	(40.20)	(35.44)	(44.08)
3	*Bacillus thuringiensis* 8L @ 0.012%	48.21	54.88	49.53	39.09	31.65	44.67
		(43.97)	(47.80)	(44.73)	(38.70)	(34.23)	(41.89)
4	Chlorantraniliprole 18.5 SC @ 0.02%	61.20	65.24	60.93	52.82	44.77	56.99
		(51.48)	(53.88)	(51.35)	(46.63)	(41.99)	(49.07)
5	Abamectin 5 SG @ 0.01%	60.40	63.80	59.74	46.89	37.46	53.66
		(51.01)	(53.02)	(50.62)	(43.22)	(37.73)	(47.12)
6	HaNPV @ 250 LE/ha	48.56	57.05	53.40	34.23	30.81	44.81
		(44.17)	(49.05)	(46.95)	(35.80)	(33.70)	(41.93)
7	Indoxacarb 14.5 SC @ 0.01%	68.72	74.13	69.12	57.77	49.11	63.77
		(56.00)	(59.46)	(56.25)	(49.47)	(44.49)	(53.13)
8	Novaluron 10 EC @ 0.01%	66.25	72.13	66.51	56.74	47.60	61.85
		(54.55)	(58.14)	(54.71)	(48.89)	(43.62)	(51.98)
9	Spinosad 2.5 SC @ 0.01%	56.59	61.43	55.97	43.42	34.91	50.46
		(48.78)	(51.61)	(48.43)	(41.22)	(36.21)	(45.25)
10	Control	31.65	32.35	30.65	23.79	18.99	27.49
		(34.22)	(34.65)	(33.62)	(29.19)	(25.83)	(31.50)
	S.Em ±	1.11	0.89	1.11	0.97	1.043	1.02
	CD at 5%	3.29	2.65	3.31	2.88	3.098	3.04

*Figure in parentheses are angular transformed values, **Days after spray.

Figure 4.2 Overall reduction in larval population of *H. armigera* in tomato after two sprays of insecticides/bio-pesticides



4.2.2 Mean fruit damage

4.2.2.1 First spray

4.2.2.1.1 Three days after spray

Data presented in Table 4.5 revealed that all treatments were found significantly superior over control in reducing fruit damage at three days after spray. Indoxacarb (0.01%) exhibited minimum mean fruit damage of 9.33 per cent followed by novaluron (0.01%) and acephate (0.037%) with 10.24, and 10.63 per cent mean fruit damage, respectively. These treatments were found statistically at par to each other. However, acephate was also at par with that of chlorantraniliprole (0.02%). The insecticides chlorantraniliprole, abamectin (0.01%) and spinosad (0.01%) formed next best group of insecticides registering 12.37, 13.59 and 13.86 per cent mean fruit damage, respectively. These were at par to each other. The maximum fruit infestation on number basis was recorded in *B. thuringiensis* (0.012%), HaNPV (250 LE/ha) and quinalphos (0.02%) with mean fruit damage of 19.25, 18.52 and 17.13 per cent, respectively as against 24.39 per cent in untreated plots.

On the basis of mean data of fruit damage the descending order of efficacy of different insecticides after three days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.1.2 Six days after spray

After six days of treatment, the order of efficacy remained the same. Indoxacarb was most effective with minimum fruit damage of 8.56 per cent followed by novaluron (9.47%) and acephate (10.09%). The next in order of efficacy were chlorantraniliprole, abamectin and spinosad which exhibited moderate effective group of insecticides against fruit borer with 11.57, 12.67 and 12.75 per cent mean fruit damage, respectively. These were at par to each other. The remaining treatments *viz*., quinalphos, HaNPV and *B. thuringiensis* were found least effective with mean fruit damage of 16.63, 18.25 and 19.11 per cent, respectively as against 30.95 per cent in untreated plots.

On the basis of data, the efficacy of different insecticides after six days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.1.3 Nine days after spray

The data presented in Table 4.5 revealed that all the insecticides significantly lowered down the infestation of borer in tomato fruits in comparison to control (29.77%). The data indicated that minimum fruit damage on number basis was recorded in indoxacarb (9.50%) followed by novaluron (10.72%) and acephate (11.24%). The insecticides *B. thuringiensis* and HaNPV exhibited least effectiveness in respect to tomato fruit borer infestation registered 20.38 and 20.15 per cent fruit infestation on number basis. The insecticides chlorantraniliprole, abamectin, spinosad and quinalphos ranked in middle order of their efficacy against fruit borer infestation causing 12.97, 14.16, 14.54 and 17.57 per cent fruit infestation, respectively. However, the insecticides chlorantraniliprole was statistically at par with that of acephate.

On the basis of data, the efficacy of different insecticides after nine days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.1.4 Twelve days after spray

The significant differences were exhibited in the infestation due to insecticides tested and were significantly superior to that of control (31.54%). The data on number basis indicated that indoxacarb proved most effective and registered minimum infestation (10.06%) followed by novaluron (11.11%) and acephate (12.05%). All these three insecticides were at par and superior to rest of the treatments. However, the treatment acephate was statistically at par to that of chlorantraniliprole. The infestation in chlorantraniliprole (13.75%) was also comparable with that of abamectin (14.95%) and spinosad (14.98%). The insecticides *B. thuringiensis,* HaNPV and quinalphos proved least effective group exhibited 20.75, 20.55 and 17.98 per cent infestation, respectively. These three insecticides were comparable to each other and significantly inferior to rest of the insecticides tested.

On the basis of data, the efficacy of different insecticides after twelve days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.1.5 Fifteen days after spray

The efficacy of all nine treatments again followed the same trend after fifteen days of spray. Indoxacarb exhibited minimum mean fruit damage of 10.97 per cent. It was followed by novaluron and acephate with 11.89, and 13.21 per cent mean fruit damage, respectively. These treatments were found statistically at par to each other. The spray of chlorantraniliprole, abamectin and spinosad was found moderately effective against fruit borer with 14.35, 15.45 and 16.41 per cent mean fruit damage, respectively and were at par to each other. The remaining treatments *viz*., quinalphos, HaNPV and *B. thuringiensis* were found least effective with mean fruit damage of 18.65, 21.56 and 21.88 per cent, respectively as against 34.65 per cent in untreated control.

On the basis of data, the efficacy of different insecticides after fifteen days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

The mean data of all the intervals after first spray indicated that indoxacarb (9.68%) proved as most effective insecticides against tomato fruit borer. It was followed by novaluron and acephate which caused 10.69 and 11.44 per cent infestation on number basis, respectively. The insecticides *B. thuringiensis* and HaNPV registered 20.27 and 19.81 per cent fruit damage proved as the least effective insecticides. These two insecticides were statistically at par to that of quinalphos (17.59%) and significantly inferior to rest of the insecticides. Chlorantraniliprole, abamectin and spinosad ranked in middle order of their efficacy registered 13.00, 14.16 and 14.51 per cent fruit infestation, respectively. All these three

Table 4.5: Efficacy of insecticides/biopesticides against *H. armigera* larvae infesting tomato fruits after 1st Spray

S. No.	Treatments	Fruit damage (%)					Mean
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS	
1	Acephate 75 SP @ 0.037%	10.63	10.09	11.24	12.05	13.21	11.44
		(19.03)*	(18.52)	(19.59)	(20.31)	(21.25)	(19.74)
2	Quinalphos 25 EC @ 0.02%	17.13	16.63	17.57	17.98	18.65	17.59
		(24.45)	(24.07)	(24.77)	(25.08)	(25.57)	(24.79)
3	*Bacillus thuringiensis* 8L @ 0.012%	19.25	19.11	20.38	20.75	21.88	20.27
		(26.02)	(25.92)	(26.83)	(27.10)	(27.89)	(26.75)
4	Chlorantraniliprole 18.5 SC @ 0.02%	12.37	11.57	12.97	13.75	14.35	13.00
		(20.59)	(19.89)	(21.07)	(21.73)	(22.23)	(21.10)
5	Abamectin 5 SG @ 0.01%	13.59	12.67	14.16	14.95	15.45	14.16
		(21.63)	(20.85)	(22.10)	(22.71)	(23.11)	(22.08)
6	HaNPV @ 250 LE/ha	18.52	18.25	20.15	20.55	21.56	19.81
		(25.48)	(25.27)	(26.67)	(26.92)	(27.63)	(26.39)
7	Indoxacarb 14.5 SC @ 0.01%	9.33	8.56	9.50	10.06	10.97	9.68
		(17.78)	(17.01)	(17.95)	(18.49)	(19.34)	(18.11)
8	Novaluron 10 EC @ 0.01%	10.24	9.47	10.72	11.11	11.89	10.69
		(18.66)	(17.92)	(19.11)	(19.47)	(20.17)	(19.07)
9	Spinosad 2.5 SC @ 0.01%	13.86	12.75	14.54	14.98	16.41	14.51
		(21.85)	(20.92)	(22.20)	(22.74)	(23.89)	(22.32)
10	Control	24.16	26.55	29.77	31.54	34.65	29.33
		(29.39)	(30.95)	(33.07)	(34.17)	(36.06)	(32.73)
	S.Em ±	0.60	0.68	0.94	0.73	0.82	0.75
	CD at 5%	1.77	2.03	2.78	2.16	2.44	2.24

*Figure in parentheses are angular transformed values, **Days after spray.

insecticides were at par to each other. However, Chlorantraniliprole is also comparable with that of novaluron and acephate.

The overall efficacy of insecticides at all the intervals of first spray descending order of efficacy was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis.*

4.2.2.2 Second spray

4.2.2.2.1 Three days after spray

Data presented in Table 4.6 revealed that all treatments were found significantly superior over control (37.80%) in reducing fruit damage on number basis at three days after spray. Indoxacarb exhibited minimum mean fruit damage of 8.57 per cent followed by novaluron (9.64%) and acephate (10.00%). All these three insecticides were found statistically at par to each other. The next in order of efficacy were chlorantraniliprole, abamectin and spinosad against fruit borer with 11.57, 12.79 and 13.36 per cent mean fruit damage, respectively. The maximum fruit infestation was recorded in *B. thuringiensis* (17.80%) followed by HaNPV (16.75%) and quinalphos (16.68%). These three insecticides were comparable to each other and significantly inferior to other insecticides.

On the basis of data, the efficacy of different insecticides after three days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis.*

4.2.2.2.2 Six days after spray

After six days of treatment application, the order of efficacy remained the same. Indoxacarb was most effective with minimum fruit damage of 7.44 per cent followed by novaluron with 9.04 per cent and acephate with 9.34 per cent fruit damage. The insecticides chlorantraniliprole, abamectin and spinosad formed next best group of efficacy against fruit borer registering 10.72, 12.12 and 12.61 per cent mean fruit damage on number basis, respectively. These were statistically at par to each other. However, chlorantraniliprole was comparable to acephate. The remaining treatments *viz.*, quinalphos, HaNPV and *B. thuringiensis* were found least effective with mean fruit damage of 15.87, 16.08 and 16.78 per cent, respectively as against 39.27 per cent in untreated plots.

On the basis of data, the efficacy of different insecticides after six days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.2.3 Nine days after spray

The data presented in Table 4.6 indicated that significant difference existed among the insecticides tested and were significantly superior to that of control (43.25%) on number basis fruit infestation. Indoxacarb proved most effective and registered minimum mean fruit damage of 8.98 per cent on number basis followed by novaluron (9.97%) and acephate (10.65%). These three treatments were found statistically at par to each other. The spray of chlorantraniliprole, abamectin and spinosad existed in moderately group of effecacy against fruit borer with 11.87, 13.06 and 13.88 per cent mean fruit damage, respectively and were at par to each other. However, chlorantraniliprole and abamectin were comparable to novaluron and acephate. The treatments quinalphos, HaNPV and *B. thuringiensis* were found least effective with mean fruit damage of 16.05, 17.11 and 17.99 per cent, respectively and statistically at par to each other, however, quinalphos is comparable to spinosad.

On the basis of data, the efficacy of different insecticides after nine days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.2.4 Twelve days after spray

All the insecticides significantly lowered down the infestation of tomato fruit borer in comparison to control (45.52%). The data of fruit damage on number basis indicated that indoxacarb was found highly effective with minimum fruit damage of 9.35 per cent followed by novaluron with 10.22 per cent and acephate with 11.04 per cent fruit damage (Table 4.6). These three treatments were statistically at par to each other. The next best group of insecticides was chlorantraniliprole (12.45%), abamectin (13.79%) and spinosad (14.16%). These three insecticides were at par and ranked in middle order of efficacy. The *B. thuringiensis* (18.35%) proved least effective followed by HaNPV (17.99%) and quinalphos (16.75%). However, quinalphos was also comparable to spinosad.

On the basis of data, the efficacy of different insecticides after twelve days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.2.5 Fifteen days after spray

Perusal of the data in Table 4.6 indicated that Indoxacarb exhibited minimum mean fruit damage of 9.96 per cent. It was followed by novaluron and acephate with 10.94 and 11.89 per cent, respectively. These treatments were found statistically at par to each other. The spray of chlorantraniliprole, abamectin and spinosad was found moderately effective against fruit borer with 13.07, 14.13 and 14.67 per cent mean fruit damage, respectively and were at par to each other. The remaining treatments *viz.*, quinalphos, HaNPV and *B. thuringiensis* were found least effective with mean fruit damage of 17.22, 18.65 and 18.96 per cent, respectively as against 47.41 per cent in untreated plots.

On the basis of data, the efficacy of different insecticides after fifteen days of spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

Table 4.6: Efficacy of insecticides/bio-pesticides against *H. armigera* larvae infesting tomato fruits after 2nd Spray

S. No.	Treatments	Fruit damage (%)					Mean
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS	
1	Acephate 75 SP @ 0.037%	10.00	9.34	10.65	11.04	11.89	10.58
		(18.43)*	(17.79)	(19.05)	(19.40)	(20.11)	(18.96)
2	Quinalphos 25 EC @ 0.02%	16.68	15.87	16.05	16.75	17.22	16.51
		(24.10)	(23.47)	(23.60)	(24.15)	(24.50)	(23.96)
3	*Bacillus thuringiensis* 8L @ 0.012%	17.80	16.78	17.99	18.35	18.96	17.98
		(24.95)	(24.18)	(25.09)	(25.36)	(25.81)	(25.08)
4	Chlorantraniliprole 18.5 SC @ 0.02%	11.57	10.72	11.87	12.45	13.07	11.94
		(19.89)	(19.11)	(20.12)	(20.63)	(21.16)	(20.18)
5	Abamectin 5 SG @ 0.01%	12.79	12.12	13.06	13.79	14.13	13.18
		(20.95)	(20.37)	(21.18)	(21.76)	(22.04)	(21.26)
6	HaNPV @ 250 LE/ha	16.75	16.08	17.11	17.99	18.65	17.32
		(24.14)	(23.63)	(24.43)	(25.06)	(25.55)	(24.56)
7	Indoxacarb 14.5 SC @ 0.01%	8.57	7.44	8.98	9.35	9.96	8.86
		(17.02)	(15.83)	(17.44)	(17.80)	(18.39)	(17.30)
8	Novaluron 10 EC @ 0.01%	9.64	9.04	9.97	10.22	10.94	9.96
		(18.08)	(17.50)	(18.22)	(18.64)	(19.31)	(18.35)
9	Spinosad 2.5 SC @ 0.01%	13.36	12.61	13.88	14.16	14.67	13.74
		(21.43)	(20.80)	(21.87)	(22.10)	(22.52)	(21.74)
10	Control	37.80	40.15	43.25	45.52	47.41	42.83
		(37.90)	(39.27)	(41.12)	(42.43)	(43.52)	(40.85)
	S.Em ±	0.76	0.88	0.79	0.63	0.77	0.77
	CD at 5%	2.26	2.60	2.36	1.86	2.30	2.28

*Figure in parentheses are angular transformed values, **Days after spray.

The pooled mean data at all the intervals of second spray revealed that indoxacarb (8.86%) was found most effective insecticides with minimum fruit damage. It was followed by novaluron and acephate which caused 9.96 and 10.58 per cent infestation on number basis, respectively. The insecticides *B. thuringiensis* and HaNPV registering 17.98 and 17.32 per cent fruit damage proved as the least effective insecticide. These two insecticides were statistically at par to that of quinalphos (16.51%) and significantly inferior to rest of the insecticides. Chlorantraniliprole, abamectin and spinosad existed in moderate group of efficacy registered 11.94, 13.18 and 13.74 per cent infestation, respectively. All these three insecticides were at par to each other. However, chlorantraniliprole is also comparable with that of novaluron and acephate.

The descending order of efficacy after second spray all the intervals was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.3 Overall efficacy of newer insecticides/biopesticides after two sprays on fruit borer infestation

4.2.2.3.1 Three days after spray

The data presented in Table 4.7 regarding that overall efficacy of different insecticides tested against fruit borer revealed that all insecticides proved significantly superior over control (30.98%) in respect of per cent fruit damage on number basis. However, significant difference existed among themselves. On the basis of data, analysis of both sprays, indoxacarb was found most effective (8.95%) followed by novaluron (9.94%) and acephate (10.31%). All these three insecticides were statistically at par to each other. The insecticide chlorantraniliprole, abamectin and spinosad ranked in middle order of efficacy registering 11.97, 13.19 and 13.61 per cent fruit damage. However, chlorantraniliprole was comparable to novaluron and acephate. The insecticide *B. thuringiensis* (18.52%) proved least effective followed by HaNPV (17.64%) and quinalphos (16.91%) and these three insecticides were statistically at par to each other.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after three days of both sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.3.2 Six days after spray

The data presented in Table 4.7 indicated that all the insecticides lowred down the fruit damage in comparison to control (33.35%). On the basis of mean of both sprays, indoxacarb (8.00%) registered minimum per cent fruit damage, hence found most effective followed by novaluron (9.26%) and acephate (9.71%). The insecticides chlorantraniliprole, abamectin and spinosad existed in the moderate group of efficacy with 11.15, 12.40 and 12.68 per cent fruit damage, respectively. However, chlorantraniliprole was also statistically at par to novaluron and acephate. The insecticide quinalphos (16.25%) was comparable to HaNPV (17.17%) and *B. thuringiensis* (17.95%) and efficacy of these three treatments were found inferior than rest of treatments.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after six days of two spray was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.3.3 Nine days after spray

All the insecticides lowered down the fruit damage significantly in comparison to control (36.51%) at ninth day interval. The pooled of mean of both two sprays indicated that indoxacarb (9.24%) was found most effective and significantly superior to rest of the insecticides. The next best insecticide was novaluron (10.34%) followed by acephate (10.95%). These two insecticides were statistically at par to indoxacarb and chlorantraniliprole. The insecticides chlorantraniliprole, abamectin and spinosad registered 12.42 to 14.21 per cent fruit damage on number basis and statistically at par to each other. The insecticide *B. thuringiensis* was found least effective with 19.19 per cent fruit damage followed by HaNPV (18.63%) and quinalphos (16.81%) and at par to each other.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after nine days of both sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.3.4 Twelve days after spray

The data presented in Table 4.7 revealed that all the insecticides proved significantly superior to that of control (38.53%) in reducing fruit damage on number basis at twelve day interval. The minimum fruit damage was recorded in the plots treated with indoxacarb (9.71%) followed by novaluron (10.67%) and acephate (11.55%). These three insecticides were statistically at par to each other. The insecticides chlorantraniliprole, abamectin and spinosad were reported as next best group of efficacy with 13.10, 14.37 and 14.57 per cent fruit damage, respectively and statistically at par to each other. However, the treatment of chlorantraniliprole was comparable to acephate. The insecticides quinalphos (17.37%), HaNPV (19.27%) and *B. thuringiensis* (19.55%) proved as least effective group of efficacy and were statically at par to each other and significantly inferior to rest of the insecticides.

On the basis of mean data of all the nine treatments, the descending order of cumulative efficacy of insecticides after twelve days of both sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

4.2.2.3.5 Fifteen days after spray

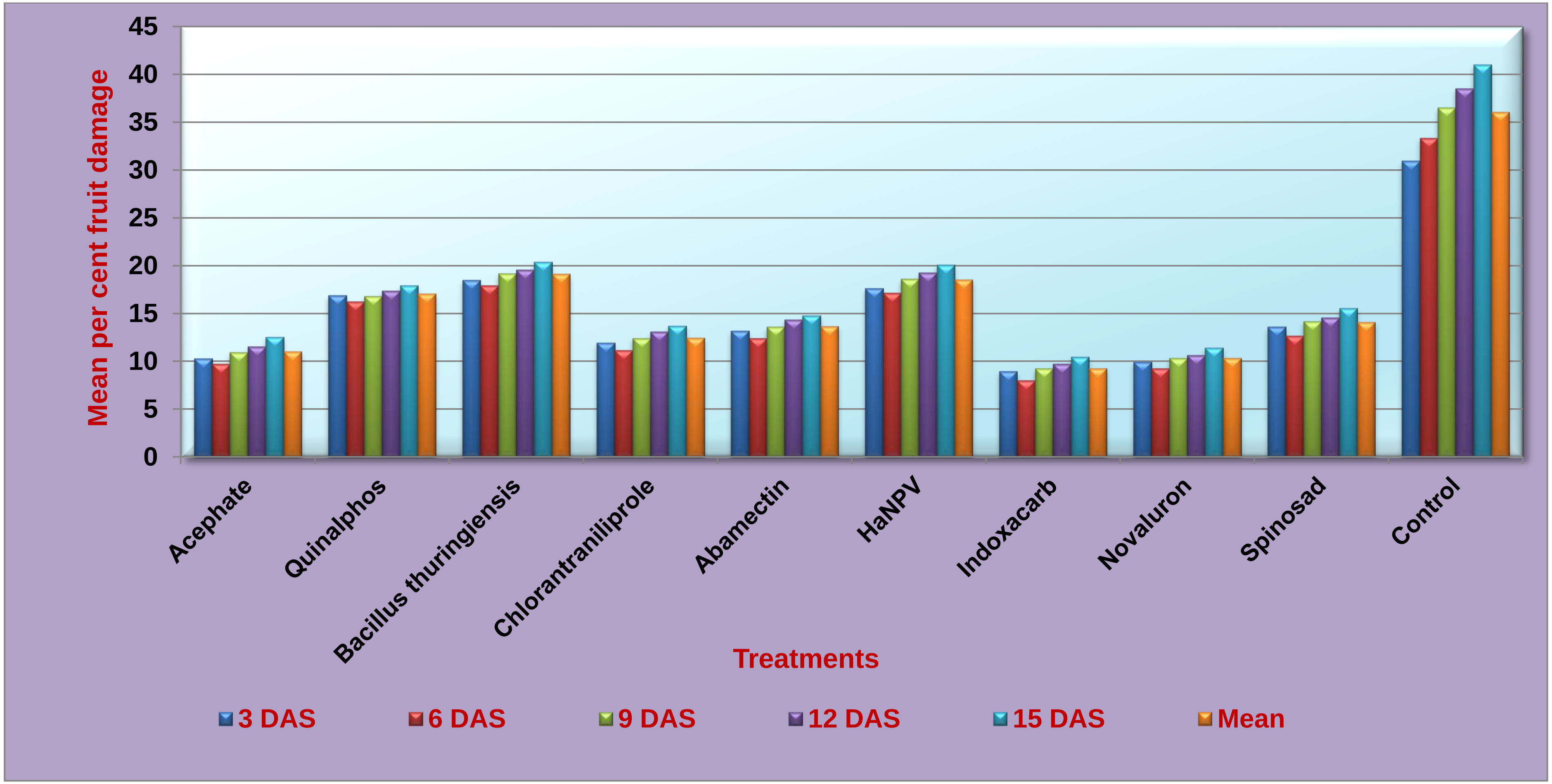
It is evident from Table 4.7 that per cent fruit damage on number basis in all nine insecticides after two spray was significantly low in comparison to control (41.03%). The pooled mean analysis indicated that the insecticide indoxacarb was reported as most effective with 10.47 per cent fruit damage. It was followed by novaluron and acephate registering

Table 4.7: Overall efficacy of insecticides/bio-pesticides on fruit damage in tomato after two sprays

S. No.	Treatments	Fruit damage (%)					Mean	Yield (q ha^{-1})
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS		
1	Acephate 75 SP @ 0.037%	10.31	9.71	10.95	11.55	12.55	11.01	258.22
		(18.73)*	(18.16)	(19.32)	(19.86)	(20.69)	(19.35)	
2	Quinalphos 25 EC @ 0.02%	16.91	16.25	16.81	17.37	17.94	17.06	220.15
		(24.28)	(23.77)	(24.19)	(24.61)	(25.04)	(24.38)	
3	*Bacillus thuringiensis* 8L @ 0.012%	18.52	17.95	19.19	19.55	20.42	19.13	206.54
		(25.49)	(25.06)	(25.98)	(26.24)	(26.86)	(25.93)	
4	Chlorantraniliprole 18.5 SC @ 0.02%	11.97	11.15	12.42	13.10	13.71	12.47	250.71
		(20.24)	(19.50)	(20.60)	(21.19)	(21.70)	(20.65)	
5	Abamectin 5 SG @ 0.01%	13.19	12.40	13.61	14.37	14.79	13.67	241.62
		(21.29)	(20.61)	(21.64)	(22.24)	(22.58)	(21.67)	
6	HaNPV @ 250 LE/ha	17.64	17.17	18.63	19.27	20.10	18.56	213.24
		(24.82)	(24.46)	(25.57)	(26.00)	(26.60)	(25.49)	
7	Indoxacarb 14.5 SC @ 0.01%	8.95	8.00	9.24	9.71	10.47	9.27	265.20
		(17.40)	(16.43)	(17.69)	(18.15)	(18.87)	(17.71)	
8	Novaluron 10 EC @ 0.01%	9.94	9.26	10.34	10.67	11.42	10.33	262.85
		(18.37)	(17.71)	(18.71)	(19.06)	(19.75)	(18.72)	
9	Spinosad 2.5 SC @ 0.01%	13.61	12.68	14.21	14.57	15.54	14.12	238.55
		(21.64)	(20.86)	(22.07)	(22.42)	(23.21)	(22.04)	
10	Control	30.98	33.35	36.51	38.53	41.03	36.08	181.56
		(33.77)	(35.22)	(37.17)	(38.37)	(39.83)	(36.87)	
	S.Em ±	0.68	0.78	0.73	0.67	0.798	0.73	4.23
	CD at 5%	2.01	2.31	2.16	1.99	2.370	2.17	12.58

*Figure in parentheses are angular transformed values, **Days after spray.

Figure 4.3 Overall efficacy of insecticides//bio-pesticides on fruit damage in tomato after two sprays



Mean per cent fruit damage
45
40
35
30
25
20
15
10
5
0
Acephate
Quinalphos
Bacillus thuringiensis
Chlorantraniliprole
Abamectin
HaNPV
Indoxacarb
Novaluron
Spinosad
Control
Treatments
3 DAS
6 DAS
9 DAS
12 DAS
15 DAS
Mean

11.42 and 12.55 per cent fruit damage, respectively and these three treatments were comparable to each other. The *B. thuringiensis* (20.42%) proved as least effective insecticide followed by HaNPV (20.10%) and quinalphos (17.94%) and statistically at par to each other. The insecticides chlorantraniliprole, abamectin and spinosad were ranked as moderate group registered 13.71, 14.79 and 15.54 per cent fruit damage, respectively and were statistically at par to each other. However, chlorantraniliprole was also comparable to novaluron and acephate.

On the basis of mean data of all the nine treatments, the descending order of overall efficacy of insecticides after fifteen day of two sprays was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis*.

The polled mean data of overall efficacy of different insecticide against fruit borer in respect of per cent fruit damage on number basis at all intervals after two sprays revealed that indoxacarb (9.27%) was found most effective insecticide followed by novaluron (10.33%) and acephate (11.01%). These three insecticides were statistically at par to each other. However, novaluron and acephate were comparable to chlorantraniliprole. *B. thuringiensis* was found least effective insecticide with 19.13 per cent fruit damage followed by HaNPV (18.56%) and quinalphos (17.06%). The insecticides chlorantraniliprole (12.47%), abamectin (13.67%) and spinosad (14.12%) existed in middle order of efficacy and were statistically at par to each other. All nine insecticides reported superior to control (36.08%) in respect of per cent fruit damage on number basis by fruit borer.

The polled mean data of overall efficacy of insecticides at all the intervals after two sprays, the descending order of efficacy was: indoxacarb> novaluron> acephate> chlorantraniliprole> abamectin> spinosad> quinalphos> HaNPV> *B. thuringiensis.*

4.2.2.3.6 Impact of insecticidal treatments on the yield of tomato fruits

The marketable yield of tomato among different treatment ranged from 181.56 to 265.20 q ha^{-1} (Table 4.7). The highest marketable yield of 265.20 q ha^{-1} was recorded in case of indoxacarb. It was followed by novaluron and acephate which yielded 262.85 and 258.22 q ha^{-1}, respectively. Minimum fruit yield was recorded from the plots treated with *B. thuringiensis* (206.54 q ha^{-1}) followed by HaNPV (213.24 q ha^{-1}) and quinalphos (220.15 q ha^{-1}). Yield of these three treatments was significantly lower than the all other insecticides and superior to that of control (181.56 q ha^{-1}). The yield obtained from chlorantraniliprole, abamectin and spinosad ranged in between 238.55 to 250.71 q ha^{-1} and ranked in middle order.

4.2.3 Economics and incremental cost benefit ratio

The data presented in Table 4.8 indicated that maximum net profit Rs. 80970 per hectare was found in indoxacarb (0.01%) followed novaluron (0.01%) and acephate (0.037%) with Rs. 77254 and 71684 net profit per hectare, respectively. The minimum net profit of Rs. 19514 was recorded in spinosad (0.01%) followed by *B. thuringiensis* (0.012%) and HaNPV (250 LE/ha) with Rs. 22664 and 29296 per hectare, respectively. The net profit ranging from Rs. 37306 to 56191 per hectare was computed in quinalphos (0.02%), chlorantraniliprole (0.02%) and abamectin (0.01%).

The highest incremental cost benefit ratio (ICBR) of 30.33 was computed in indoxacarb followed by 29.05 in quinalphos and 19.14 in novaluron. The minimum incremental cost benefit ratio 0.52 was obtained in spinosad followed by abamectin (2.26). The incremental cost benefit ratio ranging from 4.34 to 14.41 was found in acephate, *B. thuringiensis*, chlorantraniliprole and HaNPV.

4.3 Assessment of crop losses due to tomato fruit borer in tomato

The loss due to fruit borer in “RS-2” variety of tomato was estimated by transplanting crop on November 22, 2013. The studies revealed that “RS-2” variety of tomato suffered by fruit borer, which adversely affected the growth and yield of tomato crop. Actual amount of quantitative avoidable loss inflicted by this naturally occurring pest population together with their effect on various plant characters *viz.*, height of plant, number of leaves, weight of fruit were recorded (Table 4.9).

4.3.1 Height of plants

It is evident from Table 4.9 that in tomato crop, a significant reduction in height per plant between protected and unprotected plots was noticed. The height of plants in protected plots ranged from 45.85 to 67.84 cm with a mean of 59.88 cm in comparison to range of 36.75 to 53.00 cm with a mean of 43.78 cm in unprotected plots.

4.3.2 Number of leaves

It is revealed from Table 4.9 that in tomato crop, a significant reduction in number of leaves per plant between protected and unprotected plots was noticed. In protected plots the number of leaves per plant ranged from 56.01 to 69.00 with a mean of 61.10 in comparison to range of 44.09 to 56.70 with a mean of 50.13 in unprotected plots.

4.3.3 Weight of fruits

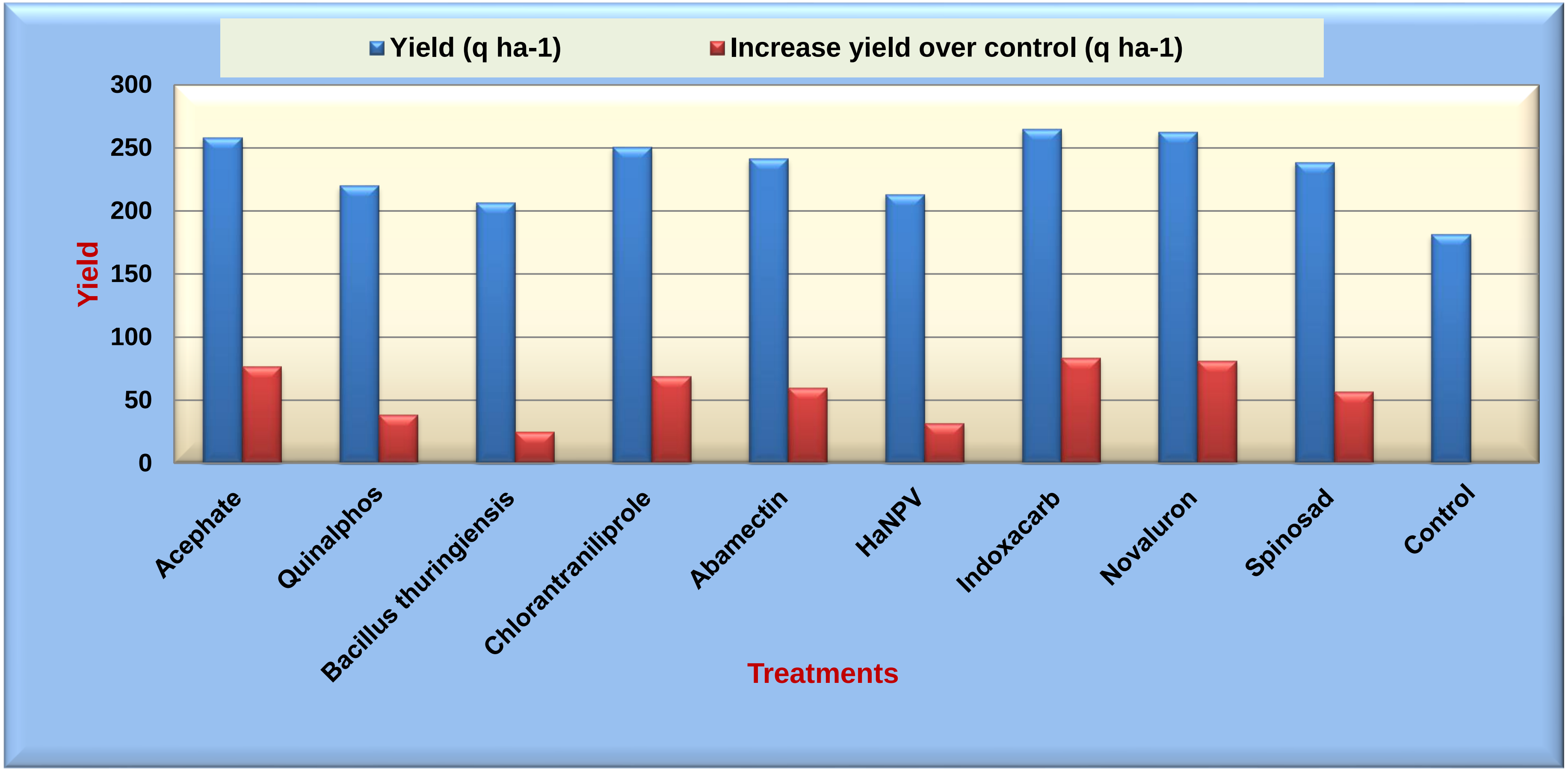
A significant difference observed in weight of fruits, thereby showing a reduction in weight of marketed fruits per plant. The average weight of fruits in protected plots ranged from 44.48 to 60.63 gm with a mean of 54.32 gm in comparison to range of 41.06 to 52.26 gm with a mean of 45.69 gm in unprotected plots (Table 4.9).

Table 4.8: Comparative economics of insecticides and bio-pesticides against, *H. armigera*

S. No.	Treatments	Mean yield (q ha^{-1})	Increased yield over control (q ha^{-1})	Cost of increased yield (Rs.)*	Total Expenditure (Rs. ha^{-1})**	Net profit (Rs. ha^{-1})	Incremental cost benefit ratio (ICBR)
1	Acephate 75 SP @ 0.037%	258.22	76.66	76660	4975.40	71684.60	1:14.41
2	Quinalphos 25 EC @ 0.02%	220.15	38.59	38590	1284.00	37306.00	1:29.05
3	*Bacillus thuringiensis* 8L @ 0.01%	206.54	24.98	24980	2316.00	22664.00	1:9.79
4	Chlorantraniliprole 18.5 SC @ 0.02%	250.71	69.15	69150	12959.00	56191.40	1:4.34
5	Abamectin 5 SG @ 0.01%	241.62	60.06	60060	18436.00	41624.00	1:2.26
6	HaNPV @ 250 LE/ha	213.24	31.68	31680	2385.00	29295.00	1:12.28
7	Indoxacarb 14.5 SC @ 0.01%	265.20	83.64	83640	2670.00	80970.00	1:30.33
8	Novaluron 10 EC @ 0.01%	262.85	81.29	81290	4036.00	77254.00	1:19.14
9	Spinosad 2.5 SC @ 0.01%	238.55	56.99	56990	37476.00	19514.00	1:0.52
10	Control	181.56	-	-	-	-	-

* Cost of fruit of tomato at current season was Rs. = 1000 per quintal, **Included cost of insecticides & labour involved in spraying.

Figure 4.4 Effect of insecticides on the yield of tomato fruits and increase yield over control



4.3.4 Losses in yield

Table 4.10 indicated that in tomato crop a significant reduction in yield of tomato fruits between protected and unprotected plots was recorded. In protected plots the yield of tomato ranged from 195.25 to 250.11 q ha^{-1} with a mean of 221.83 in comparison to range of 133.69 to 171.25 with a mean of 151.88 in unprotected plots. Reduction of 31.53 per cent was computed in unprotected plots as compared to protected plots

Table 4.9: Plant height, number of leaves and weight of fruits in protected and unprotected plots of tomato

Paired plot No.	Plant height (cm)		Number of leaves		Weight of fruit (gm)	
	Protected plots	Unprotected plots	Protected plots	Unprotected plots	Protected plots	Unprotected plots
1	52.80	45.93	59.01	49.49	50.43	44.34
2	64.54	45.58	59.01	53.11	44.48	41.54
3	67.84	43.81	63.99	51.30	54.97	52.26
4	59.40	36.75	56.01	44.09	60.63	41.06
5	62.34	53.00	69.00	56.70	60.07	49.94
6	59.40	45.23	60.99	47.71	49.58	47.60
7	58.30	40.28	62.01	49.49	54.12	45.26
8	55.74	42.75	60.99	49.49	56.10	44.80
9	58.30	39.93	59.01	50.41	56.95	42.46
10	60.14	44.52	60.99	49.49	55.82	47.60
11	53.05	41.71	66.33	55.22	49.96	47.11
12	45.85	40.15	58.65	50.98	48.09	43.33
13	60.62	49.45	62.61	50.68	51.64	47.57
14	56.93	49.39	64.35	51.17	49.17	44.17
Average	59.88	43.78	61.10	50.13	54.32	45.69
T Cal		9.07		18.50		5.37
T Tab		2.16		2.16		2.16

Significant at 5% level of significance.

Table 4.10: Yield from protected and unprotected plots of tomato and losses caused by *H. armigera*

Paired plot No.	Yield in q ha^{-1}		Difference (X_1-X_2)	Deviation from the mean of difference (d)	Square of the deviation from the mean of difference (d^2)	Value of T at 5%		Per cent reduction in unprotected plots
	Protected X_1	Unprotected X_2				**Calculated**	**Tabulated**	
1	250.11	171.25	78.86	8.92	79.527			
2	195.25	133.69	61.56	8.38	70.217	42.93	2.16	31.53
3	225.65	154.50	71.15	1.21	1.453			
4	235.52	161.26	74.26	4.32	18.642			
5	200.21	137.08	63.13	6.82	46.453			
6	198.65	136.02	62.63	7.31	53.400			
7	245.75	168.27	77.48	7.54	56.898			
8	215.26	147.39	67.87	2.07	4.287			
9	223.85	153.27	70.58	0.64	0.407			
10	241.33	165.24	76.09	6.15	37.816			
11	206.65	141.49	65.16	4.79	22.897			
12	239.16	163.75	75.41	5.47	29.869			
13	229.84	157.37	72.47	2.53	6.384			
14	198.34	135.80	62.54	7.41	54.838			
Sum	3105.57	2126.38	979.19	0.00	483.089			
Mean	221.83	151.88	69.94					

Healthy fruit

Infested fruit

Healthy plant

Infested plant

Plate 2: Infestation of *Helicoverpa armigera* (Hub.) in toma

Protected plot

Unprotected plot

Plate 3: General view of protected plot and unprotected plot

Table 4.11: Population of *H. armigera* recorded in unprotected plots of tomato

S. No.	Date of observation	Mean larvae population/10 plants
1.	5 Feb	4.80
2.	8 Feb	4.17
3.	11 Feb	2.78
4.	14 Feb	2.95
5.	17 Feb	3.24
6.	20 Feb	3.43
7.	23 Feb	3.97
8.	25 Feb	4.06
9.	28 Feb	4.12
10.	3 March	3.85
11.	6 March	3.99
12.	9 March	4.75
13.	12 March	4.91
14.	15 March	5.16
15.	18 March	6.23
16.	21 March	6.38
17.	24 March	8.69
18.	27 March	8.86
19.	30 March	5.12
20.	2 April	4.23
21.	5 April	4.01
22.	8 April	2.10
23.	11 April	1.93

Table 4.12: Per cent infestation of *H. armigera* recorded in unprotected plots of tomato

S. No.	Date of observation	Mean fruit damage %
1.	5 Feb	24.11
2.	8 Feb	26.47
3.	11 Feb	29.73
4.	14 Feb	31.49
5.	17 Feb	34.62
6.	20 Feb	37.74
7.	23 Feb	40.13
8.	25 Feb	43.19
9.	28 Feb	42.47
10.	3 March	42.96
11.	6 March	42.96
12.	9 March	43.05
13.	12 March	44.75
14.	15 March	45.34
15.	18 March	47.93
16.	21 March	48.10
17.	24 March	50.89
18.	27 March	50.97
19.	30 March	47.21
20.	2 April	46.59
21.	5 April	43.07
22.	8 April	31.92
23.	11 April	25.38

5. DISCUSSION

The results obtained from present investigations on "Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan" are discussed below:

5.1 Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* (Hub.) in tomato, in relation to weather parameters

In the present investigation, the incidence of *H. armigera* larvae was initiated after five weeks of transplanting *i.e*. in the last week of December (52nd SMW). The present results are in agreement with those of Ravi and Verma (1997) and Singh *et al.* (2011) who noticed appearance of *H. armigera* larvae in the 52nd standard week. However, contrary to the present findings, Sharma *et al.* (2006) reported the initiation of fruit borer on the tomato crop by the end of May. Variation in the onset of infestation may probably be due to the difference in the climatic conditions of the locality.

The larval population lowered down from 1st SMW to 4th SMW and thereafter, increased with fluctulating trend was reported. Peak larval population was recorded in the last week of March *i.e*. 12th SMW (4.45 larvae/five plants). The present results corroborate with those of Parihar *et al.* (1986), Reddy *et al.* (2009) and Pandey *et al.* (2012) who observed peak population of fruit borer in the last week of March. Similarly, Prasad *et al.* (1989) found highest population of *H. armigera* in 1st week of March. Ravi and Verma (1997) reported peak population in March and Singh *et al.* (2011) during 2nd week of April are in partial agreement of the present investigation. Whereas, peak period of incidence of fruit borer was reported during December by Patel and Koshiya (1997), first week of December by Kakati *et al.* (2005) and 37th standard week by Umbarkar *et al.* (2010) does not support the present findings. This difference in the activity of the pest may probably be due to difference in agro-climatic conditions of regions and transplanting time of the crop.

5.1.1 Correlation between tomato fruit borer and abiotic factors

In the present investigation, a significant positive correlation was observed between pest population with maximum and minimum temperature, whereas, it was non-significant positive with average relative humidity. A non-significant negative correlation was computed between pest population and total rainfall.

The Maximum temperature (r=0.600) had positive significant effect on the borer population. The present results get support from the work of Reddy and Kumar (2004), Sharma *et al.* (2006), Reddy *et al.* (2009), Chakraborty *et al.* (2011), Pandey *et al.* (2012), Sharma *et al.* (2013) and Waluniba and Ao (2014) who obtained similar results. Raghuwansi and Garg (2013) reported a non-significant positive correlation with maximum temperature do not support the present finding.

The minimum temperature had positive significant correlation (r=0.562) with the pest population. The present findings corroborate with those of Reddy and Kumar (2004), Reddy *et al.* (2009) and Sharma *et al.* (2013) who repoted significant positive correlation with minimum temperature, whereas, Raghuwansi and Garg (2013) found no effect of minimum temperature on population of fruit borer, contradicts the present results. Umbarkar *et al.* (2010) reported a highly significant negative correlation between minimum temperature and borer population also does not support the present investigationn.

Average relative humidity had positive non-significant correlation (r= 0.291) with borer population. The present results are in conformity with those of Prasad *et al.* (2006) and Chakraborty *et al.* (2011) who repoted positive correlation between fruit borer population and realative humidity. The present results are not in agreement with those of Reddy *et al.* (2009), Umbarkar *et al.* (2010), Pandey *et al.* (2012) and Sharma *et al.* (2013) who reported a significant negative correlation between relative humidity and fruit borer population.

The rainfall had negative non-significant correlation (r= -0.236) with fruit borer population. The present findings get support with those of Chakraborty *et al.* (2011), Pandey *et al.* (2012) and Sharma *et al.* (2013) who reported a non-significant negative correlation between pest population and rainfall. The present results contradict with those of Prasad *et al.* (2006) and Reddy *et al.* (2009) who reported a non significant positive correlation with rainfall and borer population.

5.2.1 Relative efficacy of newer and biorational insecticides against *H. armigera*

Investigation on the bio efficacy of nine insecticides against fruit borer in tomato during *rabi,* 2013-14 were carried out. Meagre work is available on some of insecticides against fruit borer; however, the available literature pertaining to efficacy of insecticides against fruit borer is being compared and discussed.

The result of effectiveness of different insecticidal treatments against tomato fruit borer, *H. armigera* showed that all the treatments were significantly superior over control in terms of mean reduction of tomato fruit borer larvae, mean fruit damage and marketable fruit yield.

The data revealed that indoxacarb (0.01%) was found most effective followed by novaluron (0.01%) and acephate (0.037%) against tomato fruit borer. The present results are in agreement with those of Murray *et al.* (2005), Singh *et al.* (2005), Patil *et al.* (2007), Kuttalam *et al.* (2008) and Dhaka *et al.* (2010) who reported indoxacarb as most effective insecticides against tomato fruit borer.The insecticide novaluron stood second in order of efficacy followed by acephate against fruit borer in present investigation. The spray of novaluron was reported most effective (Saini *et al.,* 2013) and second after indoxacarb against fruit borer (Dhaka *et al.,* 2010) corroborate the present finding. Singh *et al.* (2005) reported minimum fruit damage with the spray of acephate 75 SP partially confirm the present results.

In the present studies chlorantrailiprole (0.02%) was reported as moderately effective inseceticide followed by abamectin (0.01%) and spinosad (0.01%) against fruit borer in tomato. The present results are in partial agreement with that of Gadhiya *et al.* (2014) who reported chlorantrailiprole, abamectin and spinosad as effective insecticides against *H. armigera*on in groundnut. Abamectin was reported as significantly superior than quinalphos (Patel *et al.* 2009) and spinosad (Tatagar *et al.,* 2009) in reducing *H. armigera* population and fruit damage in tomato corroborates the present results. In the present investigation spinosad was found as moderately effective insecticide and superior than quinalphos get support from the finding of Ghosh *et al.* (2010) who reported spinosad as effective against *H. armigera* on tomato in comparison to quinalphos. Contrary to present results, Siddegowda *et al.* (2006), Patil *et al.* (2007), Kuttalam *et al.* (2008) and Jat and Ameta (2013) had reported spinosad as most effective and at par to the indoxacarb against tomato fruit borer.

In the present investigation the spray of *B. thuringiensis* (0.012%) proved least effective insecticide followed by HaNPV (250 LE/ha) and quinalphos (0.02%). The present findings are not in agreement with those of Mehta *et al.* (2000), Ravi *et al.* (2008), Ram and Singh (2011) and Rahman *et al.* (2014) who reported *B. thuringiensis* and HaNPV effective against tomato fruit borer. However, Chandrakar *et al.* (1999) and Jat and Ameta (2013) who reported the spray of *B. thuringiensis* and HaNVP @250 LE/ha as least effective against fruit borer, support the present results. Further Ravi *et al.* (2008) also reported spray of *B. thuringiensis* and HaNPV were equally effective against fruit borer in tomato.

5.2.2 Impact of insecticidal treatments on the yield of tomato fruits

The highest marketable fruit yield 265.20 q ha^{-1} was recorded in case of indoxacarb followed by novaluron and acephate which yielded 262.85 and 258.22 q ha^{-1}, respectively. The yield ranging from 18.31 q ha^{-1} to 602.78 q ha^{-1} with the indoxacarb (Patil *et al.,* 2007, Dhaka *et al.,* 2010 and Singh *et al*., 2005) have been reported earlier support the present findings.

Minimum fruit yield was recorded from the plots treated with *B. thuringiensis* (206.54 q ha^{-1}) followed by HaNPV (213.24 q ha^{-1}) and quinalphos (220.15 q ha^{-1}). Dhaka *et al.* (2010) and Ram and Singh (2011) reported lower yield with the treatment of *B. thuringiensis* and HaNPV as compared to chemical insecticides support the present results. However, contrary to the present findings, Chandrakar *et al.* (1999) and Rahman *et al.* (2014) reported highest fruit yield with the treatment of *B. thuringiensis* and HaNPV.

Yield obtained from chlorantraniliprole, abamectin and spinosad ranged in between 238.55 to 250.71 q ha^{-1} and ranked in middle order. The present findings does not corroborate with that of Ghosal *et al.* (2012) who obtained 34.74 q ha^{-1} yield in chlorantraniliprole which is highest in comparison to spinosad and indoxacarb. However, Jat and Ameta (2013) reported that yield obtained from spinosad is in middle order confirm the present results. Yield data of novaluron, abamectin and quinalphos is not available, therefore, it could not compared and discussed.

5.2.3 Economics of different insecticides

The data revealed that during the present investigation, the maximum net profit Rs. 80970 per hectare was recorded from indoxacarb (0.01%) followed by novaluron (0.01%) and acephate (0.037%) with Rs. 77254 and 71684 net profit per hectare, respectively. The minimum net profit of Rs. 19514 was recorded from spinosad (0.01%) followed by *B. thuringiensis* (0.012%) and HaNPV with Rs. 22664 and 29296 net profit per hectare, respectively. The net profit ranging from Rs. 37306 to 56191 per hectare was computed in quinalphos (0.02%), chlorantraniliprole (0.02%) and abamectin (0.01%).

The net profit of Rs. 75645 was found in acephate which was at par to the indoxacarb by Singh *et al.* (2005), corroborate the present findings. However, the net profit of Rs. 14139 by Dhaka *et al.* (2010) and Rs. 21288 by Kumar and Devi (2014) are not in agreement with the present results. The net profit of Rs. 20070.50 and Rs. 21026 reported by Moorthy *et al.* (2011) and Kumar and Devi (2014), respectively from the treatment of spinosad are in agreement with the results of present studies. Sharma and Bhardwaj (2008) reported net profit in the range of Rs. 16484 to 32937 from HaNPV and *B. thuringiensis* also corroborate the present findings.

Roopa and Kumar (2014) reported net profit of Rs. 74066 from spinosad, Rs. 651475 from abamectin, Rs. 586387 from novaluron, Rs. 574461 from indoxacarb, Rs. 551491 from chlorantraniliprole and Rs. 329863 from quinalphos does not support the present results.

The highest incremental cost benefit ratio of 30.33 was computed in indoxacarb followed by 29.05 in quinalphos and 19.14 in novaluron. The minimum incremental cost benefit ratio 0.52 was obtained in spinosad followed by abamectin (2.26). The incremental cost benefit ratio ranging from 4.34 to 14.41 was found in acephate, *B. thuringiensis*, chlorantraniliprole and HaNPV. Contrary to the present finding, Sreekanth *et al.* (2014) reported the highest incremental cost benefit ratio was computed from chlorantraniliprole followed by indoxacarb (1:3.67), abamectin (1:3.13) and spinosad (1:2.97). Jat and Ameta (2013) reportedthe highest incremental cost benefit ratio of 1:2.075 in spinosad also does not support the present results. Rahman *et al*. (2014) obtained the highest incremental cost benefit ratio (5.30) from alternate spray of HaNPV and *B. thuringiensis* followed by alone spray of HaNPV (4.46) and *B. thuringiensis* (3.37). The difference in incremental cost benefit ratio may be due to the high difference in the cost of insecticides and quantity of yield produced.

5.3 Assessment of crop losses due to tomato fruit borer in tomato

The tomato crop is attacked by fruit borer causing severe damage and consequent reduction in yield. For estimating losses due to pest in any crop, a large number of criteria can be taken into considerations. However, in present study, the effect of insect pests on yield effecting plant characters *viz.,* height of plants, number of leaves and weight of fruits and net yield have been taken into consideration.

The data recorded in the present investigation revealed that insect pest adversely affected the height of plants, number of leaves, weight of fruits and net yield as there is significantly difference in protected and unprotected plots.

In unprotected plots, the average height of plants, number of leaves and average weight of fruits per plant recorded were 43.78 cm, 50.13 and 45.69 gm, respectively. While these values in protected plots being 59.88 cm, 61.10 and 54.32 gm, respectively. On the basis of difference obtatined in net yield in protected and unprotected plots the avoidable quantitative loss was 31.53 per cent on winter sown tomato crop.

The findings of present investigations are conformity with those of Bhardwaj *et al.* (1990) in safflowers, Ameta and Bhardwaj (1996) in pigeonpea, Meena (2005) in coriander, Paliwal (2005) in sorghum, Suryawansi *et al.* (2000) in okra, Purohit and Ameta (2007) in cotton and Meena (2010) in okra, all the earlier workers have reported that insect pest infestation caused adverse effect on growth and yield attributing characters of a plant.

The results are also in agreement with the work of Kumar *et al.* (1999) who reported that 18.50 to 32.64 per cent yield losses could by avoided as a results of sprays of insecticides. However, Aheer *et al.* (1998) reported 72.19 to 77.79 per cent yield losses does not support the present findings.

6. SUMMARY AND CONCLUSION

The experiment on "Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan." was carried out at farm of Agricultural Research station, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi,* 2013-14.

The incidence of *H. armigera* larvae was started in the last week of December (52nd SMW). Thereafter, the population increased gradually and reached to its peak in last week of March (12th SMW) with a mean of 4.45 larvae/five plants. Thereafter, larval population declined gradually and negligible population was recorded when fruit picking was completed in the second week of April (14th SMW).

A significant positive correlation was observed between pest population with maximum and minimum temperature and non-significant positive with average relative humidity. Whereas, it was non-significant negative between pest population and total rainfall.

The bioefficacy of nine insecticides against tomato fruit borer, *H. armigera* showed that all the treatments were significantly superior over control in terms of mean reduction of tomato fruit borer larvae, mean fruit damage and marketable fruit yield. Two applications of indoxacarb 14.5 SC was found most effective, which caused highest mean reduction of 63.37 per cent in population of tomato fruit borer larvae. It was followed by novaluron 10 EC, acephate 75 SP and chlorantraniliprole 18.5 SC with 61.85, 59.65 and 56.99 per cent mean reduction, respectively and were at par with each other. Abamectin 5 SG, spinosad 2.5 SC and quinalphos 25 EC existed in moderate group of effectiveness with 53.66, 50.46 and 48.46 per cent mean reduction of fruit borer larvae. *Bacillus thuringiensis* 8L and HaNPV were found least effective among all the treatments and caused only 44.81 and 44.67 per cent mean reduction, respectively.

The efficacy of indoxacarb was manifested in terms of least mean fruit damage of 9.27 per cent, while, the novaluron and acephate with mean fruit damage of 10.33 and 11.01 per cent followed the indoxacarb and was next in order of effectiveness. Chlorantraniliprole, abamectin and spinosad were found moderately effective treatment with 12.47, 13.67 and 14.12 per cent mean fruit damage, respectively. Quinalphos, HaNPV and *B. thuringiensis* observed least mean fruit damage 17.06, 18.56 and 19.13 per cent, respectively.

All the insecticides increased the yield of marketable tomato fruits significantly over the control (181.56 q ha^{-1}). The maximum yield (265.20 q ha^{-1}) was recorded with the spray of indoxacarb followed by novaluron (262.85 q ha^{-1}) and acephate (258.22 q ha^{-1}). The minimum tomato fruit yield was recorded with *B. thuringiensis* (206.54 q ha^{-1}) followed by HaNPV (213.24 q ha^{-1}) and quinalphos (220.15 q ha^{-1}). The yield obtatined with chlorantraniliprole, abamectin and spinosad was 250.71, 241.62 and 238.55 q ha^{-1}, respectively.

The maximum net profit was recorded from indoxacarb (0.01%) with the highest cost benefit ratio of 1: 30.33. It was followed by novaluron (0.01%) and acephate (0.037%) with Rs. 77254 and 71684 net profit per hectare, respectively. The minimum net profit of Rs. 19514 was recorded in spinosad (0.01%) followed by *B. thuringiensis* (0.012%) and HaNPV with Rs. 22664 and 29296 net profit per hectare, respectively. The net profit ranging from Rs. 37306 to 56191 per hectare was computed in quinalphos (0.02%), chlorantraniliprole (0.02%) and abamectin (0.01%).

The highest incremental cost benefit ratio of 30.33 was computed in indoxacarb followed by 29.05 in quinalphos and 19.14 in novaluron. The minimum incremental cost benefit ratio 0.52 was obtained in spinosad followed by abamectin (2.26). The incremental cost benefit ratio ranging from 4.34 to 14.41 was computed in acephate, *B. thuringiensis*, chlorantraniliprole and HaNPV.

Under unprotected conditions, the average height of plants, number of leaves and average weight of fruit recorded were 43.78 cm, 50.13 and 45.69 gm, respectively. While, these values in protected plots being 59.88 cm, 61.10 and 54.32 gm, respectively. On the basis of difference obtatined in net yield in protected and unprotected plots 31.53 per cent avoidable quantitative loss was observed in winter sown tomato crop.

Conclusion

The trial was conducted on seasonal incidence of fruit borer of tomato. The infestation of fruit borer started five weeks after transplanting, being maximum in last week of March. Maximum and minimum temperature had significant positive correlation with fruit borer population. A positive and negative non-significant correlation was reported between average relative humidity and total rainfall, respectively with fruit borer population.

The experiment on bio-efficacy of different insecticidal treatments revealed that indoxacarb was found most effective against fruit borer followed by novaluron and acephate and resulted higher yield, while *B. thuringiensis* proved least effective followed by HaNPV and quinalphos. The treatments chlorantraniliprole, abamectin and spinosad ranked in middle order of their efficacy.

The experiment on assessment of losses due to fruit borer by taking into the consideration of yield and yield attributing characters *i.e.* height of plants, number of leaves and weight of fruits was carried out and it was found that pest infestation adversely affect the yield attributing characters causing 31.53 per cent quantitative losses.

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Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan.

Narendra Singh* (Scholar)

Dr. A. R. Naqvi** (Major Advisor)

ABSTRACT

The present investigations on **"Eco-friendly Management of Tomato Fruit Borer, *Helicoverpa armigera* (Hub.) in Hyper Arid Region of Rajasthan"** was carried out at farm of Agricultural Research station, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi*, 2013-14. The incidence of fruit borer started in the last week of December on tomato. The population lowered down upto 3^{rd} SMW and thereafter, population increased but fluctuating trend was recorded upto 9^{th} SMW. The larval population increased and reached to peak in 12^{th} SMW. Thereafter, it's population decreased gradually and negligible population was recorded upto second week of April. A significant positive correlation was observed between pest population and maximum and minimum temperature, whereas, it was non-significant positive with average relative humidity. A non-significant negative correlation was computed between pest population and total rainfall. The bio-efficacy of nine insecticides evaluated against fruit borer in tomato revealed that indoxacarb 14.5 SC (0.01%) was found most effective against fruit borer followed by novaluron 10 EC (0.01%) and acephate 75 SP (0.037%). *B. thuringiensis* 8L (0.012%) proved least effect followed by HaNPV (250 LE/ha) and quinalphos 25 EC (0.02%).The treatments of chlorantraniliprole 18.5 SC (0.02%), abamectin 5 SG (0.01%) and spinosad 2.5 SC (0.01%) ranked in middle order of their efficacy.

All the insecticides significantly increased the yield of marketable fruits over control. The maximum yield (265.20 q ha^{-1}) was recorded in indoxacarb followed novaluan (262.85 q ha^{-1}) and acephate (258.22 q ha^{-1}). The minimum yield was recorded in *B. thuringiensis* (206.54 q ha^{-1}) followed by HaNPV (213.24 q ha^{-1}).

Losses due to fruit borer were estimated by taking into the consideration of yield and yield attributing characters *i.e.* height of plants (cm), number of leaves and weight of fruits (gm). On the basis of difference obtained in net yield in protected and unprotected plots the avoidable quantitative loss was 31.53 per cent on winter sown tomato crop.

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* Post graduate student, Department of Entomology, College of Agriculture, SKRAU, Bikaner.

** Thesis submitted for partial fulfilment of master degree in Entomology under supervision of Dr. A. R. Naqvi, Professor, Department of Entomology, Datepalm Research Centre, ARS, SKRAU, Bikaner.

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APPENDIX-1

Details of economics of insecticidal treatments during 2013-14

S. No.	Treatments	Quantity of insecticides in Lit/kg	Rate Rs. per Lit/kg	Cost of insecticides (Rs.)	Cost of Labour (Rs.)	Total expenditure (Rs.)
1	Acephate 75 SP @ 0.037%	3.94	1010	3980	996	4976
2	Quinalphos 25 EC @ 0.02%	0.64	450	288	996	1284
3	*Bacillus thuringiensis* 8L @ 0.01%	1.2	1100	1320	996	2316
4	Chlorantraniliprole 18.5 SC @ 0.02%	0.86	13910	11963	996	12959
5	Abamectin 5 SG @ 0.01%	1.6	10900	17440	996	18436
6	HaNPV @ 250 LE/ha	500 LE	1250/450LE	1388	996	2384
7	Indoxacarb 14.5 SC @ 0.01%	0.54	3100	1674	996	2670
8	Novaluron 10 EC @ 0.01%	0.8	3800	3040	996	4036
9	Spinosad 2.5 SC @ 0.01%	3.2	11400	36480	996	37476

Labour Charge= Rs. 166/man/day (3 men/spray/ha)