POPULATION DYNAMICS, YIELD LOSSES AND MANAGEMENT OF THRIPS, *Scirtothrips dorsalis* Hood INFESTING CHILLI

A THESIS SUBMITTED TO THE
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IN
ENTOMOLOGY

BY

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JUNAGADH- 362 001

October- 2013

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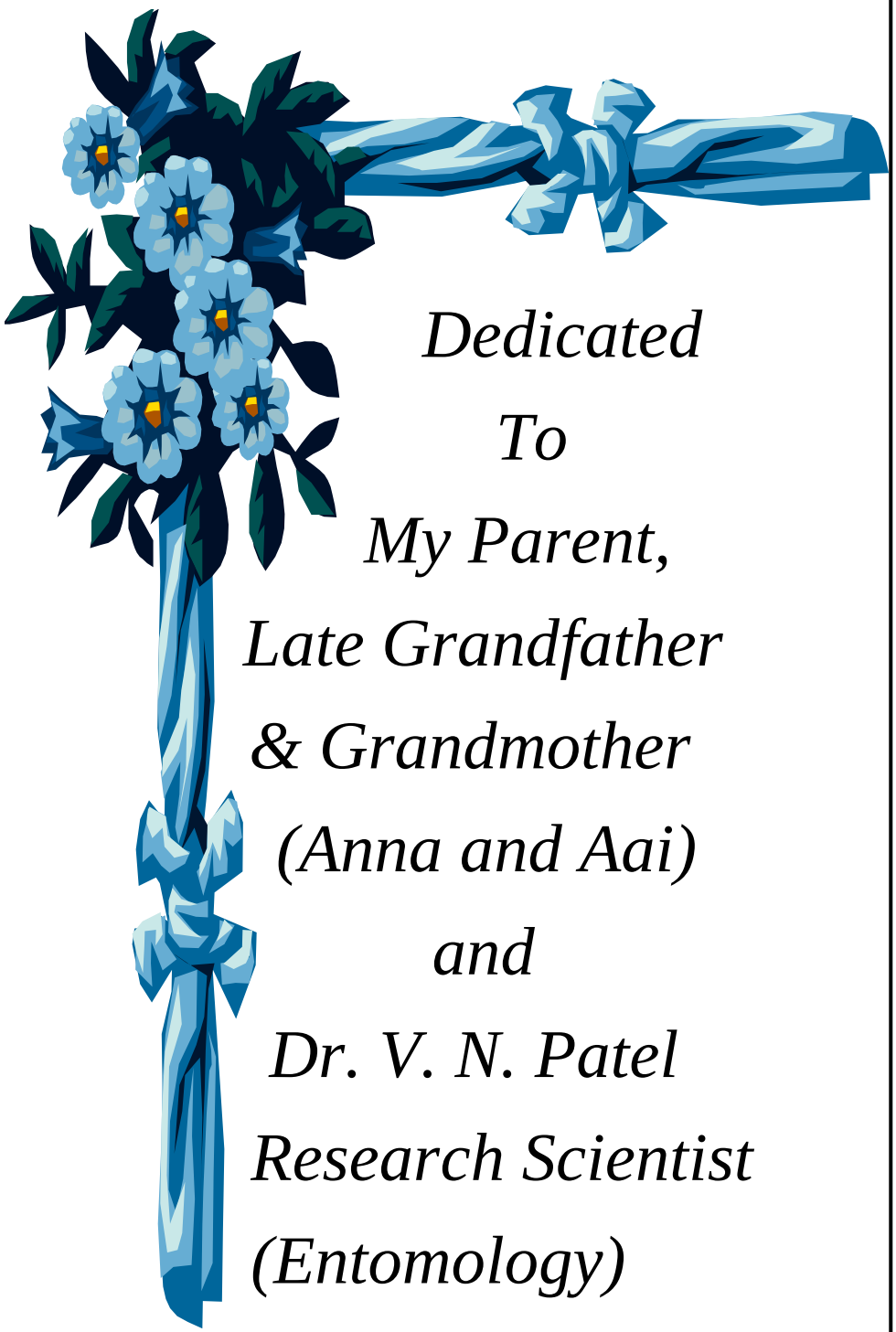

Dedicated

To

My Parent,

Late Grandfather

& Grandmother

(Anna and Aai)

and

Dr. V. N. Patel

Research Scientist

(Entomology)

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
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Shitole T. D. **Dr. V. N. Patel**

POPULATION DYNAMICS, YIELD LOSSES AND MANAGEMENT OF THRIPS, *Scirtothrips dorsalis* Hood INFESTING CHILLI

ABSTRACT

Key words: Chilli, thrips, leaf curling, losses, management and residue

The investigation on population dynamics, yield losses and management of thrips, *Scirtothrips dorsalis* Hood infesting chilli was carried out at two different location *i.e.* farmer's field (Village Devlki, Taluka: Vadia, Dist: Amreli) in North Saurashtra Agroclimatic Zone during 2011 and at Junagadh (South Saurashtra Agroclimatic Zone) during 2012.

The population dynamics of thrips, *S. dorsalis* Hood infesting chilli crop and the leaf curling appeared was studied at different two location (in North Saurashtra Agroclimatic Zone and in South Saurashtra Agroclimatic Zone) during *Kharif* 2011 and 2012. The results revealed that the thrips infested the chilli crop right from seedling stage to maturity stage of the crop. The thrips infestation commenced in 31st standard week and the pest population multiplied very fast from 33rd to 42nd standard week and reached at peak 84.13/ 3 twig. Thereafter, pest population was decreased. The chilli leaf curling was also appeared with thrips and increased fats from 14 per cent to 81 per cent with increased thrips population. The higher activity of thrips on chilli crop at both the location was found during 41st to 45th standard week. The weather parameters supported high multiplication of the thrips on chilli were maximum temperature 35℃ to 37.1℃ and minimum temperature 18.35℃ to 22.15℃, maximum relative humidity 57.5 per cent to 70 per cent and minimum relative humidity 26 per cent to 31.5 per cent, wind seed 2.65 to 4.35 km/h, bright sun shine hours 7.35 to 9.65 h/day and evaporation rate 5 to 5.6 mm/day with no rain.

The correlation study indicated that increased thrips population on chilli crop was highly positive with maximum temperature, while significantly positive correlation with evaporation rate and bright sunshine hours. However, the correlation of thrips population with minimum relative humidity was highly negative, while significantly negative correlation with maximum relative humidity. Non-significant negative correlation between thrips population and minimum temperature and rainy days was exhibited. Correlation between thrips population and leaf curling severity was existed highly significant.

The relationship of appearance of leaf curling and the thrips infesting chilli was studied by three different angles. The percentage of leaf curling (severity) was

increased with increased number of thrips per plant. The coefficient of correlation between number of thrips and percentage of leaf curling was strongly positive. After the insect were eliminated by the insecticidal spraying, the growth of plants was normal and without curling within 20 day. While the plant kept as control (untreated) were continued with thrips and pronounced leaf curling recorded. The cell sap of leaves having severe and typical symptoms of leaf curling was inoculated on the healthy tender leaves of potted healthy plants. Leaf curling symptoms not produced in the sap inoculated plants (protected). This result indicated that insect born virus was not responsible for producing the leaf curling in chilli.

The experiments on qualitative and quantitative losses caused by thrips, *S. dorsalis* infesting chilli were conducted at two different location (in North Saurashtra Agroclimatic Zone and South Saurashtra Agroclimatic Zone) during *Kharif* 2011 and 2012. The result revealed that 62.58 per cent leaf curling, 26.34 per cent plant height, 28.50 per cent branches, 33.39 per cent length and 11.01 per cent width of fruit (green chilli) and 62.83 per cent length and 64.04 per cent width of leaf were reduced due to infestation of the thrips in chilli. Further quality of green chilli *i.e.* appearance, shape, luster of green chilli was also detoriated.

The quantitative (yield of green chilli) losses was ranged 11333 kg/ha (289.77%) to 10911 kg/ha (299.39%) with an average 11122 kg/ha (294.41%). The avoidable loss was 74.34 per cent to 74.96 per cent with average of 74.65 per cent.

Bioefficacy of the twelve insecticides was evaluated against thrips, *S. dorsalis* infesting chilli on farmer's field. Three application of the insecticides was given at fifteen day interval. The result revealed that significantly the highest reduction in thrips population (7.33 thrips/3 twig) and leaf curling (13.29 per cent) was recorded on chilli crop treated with spinosad 0.009 per cent followed by profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent, profenophos 0.05 per cent, acetamiprid 0.008 per cent, diafenthiuron 0.05 per cent and indoxacarb 0.0145 per cent. The maximum thrips population 52.22/3 twig and degree of leaf curling 56.97 per cent was recorded on untreated plants (control). The significantly maximum yield (15278 kg/ha) of green chilli with 229.34 per cent increased over control was recorded from the crop treated with spinosad 0.009 per cent followed by profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent and imidacloprid 0.005 per cent. The highest monitoring net return of ₹ 212780/ha was also recorded from spinosad 0.009 per cent followed by profenophos + cypermethrin 0.044 per cent (₹ 182220/ha), abamectin 0.003 per cent (₹ 161660/ha), imidacloprid 0.005 per cent (₹ 160000/ha), acetamiprid 0.008 per cent (₹ 145000/ha) and profenophos 0.05 per cent (₹ 140560/ha).

The six insecticidal spray schedule having three to eight insecticidal applications at 30, 20, 15, 12, 10 and 8 days interval were evaluated against chilli thrips. The schedule 6 having eight insecticidal applications at eight day interval starting from 40 day after transplanting was found most effective against chilli thrips and leaf curling. The maximum yield 10875 kg/ha with the highest net monitoring return was also received by the schedule 6. The insecticides applied in schedule 6 were (i) Polytrin C (profenophos 40% + cypermethrin 4%) 0.044 per cent, (ii) abamectin 0.003 per cent, (iii) imidacloprid 0.005 per cent, (iv) spinosad 0.009 per cent, (v) Polytrin C (profenophos 40% + cypermethrin 4%) 0.044 per cent, (vi) acetamiprid 0.008 per cent, (vii) spinosad 0.009 per cent and (viii) imidacloprid 0.005 per cent.

The residue of imidacloprid 0.005 per cent, abamectin 0.003 per cent and cypermethrin 0.004 per cent (Polytrin C 0.044%), spinosad 0.009 per cent and profenophos 0.04 per cent was below maximum residue limit (MRL). The residue of these insecticides in/on green chilli was below its maximum residue limit (MRL). But the residue of acetamiprid 0.008 per cent (0.346 mg/kg) was slightly above the maximum residue limit (0.20).

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CERTIFICATE-I

This is to certify that the thesis entitled **"POPULATION DYNAMICS, YIELD LOSSES AND MANAGEMENT OF THRIPS, *Scirtothrips dorsalis* Hood INFESTING CHILLI"** submitted by **SHITOLE TUSHAR DADASAHEB** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy (Agriculture)** in the subject of **ENTOMOLOGY** to the Junagadh Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title. The candidate had fulfilled all prescribe requirements. The assistance and help received during the course of investigation have been fully acknowledged. He has successfully completed the preliminary examination held on July 25, 2012 as required under the regulation for post-graduate studies. He has submitted kachcha bound thesis on July 21, 2010.

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CERTIFICATE-II

Date: 15.10.2013

This is to certify that the thesis entitled **"POPULATION DYNAMICS, YIELD LOSSES AND MANAGEMENT OF THRIPS, *Scirtothrips dorsalis* HOOD INFESTING CHILLI"** submitted by **SHITOLE TUSHAR DADASAHEB** to Junagadh Agricultural University, Junagadh in partial fulfillment of the requirements for award of the degree of **DOCTOR OF PHILOSOPHY (Agriculture)** in the subject of **ENTOMOLOGY** after recommendation by the external examiners were defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory. We, therefore, forward with recommendation.

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Place : JUNAGADH **(SHITOLE TUSHAR DADASAHEB)**
Date : July 21, 2013.

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CHAPTER-I

INTRODUCTION

Chilli, *Capsicum annum* Linnaeus belongs to the family Solanaceae is one of the important commercial vegetable crop grown in all over India. Being a crop of tropical and sub-tropical region, it requires a warm humid climate. It is a native of tropical America and West Indies and believed to have been introduced to India by the Portuguese during 17th century (Sreeramulu, 1976). Chilli is used as a paste, powder or in whole form. A number of varieties are grown for vegetables, spices, condiments, sauce, ketchup and pickles etc. It is one of the chief sources of vitamin A, C and E. Its paste is externally used as a rubefacient and as a local stimulant for the tonsils in tonsillitis. Chilli is also known to have medicinal value, as it prevents heart attack by dilating the blood vessels (www.ikisan.com). Of late, the export value of capsaicin, further led to increase in production of chilli in India. Chilli has two important commercial qualities. Some varieties are famous for red colour because of the capsathin, others are known for biting pungency attributed by capsaicin. Out of total production of chillies 90-95 per cent consumed within the country and about 5-10 per cent exported in the form of dry chilli, chilli powder and oleoresins (Singhal, 2003).

India is the world's largest producer of chillies and the crop is grown all over the country, occupies an area of 792100 ha with a production of 1223400 MT of green chilli in 2010-11 (Anon., 2011). In Gujarat, chilli occupies an area of 43350 ha with a production of 68534 MT of dry chilli and 262011 MT of green chilli in 2011-12 (Anon., 2012-13).

Nearly 25 insects have been recorded attacking chilli leaves and fruits in India, of which thrips, *Scirtothrips dorsalis* Hood (Thripidae: Thysanoptera) is considered as the most serious and important pest (Ananthakrishnan, 1971; Butani, 1976; Krishna Kumar, 1995 and Krishna Kumar *et al.,* 1996). The symptoms of chilli leaf curl caused by feeding injury of thrips was described by Amin (1979), which is locally known as "*Kokadava*" in Gujarat. The yield losses 60.5 to 74.3 per cent of green chilli due to thrips was estimated by Patel and Gupta (1998) at Udaipur (Rajasthan).

The thrips was first collected by Ramakrishna Ayyar on shoots and fruit of chilli in Coimbatore (India) in 1916 and sent to Hood, who described it as a new species in 1919 under the name *Scirtothrips dorsalis* Hood. Since then, there has been no nomenclatural change for this insect. It has been called chilli thrips (Rao, 1928), Dreaded chilli thrips (Singh, 1944), Scab thrips of grape (Reddi, 1959), Assam thrips or tea thrips (Dev, 1964) or chilli thrips (Raizada, 1965).

Surveys conducted by AVRDC in Asia revealed that, the major sucking pests that attack chilli are thrips (*Scirtothrips dorsalis* Hood), mite (*Polyphagotarsonemus latus* Banks) and aphids (*Myzus persicae* Sulzer, *Aphis gossypi* Glover) (Berke and Sheih, 2000). Chilli thrips multiply appreciably at a faster rate during dry weather periods and caused a yield loss of 30 to 50 per cent in South India (Varadharajan, 1994).

Chilli leaf curl is one of the most destructive syndromes affecting chilli growth in India and considered to be caused by thrips. Nymphs and adults of thrips suck the sap from tender crop canopy, resulting shriveling of leaves. Patel and Gupta (1992) reported that thrips *S. dorsalis* was responsible for cause of leaf curling in chilli. The infested leaves curled upward (adaxially) presenting a boat shaped appearance and they suggested thrips management to overcome the malady of leaf curling. In addition to eruption of internal areas and puckering of leaves, upward curling of leaves is also noticed. The affected leaves and fruits are deformed, twisted, brittle and crumpled (Reddy and Puttaswamy, 1983). Feeding symptoms of the mite are downward curling, crinkling of leaves and elongation of leaf petiole followed by blister patches. If the plant is attacked at flowering stage, the flowers are transformed leafy shoots and may wither and dry (Karupachamy *et al.*, 1993).

Now-a-days build up of thrips in chillies is so much that farmers have many spray of chemical insecticides. Number of sprays have increased over the years, but in vain and on the contrary, cost of cultivation has increased enormously making cultivation of chilli highly risky. In addition to this, pesticidal sprays became a threat to chilli ecosystem causing problems of resistance, resurgence of pests, pesticides residue and menace to natural enemy fauna David (1986).

Pesticide residues in chilli are of great concern from the point of domestic consumption and exports as well. The residues in chilli have been reported by various workers in India (Nandihalli, 1980; Awasthi *et al.*, 2001; Dhotre *et al.*, 2001 and Joia *et al.*, 2001). The presence of pesticide residues in spices especially in chillies is a major non-tariff barrier for export of chillies to developed countries.

Of the various pests attacking chilli, the thrips, *S. dorsalis* is considered as one of the most destructive insect pest in India. Now- a- days, a large number of newer insecticides and biopesticde are available in market. Bioefficacy of these insecticide and biopesticide need to be studied for formulating effective and economical management strategies of any insect pest. Very less amount of work has been made in the past on population of dynamics, yield losses and management of thrips, *S. dorsalis* infesting chilli especially in South Saurashtra and North Saurashtra Agroclimatic Zone region of Gujarat.

In view of above parameters, following objectives were framed for detail study.

1) Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms
2) Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*
3) Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli
4) Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*
5) Determination of the insecticide residue on/in chilli

CHAPTER-II

REVIEW OF LITERATURE

Chilli, *Capsicum annuum* L. is one of the important commercial spice crops grown in India. Of the various pests attacking chilli, the thrips, *S. dorsalis* is considered as one of the most destructive insect pest in India (Ananthakrishnan, 1971; Butani, 1976; Krishna Kumar, 1995 and Krishna Kumar *et al.,* 1996). And chilli leaf curl is one of the most destructive syndromes affecting chilli in India and considered to be caused by the thrips (Patel, 1992). Amin (1979) described the symptoms of chilli leaf curl caused by feeding injury of thrips, locally known as "*Kokadava*" in Gujarat. Chilli crop couldn't grow successfully by the farmers in 15 km area of Junagadh because of heavy attack of the thrips and leaf curling.

An attempt was made to review the available literature on various aspects of present investigation, which are presented under various topics.

1) Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms
2) Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*
3) Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli
4) Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*
5) Determination of the insecticides residue on/in chilli

2.1 Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms

Hood (1919) first collected *S. dorsalis* on castor and chillies from Coimbatore (India). Ayyar (1928) and Ayyar *et al.* (1935) reported that *S. dorsalis* was appeared in Guntur (Andhra Pradesh) and Periyakulam-Madras (Tamil Nadu) tracts causing appreciable damage to chilli crop. The rainfall was more during north-east monsoon. However, it was early in Guntur and late in Periyakulam. In both the places, the population of thrips was low during rainy season.

The subject of leaf curling of chilli has received considerable attention, as it is known to be a greatest enemy of chilli plants it occurs in varying degree in the most

of the part of the country and therefore, know to the cultivators by various name as murda, gaja, macoda and mirya in Daccan, Chandigora or mudatha, multagariroga in Karnataka, Kokadva in Gujarat, korivi in Telengana area, churdamurda in Vidharbha area and tuntia in Rajasthan (Kulkarni, 1922; Khodawe and Talley, 1977).

Thrips, *S. dorsalis* was reported to cause appreciable damage to chilli plant at all stages of crop growth (Ramchandra Rao, 1928; Ayyar, 1928 and Ayyar *et al.*, 1935). The nymphal and adult stages of the thrips have been reported to cause damage to chilli crop. They suck the sap from the foliage resulting into development of crinkle and also curling of leaves upward and when, their attacks was severe, plants develop bronze colour. This checks setting of fruits and resulted in severe losses in yield (David and Kumaraswami, 1978; Singh, 1988).

The chillies thrips, *S. dorsalis dorsalis* is a polyphagous pest and is widely distributed in India. This pest is active throughout the year except during the rainy season and there are several over-lapping generations in a year. It feeds on a number of plants including chillies, tomato, castor, sunflower, cotton, mango, citrus and *Acacia arabica* L. (Ayyar, 1940).

Ananthakrishnan (1969) also reported that the chilli thrips, *S. dorsalis* is a polyphagous pest with a wide range plants. Both nymphs and adult lacerate the leaf tissue and suck the oozing juice. Sometime even the buds and flowers are attacked. Tender leaves and growing shoots are preferred; the old leaves are seldom attacked. The pest infestation increases in dry weather. The infested leaves are start curling, crumpling and shed, whereas buds become brittle and drop down. If there are no rain is available, the entire plant may wither and dry away. Besides it transmits leaf curl viral diseases.

According to Vevai (1969), the incidence of *S. dorsalis* on chilli was more during October in Andhra Pradesh, February to March in Bihar, August to November in Delhi, Mysore and Madhya Pradesh and throughout the year in Tamil Nadu and Maharashtra. In Karnataka, the pest was noticed almost throughout the year on chilli. The population reached its peak during October and thereafter gradually declined from November onwards reaching the lowest level in May.

Lee and Wen (1982) reported higher population of *S. dorsalis* during dry season although the pest was observed throughout the year.

Both nymphs and adults of chilli thrips suck the sap from tender crop canopy, resulting shriveling of leaves and in extreme cases the shoots hardly develop and leaves fall-off. In addition to eruption of internal areas and puckering of leaves, upward curling of leaves was also noticed in seedling and transplanted crop of chilli by Reddy and Puttaswamy, (1983 and 1985).

Sanap *et al.* (1985) recorded seasonal incidence of the thrips (*S. dorsalis*) on chilli variety NP-46A. The pest was appeared during the first week of August and population increased from the 2nd week of August, reached at peak (109 thrips/15 shoots) in the 1st week of September. Thereafter, the incidence declined towards the maturity of the crop. The most congenial weather parameters for fast multiplication of the thrips were temperature ranged between 25.8℃ and 26.9℃ combination with relative humidity ranged between 60 and 75 per cent. During rain, a decline of population was noticed and during low relative humidity period the thrips population decreased on chilli.

According to Patnaik *et al.* (1986), the incidence of chilli thrips was low during the month of August and the thrips population reached at peak during December month. They also reported that temperature, rainfall and relative humidity were negatively correlated with thrips population but diurnal temperature variation was positively correlated. The damage was very severe during cool and dry months.

Borah (1987) observed that the activity of *S. dorsalis* was found throughout the year. However, incidence was more during September to March and it was moderate in rest of the year. The incidence of *S. dorsalis* on chillies was severe from September to January. The population increased during dry periods.

Patel (1992) reported that the population of chilli thrips remains low during July and August due to rains and showed a peak in October. The congenial meteorological parameters for high multiplication of thrips on chilli crop were maximum temperature ranged 30℃ to 32.6℃, minimum temperature ranged 10.3 to 14.7 with maximum relative humidity ranged 66 to 89 per cent and minimum relative humidity ranged 28 to 41 per cent during 1990-91 and maximum temperature ranged

28.1℃ to 33.4℃, minimum temperature ranged 18.5 to 23.5 with maximum relative humidity ranged 66 to 89 per cent and minimum relative humidity ranged 21 to 79 per cent during 1991-92 at Udaipur (Rajasthan). Rainfall and temperature were negatively correlated with population density of the thrips.

Bagle (1993) revealed negative correlation with minimum temperature, rainfall and relative humidity for the incidence of leaf curl disease caused by thrips on chilli cultivars and maximum temperature showed positive correlation. Varadharajan and Veeraval (1995) reported that the correlation co-efficient between thrips population and maximum temperature was statistically significant positive and rainfall had a negative correlation with the activity of chilli thrips. Panickar (2000) showed negative correction between activities of *S. dorsalis* on chilli and temperature, vapour pressure, wind speed and relative humidity, while positive correction with bright sunshine hours. Keisa *et al*. (1994) reported higher incidence of thrips during May and September which coincided with maximum temperature.

Varadharajan and Veeravel (1995) noticed the activity of S. *dorsalis* throughout the year. The incidence of *S. dorsalis* as indicated by yellow sticky trap catches during 1994 was minimum (9.40/ trap) during the last week of July and maximum (55.25/ trap) during the first week of September.

Bhede *et al.* (2008) studied the population dynamics of the thrips on chilli at Parbhani during *kharif* 2002-03. The incidence of thrips was the highest during 40th meteorological week when the prevailing maximum temperature 35.80℃ and minimum temperature 18.0°C, morning 76% and evening 34% relative humidity, no rainfall and bright 11 sunshine hours recorded. Thrips population exhibited significant negative correlation with evening relative humidity and rainfall, positive correlation with bright sunshine hours and non-significant positive correlation with maximum temperature and non-significant negative correlation with minimum temperature.

Patel *et al.* (2009) studied the population dynamics of chilli thrips during *Kharif* season of 2002-03 and 2003-04 at Anand in Gujarat. Results revealed that the incidence of *S. dorsalis* on chilli crop commenced from first week of September and continued up to harvest of the crops. Peak activity *i.e.* of the pest was recorded in November (4.99 to 5.54 thrips/ leaf) and in February–March (5.29 to 7.38 thrips/ leaf). Significant positive correlationship was existed with bright sun shine hours and

maximum temperature, whereas significant negative correlation was found with morning, afternoon and mean relative humidity, morning, afternoon and mean vapour pressure as well as rainfall.P

Method assessment of thrips population from plant

Various methods have been used by entomologists to measure the population density of *S. dorsalis* on chilli plants. Bagle (1993) dislodged thrips from five young shoots per single plant onto a black cardboard and counted them. Likewise, Thrips population was counted from 6 leaves (two tender leaves from three twigs) per plant by Patel (1992).

Relation of thrips density and leaf curling in chilli

Gardner and Whipple (1934) reported successful transmission of tomato spotted wilt virus by thrips, *S. dorsalis* on chillies. The thrips was also found responsible for transmitting leaf-curl mosaic virus on chillies (Ananthakrishnan, 1969).

Park and Fernando (1938) initially questioned the viral infection in curled leaf of chillies. Later they observed that abaxial curling of leaves recovered, when treated with a spray of nicotine sulfate to eliminate the thrips. They concluded that leaf malformation of chilli in Jaffna Penisula was due to direct injury caused by the thrips.

Johnpulle (1939) observed a number of leaf curled plants as affected by infestation of thrips. He noticed that the first symptoms of leaf curling were appeared in potted plants containing thrips, about a week after the introduction. The tender young leaves exhibited typical signs of crinkling. After five days the curling symptoms became pronounced and all new leaves were involved. But the symptoms disappeared in plants protected from infestation of the thrips, whereas they continued to be so in those exposed to infestation of the thrips. This was also due to direct injury by the thrips and not due to an insect borne virus.

Peiris (1953) opined that the leaf curl of chilli was due to mechanical injury caused by thrips and also due to the toxic substances introduced by these organisms along with the saliva into the leaves during feeding. He recorded that affected plants

stunted. Leaves generally curved upward, presenting a "boat shaped" appearance. There was certain amount of interveinal buckling and the upper epidermis showed signs of irregular scraping by the thrips.

Puttarudraiah (1955 and 1959) stated that the thrips, *S. dorsalis* caused curled leaf margin dorsally and the insect could be seen within the curls of affected tender leaves.

Fernando and Peiris (1957) investigated the chilli leaf curl complex. According to them, leaf curl complex was due to feeding by thrips *S. dorsalis* and was also to infection of virus disease.

Ningappa (1972) observed that *S. dorsalis* was found to cause curling of chilli leaves. Twelve days after the inoculation of the thrips the tender leaves exhibited inward (adaxial) curling of laminar margin dorsally and this was followed by the inter-venial area getting raised up which appeared as buckled leaves. Further, he recorded that 20 days after infestation the curling was much pronounced and later all fruits were invariably dropped. In comparison to thrips, mite caused downward curling of leaves and cupping of leaves on 14^{th} day after infestation and was accompanied by dropping of flowers.

Chavan (1974) stated that chilli crop was very much affected with the malady called leaf-curl in the early stages of its growth due to attack of thrips.

Moghe (1977) find out the causes of "Churda Murda" (malformation) disease of chilli leaves in Vidarbha (Maharashtra). He observed that this disease might have resulted in general stunting, reduction in leaf size and upward or downward curling of leaves. The upward curling was due to infestation of thrips (*Anaphothrips dorsalis* Hood). He also reported that foliar spray with monocrotophos (1.5 ml/ L) helped such plants to produced healthy new growth. A few plants, which failed to recover even after rigorous spraying with the insecticides, harbored a viral infection, CMV-1.

According to Nandihalli (1980) reported that the potted plants of chilli inoculated with thrips, *S. dorsalis* showed inward curling of leaf margins, which appeared after 10 to 12 days of inoculation and the interveinal area had raised up.

Patangrao (1987) observed that the cultivars bearing less thrips population had less leaf curling and vice-versa. He showed clear relationship of thrips with the leaf curling appearance and stated that there was low leaf curling, if there was low population of thrips which in turn resulted into higher yield and vice-versa.

Patel and Gupta (1992) reported that malady of leaf curling (abaxial) in chillies was proved to be caused by thrips, *S. dorsalis* only. No other insect like aphids and whiteflies and virus were involved in the cause of the leaf curling. Two or more thrips per plant at seedling stage could cause leaf curling and its severity increased with increase in thrips population. The symptoms of leaf curling were first noticed on top tender leaves with typical signs of upward curling with no change in leaf colour at 11 days of feeding of two thrips per plant. The population of thrips 4, 6, 8, 10 and 15 per plant resulted in production of leaf curling symptoms after 10, 8, 8, 7 and 6 days of release, respectively, while thrips population at rate of 2, 4, 6, 8, 10 and 15 per plant produced 25, 43.75, 62.50, 75.00, 80.00 and 87.50 per cent of leaf curling symptoms, respectively after 20 days of release. The coefficient of correlation (r) between number of thrips and percentage of leaf curling was strongly positive indicating that thrips, *S. dorsalis* was responsible for leaf curling in chillies.

2.2 Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*

Qualitative losses

According to Ramchandra Rao (1928), *S. dorsalis* caused twisting and deformation of leaves of chillies and when successive shoots were attacked, the plants become stunted and finally dried up. Ayyar *et al.* (1935) observed that *S. dorsalis* caused wounds by feeding on the tender tissues resulting into malformation and shriveling of leaves, buds and fruits. In severe cases the leaves were shed, freshly formed buds became brittle and dropped down resulting into a staghead appearance in plant. This was called **"Korivi"** stage, whereas the damage caused during the earlier stages was commonly referred as **"Mudatha".**

The severe reduction in leaf size due to curling of leaves and extreme dwarfing of chilli could usually be drought out by the toxic effect of feeding by thrips (*S. dorsalis*). No organism or virus was reported to involve in the etiology of this

syndrome (Uppal, 1940; Anonymous, 1942 and Patel and Gupta, 1992). Further plants returned to their normal and healthy growth if thrips (*S. dorsalis*) were controlled by spraying with suitable insecticides (Capoor, 1967 and Patel, 1992).

However, Gattani and Mathur (1961) observed 100 per cent leaf rolls in chilli plants. The reason of this symptom was reported by them, is the infection caused through viral disease transmitted by thrips. Field survey carried out by Rataul *et al.* (1976) in the Punjab reported 21 to 57 per cent incidence of leaf curl diseases in chilli.

According to Butani (1976), nymphs and adults of *S. dorsalis* were found to lacerate the leaf tissues and suck the oozing juice; sometimes the buds and flowers were also attacked. The infested tender leaves started curling, crumpling and were shed, whereas buds became brittle and dropped down.

Moghe (1977) find out the causes of **"Churda Murda"** (malformation) disease of chilli leaves in Vidarbha (Maharashtra). He observed that the disease manifested as general stunting reducing leaf size and upward or downward curling of leaves, the upward curling was due to infestation of thrips, *S. dorsalis*.

David and Kumraswami (1978) reported that the larvae and adults of *Scirtothrips dorsalis* were found to feed on the sap of tender leaves causing curling of chilli leaves. Severe infestation caused heavy curling of leaves and stunting growth of crop, buds and flowers.

Krishna Kumar (1995) recorded the qualitative yield loss to the tune of 90 per cent in chilli.

Patel and Gupta (1996) reported that the loss in plant height was extent to 27.85 per cent. Whereas reduction in number of branches per plant was 44 per cent and the length 66.01 per cent and width 65.71 per cent of leaf observed. The length of green marketable fruits of chilli was reduced by 37.72 per cent and also affected fruit were of low quality.

Quantitative losses

Ayyar *et al.* (1935) have reported that when dry weather prevailed, severe incidence of chilli thrips could be noticed resulting into appearance of leaf curl

disease and 20 to 50 per cent of the total yield was lost in Guntur area. According to Nagaraja Rao (1955) reported the yield loss up to 30–50 per cent in chilli crop. Reddy and Puttaswamy (1983) recorded 23 to 87 per cent incidence of leaf curl due to *S. dorsalis* along with *P. latus* in Karnataka.

According to Panchabhavi and Thimmaiah (1972), 72.5 per cent yield loss could be saved by controlling thrips on chilli with insecticides. Chellaiah and Murugesan (1976) reported that a profit of ₹ 5321/ ha could be achieved by controlling insects and associated disease with use of insecticides.

Ningappa (1972) also reported 20-100 per cent yield loss due to thrips infestation and incidence of leaf curl in chilli crop at Bangalore.

Krishna Kumar (1995) recorded the yield loss caused by thrips, *S. dorsalis* was 11 to 32 per cent in chilli. Nagaraj Rao (1955) reported as high as 50 per cent loss in yield of chilli due to thrips infestation.

Patel and Gupta (1996) reported that the yield losses caused by chilli thrips, *S. dorsalis* ranged from 60.56 to 74.31 per cent of green chillies. The loss worked out in term of rupees per hectare was fund to be ₹ 22065 to ₹ 25925/ha and also reported avoided leaf curling damage 94.44 per cent to 98.55 per cent. The leaf curling percentages was recorded 55 per cent to 72 per cent leaf curling in unprotected plots of chilli, while in protected crop 1 per cent to 3 per cent leaf curling.

In extreme conditions, the leaf colour turns bronze with sharp reduction in plant height. The yield loss due to chilli thrips ranges from 50 to 90 per cent (Bagle, 1998).

2.3 Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli

Bagle (1998) evaluated varying dosages of insecticides and botanicals against thrips infesting chilli. Among the different botanicals tested, neem seed kernel extract showed the lowest rating of leaf curl in Pusa Jwala and G-4 varieties of chilli.

Chandrasekaran and Veeravel (1998) registered that Achook 1.5% recorded 72.9 per cent reduction of thrips population followed by mixture Achook 1.5% (65.5%) and neem oil 5% (60.1%). However, plant products tested were found inferior to the chemical check.

Patil *et al.* (2002) reported that imidacloprid 200 SL @ 125 ml and 150 ml/ha were highly effective against the thrips of chilli and proved to be better than monocrotophos 36 SL and dimethoate 30 EC. The treatment with imidacloprid 200 SL @ 150 ml/ha recorded significantly highest chilli fruit yield followed by imidacloprid 200 SL @ 125 ml and 100 ml/ha.

Three different dosages of diafenthiuron 50 WP *viz.*, 0.60 g/ℓ, 0.9 g/ℓ and 1.2g/ L were tested against thrips *S. dorsalis* in chilli ecosystem. Among the different dosages, diafenthiuron 50 WP @ 0.9 g/ℓ recorded better yield with least leaf curl incidence due to thrips (0.62 leaf curling index / plant), which was found equally good as compared to its higher dosage and recommended practices. Three different dosages of vertimec 1.9 EC *viz*., 0.56 ml/ℓ, 1.12 ml/ℓ and 2.24 ml/ L were tested against chilli thrips *S. dorsalis* (Hood) in chilli ecosystem. Among the different dosages, vertimec 1.9 EC @ 0.56 ml/ L was recorded low incidence due to thrips (0.48 leaf curling index/plant), which was found equally good as compared to all its higher dosages and recommended practices (Tatagar, 2004).

Hosamani (2007) reported that imidacloprid 17.8 SL and clothianidin were effective in the management of chilli thrips. These two chemicals recorded least incidence of thrips after each spray. In general, imidacloprid reduced thrips incidence to the extent of 84 per cent and clothianidin to the extent of 81 per cent, which might have resulted in good growth and yield parameters of the crop. The efficacy of imidacloprid and clothianidin was well reflected on yield. Among the new molecules imidacloprid 17.8 SL @ 20 g a.i/ha was found to be superior in recording the highest green chilli yield (133.10 q/ha) and it was followed by clothianidin 50 WDG @ 20 g a.i/ha (131.40 q/ha), which were significantly higher than other treatments. Imidacloprid 17.8 SL @ 20 g a.i/ha recorded the highest net returns of ₹. 64,625/ha with additional net returns of ₹ 18,929/ha over control.

Nagaraj *et al*. (2007) reported that the mean thrips population and leaf curl index recorded were minimum in thiamethoxam 25 WG (2.95 thrips/ leaf and 1.66 leaf curl index), which was followed by imidacloprid 17.8 SL (3.10 thrips/ leaf and 1.46 leaf curl index). But comparatively more population of thrips was registered in acetamiprid 20 SP (3.95 thrips/ leaf and 2.92 leaf curl index), which was at par with spinosad 45 SC (4.25 thrips/ leaf and 3.01 leaf curl index).

Bhede *et al.* (2008) recorded minimum thrips population (range 0.13 to 1.65/ 3 leaves) in phosphamidon 40% + imidacloprid 2% SP @ 700 g/ha. However, it was at par with phosphamidon 40% + imidacloprid 2% SP @ 600 (range 0.53 to 1.73/ 3 leaves) and 500 g/ha (range 0.84 to 1.97/ 3 leaves) and imidacloprid 17.8 SL @ 112 ml/ha (range 0.95 to 2.33/ 3 leaves) at second, seven, fourteen and twenty one days after spraying and all the insecticidal treatments were significantly superior over untreated check. Whereas, the highest marketable green chilli yield (43.52 q/ha) was recorded in phosphamidon 40% + imidacloprid 2% SP @ 700 g/ha, however, it was at par with its lower dosages 600 g/ha and 500 g/ha (41.26 q/ha and 37.30 q/ha, respectively) and imidacloprid 17.8 SL@ 112 ml/ha (35.71q/ha). The untreated check recorded the lowest yield of green chilli (26.57 q/ha).

Dharne and Kabre (2009) reported that among the different treatments, RIL-042 222 SC (indoxacarb 14.5 + acetamiprid 7.7 SC) @ 500 ml/ha recorded the lowest thrips population (4.63/ 3 leaves) and was at par with its optimum dose *i.e.*, RIL-042 222 SC @ 400 ml/ha (5.33/ 3 leaves) and acetamiprid 20 SP @ 200 g/ha (5.60/ 3 leaves), which were significantly superior over indoxacarb 14.5 SC 500 ml/ha (6.60/ 3 leaves), Koranda 505 EC 1250 ml/ha (6.67/ 3 leaves) and RIL-042 300 ml/ha (7.26/ 3 leaves)and untreated control (12.73/ 3 leaves). The maximum reduction over control in thrips population (63.63%) was noticed in RIL-042 222 SC @ 500 ml/ha followed by RIL-042 222 SC @ 400 ml/ha (58.13%), acetamiprid 20 SP @ 200 g/ha (56.00%) and indoxacarb 14.5 SC 500 ml/ha (48.15%) at three days after spraying. A similar trend was also observed at ten days after spraying.

Patel *et al.* (2009) revealed that among the different insecticidal treatments, ethion + cypermethrin (0.045%), methomyl (0.04%) and diafenthiuron (0.05%) proved to be the most effective against chilli thrips followed by imidacloprid (0.005%), lufenuron (0.005%) and triazophos (0.04%), whereas both the botanical formulations *viz.,* azadirachtin (0.00075%) and Neem Seed Kernel Suspension (5%) were found to be least effective against the thrips. They further reported that the chilli crop treated with diafenthiuron (0.05%) produced the highest (115.75 q/ha) yield followed by methomyl 0.04% (104.67 q/ha) and ethion + cypermethrin 0.045% (98.30 q/ha). Treatments of imidacloprid (0.005%) and lufenuron (0.005%) also registered

higher (75.04 to 82.30 q/ha) yields over rest of the treatments and remained at par with each other. Among the treatments evaluated, lowest (36.28 q/ha) yield was revealed in case of NSKS followed by azadirachtin 0.00075% (37.69 q/ha) and economics of different treatments showed that appreciable Incremental Cost Benefit Ratio (ICBR) were obtained in case of ethion + cypermethrin (1:19.46), methomyl (1:15.18), imidacloprid (1:15.07), triazophos (1:14.28) and diafenthiuron (1:9.05) at Anand during 2002-03 and 2003-04.

Nandihalli (2009) studied on the efficacy of newer insecticide molecules against chilli thrips at Dharwad during 2005 and 2006. Among different newer molecules, indoxacarb 14.5 SC @ 500 ml/ha (in range 0.43 to 5.00 and 0.33 to 6.33 thrips/3 leaves at 3 and 7 days after spray respectively), acetamiprid 20 SP @ 200 g/ha (in range 0.80 to 6.00 and 0.53 to 10.33 thrips/3 leaves at 3 and 7 days after spray respectively) and combination product of indoxacarb 14.5 SC + acetamiprid 7.7 SC @ 500 ml/ L (in range 0.40 to 5.37 and 0.40 to 5.00 thrips/3 leaves at 3 and 7 days after spray, respectively) were most effective and at par with each other in reducing thrips population in all three sprays during both the years and yield recorded 22.32, 19.95 and 22.33 q/ha, respectively.

Mandi and Senapati (2009) revealed that acetamiprid (0.004%) and thiamithoxam (0.005%) were most effective to minimize the thrips population 93.30 per cent and 89.93 per cent, respectively in chilli crop. Neem pesticide (54.20%) and microbial pesticide *Bt* (43.43%) were found moderately effective. However, two sprays of acetamiprid and thiamethoxam followed by two sprays of neem pesticide and *Bt* (*Bacillus thuringiensi,* subsp. kurstaki) proved to be effective for management of thrips. The highest yield of green chilli fruit (40.5 q/ha) with higher cost benefit ratio of 1: 16.97 recorded in acetamiprid followed by thiamethoxam (33.1 q/ha). It was comparable to that of accetamiprid and thiamethoxam followed either by neem pesticide or microbial pesticide.

Nandini (2010) reported that the significantly minimum thrips population (0.65 thrips/5 leaves) was recorded on chilli plant treated with thiamethoxam and diafenthiuron (0.7 thrips/5 leaves) followed by *V. lecanii* (1.1 thrips/5 leaves) and significantly the lowest leaf curling was observed in the crop treated with thiamethoxam (27.7% to 58.3%) during the crop period followed by diafenthiuron

(32.7% leaf curling), while other treatments which were promising are *V. lecanii* (35%) and DDVP (36.1%).

2.4 Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*

Patel (1992) reported that acephate 0.0375 per cent and monocrotophos 0.036 per cent were applied alternatively in four different schedules containing 2 to 5 sprays at 15 days interval starting after one month of transplantation of chilli (var. Jwala). The most effective and longer suppression of thrips and leaf curl disease with highest net return (₹ 23711 with cost benefit ratio 1: 18.94) was achieved by schedule having five alternative sprays of 0.0357 per cent acephate and 0.036 per cent monocrotophos at 15 day interval.

Nandini (2010) recorded significantly lower thrips population (0.45 thrips/ 5 leaves) in the module M-II (Imidacloprid - abamectin + Rogor – acephate - Dicofol + imidacloprid- Rogor + imidacloprid - imidacloprid + abamectin – Dicofol + Fenazaquin) followed by M-I (profenophos – abamectin - NSKE 5% - *V. lecanii*- Fenazaquin - profenophos - abamectin and NSKE 5%) (1.0 thrips/ 5 leaves) and module M-III (Imidacloprid- *V. lecanii* - Dimethoate + Dicofol - Dicofol - Neem – abamectin - thiamethoxam and *V. lecanii*) recorded was recorded least effective against thrips (1.2 thrips / 5 leaves). With reference to leaf curl due to thrips, module M-II recorded minimum leaf curling (25.0 %) as compare to M-I (47.9%) and M-III (47.9%). Significantly higher fruit yield was recorded in M – II (2304 g/plant) which was superior to M-I (1868 g/ plant) and module M-III (1428 g/ plant).

Prajapati and Agalodiya (2012) reported that spray schedule S_1 (triazophos 40 EC @ 25 ml/10 ℓ, wettable sulphur 50 WP @ 40 g/10 ℓ, imidacloprid 17.8 SL @ 5 ml/10 ℓ, wettable sulphur 50 WP @ 40 g/10 ℓ and acephate 75 SP @ 15 g/10 ℓ of water) registered the least population of thrips at three (3.30/leaf) and seven (1.30/leaf) days after spray. Similarly spray schedule S_1 had exhibited the least leaf curl incidence (2.42 to 10.20%) and also obtained the highest fruit yield (2656 kg/ha) of green chilli, while in untreated control recorded the lowest fruit yield (1698 kg/ha).

2.5 Determination of the insecticides residue on/in chilli

Patel (1992) detected residues of acephate and monocrotophos in/ on green fruits and leaves of chillies. Acephate at 0.0375 and 0.075 per cent spray resulted in initial deposits of 11.62 ppm and 22.06 ppm on green fruits and 33.51 ppm and 65.39 ppm on leaves, respectively. The half-life of 2.83 to 3.98 days on fruits and 2.63 to 2.72 days on leaves were worked out. The waiting period for residues to reach tolerance limit on green marketable fruits were 5 days for acephate spray at 0.075 per cent. Monocrotophos at 0.036 and 0.072 per cent spray resulted in initial deposits of 6.68 ppm and 13.33 ppm on green fruits and 19.81 ppm and 38.29 ppm on leaves, respectively. The half-life of 2.13 to 2.61 days on fruits and 3.03 to 4.98 days on leaves were worked out for both respective concentrations. The waiting period for residues to reach tolerance limit on green marketable fruits were 11 days and 16 days for concentration 0.036 and 0.072 per cent of monocrotophos, respectively.

Shah *et al.* (1999) sprayed Polytrin-c (Profenofos 40% + Cypermethrin 4%) on okra crop at 0.44% and studied dissipation of component insecticide of ready mix formulation by GLC method. The half-life values ($T_{1/2}$) of profenofos and cypermethrin were 1.35 and 3.95 days, respectively.

Dharma Reddy *et al.* (2007) studied the dissipation of profenofos (@ 0.1% a.i.) on chillies by spraying at 15 days interval, starting from 45 days after transplanting. A total of four sprays were given. Samples of green chillies were collected at 0, 1, 3, 5, 10, 15, 20 and 30 days after the fourth spray and red chilli fruit samples collected at harvest and dried for 15 days in sun. The initial deposits of profenofos after last spray were 0.36 mg per kg, which dissipated to 0.02 mg per kg by 30 days amounting to the loss of 92.4 per cent. A half-life value for profenofos was 41.0 days. However, 19 days suggested for harvesting green chilli after the last spray of profenofos @ 0.1 per cent. But, the residue in dried chillies was below detectable level.

Sarangdevot *et al.* (2010) sprayed ready mix insecticide Roket 44% (Profenofos 40% + Cypermethrin 4%) @ 440 and 660 g a.i./ha and residue reached below detectable limit in 11 and 13 days after spraying in both respective doses. The safe waiting period and half-life value 2.75, 2.36 and 3.34, 2.47 days, respectively

during the year 2000-2001 and 2.70, 2.16 and 3.38, 2.52 days, respectively during the year 2001-2002.

Tatagar (2010) reported the level of residues of commonly used chemicals in green chilli. Dimethoate 30 EC @ 1.7 ml//ℓ, imidacloprid 200 SL @ 0.25 ml/ℓ, dicofol 18.5 EC @ 2.5 ml/ℓ, carbaryl 50 WP @ 4.0 g/ℓ and vertimec 1.9 EC @ 0.5 ml/ℓ were sprayed at different intervals. Week after the last spray green chillies were harvested for residue analysis. None of the residue of the insecticides could be detected in green chilli.

CHAPTER-III

MATERIALS AND METHODS

The present investigation was carried out on population dynamics, yield losses and management of thrips, *Scirtothrips dorsalis* Hood infesting chilli. Materials and methodology adopted during the course of investigation are described in this chapter under following aspect.

1) Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms
2) Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*
3) Bioefficacy of insecticides against thrips, *S. dorsalis*, infesting chilli
4) Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*
5) Determination of the insecticides residue on/in chilli

3.1 Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms

A field experiment was conducted for two cropping season *i.e.* during 2011-12 and 2012-13 to study the population dynamics of chilli thrips, *S. dorsalis* and it's relationship with appearance of the leaf curling symptoms.

The details of the field experiment are as follows:

Location and Agroclimatic Zone	:	A) At Farmer's Field (Village: Devlki, Tal: Vadia, Dist: Amreli.) during 2011-12 (North Saurashtra Agroclimatic Zone) and B) At Central Experimental Research Station, JAU, Junagadh during 2012-13 (South Saurashtra Agroclimatic Zone)
Crop	:	Chilli
Variety	:	Reshampata (Local)
Plot Size	:	9.0 m × 12.0 m
Spacing	:	75 cm× 60 cm (row to row and plant to plant)
Date of transplanting	:	1) 3 July 2011 and 2) 4 July 2012

Methodology:

The recommended agronomic practices were followed for raising the crop. Population of thrips was recorded on 60 plants at weekly interval. The 10 quadrates of 1.5m X 1.8m sized were randomly selected from whole plot. Six plants from each quadrate were randomly selected and tagged. From each plant 3 twigs with 5 cm length were selected from top portion of the plant. The thrips was dislodged by jerking the twig on a white paper and the number of thrips (nymphs) counts was recorded (Plate 1). Bagle (1993) used this type of method for measurement of thrips population on a plant. The observations were started from the appearance of thrips and continue up to maturity of the crop. The data on weekly weather parameters were collected from the meteorological observatory situated near the experimental site at JAU, Junagadh. The weekly thrips population was correlated with meteorological parameters by using statistical method.

The weekly observation on leaf curling severity on visual basis of grade criteria was recorded from the same plants, which were selected for observation of thrips (Plate 2). Such observations were started with the appearance of thrips and continue up to maturity of the crop. The coefficient of correlation of thrips with leaf curling was work out. The criteria for grading the severity of leaf curling given by Niles (1980) was adopted.

Sr. No.	Grade	Criteria
1	0	No leaf curl symptom.
2	1	Mild curling on 1-25% leaves.
3	2	Moderately curling, puckering symptom on 26-50% leaves.
4	3	Severe curling, puckering symptom on 51-75% leaves with stunting of plant growth.
5	4	Severe curling, puckering symptom on > 75% leaves with severe stunting of plant growth, bushy appearance.

The grade of leaf curling symptoms recorded was converted into the percentage of leaf curling and it was worked out by using following formula.

$$\text{Percentge of leaf curling} = \frac{\text{Sum of numerical value (leaf curling grade)}}{\text{Number of observations} \times \text{Maximum rating}} \times 100$$

3.1.1 Relation of thrips density and leaf curling symptom in chilli

The experiment was carried out to know whether the leaf curling produced in the chilli plants in field was due to thrips, *S. dorsalis* feeding or due to virus transmission. To conform the cause of chilli leaf curl various techniques were applied as under.

3.1.1.1 Correlation of thrips density and degree of leaf curling

Experiment was carried out to know the effect of number of thrips in producing leaf curling symptoms and intensity of leaf curling in chilli plants.

The seeds of Reshampata (local) variety of chilli was sown in earthen pots and plant of chilli grow, which were kept in enclosed wire gauge cage in order to avoid thrips infestation. The 40 day old seedlings of chilli were transplanted in 40 earthen pots (one in each pot). The thrips nymphs were collected from heavily infested plants from field showing the 4^{th} grade of leaf curling. The collected thrips were released on plant in each pot with variable number *i.e.* 1, 2, 3, 5, 8, 10 and 15. The number of thrips/plant was maintained by replacing the new thrips in the potted plant daily. The plants of control treatment keep free from thrips. The experiment was replicated five time. The potted plants were covered with glass chimney and muslin cloth. Day to day observations pertaining to appearance of symptoms of leaf curl (0-4) was recorded up to 20 days. The correlation of number of thrips per plant and degree of leaf curling (percentage) was worked out.

3.1.1.2 Recovery of chilli from leaf curling

Recovery test conducted in order to find out, whether the leaf curling symptoms appeared in chilli plants in field was due to thrips feeding or due to viral transmission by insect.

For these purpose, seeds of Reshampata variety (local) of chilli was sown on two different seed bed (1m X 1m) keeping 1m distance between them. The growing chilli plants was kept free from insecticides and natural infestation to of the thrips was allowed up to 45 day. When 4^{th} grade leaf curling symptom appeared on the seedlings in the nursery, the seedling of one seed bed was sprayed with spinosad 0.009 per cent two time at five day interval to eliminate the thrips and unprotected seed bed kept free from the insecticide (control). Observations were recorded from selected and tagged

35 plant from treated and chilli seedlings. The observation on the thrips and leaf curling was recorded up to healthy leaves appeared on treated chilli plants.

3.1.1.3 Sap inoculation test

Sap inoculation study was conducted at laboratory of the Department of Entomology. The leaves having upward curling (abaxial) and boat shaped from the 15 plant showing grade 4th leaf curling symptoms and 45 to 60 thrips/ twig were collected (200 g) from field. The collected leaves were washed by using distilled water and triturated with mortar and pestle by adding 200 ml distilled water. The sap filtered through a fine muslin cloth and it was immediately rubbed over the surface of three top most fully opened healthy leaves of 45 days old chilli plants. Prior to sap inoculation, the treated leaves were dusted with a small quantity of 600 mesh carborandom powder as abrasive. After sap inoculation, the plants were covered with glass chimneys to avoid thrips infestation. Total 15 plants were inoculated and 15 plants kept as control (untreated). Observation on appearance of leaf curling was recorded up to 30 day on the treated and untreated plants.

3.2 Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*

An experiment was carried out to estimate qualitative and quantitative losses in chilli caused by thrips, *S. dorsalis*, with following details (Plate 3).

Location and Agroclimatic Zone	:	A) At farmer's field (Village: Devlki, Tal: Vadia, Dist: Amreli) during 2011-12 (North Saurashtra Agroclimatic Zone) and B) At Central Experimental Research Station JAU, Junagadh, during 2012-13 (South Saurashtra Agroclimatic Zone)
Crop	:	Chilli
Variety	:	Reshampata (Local)
Treatments	:	Two (a) Unprotected crop and (b) Protected crop
a) Unprotected crop (Untreated plot)	:	The crop was kept insecticide free and allowed for natural occurrence of thrips
b) Protected crop (Treated plot)	:	The crop was protected against thrips through alternate application of spinosad 0.009 per cent and abamectin

0.003 per cent at 10 days interval.

No of Replication : 15 (*i.e.* quadrate sized:1.5 m x 1.8 m) of each (protected plot and unprotected plot)

Plot Size : 11.25 m × 12.0 m

Spacing : 75 cm× 60 cm (row to row and plant to plant)

Date of transplanting : 1) 3 July 2011 and
2) 4 July 2012

Methodology:

1 The recommended agronomical practices were adopted for raising good crop.

2 All over from the treated plot, 15 quadrates (sized 1.5 m x 1.8 m) and 15 quadrates (sized 1.5 m x 1.8 m) from untreated plot were randomly selected.

3 From each selected quadrate six plants were tagged on which the observations were recorded as under:

a) No of thrips 3 twigs/plant (5 cm twig) was recorded at 24 hrs. before and 5 day after each insecticidal application.

b) Leaf curling grade (0 to 4) was recorded on visual basis at 24 hrs. before and 5 day after the insecticidal application.

c) No. of branches and height of the plant was recorded.

d) Size of fruits (length and width) in each quadrate (10 fruits) was recorded during the different pickings.

e) Size of leaf (length and width) in each quadrate (10 leaves) was recorded.

f) Yield of green marketable chilli (kg/ quadrate) was recorded during the different pickings.

4 The insecticides, spinosad 0.009 per cent and abamectin 0.003 per cent were applied alternatively at 10 day interval in protected plot starting from 45 day after transplanting of chilli seedling.

5 Avoidable yield losses were worked out by using the following formula given by Pradhan (1969).

$$\text{Avoidable yield loss (\%)} = 100 \times \left(\frac{T - C}{T} \right)$$

Where,

T = Yield of green chillies from treated (Protected) crop (kg/ha).

C = Yield of green chillies from untreated (Unprotected) crop (kg/ha).

6 The percentage of yield increased was worked out by using the following formula.

$$\text{Yield increase } (\%) = 100 \times \left(\frac{T - C}{C} \right)$$

Where,

T = Yield of green chillies from treated (Protected) crop (kg/ha).

C = Yield of green chillies from untreated (Unprotected) crop (kg/ha).

3.3 Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli

A field experiment was conducted at farmer's field to evaluate the bioefficacy of different insecticides against the thrips, *S. dorsalis* infesting chilli (Plate 4 and 5).

The details of the field experiment are given below:

Location and Agroclimatic Zone	:	Farmer's Field (Village: Devlki, Tal: Vadia, Dist: Amreli.) (North Saurashtra Agroclimatic Zone)
Crop	:	Chilli
Variety	:	Reshampata (Local)
Season	:	*Kharif* 2011-12
Design	:	RBD
Treatment	:	Thirteen (Details given below)
Replication	:	Three
Plot Size Gross	:	3.7 m × 4.8 m
Net	:	2.25 m × 3.6 m
Spacing	:	75 cm X 60 cm (row to row and plant to plant)
Date of transplanting	:	3 July 2011

Method of Application

The spraying of all the insecticidal treatments was carried out with the help of knapsack sprayer. First spray was carried out at 45 day after transplanting of the chilli seedlings, when the thrips population started to build up. Three application of insecticides were carried out at an interval of 15 days and the control plot was sprayed with water only. In order to evaluate the bioefficacy of different insecticides, observations on thrips population and leaf curling grade were recorded from six randomly selected and tagged plants from each net plot area. Observation of thrips

was recorded by the jerking a twig of 5 cm length on a white paper to dislodged the thrips and number of thrips on paper was counted. The intensity of leaf curl on grade (0 to 4) basis was recorded from six randomly selected plants from each net plot area. The observations of thrips population and leaf curling were recorded at one day before and three, seven and 14 days after each spray.

Treatment details

Sr. No.	Name of insecticides	Trade name	Dose	Producer company
1.	Imidacloprid 17.8 SL	Sensex	0.005%	GSP Crop Scince Pvt., Ltd. Ahmedabad
2.	Acetamiprid 20 SP	RaxaPRID	0.008%	Molraxa Agro Chemicals, Ahmedabad
3.	Indoxacarb 14.5 SC	Hindoxa	0.0145%	Gujarat Industries Ltd., Ankleshowr
4.	Spinosad 45 SC	Tracer	0.009%	DE Nocil Crop Protection Ltd., Mumbai
5.	Profenophos 40 EC + Cypermethrin 4 EC	Polytrin C	0.044%	Syngenta India Ltd., Mumbai
6.	Profenophos 50 EC	Carina	0.05%	P I Indusrues Ltd., Ankleshowr
7.	Diafenthiuron 50 WP	Polo	0.05%	Syngenta India Ltd., Mumbai
8.	Abamectin 1.9 EC	Abacin	0.003%	Crystal Phosphate Ltd., Sonepat
9.	*Metarhizium anisopliae* (2×10^8 CFU/g)	Metasoft	2.0 kg/ha	Agriland Bio Tech Ltd., Vadodara
10.	*Verticillium lecanii* (2×10^8 CFU/g)	Vetilife	2.0 kg/ha	Gujarat Life Science Ltd., Vadodara
11.	*Beauveria bassiana* (2×10^8 CFU/g)	Biosoft	2.0 kg/ha	Agriland BioTech Ltd., Vadodara
12.	Azadirachtin 1% w/w	Azaten	0.001%	Osho workshop center Shaper (Veraval)- Rajkot
13.	Control (Water spray)	-	-	-

Yield and Economics

The yield of green chilli received from different treatments (kg/plot) along with control, recorded during each picking. The total yield of green chilli (kg/plot) was converted on hectare basis and subjected to statistical analyze. The percentage of yield increased over control and avoidable yield losses were worked out by using the following formula.

$$\text{Yield increase } (\%) = 100 \times \left(\frac{T - C}{C} \right)$$

$$\text{Avoidable yield loss } (\%) = 100 \times \left(\frac{T - C}{T} \right)$$

Where,

T = Yield from treated (Protected) plots (kg/ha).

C = Yield from control (untreated) plots (kg/ha).

Economics of all the insecticidal treatments were worked out by considering the current market price of green chilli, cost of insecticide and labour charges. Cost benefit ratio (CBR) was also worked out to compare the economics of different insecticidal treatments by the following formula.

i. Gross realization (₹/ha) =

Yield from treated crop (kg/ha) × Market price of produce (₹/kg)

ii. Net realization (₹/ha) =

Gross realization of treated plot (₹/ha) - Gross realization of control plot (₹/ha)

iii. Total cost of control measure (₹/ha) =

Cost of insecticide (₹/ha) + Labour charge (₹/ha)

iv. C:B ratio = Net realization (₹/ha) ÷ Total cost of control measure (₹/ha)

3.4 Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*

A field experiment was conducted during 2012-13 to evaluate the effective spray schedule against the chilli thrips, *S. dorsalis* (Plate 6).

The details of the field experiment are given below:

Location and Agroclimatic Zone	:	Central Experimental Research Station, JAU, Junagadh during 2012-13 (South Saurashtra Agroclimatic Zone)
Crop	:	Chilli
Variety	:	Reshampata (Local)
Season	:	*Kharif* 2012-13
Design	:	RBD
Treatment	:	Seven insecticidal spray schedules (detail given on next page)
Replication	:	Four
Plot Size Gross	:	3.7 m × 4.8 m
Net	:	2.25 m × 3.6 m
Spacing	:	75 cm X 60 cm (row to row and plant to plant)
Date of transplanting	:	4 July 2013
Date of harvesting	:	31 January , 2013

Methodology:

The insecticides which found the most effective in the previous year experiment (on bioefficacy of insecticide against thrips, *S. dorsalis* infesting chilli during 2011-12) were selected for the various spray schedules. The spraying of insecticides of the different schedules was carried out with the help of knapsack sprayer. In control plot, only water spraying was carried out. The experimental crop was treated with two application of each mancozeb 0.2 per cent and carbendazium 0.05 per cent alternatively at fifteen day interval during August and September for control of anthracnose and powdery mildew diseases (blanket spray). The experimental crop was also treated by application of propergite 0.14 per cent and dicofol 0.03 per cent alternatively at fifteen day interval during October and September against mite *Polyphagtarsonemus latus* (blanket spray). The experimental crop was protected against Spodoptera with the application of SNPV @ 250 LE/ha during October (blanket spray).

Details of insecticidal Spray schedule against chilli thrips

Schedule No.	No. of spray	Spray Interval (Days)	Days after transplanting	Name of insecticide
1	3	30	40	Spinosad 0.009 %
			70	Profenophos 0.04% + Cypermethrin 0.004 %
			100	Spinosad 0.009 %
2	4	20	40	Spinosad 0.009 %
			60	Profenophos 0.04% + Cypermethrin 0.004 %
			80	Imidacloprid 0.005 %
			100	Spinosad 0.009 %
3	5	15	40	Spinosad 0.009 %
			55	Imidacloprid 0.005 %
			70	Profenophos 0.04% + Cypermethrin 0.004 %
			85	Spinosad 0.009 %
			100	Acetamiprid 0.008 %
4	6	12	40	Spinosad 0.009 %
			52	Imidacloprid 0.005 %
			64	Profenophos 0.04% + Cypermethrin 0.004 %
			76	Spinosad 0.009 %
			88	Acetamiprid 0.008 %
			100	Profenophos 0.04% + Cypermethrin 0.004 %
5	7	10	40	Profenophos 0.04% + Cypermethrin 0.004 %
			50	Imidacloprid 0.005 %
			60	Profenophos 0.05 %
			70	Spinosad 0.009 %
			80	Profenophos 0.04% + Cypermethrin 0.004 %
			90	Imidacloprid 0.005 %
			100	Profenophos 0.05 %
6	8	8	40	Profenophos 0.04% + Cypermethrin 0.004 %
			48	Abamectin 0.003 %
			56	Imidacloprid 0.005 %
			64	Spinosad 0.009 %
			72	Profenophos 0.04% + Cypermethrin 0.004 %
			80	Acetamiprid 0.008 %
			88	Spinosad 0.009 %
			96	Imidacloprid 0.005 %
7	Control			Water spray

In order to evaluate the effective spray schedule, observations on thrips/3 twig and leaf curling grade were recorded from six randomly selected and tagged plant per plot (the details of methodology for observation of thrips and leaf curling is described in 3.4 on page 23-24). The observations were recorded at one day before spraying and three, seven and 14 day after each insecticidal.

Yield and Economics

The yield of green chilli received from different spray schedules (kg/plot) recorded during each picking. The yield data obtained (kg/plot) were transformed on hectare basis and subjected to statistical analyze. The percentage of yield increased over control and avoidable yield loss was worked out by using the following formula.

$$\text{Yield increase } (\%) = 100 \times \left(\frac{T - C}{C} \right)$$

$$\text{Avoidable yield loss } (\%) = 100 \times \left(\frac{\mathrm{T} - \mathrm{C}}{\mathrm{T}} \right)$$

Where,

T = Yield from treated (Protected) plots (kg/ha).

C = Yield from control (untreated) plots (kg/ha).

Economics of all the spray schedules was worked out by considering the current market price of green chilli, cost of insecticide and labour charges. Cost benefit ratio (CBR) was also worked out to compare the economics of different insecticidal treatments.

3.5 Determination of the insecticides residue on/in chilli

The residue of spinosad 45 SC @ 0.009 per cent, acetamiprid 20 SP @ 0.008 per cent, profenophos 40 EC + cypermethrin 4 EC @ 0.044 per cent, abamectin 1.9 EC @ 0.003 per cent and imidacloprid 17.8 SL @ 0.005 per cent was determined from green marketable chilli (fruits) harvested at 8 day after application .

Uniform spraying of these insecticides in three replication was carried out on chilli crop using knapsack sprayer. The spray solution of the insecticides @ 750 Liter/ ha was used.

The application of insecticides was given on dated 21st January 2013. The marketable green chilli was harvested on 29th January 2013. The weather parameters during the January 21-29 were maximum temperature 28.6℃ to 32℃ minimum temperature 9.4℃ to 14.4℃, relative humidity maximum 32 to 60 per cent, minimum 9 to 24 per cent, sunshine hours 8.8 to 9.0 h/day and wind velocity 2.9 to 6 km/h.

Total sample size of chilli fruit was made 600 g from three replications. Each sample was separately packed in polyethylene bag and kept in a ice box which was sent on same day to the Pesticide Residue Laboratory, Anand Agricultural University, Anand (Gujarat) for the residue determination. The analytical method used by the Pesticide Residue Laboratory was QuEChERS.

CHAPTER-IV

RESULTS AND DISCUSSION

The investigations were carried out on population dynamics, yield losses and management of thrips, *Scirtothrips dorsalis* Hood infesting chilli, during two consecutive year's *i.e.* 2011-12 and 2012-13. Result of investigations are presented and discussed in this chapter under following feature.

1) Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms
2) Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*
3) Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli
4) Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*
5) Determination of the insecticides residue on/in chilli

4.1 Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms

4.1.1 During cropping season 2011-12

The data presented in Table 4.1 on population dynamics of the thrips infesting chilli and the leaf curl produced during 2011. Initial thrips population was at low level during 31st and 32nd standard week. The pest population increased rapidly from 33rd standard week and reached at first peak (22.25 thrips/3 twig) during 37th standard week. Thereafter, the thrips population slightly decreased in 38th standard week and increased continuously up to 45th standard week to reach at second and the highest peak (81.96 thrips/3 twig). After forming the peak, the thrips population decreased drastically during 46th standard week and again the pest population increased during next week *i.e.* 47th standard week. Thereafter, thrips population was decreased gradually.

The data presented in Table 4.1 on the chilli leaf curling revealed that the curling symptoms appeared during 32nd standard week (8.33%). The leaf curling percentage gradually increased during succeeding weeks and the maximum

Table 4.1: Population of chilli thrips, *S. dorsalis*, percentage of leaf curling and meteorological parameters during *Kharif-* 2011 (n=22)

Sr. No.	Month	Age of crop WATP	Std. Week	Thrips/ 3 twig	Leaf curling (%)	Temperature (°C)		Relative humidity (%)		Wind Speed (km/h)	Bright Sunshine hours (h/day)	Evaporation (mm/day)	Rainfall (mm)	Rainy Days
						Max.	Min.	Max.	Min.					
1	July	3	31	0.48	0.00	29.9	24.6	95	88	5.0	0.9	2.0	194.1	6
2	August	4	32	1.10	8.33	30.8	26.3	91	81	11.1	0.6	3.0	25.7	2
3		5	33	4.10	10.00	29.9	25.2	91	82	6.7	0.7	2.1	38.8	3
4		6	34	5.50	11.25	30.2	24.6	92	86	3.2	0.6	1.9	87.4	6
5		7	35	10.50	16.67	30.9	24.7	90	79	5.7	1.8	2.8	69.8	4
6	September	8	36	15.58	16.67	30.3	25.1	92	83	8.5	1.7	2.4	168.8	5
7		9	37	22.25	20.83	30.0	24.8	93	82	5.4	1.6	1.8	34.4	3
8		10	38	18.00	20.83	30.6	23.7	87	65	5.1	6.9	3.5	30.4	1
9		11	39	23.96	21.94	32.3	22.8	84	58	3.4	7.6	3.9	5.8	0
10	October	12	40	23.33	25.56	33.3	23.4	75	50	4.2	13.6	4.7	0	0
11		13	41	32.67	45.83	35.4	25.5	66	37	5.4	9.1	5.9	0	0
12		14	42	34.04	45.83	36.5	24.1	70	36	2.9	7.0	5.2	0	0
13		15	43	46.67	48.96	35.9	19.0	69	28	2.8	9.6	5.2	0	0
14		16	44	70.63	61.46	35.7	22.8	64	31	3.1	6.4	4.7	0	0
15	November	17	45	81.96	75.00	36.0	21.1	71	31	2.4	9.2	5.4	0	0
16		18	46	48.50	68.75	34.8	19.4	72	30	3.5	9.5	5.1	0	0
17		19	47	59.33	64.58	34.4	16.6	66	27	2.7	9.5	4.6	0	0
18		20	48	34.67	56.25	33.3	21.3	64	38	4.2	4.8	4.9	0	0
19	December	21	49	25.33	51.04	33.6	17.1	78	36	3.1	9.3	5.0	0	0
20		22	50	19.20	48.96	30.9	12.9	55	22	4.2	9.3	4.8	0	0
21		23	51	10.33	35.56	30.6	12.5	66	26	4.4	8.4	4.7	0	0
22		24	52	6.03	30.56	28.5	10.8	58	24	4.8	8.5	5.6	0	0

WATP: Week after transplanting, Std. Week: standard week, Max.: maximum and Min.: minimum

leaf curling (75%) was recorded in standard week 45th, thereafter the severity of leaf curling gradually decreased.

The data given in Table 4.1 indicated that the weather condition during the higher activity period of thrips (32 to 82 thrips/3 twig) were maximum temperature 35.4℃ to 36.5℃, minimum temperature 19.0℃ to 25.5℃ with relative humidity maximum 64 to 71 per cent and minimum 28 to 37 per cent. The wind speed was to 2.4 to 5.4 km/h, bright sun shine hours was 6.4 to 9.6 h/day and evaporation rate was 4.7 to 5.9 mm/day with no rain.

The data on correlation between thrips population and leaf curling with meteorological parameters are presented in Table 4.4. The data revealed that the correlation between leaf curling severity and thrips population on chilli crop was found highly positive (r= 0.8719). The correlation between thrips population and maximum temperature (r= 0.8364) and evaporation rate (r= 0.5709) were highly positive, while thrips population was exhibited significant positive correlation with bright sunshine hours (r= 0.5165). However, the correlation with thrips population and minimum relative humidity (r= -0.6030), wind speed (r= -0.5916) and rainy days were highly negative (r= -0.5522). Further, it was found that the thrips population significantly negative correlated with maximum relative humidity (r= -0.4987) and rainfall (r= -0.4666). Whereas, non-significant negative correlation between thrips population and minimum temperature (r= -0.1045) was exhibited.

4.1.2 During cropping season 2012-13

The data on population dynamics of the thrips infesting chilli and the leaf curl produced during 2012 are presented in Table 4.2. Initial thrips population was at low level during 31st and 32nd standard week. The pest population increased rapidly from 33rd standard week and reached at first peak (27.40 thrips/3 twig) during 34th standard week. Thereafter, the thrips population slightly decreased from standard week 35th (23.78 thrips/3 twig) to 38th standard week (14.38 thrips/3 twig). Again the thrips population increased rapidly and reached at second peak in next week *i.e.* 40th standard week (24.92/ 3 twig). Again the pest rapidly multiplied from 41st standard week and reached at the highest peak (97.63 thrips/ twig) during 44th standard week.

Table 4.2: Population of chilli thrips, *S. dorsalis*, percentage of leaf curling and meteorological parameters during *Kharif*- 2012 (n=22)

Sr. No.	Month	Age of crop WATP	Std. Week	Thrips /3 twig	Leaf curling (%)	Temperature (°C)		Relative humidity (%)		Wind Speed (km/h)	Bright Sunshine hours (h/day)	Evaporation (mm/day)	Rainfall (mm)	Rainy Days
						Max.	Min.	Max.	Min.					
1	July	3	31	1.83	8.33	30.9	25.8	89	77	13	0	3.5	6.2	1
2	August	4	32	2.83	8.33	32.9	25.3	91.6	64.3	9.8	0.1	4	3.4	0
3		5	33	8.27	17.08	32.7	25.1	88.3	64.1	9.1	0.1	4.4	1	0
4		6	34	27.40	28.33	31.4	23.9	90.7	70.1	7.4	0.4	2.8	23.4	3
5		7	35	24.35	30.56	33.1	25.9	87.8	65.8	3.1	1.1	4.3	59.8	4
6	September	8	36	23.78	50.00	30.5	25	94.9	85	5.5	0.9	2	111.4	5
7		9	37	22.30	49.17	29.9	24.6	92.7	78.4	6.8	1.4	2.1	67.5	4
8		10	38	14.38	49.17	33	24.3	86	56	4.7	5.2	4.2	0	0
9		11	39	19.67	51.94	34	23.9	82.9	46.4	4.4	7.4	5	0	0
10	October	12	40	24.92	50.83	36.6	25.2	76	44	4	8.8	5.7	0	0
11		13	41	34.67	55.56	36.7	21.5	67	26	3.3	9.2	6.5	0	0
12		14	42	40.35	58.06	37.7	20.2	68	25	2.9	9.5	6	0	0
13		15	43	62.95	69.44	36.9	20	60	29	2.5	9.7	6	0	0
14		16	44	97.63	88.61	35.8	17.6	51	21	2.8	8.3	5.9	0	0
15	November	17	45	58.83	87.50	34	15.6	68.9	24.9	2.9	9.6	4.7	0	0
16		18	46	39.98	86.25	34.4	16.6	58.3	21.3	2.7	9.4	5.3	0	0
17		19	47	45.97	86.25	33.3	14.1	62	20.9	2.6	9.3	4.7	0	0
18		20	48	44.18	83.33	31.7	13.3	63.9	24.7	3.1	9.5	5.1	0	0
19	December	21	49	18.22	81.25	34.2	18.3	64	27	3.7	7.9	5	0	0
20		22	50	10.57	70.83	31.3	17.7	77	29	3.6	8.6	4.6	0	0
21		23	51	9.23	66.07	32.8	15.4	60	24	4.1	8.8	5.4	0	0
22		24	52	6.63	35.42	30.7	12.4	48	18	4.6	9	5.8	0	0

WATP: Week after transplanting, Std. Week: standard week, Max.: maximum and Min.: minimum

After forming the highest peak, the pest population decreased drastically during 45th and 46th standard week and again increased during next week *i.e.* 47th standard week. Thereafter, thrips population gradually decreased.

The data presented in Table 4.2 revealed that the leaf curling symptoms on chilli appeared during 31st standard week (8.33%) and it gradually increased from 33rd standard week (17.08%) to 36th standard week (50%). Thereafter, leaf curling slightly decreased in 37th and 38th standard week (49.17 per cent). Again leaf curling percentage gradually increased from 41st standard week and reached at maximum leaf curling 88.61 per cent was recorded in standard week 44th. Thereafter, the severity of leaf curling gradually decreased.

The data given in Table 4.2 also indicated that the weather condition during the higher activity period of thrips (25 to 98 thrips/3 twig) were maximum temperature 35.8℃ to 37.7℃, minimum temperature 17.6℃ to 25.2℃ with relative humidity maximum 51 per cent to 76 per cent and minimum 21 per cent to 44 per cent. The wind speed was to 2.5 to 4.0 km/h, bright sun shine hours was 8.3 to 9.7 h/day and evaporation rate was 5.7 to 6.5 mm/day with no rain.

The data on correlation between thrips population and leaf curling with meteorological parameters are presented in Table 4.4. The data revealed that the correlation between percentage of leaf curling and thrips density on chilli crop was found highly positive (r= 0.6744). The correlation between thrips population and maximum temperature (r= 0.8364) and bright sunshine hours (r= 0.4760) were significantly positive, while with the evaporation rate (r= 0.3677) was non-significantly positive. However, the correlation with thrips population and wind speed found highly negative (r= -0.5868). Further, it was found that the thrips population significantly negative correlated with maximum relative humidity (r= -0.5185) and minimum relative humidity (r= -0.4632). Whereas, correlation between thrips population and minimum temperature (r= -0.3665), rainfall (r= -0.1164) and rainy days (r= -0.1343) were non-significantly negative.

4.1.3 Pooled of two cropping season 2011 and 2012

The population dynamics of chilli thrips and leaf curl produced was studied two different location during year 2011 and 2012. The pooled data of the two year are presented in Table 4.3 and depicted in Fig. 4.1. The data revealed that the activity of thrips, *S. dorsalis* commenced during 31st standard week (month of July) when the crop was in seedling stage. The thrips population was at low level (1 to 2 thrips/3 twig) during 31st and 32nd standard week. But from 33rd standard week, it was multiplied very fast and reached at first peak (22.28/ 3 twig) during 37th standard week. Thereafter, it was slightly decreased during next two weeks and again the thrips population increased continuously from 41st standard week and reached at second (the highest) peak (84.13/ 3 twig) during 44th standard week. Thereafter, thrips population decreased gradually during subsequent weeks.

During the present investigation the activity of thrips on chilli crop during entire growth period was found at both the location. Similar result was also reported by Ramchandra Rao (1928), Ayyer (1928), Ayyer *et al.* (1935), Vevai (1969), David and kumaraswami (1978), Borah (1987), Patel (1992) and Patel *et al.* (2009).

From the present investigation it was found that thrips population multiplied very high during the month of September and November being peak during October in South and North Saurashtra Agroclimatic Zone of Gujarat. Further it was found that the severity of leaf curling in chilli was increased with increasing population of the thrips. Peak activity of chilli thrips during September, October and November was also reported by Vevai (1969), Sanap *et al.* (1985), Borah (1987), Patel (1992) and Patel *et al.* (2009).

The pooled data given in Table 4.3 and depicted in Fig. 4.1 also revealed that the leaf curling symptoms on chilli seedling was appeared (4.17%) during 31st standard week (during July at seedling stage of crop). The percentage of leaf curling increased from 33rd to 45th standard week and produced maximum 81.25 per cent leaf curling intensity (Grade 4). Thereafter, the percentages of leaf curling decreased continuously in each subsequent week.

Table 4.3: Population of chilli thrips, *S. dorsalis*, percentage of leaf curling and meteorological parameters ***(*Pooled data of the *Kharif*- 2011 *and Kharif*- 2012)*** (n=22)

Sr. No.	Month	Age of crop WATP	Std. Week	Thrips /3 twig	Leaf curling (%)	Temperature (℃)		Relative humidity (%)		Wind Speed (km/h)	Bright Sunshine hours (h/day)	Evaporation (mm/day)	Rainfall (mm)	Rainy Days
						Max.	Min.	Max.	Min.					
1	July	3	31	1.16	4.17	30.4	25.2	92	82.5	9	0.45	2.75	100.15	3.50
2	August	4	32	1.97	8.33	31.85	25.8	91.3	72.65	10.45	0.35	3.5	14.55	1.00
3		5	33	6.19	13.54	31.3	25.15	89.65	73.05	7.9	0.4	3.25	19.9	1.50
4		6	34	16.45	19.79	30.8	24.25	91.35	78.05	5.3	0.5	2.35	55.4	4.50
5		7	35	17.43	23.61	32	25.3	88.9	72.4	4.4	1.45	3.55	64.8	4.00
6	September	8	36	19.68	33.33	30.4	25.05	93.45	84	7	1.3	2.2	140.1	5.00
7		9	37	22.28	35.00	29.95	24.7	92.85	80.2	6.1	1.5	1.95	50.95	3.50
8		10	38	16.19	35.00	31.8	24	86.5	60.5	4.9	6.05	3.85	15.2	0.50
9		11	39	21.81	36.94	33.15	23.35	83.45	52.2	3.9	7.5	4.45	2.9	0.00
10	October	12	40	24.13	38.19	34.95	24.3	75.5	47	4.1	11.2	5.2	0	0.00
11		13	41	33.67	50.69	36.05	23.5	66.5	31.5	4.35	9.15	6.2	0	0.00
12		14	42	37.20	51.94	37.1	22.15	69	30.5	2.9	8.25	5.6	0	0.00
13		15	43	54.81	59.20	36.4	19.5	64.5	28.5	2.65	9.65	5.6	0	0.00
14		16	44	84.13	75.03	35.75	20.2	57.5	26	2.95	7.35	5.3	0	0.00
15	November	17	45	70.40	81.25	35	18.35	69.95	27.95	2.65	9.4	5.05	0	0.00
16		18	46	44.24	77.50	34.6	18	65.15	25.65	3.1	9.45	5.2	0	0.00
17		19	47	52.65	75.42	33.85	15.35	64	23.95	2.65	9.4	4.65	0	0.00
18		20	48	39.42	69.79	32.5	17.3	63.95	31.35	3.65	7.15	5	0	0.00
19	December	21	49	21.78	66.15	33.9	17.7	71	31.5	3.4	8.6	5	0	0.00
20		22	50	14.89	59.90	31.1	15.3	66	25.5	3.9	8.95	4.7	0	0.00
21		23	51	9.78	50.81	31.7	13.95	63	25	4.25	8.6	5.05	0	0.00
22		24	52	6.33	32.99	29.6	11.6	53	21	4.7	8.75	5.7	0	0.00

WATP: Week after transplanting, Std. Week: standard week, Max.: maximum and Min.: minimum

Table 4.4: Correlation between chilli thrips with percentage of leaf curling and meteorological parameter (n=22)

Sr. No.	Different parameter	2011	2012	Pooled
		Thrips	Thrips	Thrips
1	Leaf curling (%)	0.8719**	0.6744**	0.8026**
2	Temperature (℃)			
	a) Maximum	0.8364**	0.5316*	0.7230**
	b) Minimum	-0.1045	-0.3665	-0.2509
3	Relative humidity (%)			
	a) Maximum	-0.4987*	-0.5185*	-0.5336*
	b) Minimum	-0.6030**	-0.4632*	-0.5484**
4	Wind Speed (km/h)	-0.5916**	-0.5868**	-0.6891**
5	Bright Sunshine hours (h/ day)	0.5165*	0.4760*	0.5106*
6	Evaporation (mm/day)	0.5709**	0.3677	0.4697*
7	Rainfall (mm)	-0.4666*	-0.1164	-0.3674
8	Rainy Days	-0.5522**	-0.1343	-0.3893

*Significant at 5 % 0.423
** Significant at 1 % 0.537

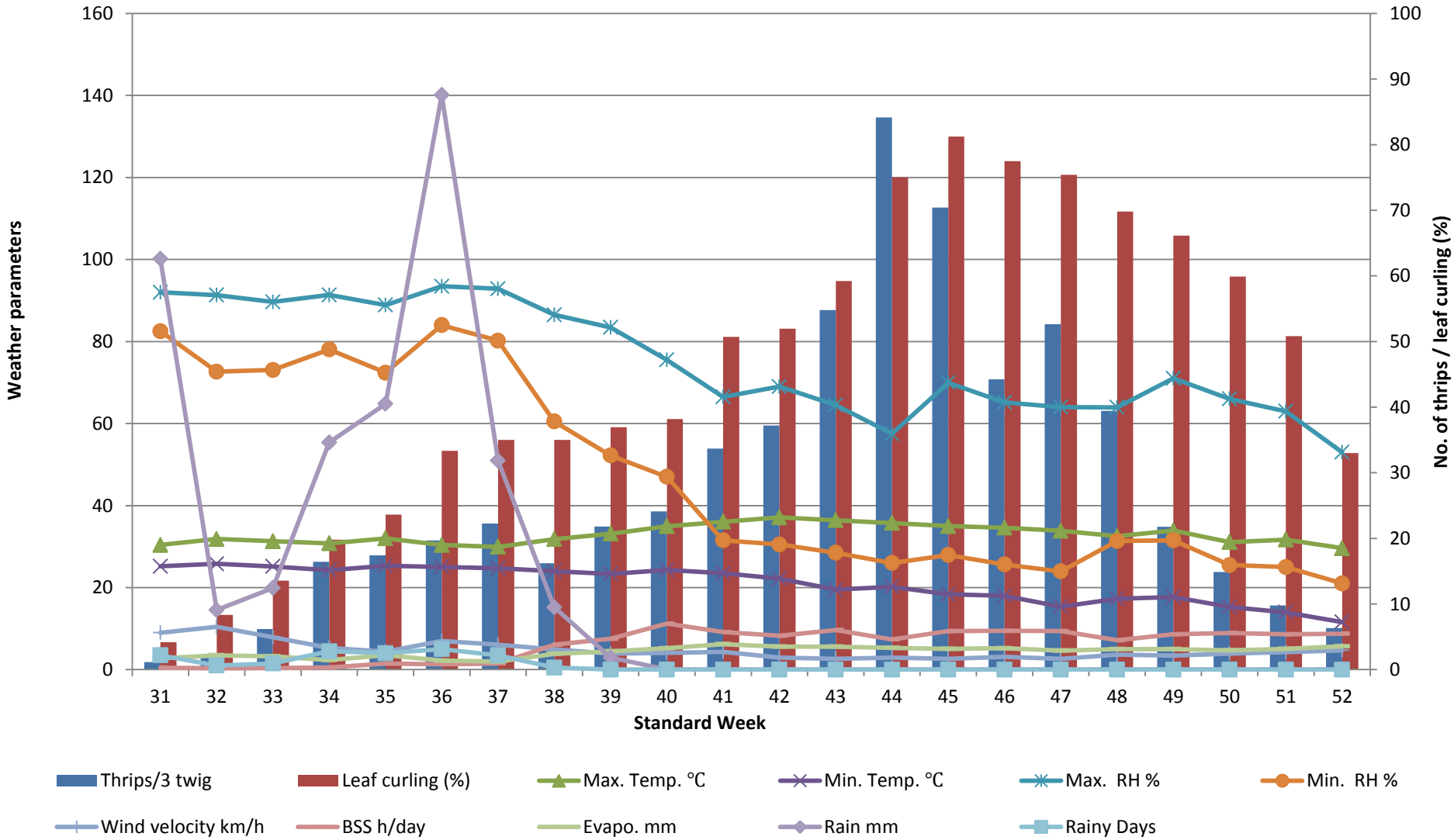

Fig. 4.1: Correlation of weekly population of thrips and leaf curling with weather parameters (Pooled data of *Kharif*- 2011 and *Kharif*- 2012)

It was further revealed that, when thrips population increased the percentage of leaf curling was also increased. The typical leaf curling symptoms were produced in chilli field at both the location. The thrips infested tender leaves started upward curling of leaf margin dorsally (adaxil) and the inter-veinal area getting raised up which appeared as buckled leaves and resulted in formation of narrow star (boat) shaped leaves. The mechanical injury and some toxic substance introduced along with saliva into the leaves during feeding of thrips might have caused the upward type curling. Size of the leaf was reduced and malformed appetence observed on shoot (growing point) and plant growth was stunted. There was certain amount of interveinal buckling and the upper epidermis showed signs of irregular scraping by the thrips (Plate 7). The insect could also be seen within the curl affected leaves. Such type of leaf curling in chilli due to the thrips, *S. dorsalis* was also reported by Park and Fernando (1938), Johnpulle (1939), Peiris (1953), Puttarudraiah (1955 and 1959), Ningappa (1972), Chavan (1974), Nandihalli (1980) and Patel (1992).

The damage caused by the thrips on green chilli fruits was recorded with scraping, crinkle, abnormal, curved, colour of fruit become dark green and reduced size of fruit. Further quality of green chilli *i.e*. appearance, shape, luster of green chilli was also detoriated. Such type of damage on chilli fruit due to the thrips, *S. dorsalis* was also reported by Patel (1992).

The correlation study (Table 4.4) also indicated that highly positive correlation between thrips population and leaf curling was existed (r= 0.8026). Therefore, it can be concluded that the leaf curling produced in field planted chilli was due to thrips.

The correlation between thrips population and maximum temperature was highly positive (r= 0.7230), while thrips population was exhibited significant positive correlation with evaporation rate (r= 0.4697) and bright sunshine hours (r= 0.5106). However, the correlation of thrips population with minimum relative humidity (r= -0.5484) and wind speed (r= -0.6891) were highly negative. Further, it was found that the thrips population significant negatively correlated with maximum relative humidity (r= -0.5336). Whereas, non-significant negative correlation between thrips population and minimum temperature (r=-0.2509), rainfall (r= -0.3674) and rainy days (r= -0.3893) was exhibited. The significant positive correlation of thrips, *S. dorsalis* on chilli with maximum temperature, bright sunshine hours and

evaporation was also recorded by Patel (1992), Keisa *et al*. (1994), Varadharajan and Veeraval (1995), Panickar (2000), Bhede *et al.* (2008) and Patel *et al.* (2009). While significantly negative correlation of the thrips with maximum and minimum relative humidity and wind speed was reported by Patnaik *et al.* (1986), Patel (1992), Panickar (2000), Bhede *et al.* (2008), Bagle (1993) and Patel *et al.* (2009).

The data given in Table 4.3 revealed that the meteorological parameters for high multiplication of thrips (34 to 84 thrips/3 twig) on chilli crop during 41st to 45th standard week were maximum temperature ranged 35℃ to 37.1℃ and minimum temperature ranged 18.35℃ to 22.15℃ with maximum relative humidity ranged 57.5 per cent to 70 per cent and minimum relative humidity ranged 26 per cent to 31.5 per cent, wind speed ranged 2.65 to 4.35 km/h, bright sun shine hours ranged 7.35 to 9.65 h/day and evaporation rate ranged 5 to 5.6 mm/day.

Patel (1992) reported that congenial meteorological parameters for high multiplication of thrips on chilli crop were maximum temperature ranged 30℃ to 32.6℃, minimum temperature ranged 10.3 to 14.7 with maximum relative humidity ranged 66 to 89 per cent and minimum relative humidity ranged 28 to 41 per cent during 1990-91 and maximum temperature ranged 28.1℃ to 33.4℃, minimum temperature ranged 18.5 to 23.5 with maximum relative humidity ranged 66 to 89 per cent and minimum relative humidity ranged 21 to 79 per cent during 1991-92 at Udaipur (Rajasthan). Sanap *et al.* (1985) observed that an average temperature between 25.8℃ and 26.9℃ in combination with relative humidity between 60 and 75 per cent were most congenial for multiplication of the thrips at Maharashtra. Bhede *et al.* (2008) reported the highest incidence of thrips during 40th meteorological week when the prevailing maximum and minimum temperatures, morning and evening relative humidity, rainfall and bright sunshine hours were 35.8℃ and 18.0℃ and 76 per cent and 34 per cent, 0.00 mm and 11 h, respectively at Parbhani (Maharashtra).

During the present study, it was found that the thrips population on chilli was at low level during period of high rainfall. Similar result was also reported by Sanap *et al.* (1985), Borah (1987), Patel (1992), Varadharajan and Veeraval (1995), Panickar (2000) and Bhede *et al.* (2008).

4.1.4 Relation of thrips density with leaf curling in chilli

The trials were carried out to know whether the leaf curling produced in the field was due to thrips feeding or due to virus transmission by the thrips. The subject of leaf curling of chilli has received considerable attention, as it is known to be a greatest enemy of chilli plants and occurs in all chilli growing area of our country.

4.1.4.1 Correlation of thrips density and degree of leaf curling

During the present study the thrips was found to lacerate the tender leaves tissue and suck the oozing juice on upper and lower of chilli plant. The infested tender leaves started upward curling of leaf margin dorsally (upward) and the inter-veinal area getting raised up which appeared as buckled leaves and resulted in formation of narrow star (boat) shaped leaves. The insect could also be seen within the curl affected leaves.

The thrips was collected from the field plants of chilli severely infested and showing 4th grade leaf curling. The field collected thrips was released in variable numbers on different potted plants (45 day old) and commencement and severity of leaf curling was recorded daily up to 20 day (Plate 8).

The data presented in Table 4.5 and depicted in Fig. 4.2 revealed that the symptoms of leaf curling first appeared on the top tender leaves by 12 days feeding of two thrips per plant. The number of thrips at the rate 3, 5, 8, 10 and 15 per plant resulted in production of leaf curling symptoms after 11, 10, 8, 7 and 3 days of release respectively. Thus the data indicated that two or more thrips/ plant can produce leaf curling. As the number of thrips per plant increased the period for appearance of leaf curling symptoms was shorter. The similar observation were also reported by Johnpulle (1939), Ningappa (1972), Nandihalli (1980), Patangrao (1987) and Patel and Gupta (1992).

The intensity of leaf curling was observed at 20 days after release of thrips on chilli seedlings. The data given in Table 4.5 also revealed that the chilli plant having 2, 3, 5, 8, 10 and 15 thrips produced 25, 30, 50, 70, 75 and 80 per cent of leaf curling (index) after 20 days. The leaf curling symptoms observed in potted plants were of similar type as observed in infested plants in the field. The coefficient of correlation between number of thrips and percentage of leaf curling was strongly positive

(r= 0.9137). These result clearly indicated that the thrips *S. dorsalis* was responsible to cause upward type of leaf curling symptoms in chillies. The mechanical injury caused by thrips and some toxic substance introduced along with saliva into the leaves during feeding might have caused of the leaf curling. The present finding are corroborate with Johnpulle (1939) and Patel and Gupta (1992) who also reported that thrips, *S. dorsalis* was a major pest of chillies and in responsible for causing leaf curl in chilli plants.

Table 4.5 : Thrips density and leaf curling percentage in chilli plant

Treatment No.	Number of thrips released / plant	Leaf curling symptoms produced after thrips release (day)	Leaf curling intensity on 20 day after release (%)
1	0	No curling	0
2	1	No curling	0
3	2	12	25
4	3	11	30
5	5	10	50
6	8	8	70
7	10	7	75
8	15	6	80

Correlation coefficient r = 0.9137 (Significant at 5% and 1%)

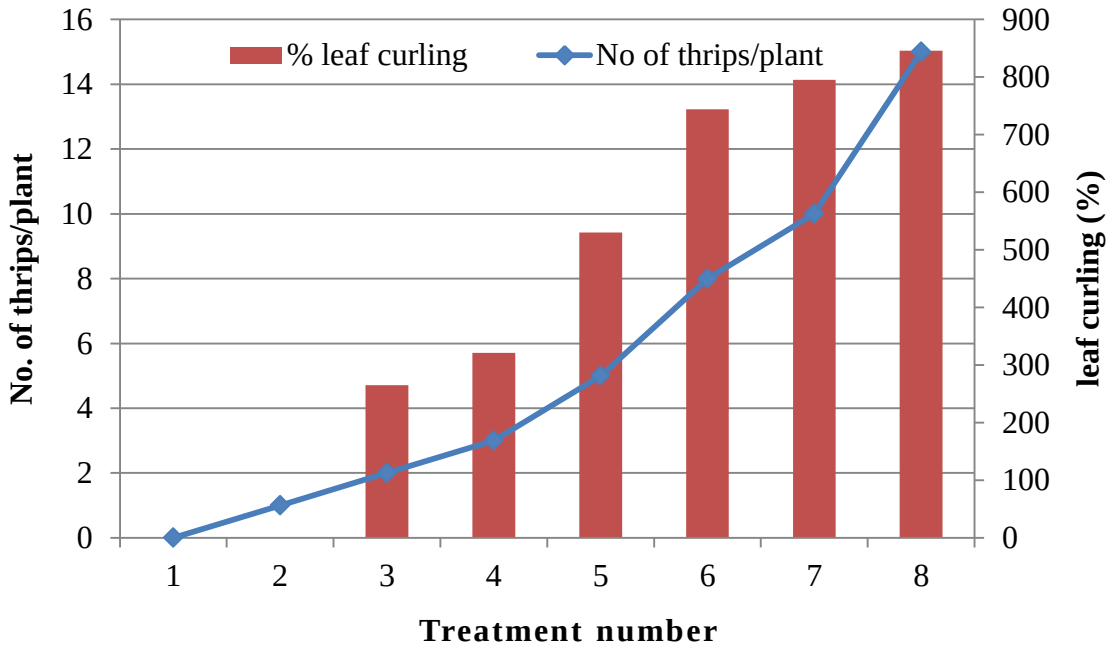

Fig. 4.2: Number of thrips/ plant and leaf curling percentage in chilli plant

4.1.4.2 Recovery of chilli from leaf curling

The thrips was eliminated from chilli plants having 4th grade leaf curling using spinosad 0.009 per cent.

It was observed that after elimination of thrips from infested plants, the growth of plants was normal (without leaf curling) within 15 day. While the plants kept as control (untreated) were continued with thrips and pronounced leaf curling (Table 4.6). It was concluded that the thrips infestation in chilli was responsible for the leaf curling.

Similar conclusion was also reported by Johnpulle (1939), Moghe (1977) and Patel (1992).

Table 4.6: Recovery of chilli from leaf curling

Day after treatment	Protected seedling		Unprotected seedling*	
	Thrips/plant	Leaf curling (%)	Thrips/plant	Leaf curling (%)
1	0.00	75.71	6.86	75.00
2	0.00	75.71	7.00	75.00
3	0.00	73.57	7.17	75.71
4	0.21	65.71	7.57	77.14
5	0.00	50.71	8.00	77.86
6	0.00	44.29	8.14	77.86
7	0.00	39.29	8.20	78.57
8	0.00	34.29	8.34	79.29
9	0.26	28.57	8.51	79.29
10	0.00	25.71	8.91	80.00
11	0.00	18.57	9.03	80.71
12	0.00	7.14	9.17	82.14
13	0.00	2.86	9.29	85.00
14	0.15	0.71	9.57	87.14
15	0.00	0.00	9.77	88.57
16	0.00	0.00	10.14	90.00
17	0.00	0.00	10.57	90.71
18	0.00	0.00	11.14	94.29
19	0.00	0.00	11.43	97.14
20	0.18	0.00	11.86	98.57

* Correlation coefficient r= 0.9775 (Significant at 5% and 1%)

4.1.4.3 Sap inoculation study

The cell sap of leaves showing severe and typical symptoms of leaf curling was inoculated on the healthy tender leaves of potted healthy plants of 45 days old (Plate 9). The leaf curl symptom was not produced up to one month in the sap inoculated plants but severe leaf curling (68.78%) recorded on unprotected plants (Table 4.7).

This result indicated that thrips born virus was not responsible for producing the leaf curling in chilli. Patel and Gupta (1992) also reported this type of observations at Udaipur (Rajasthan).

Table 4.7: Sap inoculation study

Day after sap inoculation	Sap inoculated seedling		Unprotected seedling*	
	Thrips/plant	Leaf curling (%)	Thrips/plant	Leaf curling (%)
1	0	0	0.00	0.00
2	0	0	0.00	0.00
3	0	0	0.00	0.00
4	0	0	0.00	0.00
5	0	0	0.00	0.00
6	0	0	0.27	0.00
7	0	0	0.27	0.00
8	0	0	0.33	1.67
9	0	0	0.47	3.33
10	0	0	0.93	3.33
11	0	0	1.33	5.00
12	0	0	1.53	5.00
13	0	0	1.67	6.67
14	0	0	1.87	6.67
15	0	0	2.00	8.33
16	0	0	2.20	8.33
17	0	0	2.47	13.33
18	0	0	2.67	15.00
19	0	0	2.93	16.67
20	0	0	3.13	20.00
21	0	0	3.33	21.67
22	0	0	3.80	26.67
23	0	0	4.00	31.67
24	0	0	4.27	38.33
25	0	0	4.53	40.00
26	0	0	4.60	45.00
27	0	0	4.73	58.33
28	0	0	4.87	61.67
29	0	0	5.00	63.33
30	0	0	5.20	66.67

* Correlation coefficient r= 0.9298 (Significant at 5% and 1%)

4.2 Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*

The estimation of qualitative loss was done by measuring leaf curl severity and plant growth characters *viz.*, plant height, no. of branches, length and width of fruit. The quantitative losses were measured on the basis of yield data obtain from protected and unprotected crops against chilli thrips. The eight application with spinosad 0.009 per cent and abamectin 0.003 per cent alternatively at 10 day interval was given to protect chilli against the thrips.

4.2.1 Qualitative losses

4.2.1.1 Leaf curling intensity and thrips density in protected and unprotected crop

Year 2011

The data are presented in Table 4.8 and depicted in Fig. 4.3 on thrips population and percentage of leaf curling in protected and unprotected crop during *Kharif*-2011. The data revealed that five day after 1st, 2nd, 3rd, 4th, 5th, 6th, 7th and 8th insecticidal spray the thrips population was recorded significantly the lower in protected crop (1.99, 2.66, 3.50, 5.17, 7.80, 10.98, 4.12 and 2.11/ 3 twig, respectively) over unprotected crop (22.30, 24.07, 36.11 30.60, 39.03, 42.83, 60.31, 48.67 and 51.67/ 3 twig, respectively). Whereas, percentage of leaf curling was recorded significantly lower in protected crop (17.22, 18.61, 20.56, 17.78, 24.44, 25.83, 20.83 and 15.56%, respectively) over unprotected crop (28.89, 36.11, 44.44, 49.72, 54.44, 65.56, 56.94 and 51.67%, respectively). The average (pooled) thrips population (4.79/ 3 twig) and leaf curling (20.10%) in protected plants was significantly the lower over unprotected plants.

Table 4.8: Population of thrips and leaf curling in protected and unprotected chilli crop during *Kharif* -2011

Sr. No.	Treatment	5th day after spray																		% loss in Lc
		1st Spray		2nd Spray		3rd Spray		4th Spray		5th Spray		6th Spray		7th Spray		8th Spray		Pooled (Average)		
		Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	
1	Protected	1.99	17.22	2.66	18.61	3.50	20.56	5.17	17.78	7.80	24.44	10.98	25.83	4.12	20.83	2.11	15.56	4.79	20.10	-
2	Unprotected	22.30	28.89	24.07	36.11	30.06	44.44	39.03	49.72	42.83	54.44	60.31	65.56	48.67	56.94	39.03	51.67	38.29	48.47	58.53
S.Em.±		0.62	1.17	0.67	1.35	0.70	1.09	0.71	1.51	0.81	0.96	1.84	1.82	1.35	1.94	0.71	1.14	0.36	0.93	
C.D. at 5 %		1.88	3.55	2.05	4.11	2.12	3.32	2.15	4.59	2.44	2.92	5.58	5.51	4.09	5.90	2.16	3.45	1.08	2.81	
C.V.%		19.79	19.64	19.55	19.18	16.16	13.03	12.43	17.36	12.33	9.45	19.99	15.39	19.79	19.37	13.43	13.11	6.42	10.46	

Tp: Number of thrips/ 3 twig/ plant Lc: Percentage of leaf curling (%)

Year 2012

The data are presented in Table 4.9 and depicted in Fig. 4.3 on thrips population and percentage of leaf curling in protected and unprotected crop during *Kharif*-2012. The data revealed that five day after 1st, 2nd, 3rd, 4th, 5th, 6th, 7th and 8th insecticidal spray the thrips population was recorded significantly the lower in protected crop (2.02, 2.54, 3.68, 5.47, 7.69, 21.52, 3.33 and 3.10/ 3 twig, respectively) over unprotected crop (23.77, 14.38, 24.92, 34.67, 58.83, 70.63, 51.76 and 37.21/ 3 twig, respectively). Whereas, percentage of leaf curling was recorded significantly lower in protected crop (19.17, 16.67, 20.83, 21.94, 25.56, 34.17, 24.44, and 18.89%, respectively) over unprotected crop (50.00, 49.17, 50.83, 55.56, 63.61, 88.61, 88.06 and 81.94%, respectively). The average (pooled) thrips population (6.17/ 3 twig) and leaf curling (22.71%) in protected plants was significantly the lower over unprotected plants.

Pooled effect

The data are presented in Table 4.10 and depicted in Fig. 4.3 on average (pooled over year) thrips population and percentage of leaf curling in protected and unprotected crop. The data revealed that five day after 1st, 2nd, 3rd, 4th, 5th, 6th, 7th and 8th insecticidal spray the average thrips population was recorded significantly the lower in protected crop (2.34, 2.60, 3.59, 5.32, 7.74, 16.25, 3.73 and 2.61/ 3 twig, respectively) over unprotected crop (23.92, 19.22, 27.49, 36.85, 50.83, 65.47, 50.21 and 38.12/ 3 twig, respectively). The percentage of leaf curling was also significantly lower in protected crop (18.19, 17.64, 20.69, 19.86, 25.00, 30.00, 22.64 and 17.22%, respectively) over unprotected crop (39.44, 42.64, 47.64, 52.64, 59.03, 77.08, 72.50 and 66.81%, respectively). The average (pooled) thrips population (5.48/ 3 twig) and leaf curling (21.41%) in protected was significantly the lower over unprotected crop.

The percentage of leaf curling 48.47 to 65.97 was estimated in unprotected crop as against 20.10 to 22.71 in protected crop during both the years. Thus, there was 58.53 to 65.57 per cent with on average of 62.58 per cent more leaf curl in unprotected crop was recorded. Patel and Gupta (1992) reported 55.28 per cent to 71.78 per cent leaf curling in unprotected plots as against 1 per cent to 3 per cent in protected plots and there was 94.44 per cent to 98.55 per cent more leaf curl in unprotected plots than protected plots.

Table 4.9: Population of thrips and leaf curling in protected and unprotected chilli crop during *Kharif*-2012

Sr. No.	Treatment	5th day after spray																		% loss in Lc
		1st Spray		2nd Spray		3rd Spray		4th Spray		5th Spray		6th Spray		7th Spray		8th Spray		Pooled (Average)		
		Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	
1	Protected	2.02	19.17	2.54	16.67	3.68	20.83	5.47	21.94	7.69	58.53	21.52	34.17	3.33	24.44	3.10	18.89	6.17	22.71	-
2	Unprotected	23.77	50.00	14.38	49.17	24.92	50.83	34.67	55.56	58.83	63.61	70.63	88.61	51.76	88.06	37.21	81.94	39.52	65.97	65.57
S.Em.±		0.57	1.72	0.43	1.55	0.71	1.61	0.98	1.48	1.43	1.03	1.83	1.51	1.06	1.76	0.83	1.37	0.47	0.88	
C.D. at 5 %		1.74	5.22	1.32	4.71	2.15	4.87	2.97	4.49	4.34	3.13	5.56	4.57	3.22	5.34	2.52	4.17	1.42	2.66	
C.V.%		17.22	19.27	19.85	18.28	19.22	17.36	18.91	14.78	16.67	8.96	15.41	9.51	14.91	12.12	15.96	10.56	7.94	7.65	

Tp: Number of thrips/ 3 twig/ plant Lc: Percentage of leaf curling (%)

Table 4.10: Population of thrips and leaf curling in protected and unprotected chilli crop (Pooled data of *Kharif* -2011 and *Kharif* -2012)

Sr. No.	Treatment	5th day after spray																		% loss in Lc
		1st Spray		2nd Spray		3rd Spray		4th Spray		5th Spray		6th Spray		7th Spray		8th Spray		Pooled (average)		
		Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	Tp	Lc (%)	
1	Protected	2.34	18.19	2.60	17.64	3.59	20.69	5.32	19.86	7.74	25.00	16.25	30.00	3.73	22.64	2.61	17.22	5.48	21.41	-
2	Unprotected	23.92	39.44	19.22	42.64	27.49	47.64	36.85	52.64	50.83	59.03	65.47	77.08	50.21	72.50	38.12	66.81	38.90	57.22	62..58
S.Em.±		0.51	1.29	0.46	1.13	0.47	0.95	0.70	1.06	0.70	1.10	1.14	1.23	0.79	1.67	0.58	1.07	0.60	0.96	
C.D. at 5 %		1.54	3.91	1.39	3.43	1.42	2.88	2.11	3.22	2.12	3.34	3.47	3.72	2.40	5.06	1.75	3.23	1.81	2.91	
C.V.%		15.01	17.32	16.3	14.55	11.66	10.74	12.78	11.34	9.23	10.16	10.83	8.87	11.35	13.57	10.95	9.82	10.39	9.46	

Tp: Number of thrips/ 3 twig/ plant Lc: Percentage of leaf curling (%)

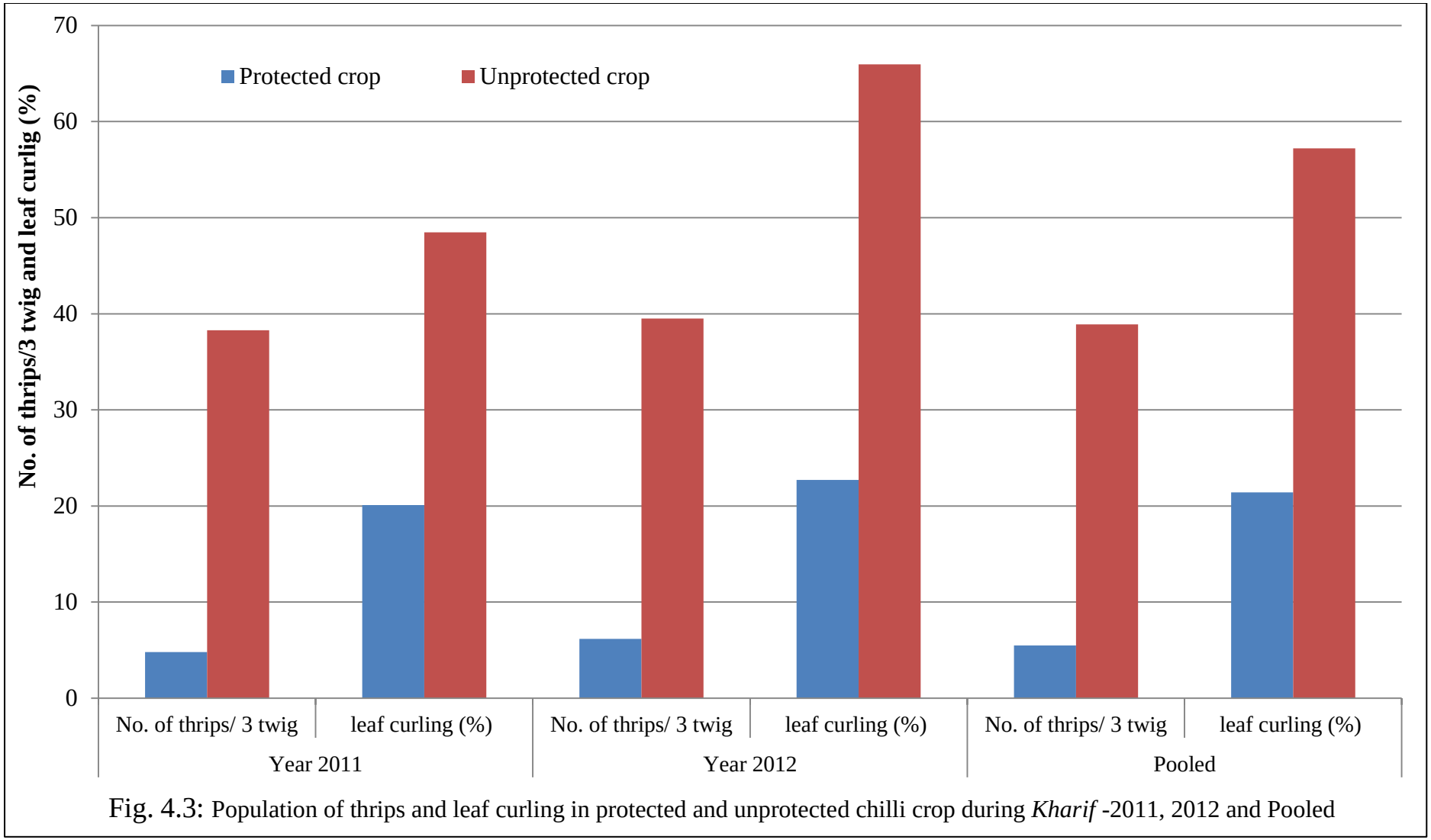

Fig. 4.3: Population of thrips and leaf curling in protected and unprotected chilli crop during *Kharif* -2011, 2012 and Pooled

4.2.1.2 Losses in plant growth character

Year 2011

The data revealed on the plant growth characters *viz.*, size of green chilli, height, no of branches and size of leaf on unprotected and protected plants of chilli are presented in Table 4.11 and depicted in Fig. 4.4 and 4.5.

The length (10.68 cm) and width (2.99 cm) of fruit, plant height (87.26 cm), number of branches per plant (9.46) and length (8.42 cm) and width (2.92 cm) of leaf significantly increased in protected crop over the unprotected crop in which length (6.26 cm) and width (2.65 cm) of fruit, plant height (63.90 cm), number of branches per plant (6.91), length (3.30 cm) and width (1.08 cm) of leaf were recorded. The loss in plant height was to the extent of 26.76 per cent. The reduction in number of branches per plant was 26.93 per cent. The loss in length and width of leaf was 60.84 per cent and 63.16 per cent, respectively. The loss in length and width of green marketable fruit was 41.43 per cent and 9.32 per cent, respectively and also the affected fruits were of low quality.

Year 2012

The data are presented in Table 4.12 and depicted in Fig. 4.4 and 4.5 revealed that the length (10.47 cm) and width (2.79 cm) of fruit, plant height (89.03 cm), number of branches per plant (10.01) and length (8.29 cm) and width (2.70 cm) of leaf was significantly increased in protected crop over the unprotected crop in which length (6.99 cm) and width (2.43 cm) of fruit, plant height (65.94 cm), number of branches per plant (7.01), length (2.91 cm) and width (0.95 cm) of leaf were recorded.

The loss in plant height was 25.93 per cent. The reduction in number of branches per plant was 29.98 per cent. The loss in length and width of leaf was 64.86 per cent and 64.98 per cent, respectively. The losses of length and width of green marketable chilli (fruit) was 33.27 per cent and 12.70 per cent, respectively and also the affected fruits were of low quality.

Table 4.11: Qualitative yield losses in chilli due to infestation of thrips, *S. dorsalis* during *Kharif*- 2011

Sr. No.	Plant growth character	Protected	Unprotected	Difference	% losses	S.Em.±	C.D. at 5 %	C.V.%
1	Length of fruit (cm)	10.68	6.26	4.43	41.43	0.32	0.96	14.53
2	Width of fruit (cm)	2.93	2.65	0.28	9.32	0.09	0.27	12.32
3	Height of plant (cm)	87.26	63.90	23.35	26.76	1.69	5.13	8.67
4	No. of branches/plant	9.46	6.91	2.55	26.93	0.22	0.68	10.6
5	Length of leaf (cm)	8.42	3.30	5.12	60.84	0.23	0.70	15.19
6	Width of leaf (cm)	2.92	1.08	1.84	63.16	0.09	0.29	18.39

Table 4.12: Qualitative yield losses in chilli due to infestation of thrips, *S. dorsalis* during *Kharif*- 2012

Sr. No.	Plant growth character	Protected	Unprotected	Difference	% losses	S.Em.±	C.D. at 5 %	C.V.%
1	Length of fruit (cm)	10.47	6.99	3.48	33.27	0.18	0.53	7.8
2	Width of fruit (cm)	2.79	2.43	5.34	12.78	0.07	0.22	10.64
3	Height of plant (cm)	89.03	65.94	23.09	25.93	1.88	5.69	9.52
4	No. of branches/plant	10.01	7.01	3.00	29.98	0.26	0.80	11.93
5	Length of leaf (cm)	8.29	2.91	5.38	64.86	0.22	0.67	15.28
6	Width of leaf (cm)	2.70	0.95	1.76	64.98	0.07	0.23	15.83

Pooled effect

The data on plant characters were recorded during the two year pooled and presented in Table 4.13 and depicted in Fig. 4.4 and 4.5.

The average length (10.58 cm) and width (2.86 cm) of fruit, plant height (88.14 cm), number of branches per plant (9.73) and length (8.36 cm) and width (2.81 cm) of leaf significantly higher in protected crop over the unprotected crop in which length (6.62 cm) and width (2.54 cm) of fruit, plant height (64.92 cm), number of branches per plant (6.96), length (3.11 cm) and width (1.01 cm) of leaf were recorded.

The loss in plant height was 25.93 to 26.76 per cent with an average of 26.34 per cent. Whereas, reduction in number of branches per plant was 26.93 to 29.98 per cent with an average of 28.50 per cent. The loss in length and width of leaf was 60.84 to 84.86 per cent with an average 62.83 per cent and 63.16 to 64.98 per cent with an average 64.04 per cent, respectively. The loss in length and width of green marketable fruit was 33.27 to 41.63 per cent with an average 33.39 per cent and 9.32 to 12.78 per cent with an average 11.01 per cent, respectively. The damage caused by the thrips, on green chilli fruits was recorded with scraping, crinkle, abnormal, curved, colour of fruit become dark green and size of the fruit significantly reduced in both the year. Further quality of green chilli *i.e.* appearance, shape and luster of green chilli were also detoriated (Plate 10).

Patel and Gupta (1992) reported that the loss in plant height was to the extent 27.85 per cent. Whereas, reduction in number of branches per plant was 44 per cent and the length 66.01 per cent and width 65.71 per cent of leaf observed. The length of green marketable fruits of chilli was reduced by 37.72 per cent and also affected fruit were of low quality. Thus the present results are in agreement with the reported research.

Table 4.13: Qualitative yield losses in chilli due to infestation of thrips, *S. dorsalis* (Polled data of *Kharif*- 2011 and *Kharif*- 2012)

Sr. No.	Plant growth character	Protected	Unprotected	Difference	% losses	S.Em.±	C.D. at 5 %	C.V.%
1	Length of fruit (cm)	10.58	6.62	3.96	33.39	0.23	0.70	10.32
2	Width of fruit (cm)	2.86	2.54	0.31	11.01	0.06	0.17	8.04
3	Height of plant (cm)	88.14	64.92	23.22	26.34	1.69	5.12	8.55
4	No. of branches/plant	9.73	6.96	2.77	28.50	0.18	0.54	8.27
5	Length of leaf (cm)	8.36	3.11	5.25	62.83	0.22	0.66	14.69
6	Width of leaf (cm)	2.81	1. 01	1.80	64.04	0.08	0.24	15.86

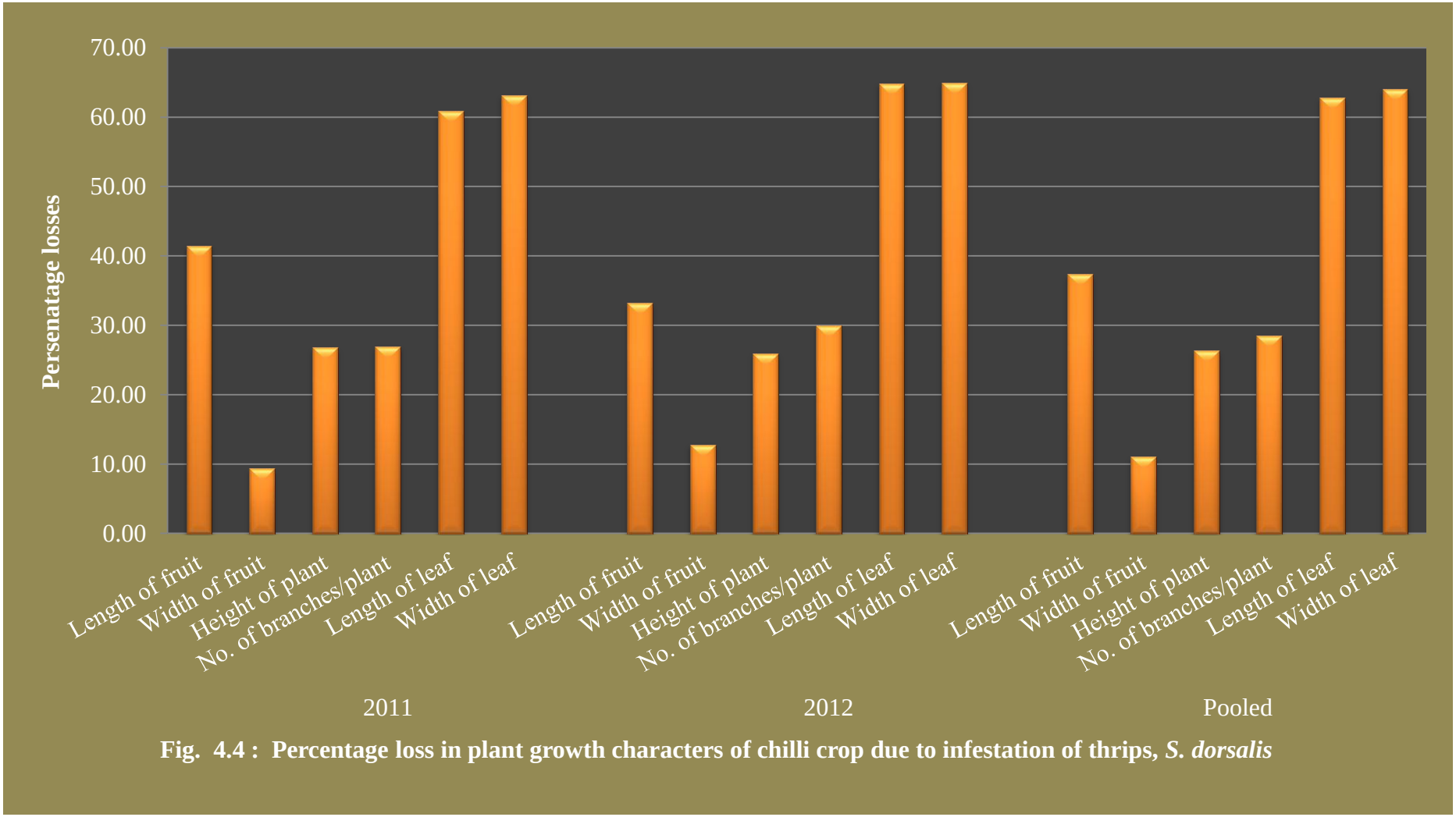

Fig. 4.4 : Percentage loss in plant growth characters of chilli crop due to infestation of thrips, *S. dorsalis*

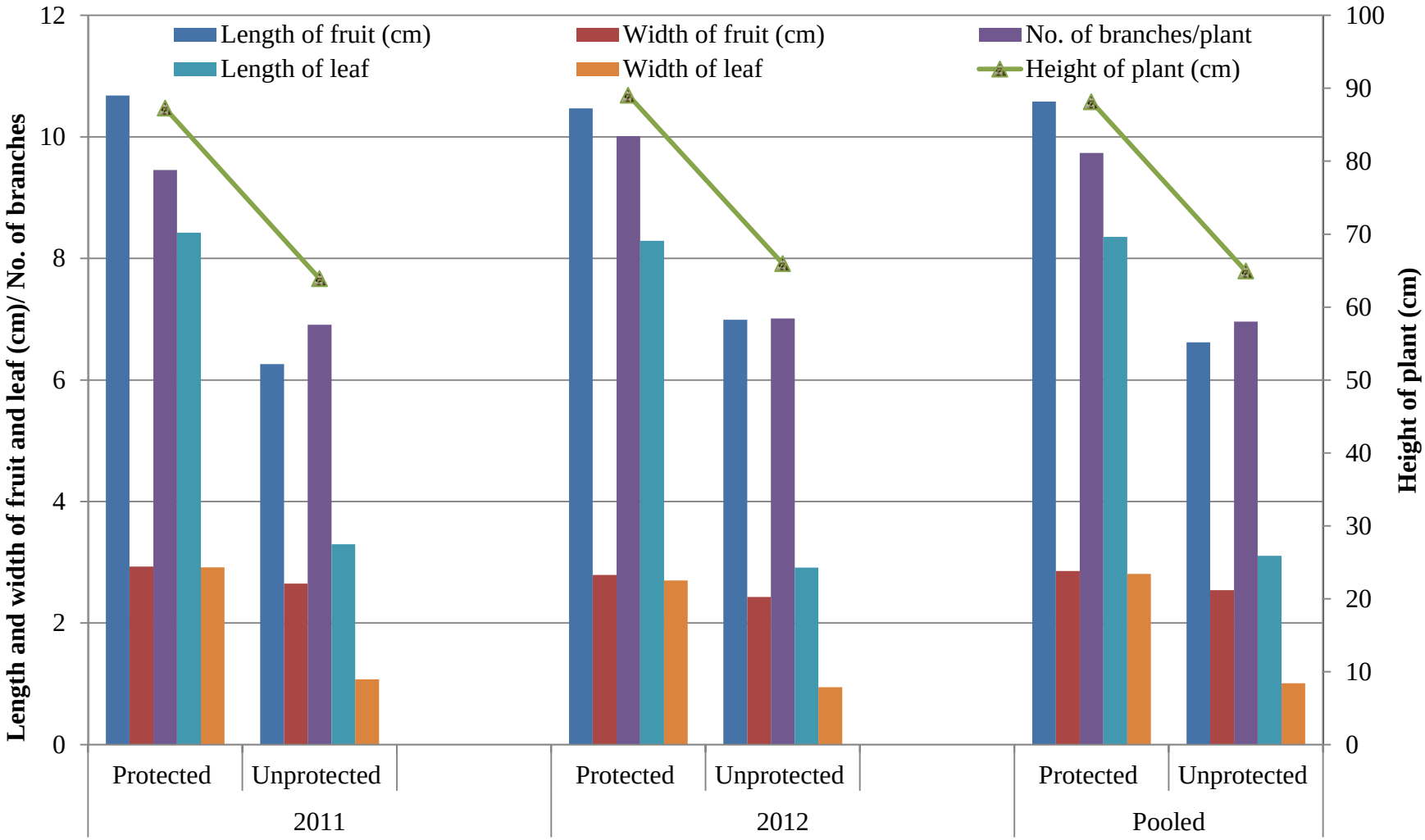

Fig. 4.5: Losses in plant growth characters of chilli crop due to infestation of thrips, *S. dorsalis*

4.2.2 Estimation of quantitative losses caused by chilli thrips, *S. dorsalis*

The data on yield of green chilli obtained from protected and unprotected crop during year 2011, 2012 and pooled are summarized in Table 4.14, 4.15 and 4.16 and depicted in Fig 4.7 and Fig. 4.6.

4.2.2.1 Yield loss in 2011

The data presented in table 4.14 revealed that the yield received from protected crop 15244 kg/ha was significantly superior over the yield from unprotected crop 3911 kg/ha. The yield increased in protected crop over unprotected crop was 11333 kg/ha. This showed 289.77 per cent increase in yield and 74.34 per cent avoidable loss during *Kharif*- 2011.

Table 4.14: Yield loss in green chilli due to infestation of thrips, *S. dorsalis* during *Kharif*- 2011

Sr. No.	Treatment	Yield of marketable green chilli (kg/ha)	Yield loss (kg/ha)	Increase in yield over control (%)	Avoidable yield loss (%)
1	Protected crop	15244	-	289.77	-
2	Unprotected crop	3911	11333	-	74.34
	S.Em.±	470.22			
	C.D. at 5 %	1426.44			
	C.V.%	19.01			

4.2.2.2 Yield loss in 2012

The data presented in Table 4.15 revealed that the yield obtained from protected crop 14556 kg/ha was significantly superior over the yield from unprotected crop 3644 kg/ha. The yield increased in protected crop over unprotected crop was 10911 kg/ha. This showed 299.39 per cent increase in yield and 74.96 per cent avoidable loss during *Kharif*- 2012.

Table 4.15: Yield loss in green chilli due to infestation of thrips, *S. dorsalis* during *Kharif*- 2012

Sr. No.	Treatment	Yield of marketable green chilli (kg/ha)	Yield loss (kg/ha)	Increase in yield over control (%)	Avoidable yield loss (%)
1	Protected crop	14556	-	299.39	-
2	Unprotected crop	3644	10911	-	74.96
	S.Em.±	213.78			
	C.D. at 5 %	648.44			
	C.V.%	9.10			

4.2.2.3 Pooled effect

The average of two year (pooled) data on yield of green chilli recorded from unprotected and protected chilli crop against thrips, *S. dorsalis* are presented in Table 4.16 and depicted in Fig. 4.6 and 4.7. The data revealed that the yield of green chilli 14900 kg/ha from protected crop was significantly higher over unprotected crop (3778 kg/ha). The yield increased from protected crop over unprotected crop was 11122 kg/ha. Thus, 294.41 per cent green chilli yield was increased in crop protected against thrips. The avoidable loss of 74.65 per cent which can be saved by application of spinosad 0.009 per cent and abamectin 0.003 per cent alternatively at 10 day interval against thrips, starting from 45 day after transplanting of chilli seedling.

Table 4.16: Yield loss in green chilli due to infestation of thrips, *S. dorsalis* (Polled data of *Kharif*- 2011 and *Kharif*- 2012)

Sr. No.	Treatment	Yield of marketable green chilli (kg/ha)	Yield loss (kg/ha)	Increase in yield over control (%)	Avoidable yield loss (%)
1	Protected crop	14900	-	294.41	-
2	Unprotected crop	3778	11122	-	74.65
	S.Em.±	236.00			
	C.D. at 5 %	715.89			
	C.V.%	9.79			

Patel and Gupta (1996) have also reported the yield losses 60.5 to 74.3 per cent caused by chilli thrips, *S. dorsalis* at Udaipur (Rajasthan). According to Panchabhavi and Thimmaiah (1972), 72.5 per cent yield loss could be saved by

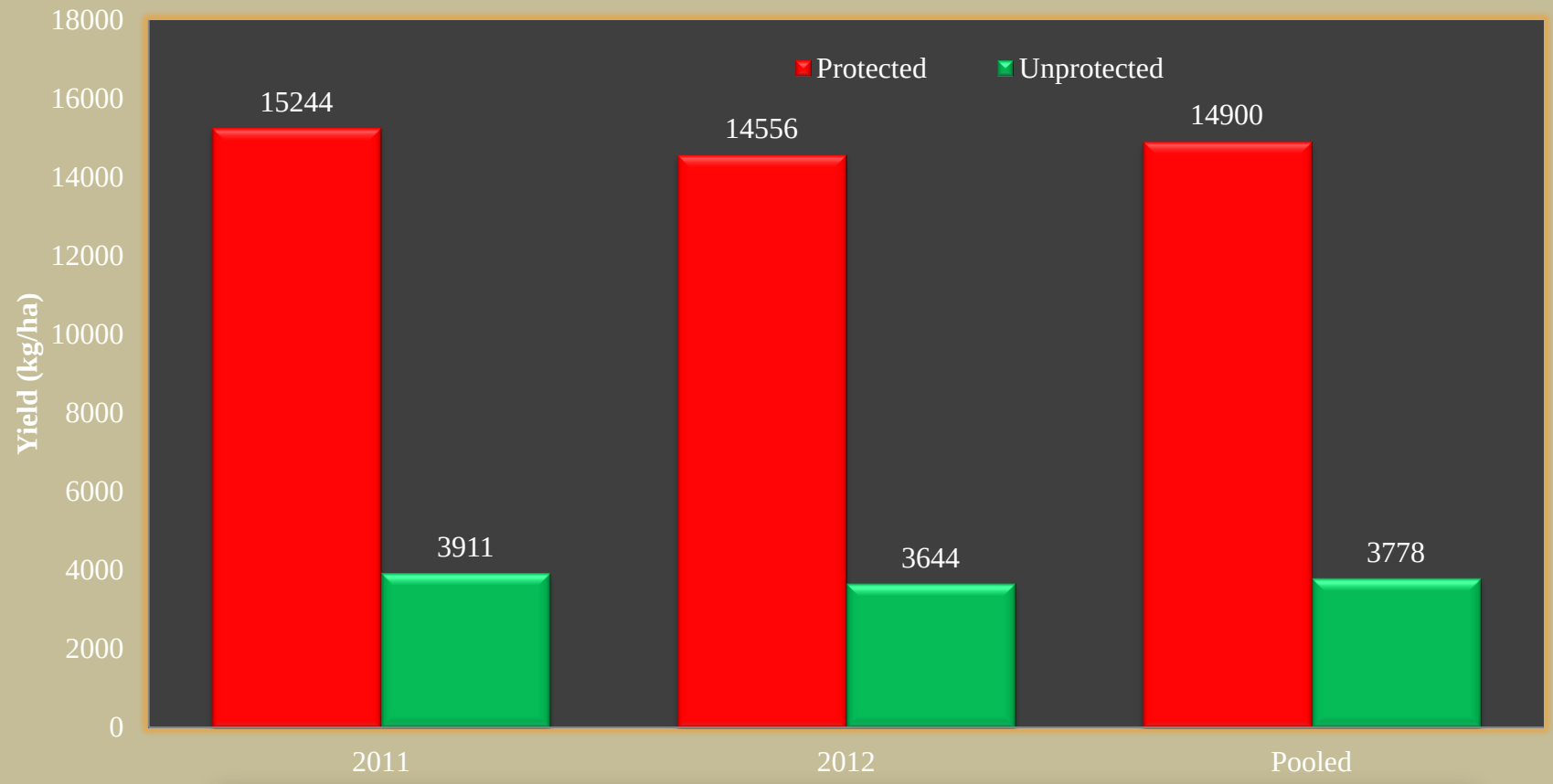

Fig. 4.6 : Yield of green chilli received from protected and from unprotected crops

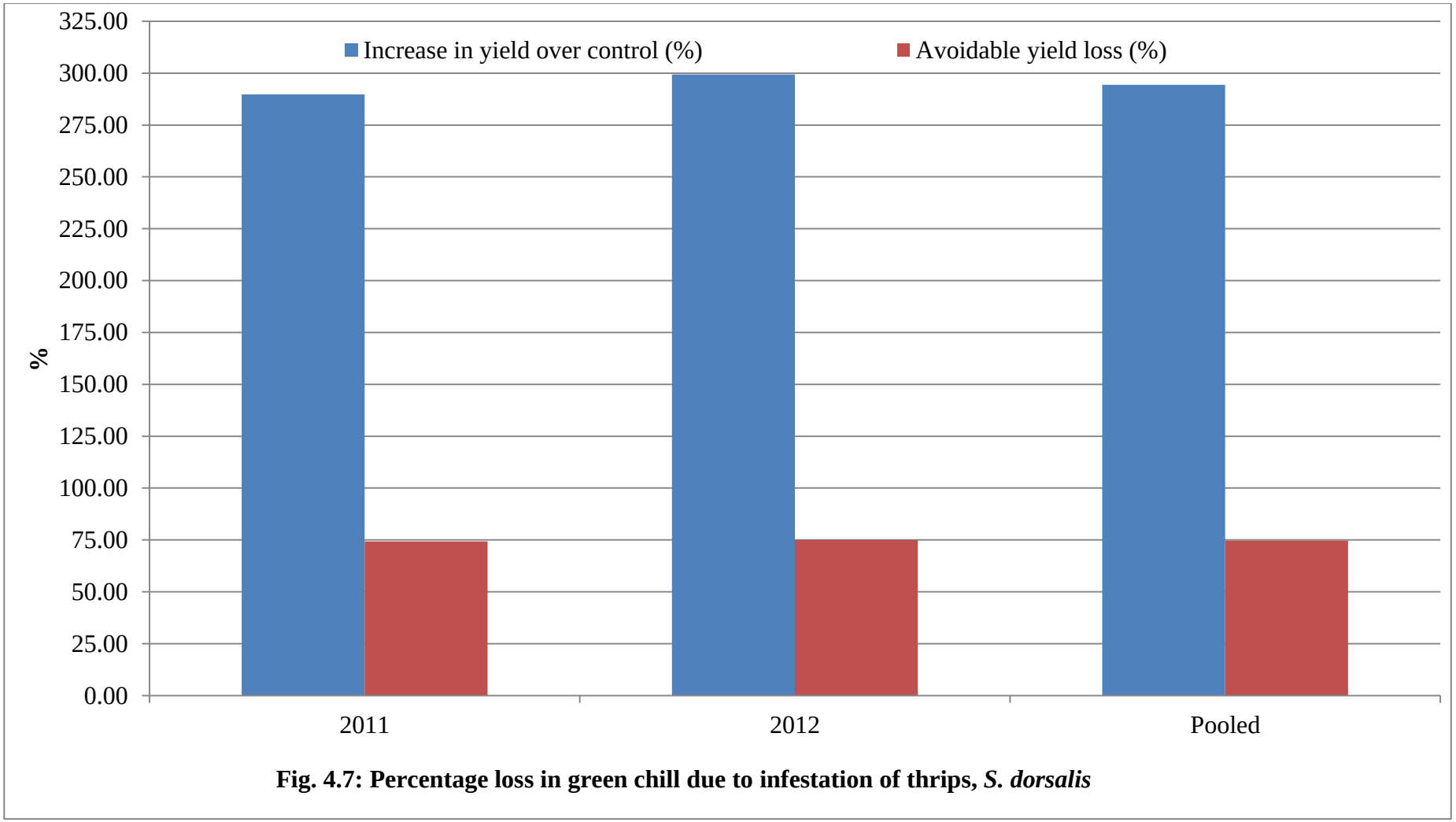

Fig. 4.7: Percentage loss in green chill due to infestation of thrips, *S. dorsalis*

controlling thrips on chilli with insecticides. Nagaraj Rao (1955) who reported as high as 50 per cent loss in yield of chilli due to thrips infestation, while Ningappa (1972) reported 20-100 per cent yield loss due to the thrips infestation and incidence of leaf curl at Bangalore.

4.3 Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli during *Kharif* 2011

The twelve insecticide were evaluated against thrips, *S. dorsalis* infesting chilli crop at Farm Field (Village: Devlki, Tal: Vadia, Dist: Amreli) during *Kharif* 2011. Total three application of the various insecticides were given at 15 day interval. The thrips population and percentage of leaf curling were recorded at 3, 7 and 14 day after each application.

4.3.1 Bioefficacy of insecticides against chilli thrips, *S. dorsalis* at first application

The first application of insecticides was given at 45 day after transplanting of chilli, when the thrips population was build up high. Number of thrips on six plants from three twig per plant was recorded at one day before, and at three, seven and fourteen day after each insecticide spray. The data on number of thrips in different insecticidal treatments are presented in Table 4.17.

Before spray

The data given in Table 4.17 revealed that the thrips population of 40.03 to 48.81 thrips/3 twig was recorded in different plots one day before the 1st spray insecticides application and was non-significantly differed with each other.

After three day

The data on population of thrips in different insecticidal treatments recorded at three days after the first spray are presented in Table 4.17. The data was revealed that in all the treatments thrips population reduced significantly over control. The maximum reduction in thrips population was by treatment of profenophos + cypermethrin (0.044%) in which 2.64 thrips/3 twig recorded. The treatment with

Table 4.17: Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli during 2011

Sr. No.	Treatment	Average no. of thrips/3 twig									
		After 1st spray				After 2nd spray			After 3rd spray		
		Before	3 day	7 day	14 day	3 day	7 day	14 day	3 day	7 day	14 day
1	Imidacloprid 0.005 %	6.75* (45.52)	1.81 (3.28)	3.55 (12.63)	5.29 (27.95)	1.66 (2.74)	3.55 (12.63)	5.74 (32.99)	1.81 (3.29)	3.50 (12.27)	5.29 (27.81)
2	Acetamiprid 0.008 %	6.64 (44.05)	2.30 (5.27)	3.88 (15.03)	5.83 (33.95)	2.94 (8.64)	4.37 (19.10)	5.97 (35.64)	1.72 (2.96)	3.27 (10.71)	4.93 (23.94)
3	Indoxacarb 0.0145	6.67 (44.44)	2.41 (5.82)	3.95 (15.63)	5.77 (33.33)	2.53 (6.38)	3.95 (15.60)	5.91 (34.93)	2.30 (5.29)	4.17 (17.42)	5.49 (30.14)
4	Spinosad 0.009%	6.99 (48.81)	1.82 (3.30)	3.11 (9.69)	4.19 (17.53)	1.95 (3.79)	2.41 (5.79)	3.02 (9.10)	1.82 (3.30)	2.55 (6.49)	3.50 (11.90)
5	Profenophos 40% + Cypermethrin 4% (0.044%)	6.84 (46.83)	1.62 (2.64)	3.55 (12.58)	5.18 (26.87)	1.82 (3.30)	3.55 (12.58)	5.17 (26.76)	1.91 (3.65)	3.12 (9.76)	4.58 (20.98)
6	Profenophos 0.05%	6.82 (46.47)	1.70 (2.90)	3.87 (14.95)	5.36 (28.77)	1.66 (2.74)	3.54 (12.53)	5.60 (31.32)	2.03 (4.31)	3.50 (12.25)	5.23 (27.39)
7	Diafenthiuron 0.05%	6.82 (46.47)	2.23 (4.99)	3.86 (14.93)	5.73 (32.87)	2.62 (6.86)	4.03 (16.24)	5.76 (33.22)	2.32 (5.38)	3.71 (13.79)	5.32 (28.02)
8	Abamectin 0.003%	6.72 (45.16)	1.81 (3.28)	3.58 (12.79)	5.19 (26.97)	1.80 (3.25)	3.54 (12.51)	5.54 (30.65)	1.96 (3.85)	3.21 (10.30)	4.78 (22.88)
9	*M. anisopliae* @ 2.0 kg/ha	6.69 (44.80)	3.16 (9.96)	5.16 (26.66)	6.20 (38.48)	3.28 (10.76)	5.07 (25.67)	6.71 (44.98)	2.47 (6.10)	4.33 (18.72)	6.38 (40.88)
10	*V. lacanii* @ 2.0 kg/	6.719 (44.98)	2.50 (6.25)	4.78 (22.85)	6.00 (36.04)	2.26 (5.12)	4.24 (18.01)	6.52 (42.47)	3.03 (9.18)	3.84 (14.75)	6.20 (38.03)
11	*B. bassiana* @ 2.0 kg/ha	6.64 (44.05)	3.17 (10.05)	5.39 (29.02)	6.22 (38.73)	3.31 (10.96)	5.17 (26.76)	6.69 (44.80)	2.76 (7.64)	4.43 (19.65)	6.37 (40.15)
12	Azadirachtin 0.001%	6.83 (46.60)	2.32 (5.37)	4.01 (16.11)	5.92 (35.05)	2.94 (8.62)	3.94 (15.55)	6.19 (38.32)	2.42 (5.87)	4.25 (18.09)	5.91 (34.34)
13	Control	6.33 (40.03)	6.44 (41.43)	6.75 (45.61)	7.54 (56.80)	7.94 (63.04)	7.77 (60.42)	7.48 (55.90)	7.68 (58.98)	7.11 (50.60)	6.75 (45.61)
	S.Em.±	0.11	0.16	0.28	0.32	0.21	0.31	0.34	0.16	0.26	0.32
	C.D. at 5 %	NS	0.47	0.81	0.94	0.61	0.92	0.99	0.45	0.77	0.93
	C.V.%	2.84	10.93	11.24	9.73	12.84	12.82	10.05	10.23	11.65	10.22

* $\sqrt{x+1}$ transformations. Figures in parenthesis are retransformed values.

profenophos 0.05 per cent (2.90 thrips/3 twig), imidacloprid 0.005 per cent (3.28 thrips/3 twig), abamectin 0.003 per cent (3.28 thrips/3 twig) and spinosad 0.009 per cent (3.30 thrips/3 twig), were statistically at par with the profenophos + cypermethrin (0.044%). These five insecticides found top most effective against chilli thrips at three day after their application.

Diafenthiuron 0.05 per cent (4.99 thrips/3 twig), acetamiprid 0.008 per cent (5.27 thrips/3 twig), indoxacarb 0.0145 per cent (5.82 thrips/3 twig), *V. lecanii* @ 2 kg/ha (6.25 thrips/3 twig) and azadirachtin 0.001 per cent (6.83 thrips/3 twig) statistically stood at second.

The rest of the treatments *viz*., *M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha were found relatively least effective against thrips, which recorded 9.96 and 10.05 thrips/3 twig, respectively. The thrips population recorded in untreated (control) chilli plants was as high as 41.43 thrips/3 twig.

After seven day

The data presented in Table 4.17 on population of thrips recorded at seven days after first spray, showed that the thrips population was increased in all treatment as compared to thrips population recorded at three day after the spray. However, the comparatively minimum thrips was recorded on the plants treated with spinosad 0.009 per cent (9.69 thrips/3 twig) and it was at par with imidacloprid 0.005 per cent (12.63 thrips/3 twig), profenophos + cypermethrin 0.044 per cent (12.58 thrips/3 twig), abamectin 0.003 per cent (12.79 thrips/3 twig), diafenthiuron 0.05 per cent (14.93 thrips/3 twig), profenophos 0.05 per cent (14.95 thrips/3 twig) and acetamiprid 0.008 per cent (15.03 thrips/3 twig).

The number of thrips recorded after seven day in the treatment of indoxacarb 0.0145 per cent (15.63 thrips/3 twig) and azadirachtin 0.001 per cent (16.46 thrips/3 twig) were at par with each other formed second group of effective treatments.

The rest of the treatments were found relatively least effective against thrips *viz*., *V. lecanii* @ 2 kg/ha, *M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha, in which 22.85, 26.66 and 29.02 thrips/3 twig recorded, respectively.

After fourteen day

The data on number of thrips recorded in the different insecticidal treatment at fourteen day after first spray are presented Table 4.17. The data revealed that the number of thrips in all the chemical treatments increased 5 to 9 time compared to the thrips recorded at three day after their application. However, the minimum thrips population over control was recorded in treatment spinosad 0.009 per cent (17.53 thrips/3 twig) and it was significantly superior over all other treatments.

The number of thrips recorded in the treatment of profenophos + cypermethrin 0.044 per cent (26.87 thrips/3 twig), abamectin 0.003 per cent (26.97 thrips/3 twig), imidacloprid 0.005 per cent (27.95 thrips/3 twig), profenophos 0.05 per cent (28.77 thrips/3 twig), indoxacarb 0.0145 per cent (33.33 thrips/3 twig), diafenthiuron 0.05 per cent (33.33 thrips/3 twig), acetamiprid 0.008 per cent (35.05 thrips/3 twig), azadirachtin 0.001 per cent (35.13 thrips/3 twig) and *V. lecanii* @ 2 kg/ha (36.04 thrips/3 twig) were at par with each other formed second group of effective treatments.

The rest of the treatments were found relatively least effective against the thrips *viz*., *M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha, which recorded 38.48 and 38.73 thrips/3 twig, respectively. The thrips population in control plots was recorded as high as 56.80 thrips/3 twig.

4.3.2 Bioefficacy of insecticides against chilli thrips, *S. dorsalis* at second application

After three day

The data on population of thrips in different insecticidal treatments recorded at three day after the second spray are presented in Table 4.17. The data revealed that by all the treatments, thrips population reduced significantly over control. The maximum reduction in thrips population (2.74 thrips/3 twig) was obtained by treatment of imidacloprid 0.005 per cent closely followed by profenophos 0.05 per cent (2.74 thrips/3 twig) abamectin 0.003 per cent (3.25 thrips/3 twig), profenophos + cypermethrin 0.044 per cent (3.30 thrips/3 twig), spinosad 0.009 per cent (3.79

thrips/3 twig) and *V. lecanii* @ 2 kg/ha (5.12 thrips/3 twig). These six insecticides found top most effective against chilli thrips at three day after the second application.

Indoxacarb 0.0145 per cent (6.38 thrips/3 twig), acetamiprid 0.008 per cent (8.64 thrips/3 twig), diafenthiuron 0.05 per cent (6.86 thrips/3 twig) and azadirachtin 0.001 per cent (8.64 thrips/3 twig) were statistically at par with each other and formed second group of effective treatments.

The rest of the treatments were found relatively least effective against thrips *i.e. M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha, which recorded 10.76 and 10.96 thrips/3 twig, respectively. The thrips population recorded in chilli plants of control plots was as high as 63.04 thrips / twig.

After seven day

The data presented in Table 4.17 on population of thrips recorded on seven days after second spray showed that the thrips population was increased as compared to thrips population recorded on three day after the spray. However, comparatively minimum thrips over control was recorded on the plants treated with spinosad 0.009 per cent (5.79 thrips/3 twig).

The number of thrips recorded after seven day in the treatment of abamectin 0.003 per cent (12.51 thrips/3 twig), profenophos 0.05 per cent (12.63 thrips/3 twig), profenophos + cypermethrin 0.044 per cent (12.58 thrips/3 twig), imidacloprid 0.005 per cent (12.63 thrips/3 twig), azadirachtin 0.001 per cent (15.55 thrips/3 twig) indoxacarb 0.0145 per cent (15.60 thrips/3 twig), diafenthiuron 0.05 per cent (16.24 thrips/3 twig), *V. lecanii* @ 2 kg/ha (18.01 thrips/3 twig) and acetamiprid 0.008 per cent (19.10 thrips/3 twig) were at par with each other formed second group of effective treatments.

The rest of the treatments were found relatively least effective against thrips *viz., M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha, and were recorded 25.67, and 26.76 thrips/3 twig, respectively.

After fourteen day

The data on number of thrips recorded in the different insecticidal treatment at fourteen day after second spray are presented in Table 4.17. The data revealed that

number of thrips in all the chemical treatment was increased 2 to 10 times compared to the thrips recorded at three day after their application. However, the minimum thrips population over control was recorded in treatment spinosad 0.009 per cent (9.10 thrips/3 twig) and it was significantly higher than all other treatments.

Profenophos + cypermethrin 0.044 per cent (26.76 thrips/3 twig), abamectin 0.003 per cent (30.65 thrips/3 twig), profenophos 0.05 per cent (31.32 thrips/3 twig), imidacloprid 0.005 per cent (32.99 thrips/3 twig), diafenthiuron 0.05 per cent (33.22 thrips/3 twig), indoxacarb 0.0145 per cent (34.97 thrips/3 twig) and acetamiprid 0.008 per cent (35.64 thrips/3 twig) were at par with each other forming second group of effective treatments.

The rest of the treatments were found relatively least effective against thrips *i.e.* azadirachtin 0.001 per cent, *V. lecanii @* 2 kg/ha, *M. anisopliae* 2 kg/ha and *B. bassiana @* 2 kg/ha, which recorded 38.32, 42.47, 44.98 and 44.80 thrips/3 twig, respectively. The thrips population in control plots was also increased and recorded as high as 55.90 thrips/3 twig.

4.3.3 Bioefficacy of insecticides against chilli thrips, *S. dorsalis* at third application

After three day

The data on population of thrips in different insecticidal treatments recorded at three days after the third spray are presented in Table 4.17. The data revealed that by all the treatments thrips population was reduced significantly over control. The maximum reduction in thrips population was by treatment of acetamiprid 0.008 per cent (2.96 thrips/3 twig) and closely followed by imidacloprid 0.005 per cent (3.29 thrips/3 twig), spinosad 0.009 per cent (3.30 thrips/3 twig), profenophos + cypermethrin 0.044 per cent (3.65 thrips/3 twig), abamectin 0.003 per cent (1.85 thrips/3 twig) and profenophos 0.05 per cent (4.31 thrips/3 twig). These six insecticides found top most effective against chilli thrips at three day after the third application.

Indoxacarb 0.0145 per cent (5.29 thrips/3 twig), diafenthiuron 0.05 per cent (5.38 thrips/3 twig), azadirachtin 0.001 per cent (5.87 thrips/3 twig) and *M. anisopliae*

@ 2 kg/ha (6.10 thrips/3 twig), were statistically at par with each other and formed second group of the effective treatments.

The rest of the treatments were found relatively least effective against thrips *i.e. B. bassiana* @ 2 kg/ha and *V. lecanii* @ 2 kg/ha which recorded 7.64 and 9.18 thrips/3 twig, respectively. The thrips population recorded in chilli plants of control plots was as high as 58.98 thrips/3 twig.

After seven day

The data presented in Table 4.17 revealed that the thrips population was increased on seven day as compared to thrips population on three day after the spray. However, the comparatively minimum thrips population over control was recorded on the plants treated with spinosad 0.009 per cent (6.49 thrips/3 twig) and it was at par with profenophos + cypermethrin 0.044 per cent (9.76 thrips/3 twig), abamectin 0.003 per cent (10.30.79 thrips/3 twig), acetamiprid 0.008 per cent (10.71 thrips/3 twig) and imidacloprid 0.005 per cent (12.27 thrips/3 twig).

The number of thrips recorded after seven day in the treatment of profenophos 0.05 per cent (12.25 thrips/3 twig) diafenthiuron 0.05 per cent (13.79 thrips/3 twig), *V. lecanii* @ 2 kg/ha (15.08 thrips/3 twig), indoxacarb 0.0145 per cent (14.75 thrips/3 twig) and azadirachtin 0.001 per cent (18.09 thrips/3 twig) were statistically at par with each other and formed second effective group of treatments.

The rest of the treatments were found relatively least effective against thrips *i.e. M. anisopliae* 2 kg/ha and *B. bassiana* @ 2 kg/ha, and were recorded 18.72 and 18.09 thrips/3 twig, respectively.

After fourteen day

The data on number of thrips recorded in the different insecticidal treatment at fourteen day after the third spray are presented Table 4.17. The data revealed that the number of thrips in all the chemical treatment was increased more 5 to 6 times on fourteen day compared to the thrips recorded on three day after the third application. However, the minimum thrips population over control was recorded in treatment

spinosad 0.009 per cent (12.23 thrips/3 twig) and it was significantly higher than all other treatments.

Profenophos + cypermethrin 0.044 per cent (20.98 thrips/3 twig), abamectin 0.003 per cent (22.88 thrips/3 twig), acetamiprid 0.008 per cent (23.94 thrips/3 twig), profenophos 0.05 per cent (27.39 thrips/3 twig), imidacloprid 0.005 per cent (27.81 thrips/3 twig), diafenthiuron 0.05 per cent (28.02 thrips/3 twig and indoxacarb 0.0145 per cent (30.14 thrips/3 twig) were at par with each other forming second group of effective treatments.

The rest of treatments were found relatively least effective against the thrips *i.e.* azadirachtin 0.001 per cent, *V. lecanii* @ 2 kg/ha, *B. bassiana* @ 2 kg/ha and *M. anisopliae* 2 kg/ha, which were recorded 34.34, 38.03, 40.15 and 40.88 thrips/3 twig, respectively. The thrips population in control plots was recorded as high as 45.61 thrips/3 twig.

4.3.4 Pooled results

The data are given in Table 4.18 and depicted in Fig. 4.8 on pooled result of effectiveness of insecticides against chilli thrips during all three spray applications. The data revealed that maximum reduction of chilli thrips was by treatment imidacloprid 0.005 per cent (3.13 thrips/3 twig) over control in which average 54.52 thrips/3 twig recorded. Further it was found that the reduction in thrips population due to profenophos + cypermethrin 0.044 per cent (3.22 thrips/3 twig), profenophos 0.05 per cent (3.35 thrips/3 twig), spinosad 0.009 per cent (3.47 thrips/3 twig) and abamectin 0.003 per cent (3.47 thrips/3 twig) was statistically equal with imidacloprid 0.005 per cent. Thus these five insecticides were found top most effective against chilli thrips at three day after their application on the crop.

On seven day, the thrips population increased in all the insecticidal treatments compared to thrips population recorded at three day after application. It might be due to short persistency of the insecticides applied. However, significantly minimum thrips (7.33 thrips/3 twig) was recorded on chilli plants treated with spinosad 0.009 per cent, found top most effective over rest of treatments at seven day after applications. It was also reflected from the data (Table 4.18 and Fig 4.9) that the significantly higher reduction of thrips was due to treatment of profenophos +

cypermethrin 0.044 per cent (11.76 thrips/3 twig), abamectin 0.003 per cent (12.02 thrips/3 twig), imidacloprid 0.005 per cent (12.58 thrips/3 twig), profenophos 0.05 per cent (13.44 thrips/3 twig), acetamiprid 0.008 per cent (15.03 thrips/3 twig), diafenthiuron 0.05 per cent (15.03 thrips/3 twig) and indoxacarb 0.0145 per cent (16.32 thrips/3 twig) were statistically equally effective against chilli thrips on seven day after application.

Table 4.18: Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli during 2011 (Pooled data of three spray application)

Sr. No.	Treatment	Average no. of thrips/3 twig days after spray		
		3 day	7 day	14 day
1	Imidacloprid 0.005 %	1.77* (3.13)	3.55 (12.58)	5.44 (29.63)
2	Acetamiprid 0.008 %	2.39 (5.71)	3.88 (15.03)	5.59 (31.29)
3	Indoxacarb 0.0145	2.44 (5.97)	4.04 (16.32)	5.73 (32.83)
4	Spinosad 0.009%	1.86 (3.47)	2.71 (7.33)	3.60 (12.96)
5	Profenophos 40% + Cypermethrin 4% (0.044%)	1.79 (3.22)	3.43 (11.76)	4.99 (24.93)
6	Profenophos 0.05%	1.83 (3.35)	3.67 (13.44)	5.41 (29.30)
7	Diafenthiuron 0.05%	2.40 (5.76)	3.88 (15.03)	5.60 (31.40)
8	Abamectin 0.003%	1.86 (3.47)	3.47 (12.02)	5.19 (26.90)
9	*M. anisopliae* @ 2.0 kg/ha	2.99 (8.96)	4.87 (23.72)	6.43 (41.34)
10	*V. lacanii* @ 2.0 kg/ha	2.62 (6.88)	4.32 (18.66)	6.24 (38.90)
11	*B. bassiana* @ 2.0 kg/ha	3.10 (9.59)	5.02 (25.20)	6.42 (41.26)
12	Azadirachtin 0.001%	2.58 (6.67)	4.08 (16.65)	5.99 (35.92)
13	Control	7.38 (54.52)	7.23 (52.22)	7.27 (52.80)
	S.Em.±	0.12	0.22	0.28
	C.D. at 5 %	0.36	0.63	0.81
	C.V.%	8.00	8.95	8.45

* $\sqrt{x+1}$ transformations. Figures in parenthesis are retransformed values.

The data (Table 4.18 and Fig. 4.10) also revealed that the effectiveness of the insecticides against chilli thrips was existed on fourteen day after application. Significantly minimum thrips (12.96 thrips/3 twig) was recorded on chilli plants treated with spinosad 0.009 per cent, found top most effective over rest of treatments at fourteen day after applications. It was also reflected from the data (Table 4.18 and Fig 4.10) the that significantly higher reduction of thrips was due to treatment of

profenophos + cypermethrin 0.044 per cent (24.93 thrips/3 twig), abamectin 0.003 per cent (26.90 thrips/3 twig), imidacloprid 0.005 per cent (29.63 thrips/3 twig), profenophos 0.05 per cent (29.30 thrips/3 twig), acetamiprid 0.008 per cent (31.29 thrips/3 twig), diafenthiuron 0.05 per cent (31.40 thrips/3 twig) and indoxacarb 0.0145 per cent (32.83 thrips/3 twig) were statistically equal effective against chilli thrips on fourteen day after application. However, it was found that the thrips population in all the insecticidal treatments increased two times or more on fourteen day compared to seventh day.

During present study it was found that the bioefficacy of biopesticides (*Beauveria*, *Verticillium* and *Metarhizium*) and the botanical pesticide (azadirachtin) was least effective as compared to the chemical pesticides. However, all the biopesticides and the botanical were significantly superior over control in reducing chilli thrips.

The effectiveness against the chilli thrips of spinosad 0.009 per cent was reported by Nagaraj *et al*. (2007); abamectin 1.9 EC @ 0.56 ml/ℓ was reported by (Tatagar, 2004); imidacloprid 200 SL @ 125 ml and 150 ml/ha were highly effective against the thrips imidacloprid 0.005 per cent was reported by Patil *et al.* (2002), imidacloprid 17.8 SL @ 20 g a.i/ha was reported by Nagaraj *et al*. (2007), Hosamani (2007), imidacloprid 17.8 SL@ 112 ml/ha was reported by Bhede *et al.* (2008) and also imidacloprid (0.005%) effective against thrips reported by Patel *et al.* (2009); profenophos 0.05 per cent was reported by Nandini (2010); acetamiprid 0.008 per cent was reported by Nagaraj *et al*. (2007), Nandihalli (2009), Dharne and Kabre (2009) and Mandi and Senapati (2009); diafenthiuron 0.05 per cent was reported by (Tatagar, 2004) and Patel *et al.* (2009) and indoxacarb 14.5 SC @ 500 ml/ha was reported by Dharne and Kabre (2009) and Nandihalli (2009). The reported research work was not found pertaining to effectiveness of ready mixed of profenophos 40 per cent + cypermethrin 4 per cent (Polytrin C) 0.044 per cent against chilli thrips.

Nandini (2010) recorded that *Verticillium lecanii* was the least effective for controlling the chilli thrips, while Patel *et al.* (2009) reported that azadirachtin 0.00075 per cent to be least effective against the thrips.

4.3.5 Effect of insecticidal treatment on leaf curling of chilli after first spray

One day before spray

The data recorded on leaf curling percentages at one day before and at three, seven and fourteen day after each insecticidal application are presented in Table 4.19. The data revealed that there was non-significant difference in percentage of leaf curling (38.83 to 44.44%) among all experimental plots recorded before the first application of the insecticides.

After three day

The data presented in Table 4.19 indicated that significantly minimum 27.70 per cent leaf curling was recorded in plants treated with profenophos + cypermethrin 0.044 per cent and it was at par with profenophos 0.05 per cent (29.11%), imidacloprid 0.005 per cent (29.11), spinosad 0.009 per cent (30.47%), diafenthiuron 0.05 per cent (34.40%) and abamectin 0.003 per cent (31.93%).

The leaf curling observed in treatment acetamiprid 0.008 per cent (36.07%), azadirachtin 0.001 per cent (36.10%), indoxacarb 0.0145 per cent (37.46%) and *M. anisopliae* @ 2 kg/ha (39.39%) was statistically at par with each other and formed second effective group of treatments.

The leaf curling in plants treated with *M. anisopliae*, *B. bassiana* and *V. lecanii* @ 2 kg/ha recorded 40.27, 41.64 and 41.66 per cent were at par with control (44.41%). Thus these treatments were not effective in reducing leaf curling on three day after their application.

After seven day

The data on leaf curling of chilli recorded at seven day after the first spray (Table 4.19) revealed that significantly maximum reduction in leaf curling (19.15%) recorded on plant treated with spinosad 0.009 per cent and it was at par with profenophos + cypermethrin 0.044 per cent (22.01%), profenophos 0.05 per cent (23.40%), imidacloprid 0.005 per cent (23.40%), abamectin 0.003 per cent (23.51%) and diafenthiuron 0.05 per cent (26.37%). This group of insecticides found top most effective in reducing the chilli leaf curling at seven day after their application.

Table 4.19: Effect of insecticidal treatments on leaf curling of chilli caused by thrips, *S. dorsalis* during 2011

Sr. No.	Treatment	Leaf curling (%)									
		After 1st spray				After 2nd spray			After 3rd spray		
		Before	3 day	7 day	14 day	3 day	7 day	14 day	3 day	7 day	14 day
1	Imidacloprid 0.005 %	39.39* (40.27)	32.65 (29.11)	28.93 (23.40)	30.84 (26.29)	29.00 (23.51)	25.12 (18.02)	29.05 (23.58)	27.08 (20.73)	20.53 (12.29)	23.99 (16.52)
2	Acetamiprid 0.008 %	41.80 (44.43)	36.07 (34.67)	31.70 (27.62)	32.54 (28.93)	29.86 (24.79)	26.85 (20.40)	29.79 (24.68)	28.10 (22.19)	19.40 (11.03)	21.66 (13.62)
3	Indoxacarb 0.0145	40.10 (41.49)	37.74 (37.46)	32.37 (28.67)	35.04 (32.97)	32.37 (28.67)	27.80 (21.75)	32.54 (28.93)	28.84 (23.27)	23.80 (16.29)	26.85 (20.40)
4	Spinosad 0.009%	39.30 (40.11)	33.51 (30.47)	25.95 (19.15)	27.98 (22.01)	24.93 (17.77)	21.83 (13.83)	25.12 (18.02)	20.53 (12.29)	15.11 (6.80)	18.09 (9.64)
5	Profenophos 40% + Cypermethrin 4% (0.044%)	41.81 (44.44)	31.75 (27.70)	27.98 (22.01)	29.79 (24.68)	28.93 (23.40)	24.93 (17.77)	26.90 (20.47)	25.12 (18.02)	18.86 (10.45)	22.68 (14.86)
6	Profenophos 0.05%	40.19 (41.65)	32.65 (29.11)	28.93 (23.40)	31.51 (27.32)	28.66 (23.00)	25.01 (17.87)	26.85 (20.40)	24.93 (17.77)	20.53 (12.29)	23.99 (16.52)
7	Diafenthiuron 0.05%	39.34 (40.19)	34.40 (31.92)	30.90 (26.37)	32.65 (29.11)	29.95 (24.92)	28.10 (22.19)	31.75 (27.70)	29.05 (23.58)	22.86 (15.09)	25.12 (18.02)
8	Abamectin 0.003%	38.55 (38.83)	34.41 (31.93)	29.00 (23.51)	30.81 (26.23)	28.93 (23.40)	25.12 (18.02)	27.98 (22.01)	26.14 (19.41)	19.99 (11.69)	23.99 (16.52)
9	*M. anisopliae* @ 2.0 kg/ha	41.81 (44.44)	39.39 (40.27)	36.88 (36.02)	39.36 (40.22)	37.74 (37.47)	34.34 (31.82)	38.56 (38.85)	36.88 (36.02))	30.81 (26.23)	33.35 (30.22)
10	*V. lacanii* @ 2.0 kg/ha	41.78 (44.40)	40.20 (41.66)	36.93 (36.10)	38.56 (38.85)	36.93 (36.10)	34.41 (31.93)	37.74 (37.47)	34.38 (31.88)	29.86 (24.79)	32.37 (28.67)
11	*B. bassiana* @ 2.0 kg/ha	40.19 (41.65)	40.19 (41.64)	36.91 (36.07)	40.17 (41.62)	39.34 (40.19)	36.85 (35.97)	39.31 (40.13)	36.79 (35.87)	31.75 (27.70)	34.21 (31.61)
12	Azadirachtin 0.001%	39.38 (40.25)	36.93 (36.10)	33.55 (30.54)	36.05 (34.64)	35.16 (33.15)	30.81 (26.23)	34.41 (31.93)	32.65 (29.11)	28.10 (22.19)	30.90 (26.37)
13	Control	38.55 (38.83)	41.79 (44.41)	42.60 (45.82)	45.00 (50.00)	48.21 (55.59)	51.45 (61.17)	52.26 (62.53)	53.93 (65.33)	53.12 (63.98)	49.84 (58.41)
S.Em.±		2.26	1.28	1.70	2.04	2.26	1.96	2.04	1.80	2.10	2.47
C.D. at 5 %		NS	3.75	4.96	5.95	6.59	5.71	5.95	5.24	6.14	7.20
C.V.%		9.70	6.13	9.06	10.19	11.82	11.23	10.62	10.00	14.15	15.14

* Angular transformation. Figures in parenthesis are retransformed values.

The leaf curling observed in the treatment of acetamiprid 0.008 per cent (27.62%), indoxacarb 0.0145 per cent (28.67%) and azadirachtin 0.001 per cent (30.54%) were statistically at par with each other and formed second effective group of treatments.

The treatments found least effective for reducing the leaf curling were *M. anisopliae* @ 2 kg/ha, *B. bassiana* @ 2 kg/ha and *V. lecanii* @ 2 kg/ha, which recorded 36.02, 36.07 and 36.10 per cent leaf curling, respectively.

After fourteen day

The data given in Table 4.19 revealed that significantly minimum 22.01 per cent leaf curling was recorded on plants treated with spinosad 0.009 per cent and it was at par with profenophos + cypermethrin 0.044 per cent (24.68%), abamectin 0.003 per cent (26.23%), imidacloprid 0.005 per cent (26.29%), profenophos 0.05 per cent (27.32%), acetamiprid 0.008 per cent (28.93%) and diafenthiuron 0.05 per cent (29.11%) at fourteen day after the third application.

The treatments found relatively least effective for reducing the leaf curling were indoxacarb 0.0145 per cent (32.97%), azadirachtin 0.001 per cent (34.64%), *V. lecanii* @ 2 kg/ha (38.56), *M. anisopliae* @ 2 kg/ha (40.22) and *B. bassiana* @ 2 kg/ha (41.62) and were statistically at par with each. However, these treatments were significantly superior in reducing leaf curling over the unprotected (control) crop in which 50.00 per cent leaf curling was recorded. While, *M. anisopliae* @ 2 kg/ha and *B. bassiana* @ 2 kg/ha were statistically at par with control (45%). Therefore, later two treatments were not effective in reducing leaf curling on 14 day after their application.

4.3.6 Effect of insecticidal treatments on leaf curling in chilli after second spray

After three day

The data given in Table 4.19 revealed that significantly minimum leaf curling 17.77 per cent was recorded in plants treated with spinosad 0.009 per cent and it was at par with profenophos 0.05 per cent (23.00%), profenophos + cypermethrin 0.044 per cent (23.40%), abamectin 0.003 per cent (23.40%), imidacloprid 0.005 per cent (23.51%), azadirachtin 0.001 per cent (24.79%) and diafenthiuron 0.05 per cent (24.92%) at third day after the second application.

The leaf curling observed in treatment with indoxacarb 0.0145 per cent (28.67%), azadirachtin 0.001 per cent (33.15%), *V. lecanii* @ 2 kg/ha (36.93%) and *M. anisopliae* @ 2 kg/ha (37.74%) were statistically at par with each other and formed second effective group of treatments.

The treatment of *B. bassiana* @ 2 kg/ha (40.19%) was found least effective for reducing the leaf curling in chilli crop but it was significantly superior over control (55.59%).

After seven day

The data on leaf curling of chilli recorded at seven day after the second spray (Table 4.19) revealed that significantly maximum reduction (minimum leaf curling) 13.83 per cent was recorded in crop treated with spinosad 0.009 per cent and it was at par with profenophos + cypermethrin 0.044 per cent (17.77%), profenophos 0.05 per cent (17.87%), imidacloprid 0.005 per cent (18.02%), abamectin 0.003 per cent (18.02%) and acetamiprid 0.008 per cent (20.40%). This group of insecticides was found top most effective in reducing the chilli leaf curling at seven day after their application.

The leaf curling observed in treatment with indoxacarb 0.0145 per cent (21.75%), diafenthiuron 0.05 per cent (22.19%), and azadirachtin 0.001 per cent (26.23%) were in the second effective group of treatments.

The treatments found relatively least effective for reducing the percentage of leaf curling were *V. lecanii* @ 2 kg/ha (37.74%), *M. anisopliae* @ 2 kg/ha (38.56) and *B. bassiana* @ 2 kg/ha (39.31) but they were significantly superior over control in which 61.17 per cent leaf curling was recorded.

After fourteen day

The data (Table 4.18 and Fig. 4.16) showed that significantly minimum 18.02 per cent leaf curling was recorded on plants treated with spinosad 0.009 per cent and it was at par with profenophos 0.05 per cent (20.40%), profenophos + cypermethrin 0.044 per cent (20.47%), abamectin 0.003 per cent (22.01%), imidacloprid 0.005 per cent (23.58%) and acetamiprid 0.008 per cent (24.68%).

The leaf curling observed on plant treated with diafenthiuron 0.05 per cent (27.70%), indoxacarb 0.0145 per cent (28.93%) and azadirachtin 0.001 per cent (31.93%) were statistically at par with each other and formed second effective group of treatments.

The treatments found relatively least effective for reducing the per cent of leaf curling were *V. lecanii* @ 2 kg/ha (37.47%), *M. anisopliae* @ 2 kg/ha (38.85%) and *B. bassiana* @ 2 kg/ha (40.13%) but they were significantly superior over control in which 62.53 per cent leaf curling was recorded.

4.3.7 Effect of insecticidal treatments on leaf curling in chilli after third spray

After three day

The data presented in Table 4.19 revealed that significantly minimum 12.19 per cent leaf curling was recorded on plants treated with in spinosad 0.009 per cent and it was at par with the leaf curling in profenophos 0.05 per cent (17.77%) and profenophos + cypermethrin 0.044 per cent (18.02%).

The leaf curling observed on the chilli plants treated with abamectin 0.003 per cent (19.41%), imidacloprid 0.005 per cent (20.73%), acetamiprid 0.008 per cent (22.19%), indoxacarb 0.0145 per cent (23.027%) and diafenthiuron 0.05 per cent (23.58%) were statistically at par with each other and formed second effective group of treatments.

The treatments with azadirachtin 0.001 per cent (29.11%), *V. lecanii* @ 2 kg/ha (31.88%), *B. bassiana* @ 2 kg/ha (35.87%) and *M. anisopliae* @ 2 kg/ha (36.02%) were found relatively least effective for reducing the percentage of leaf curling compare with other treatments. However, all these treatments were significantly superior over control. Maximum percentage of leaf curling (55.59%) was produced in control (untreated).

After seven day

The data (Table 4.19) revealed that significantly maximum reduction (minimum leaf curling) 6.80 per cent was recorded in the plants treated with spinosad 0.009 per cent and it was at par with profenophos + cypermethrin 0.044 per cent

(10.45%), acetamiprid 0.008 per cent (11.03%), abamectin 0.003 per cent (11.69%), imidacloprid 0.005 per cent (12.29%) and profenophos 0.05 per cent (12.29%). This group of insecticides found top most effective in reducing the chilli leaf curling on seventh day after their application.

The leaf curling observed in treatment diafenthiuron 0.05 per cent (15.09%), indoxacarb 0.0145 per cent (16.29%) and azadirachtin 0.001 per cent (22.19%) were statistically at par with each other and formed second effective group of treatments.

The treatments with *V. lecanii* @ 2 kg/ha (24.79%), *M. anisopliae* @ 2 kg/ha (26.23%) and *B. bassiana* @ 2 kg/ha (27.70%) were found relatively least effective for reducing the percentage of leaf curling when compared compare with other treatments. However, all these treatments were significantly superior over control. Maximum percentage of leaf curling (63.98%) was produced in control.

After fourteen day

The data (Table 4.19) showed that significantly minimum leaf curling 9.64 leaf curling was recorded on plants treated with spinosad 0.009 per cent and it was at par with acetamiprid 0.008 per cent (13.62%), profenophos + cypermethrin 0.044 per cent (14.86%), profenophos 0.05 per cent (16.52%), abamectin 0.003 per cent (16.52%), imidacloprid 0.005 per cent (16.52%) and diafenthiuron 0.05 per cent (18.02%) at fourteen day after the third application.

The leaf curling observed in plants treatment with indoxacarb 0.0145 per cent (20.40%), azadirachtin 0.001 per cent (26.37%), *V. lecanii* @ 2 kg/ha (28.37) and *M. anisopliae* @ 2 kg/ha (30.22) were statistically at par with each other and formed second effective group of treatments.

The treatment with *B. bassiana* @ 2 kg/ha (31.62%) was found relatively least effective for reducing the leaf curling in chilli crop. However, all these treatments were significantly superior over control. Maximum percentage of leaf curling (58.41%) was produced in control.

4.3.8 Pooled effect of insecticidal treatments on leaf curling of chilli

Total three application of different twelve insecticide were given at fifteen day interval against chilli thrips. The observation on number of thrips/ 3 twig and leaf curling severity grade (0-4) was recorded on three, seven and fourteen day after each spray application. The pooled effect of three spray application of the various insecticides on leaf curling caused due to thrips, *S. dorsalis* infesting chilli is presented in Table 4.20 and depicted in Fig. 4.8, 4.9 and 4.10.

After three day

The data revealed that the percentage of leaf curling was significantly lower (over control) due to all the treatments on third day after insecticidal spray. However, significantly minimum leaf curling 22.56 recorded on plants treated with spinosad 0.009 per cent and it was statistically at par with leaf curling recorded on plants treated with profenophos + cypermethrin 0.044 per cent (24.86%), profenophos 0.05 per cent (25.17%), imidacloprid 0.005 per cent (26.28%) and abamectin 0.003 per cent (26.73%). These five insecticides were found top most effective in reducing the leaf curling in chilli at three day after application.

The leaf curling recorded on plants treated with diafenthiuron 0.05 per cent (28.49%), acetamiprid 0.008 per cent (28.89%), indoxacarb 0.0145 per cent (31.06%), and azadirachtin 0.001 per cent (33.47%) were statistically at par with each other and formed second effective group of insecticides.

The rest of the treatments *i.e. V. lecanii* @ 2 kg/ha, *M. anisopliae* @ 2 kg/ha and *B. bassiana* @ 2 kg/ha were found relatively least effective but were significantly superior over control.

After seven day

The data (Table 4.20) revealed that the percentage of leaf curling was significantly lower (over control) due to all the treatments at seven day after insecticidal spray. However, significantly minimum leaf curling (13.29%) was recorded on plants treated with spinosad 0.009 per cent and it was statistically at par with leaf curling on plants treated with profenophos + cypermethrin 0.044 per cent (16.91%), abamectin 0.003 per cent (17.93%), profenophos 0.05 per cent (17.95%)

and imidacloprid 0.005 per cent (17.96%). These five insecticides were found top most effective in reducing the leaf curling in chilli at seven day after application.

The leaf curling recorded in treatment with acetamiprid 0.008 per cent (19.79%), diafenthiuron 0.05 per cent (21.24%) and indoxacarb 0.0145 per cent (22.32%) were statistically at par with each other and formed second effective group of treatments.

The rest of the treatments *i.e.* azadirachtin 0.001 per cent, *V. lecanii* @ 2 kg/ha, *M. anisopliae* @ 2 kg/ha and *B. bassiana* @ 2 kg/ha were found comparatively least effective in reducing the leaf curling.

After fourteen day

The data (Table 4.20) revealed that the percentage of leaf curling was significantly lower (over control) due to all the treatments at fourteen day after insecticidal spray. However, significantly minimum in leaf curling (16.56%) was recorded on plants treated with spinosad 0.009 per cent and it was at par with profenophos + cypermethrin 0.044 per cent (20.18%), profenophos 0.05 per cent (21.56%), abamectin 0.003 per cent (21.69%), imidacloprid 0.005 per cent (22.18%) and acetamiprid 0.008 per cent (22.52%). These six insecticides were found top most effective in reducing the leaf curling in chilli at fourteen day after application.

The leaf curling recorded on plants treated with diafenthiuron 0.05 per cent (24.94%), indoxacarb 0.0145 per cent (27.46%) and azadirachtin 0.001 per cent (31.01%) were statistically at par with each other and formed second effective group of insecticides.

The rest of the treatments *i.e. V. lecanii* @ 2 kg/ha, *M. anisopliae* @ 2 kg/ha and *B. bassiana* @ 2 kg/ha were found least effective.

The data presented in Table 4.20 and depicted in Fig 4.8, 4.9 and 4.10 on leaf curling of chilli showed that the maximum reduction in leaf curling was recorded at seven day after application of all the insecticides. But percentage of leaf curling increased at fourteen day after insecticides spray application.

The effectiveness of insecticides *viz.*, abamectin @ 0.56 ml/ℓ was reported against leaf curling by Tatagar (2004); imidacloprid 17.8 SL @ 20 g a.i/ha was reported against leaf curling by Nagaraj *et al*. (2007) and Hosamani (2007).

The data (Table 4.17, 4.18, 4.19, 4.20 and Fig 4.8, 4.9, 4.10) clearly indicated that the chilli crop was severely infested with thrips, *S. dorsalis* (40 to 60 thrips/3 twig), which produced 39 to 65 per cent leaf curling in untreated (control) plots. Further, the leaf curling percentage reduced, where the thrips population reduced by application of the effective insecticides. Maximum reduction in thrips population and leaf curling was recorded in the chilli crop treated with spinosad 0.009 per cent, profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent, profenophos 0.05 per cent, acetamiprid 0.008 per cent and diafenthiuron 0.05 per cent.

Spinosad 0.009 per cent was reported most effective in reducing thrips by Nagaraj *et al*. (2007). Abamectin @ 0.56 ml/ℓ was reported the effectiveness of against thrips and leaf curling by Tatagar (2004). imidacloprid 200 SL @ 125 ml and 150 ml/ha were highly effective against the thrips imidacloprid 0.005 per cent was reported by Patil *et al.* (2002), imidacloprid 17.8 SL @ 20g a.i/ha was reported by Nagaraj *et al*. (2007), Hosamani (2007), imidacloprid 17.8 SL@ 112 ml/ha was reported by Bhede *et al.* (2008) and also imidacloprid (0.005%) effective against thrips reported by Patel *et al.* (2009); Acetamiprid 0.008 per cent was reported effective against thrips by Nagaraj *et al*. (2007), Nandihalli (2009), Dharne and Kabare (2009) and Mandi and Senapati (2009). Diafenthiuron 0.05 per cent was reported effective against chilli thrips by Tatagar (2004) and Patel *et al.* (2009).

Table 4.20: Effect of insecticidal treatments on leaf curling of chilli caused by thrips, *S. dorsalis* (Pooled data of three spray application) during 2011

Sr. No.	Treatment	Average percentage of leaf curling (After spray)		
		3 day	7 day	14 day
1	Imidacloprid 0.005 %	30.84* (26.28)	25.08 (17.96)	28.10 (22.18)
2	Acetamiprid 0.008 %	32.52 (28.89)	26.41 (19.79)	28.33 (22.52)
3	Indoxacarb 0.0145%	33.87 (31.06)	28.19 (22.32)	31.60 (27.46)
4	Spinosad 0.009%	28.36 (22.56)	21.38 (13.29)	24.02 (16.56)
5	Profenophos 40% + Cypermethrin 4% (0.044%)	29.91 (24.86)	24.28 (16.91)	26.69 (20.18)
6	Profenophos 0.05%	30.11 (25.17)	25.07 (17.95)	27.66 (21.56)
7	Diafenthiuron 0.05%	32.26 (28.49)	27.44 (21.24)	29.96 (24.94)
8	Abamectin 0.003%	31.13 (26.73)	25.05 (17.93)	27.76 (21.69)
9	*M. anisopliae* @ 2.0 kg/ha	38.07 (38.02)	34.07 (31.38)	37.16 (36.48)
10	*V. lacanii* @ 2.0 kg/ha	37.37 (36.84)	33.83 (30.99)	36.32 (35.08)
11	*B. bassiana* @ 2.0 kg/ha	38.63 (38.98)	35.21 (33.25)	37.96 (37.83)
12	Azadirachtin 0.001%	35.35 (33.47)	30.88 (26.34)	33.84 (31.01)
13	Control	46.52 (52.65)	49.01 (56.97)	49.01 (56.97)
S.Em.±		1.19	1.49	1.63
C.D. at 5 %		3.46	4.36	4.76
C.V.%		6.00	8.71	8.78

* Angular transformation. Figures in parenthesis are retransformed values.

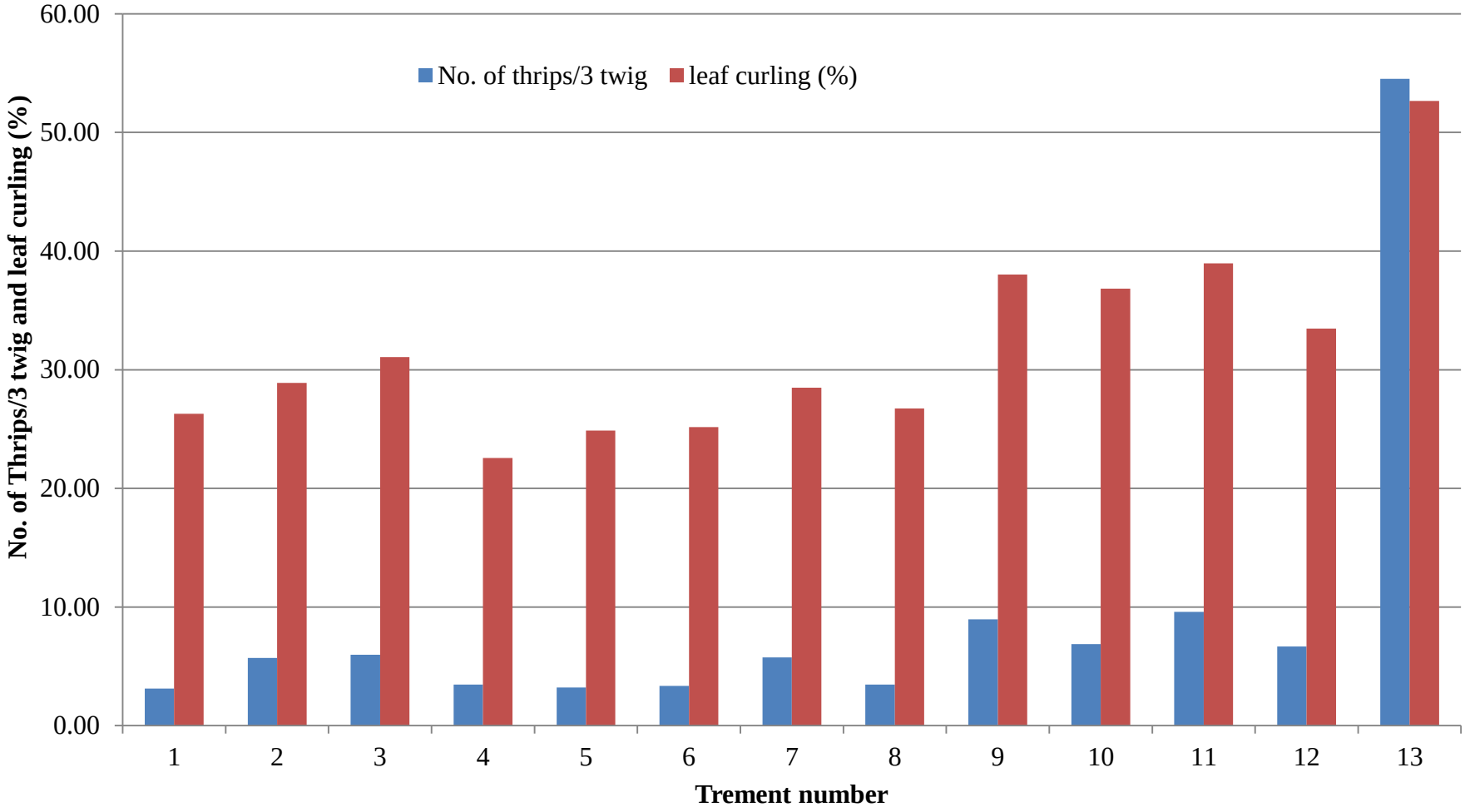

Fig. 4.8: Bioefficacy of insecticides against chilli thrips and leaf curling percentage after third day during 2011 (Year pooled)

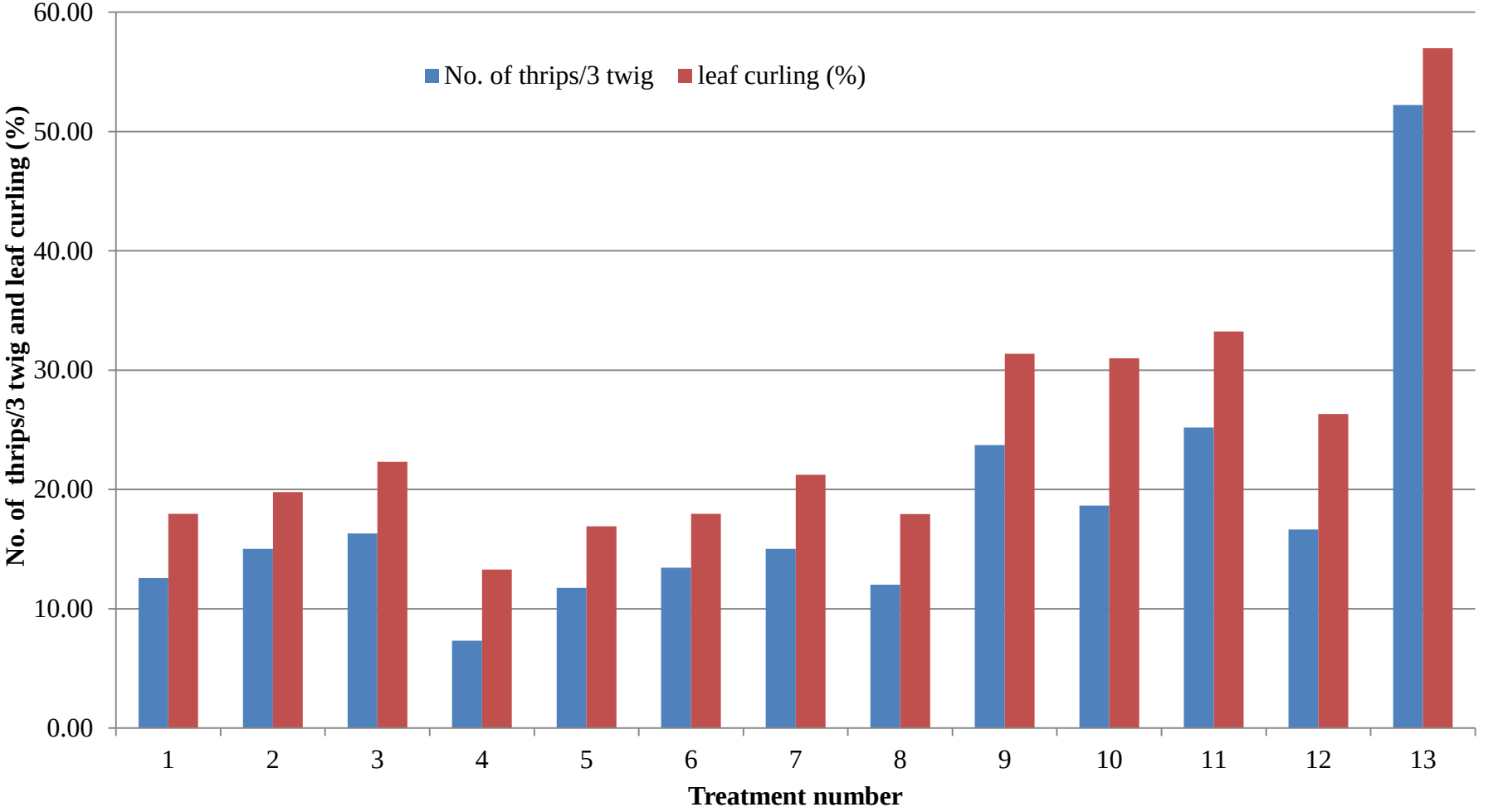

Fig. 4.9: Bioefficacy of insecticides against chilli thrips and leaf curling percentage after seventh day during 2011 (Year pooled)

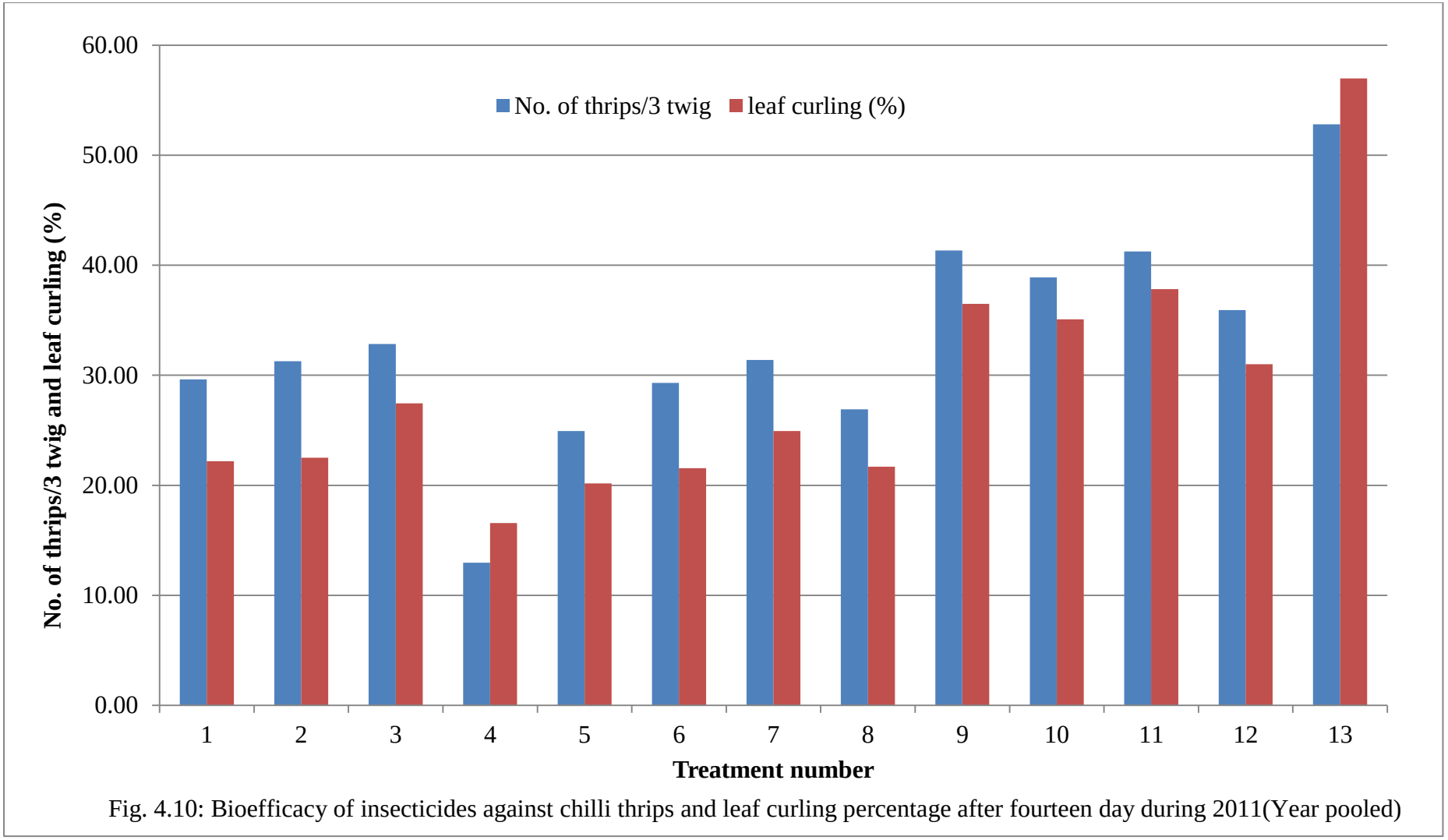

Fig. 4.10: Bioefficacy of insecticides against chilli thrips and leaf curling percentage after fourteen day during 2011(Year pooled)

4.3.9 Yield and economics of different insecticidal treatments

4.3.9.1 Yield

Total three application of different twelve insecticide at fifteen day interval were given against thrips infesting chilli. The treatment wise data recorded on yield of green chilli are presented in Table 4.21 and depicted in Fig. 4.11.

The data revealed that the yield of green chilli received from treated crop were significantly higher (7222 to 15278 kg/ha) over untreated (control) (4639 kg/ha). However significantly maximum yield of 15278 kg/ha with 229.34 per cent increase was obtained from the crop treated with spinosad 0.009 per cent. While the yield of green chilli obtained from the treatment of profenophos + cypermethrin 0.044 per cent (13750 kg/ha with 196.41 increased, abamectin 0.003 per cent (12722 kg/ha with 174.25% increased) and imidacloprid 0.005 per cent (12639 kg/ha with 172.46% increased) was statistically at par and stood at second.

Table 4.21: Effect of different insecticidal treatments on the yield of green chilli during *Kharif*- 2011

Sr. No.	Treatment	Yield of marketable green chilli (kg/ha)	Increase in yield over control (%)	Avoidable yield loss (%)
1	Imidacloprid 0.005 %	12639	172.46	63.30
2	Acetamiprid 0.008 %	11889	156.29	60.98
3	Indoxacarb 0.0145	11250	142.51	58.77
4	Spinosad 0.009%	15278	229.34	69.64
5	Profenophos + cypermethrin 0.044%	13750	196.41	66.26
6	Profenophos 0.05%	11667	151.50	60.24
7	Diafenthiuron 0.05%	11528	148.50	59.76
8	Abamectin 0.003%	12722	174.25	63.54
9	*M. anisopliae* @ 2.0 kg/ha	7500	61.68	38.15
10	*V. lacanii* @ 2.0 kg/ha	7639	64.67	39.27
11	*B. bassiana* @ 2.0 kg/ha	7222	55.69	35.77
12	Azadirachtin 0.001%	8444	82.04	45.07
13	Control	4639		
	S.Em.±	426		
	C.D. at 5 %	1244		
	C.V.%	7.05		

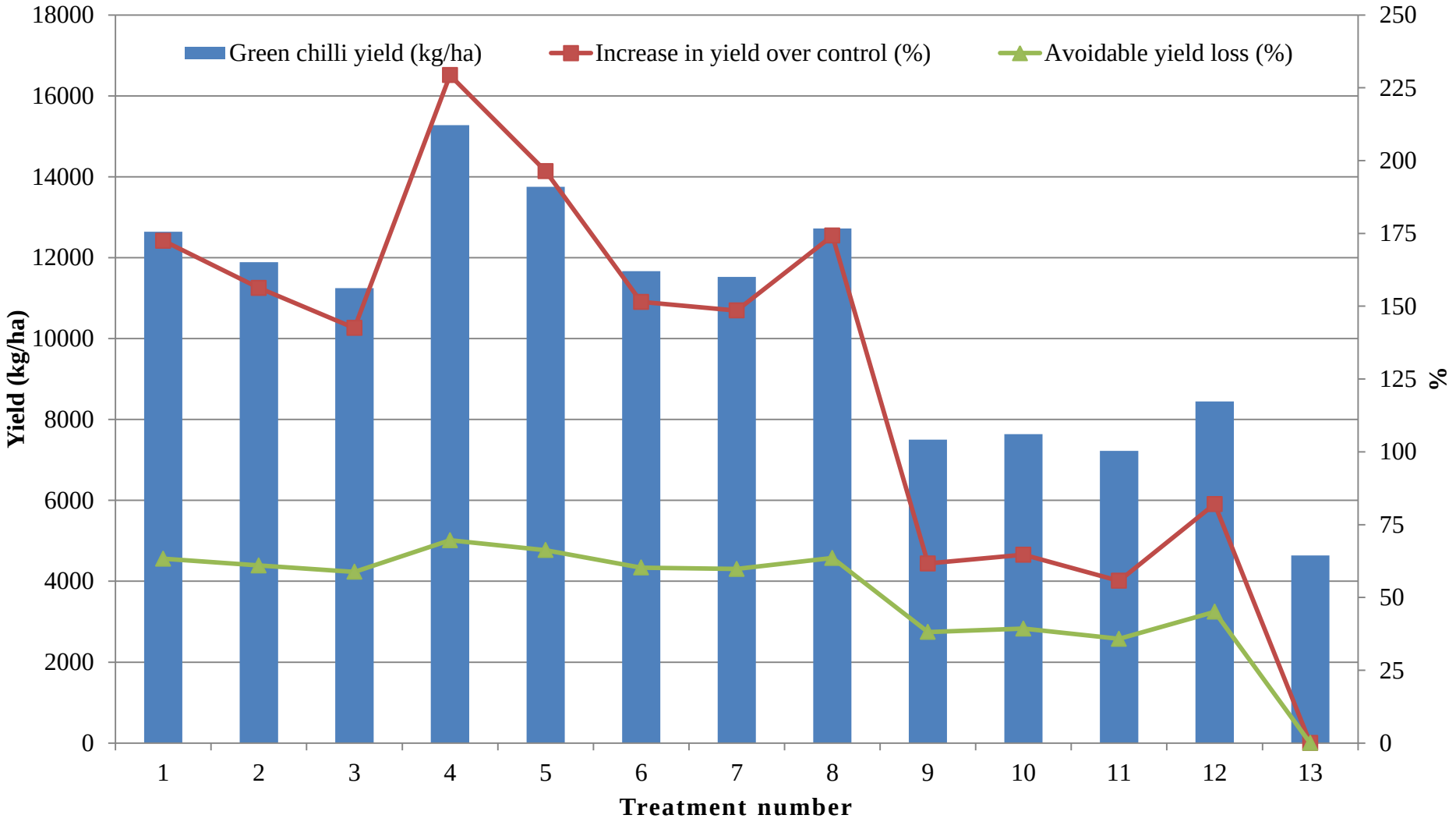

Fig. 4.11: Effect of different insecticidal treatments on the yield of green chilli during *Kharif*- 2011

The yield of green chilli recorded from the crop treated with acetamiprid 0.008 per cent (11889 kg/ha with 156.29% increased), profenophos 0.05 per cent (11666 kg/ha with 151.50% increased), diafenthiuron 0.05 per cent (11528 kg/ha with 148.50% increased) and indoxacarb 0.0145 per cent (11250 kg/ha with 142.51% increased) were statistically at par with each other. These four insecticide formed third effective group.

The yield of green chilli received from the crop treated with the biopesticides *viz.*, azadirachtin 0.001 per cent, *V. lacanii* @ 2.0 kg/ha, *M. anisopliae* @ 2.0 kg/ha and *B. bassiana* @ 2.0 kg/ha was 88844, 7639, 7500 and 7222 kg/ha, respectively with 82.04, 64.67, 61.68 and 55.69 per cent increased yield over control, respectively.

The three application of the twelve insecticides was given at fifteen day interval against thrips infesting chilli and associated malady of leaf curling. The data (Table 4.21) clearly indicated that the highest yield of green chilli 15278 kg/ha with 229.34 per cent increased over control and 69.64 percent yield can be save due to treatment of spinosad 0.009 per cent. Further it was found that the green chilli yield received from the crop treated with profenophos + cypermethrin (Polytrin. C 44%) 0.044 per cent (13750 kg/ha with 196.41% yield increased and 66.26% avoidable loss) followed by abamectin 0.003 per cent (12722 kg/ha, 174.25% increased yield and 63.54% avoidable loss) and imidacloprid 0.005 per cent (12639 kg/ha, 172.46 % increased yield and 63.3% avoidable loss) were statistically equal but significantly higher over rest of insecticidal treatment. The reduction in thrips population and leaf curling was also higher in crop treated with these insecticides.

Patil *et al.* (2002) reported that imidacloprid 200 SL @ 125 ml and 150 ml/ha were highly effective against the thrips. The treatment with imidacloprid 200 SL @ 150 ml/ha recorded significantly the highest chilli fruit yield followed by imidacloprid 200 SL @ 125 ml and 100 ml/ha. Mandi and Senapati (2009) reported that the highest yield of green chilli fruit (40.5 q/ha) with higher cost benefit ratio of 1: 16.97 recorded in acetamiprid. Patel *et al.* (2009) reported that the crop treated with diafenthiuron 0.05 per cent registered the highest (115.75 q/ha) yield of green chilli followed by treatment imidacloprid 0.005 per cent produced satisfactory yield 69.66

q/ha. Nandihalli (2009) recorded yield in chilli crop treated with acetamiprid 0.008 per cent 8.96 q/ha during 2005 and 19.95 q/ha during 2006.

4.3.9.2Economics of different insecticidal treatments

The data on economics of three application of the twelve different insecticides against thrips, *S. dorsalis* infesting chilli during *Kharif*-2011 are presented in Table 4.22 and depicted in Fig 4.12.

The data revealed that the cost of treatment was maximum in abamectin 0.003 per cent (₹ 18363/ha) followed by indoxacarb 0.0145 per cent (₹ 10163/ha), diafenthiuron 0.05 per cent (₹ 8700/ha), spinosad 0.009 per cent (₹ 7500/ha), imidacloprid 0.005 per cent (₹ 2622) and acetamiprid 0.008 per cent (₹ 1950/ha).

The gross realization was maximum from treatment of spinosad 0.009 per cent (₹ 305560/ha) followed by profenophos + cypermethrin 0.044 per cent (₹ 275000/ha), abamectin 0.003 per cent (₹ 254440/ha), imidacloprid 0.005 per cent (₹ 252780/ha), acetamiprid 0.008 per cent (₹ 237780) and profenophos 0.05 per cent (₹ 233340/ha).

Net realization (net gain) was received maximum ₹ 212780/ha from treatment of spinosad 0.009 per cent with 28.37 C:B followed by profenophos + cypermethrin 0.044 per cent (₹ 182220 with 97.97 C:B), abamectin 0.003 per cent (₹ 161660 with 8.80 C:B), imidacloprid 0.005 per cent (₹ 160000/ha with 61.02 C:B), acetamiprid 0.008 per cent (₹ 145000/ha with 74.36 C:B) and profenophos 0.05 per cent (₹ 140560/ha with 71.24 C:B).

It was found that the botanical (azadirachtin 0.001 per cent) and microbial (*M. anisopliae, V. lecanii* and *B. bassiana*) found least effective compared to chemical insecticides for the control of chilli thrips and register the lower yield and economics.

Table 4.22: Economics of different insecticidal treatments against thrips, *S. dorsalis* infesting chilli during *Kharif* - 2011

Sr. No.	Treatment	Insecticide used for 3 spray (lit or kg/ha)	Cost of insecticide (₹/ha)	Total cost for 3 application* (₹/ha)	Yiled (kg/ha)	Gross** realization (₹/ha)	Net realization (₹/ha)	C:B Ration (CBR)
1	Imidacloprid 0.005 %	632	2022	2622	12639	252780	160000	61.02
2	Acetamiprid 0.008 %	900	1350	1950	11889	237780	145000	74.36
3	Indoxacarb 0.0145	2250	9563	10163	11250	225000	132220	13.01
4	Spinosad 0.009%	450	6900	7500	15278	305560	212780	28.37
5	profenophos + cypermethrin 0.044%	2250	1260	1860	13750	275000	182220	97.97
6	Profenophos 0.05%	2250	1373	1973	11667	233340	140560	71.24
7	Daifenthiuron 0.05%	2250	8100	8700	11528	230560	137780	15.84
8	Abamectin 0.003%	3553	17763	18363	12722	254440	161660	8.80
9	*M. anasopli* @ 2.0 kg/ha	6000	1500	2100	7500	150000	57220	27.25
10	*V. lacanii* @ 2.0 kg/ha	6000	1380	1980	7639	152780	60000	30.30
11	*B. bassiana* @ 2.0 kg/ha	6000	1320	1920	7222	144440	51660	26.91
12	Azadirachtin 0.001%	2250	1238	1838	8444	168880	76100	41.40
13	Control	-	-	600	4639	92780	-	-

*Labour charges @ ₹. 200/ha/spray. ** Market value of chillies @ ₹ 20/kg.

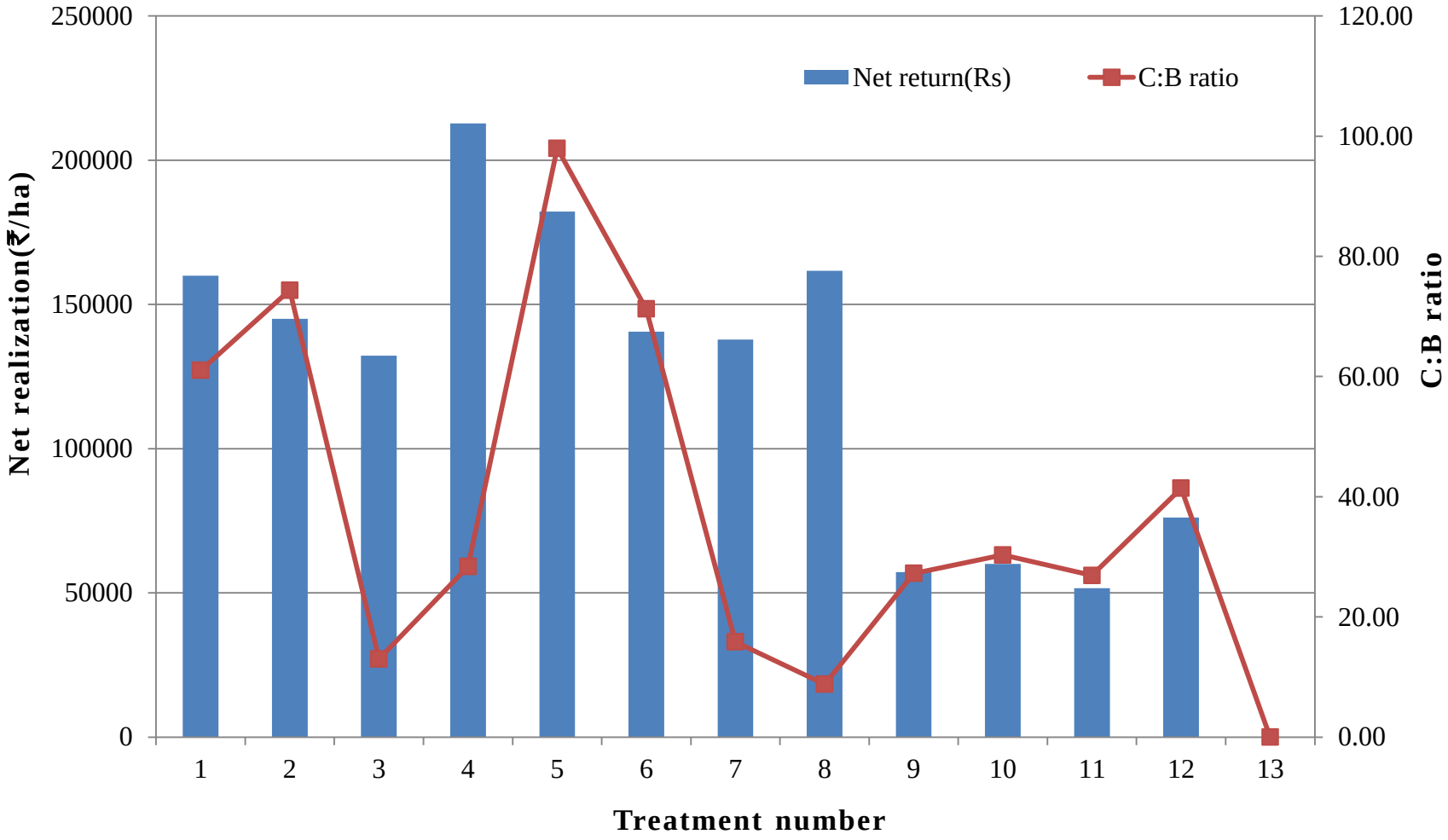

Fig. 4.12: Economics of different insecticidal treatments against thrips, *S. dorsalis* infesting chilli during *Kharif* – 2011

4.4 Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*

The most effective insecticide spinosad 0.009 per cent, profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent, profenophos 0.05 per cent and acetamiprid 0.008 per cent were selected for the spray schedule. Total six schedule formed and in each schedule number of application of insecticides was 3 or 4 or 5 or 6 or 7 or 8 with interval of 30 or 20 or 15 or 12 or 10 and 8 day, respectively.

4.4.1 Effect of insecticidal spray schedule on the mean population of chilli thrips, *S. dorsalis* and leaf curling during *Kharif*-2012

The data on thrips population and leaf curling intensity recorded at eight day interval in each schedule are presented in Table 4.23 and depicted in Fig. 4.13. The data revealed that significantly maximum reduction of thrips population and percentage of leaf curling was recorded in spray schedule 6 (13.69 thrips/3 twig and 36.30% leaf curling) and it was followed by schedule 5 (13.97 thrips/3 twig and 38.58% leaf curling), 4 (14.27 thrips/3 twig and 37.77% leaf curling), schedule 3 (16.06 thrips/3 twig and 38.58% leaf curling) and schedule 2 (16.83 thrips/3 twig and 40.80% leaf curling).

Spray schedule 1 found least effective against thrips (22.80 thrips/ 3 twig) and the leaf curling (41.80%). But it was superior over schedule 7 (untreated). The maximum 35.97 thrips/3 twig with 58.70 per cent leaf curling was recorded in schedule 7 (untreated control).

Patel (1992) reported that acephate 0.0375 per cent and monocrotophos 0.036 per cent were applied 5 sprays alternate at 15 days interval starting after one month of transplantation of chilli (var. Jwala) was found the most effective with longer suppression of chilli thrips and leaf curl disease.

Prajapati and Agalodiya (2012) reported that spray schedule S_1 (triazophos 40 EC @ 25 ml per 10ℓ, wettable sulphur 50 WP @ 40 g per 10 ℓ, imidacloprid 17.8 SL @ 5 ml per 10ℓ, wettable sulphur 50 WP @ 40 g per 10ℓ and acephate 75 SP @ 15 g per 10ℓ of water) registered the least population of thrips (3.30 to 1.30/leaf) and leaf curl incidence (2.42 to 10.20%).

Table 4.23: Mean population of chilli thrips, *S. dorsalis* and leaf curling during *Kharif* - 2012 (pooled data of eight day after spray)

Sr. No.	Treatment	Thrips/3 twig	Leaf curling severity (%)
1	Schedule 1	4.78* (22.80)	41.89** (44.58)
2	Schedule 2	4.10 (16.83)	39.40 (40.80)
3	Schedule 3	4.01 (16.06)	38.40 (38.58)
4	Schedule 4	3.78 (14.27)	37.92 (37.77)
5	Schedule 5	3.74 (13.97)	38.34 (38.58)
6	Schedule 6	3.70 (13.69)	37.05 (36.30)
7	Schedule 7 (Control)	6 (35.97)	50.01 (58.70)
S.Em.±		0.16	1.91
C.D. at 5 %		0.48	5.68
C.V.%		7.11	9.45

* $\sqrt{x+1}$ transformations. ** Angular transformation. Figures in parenthesis are retransformed values.

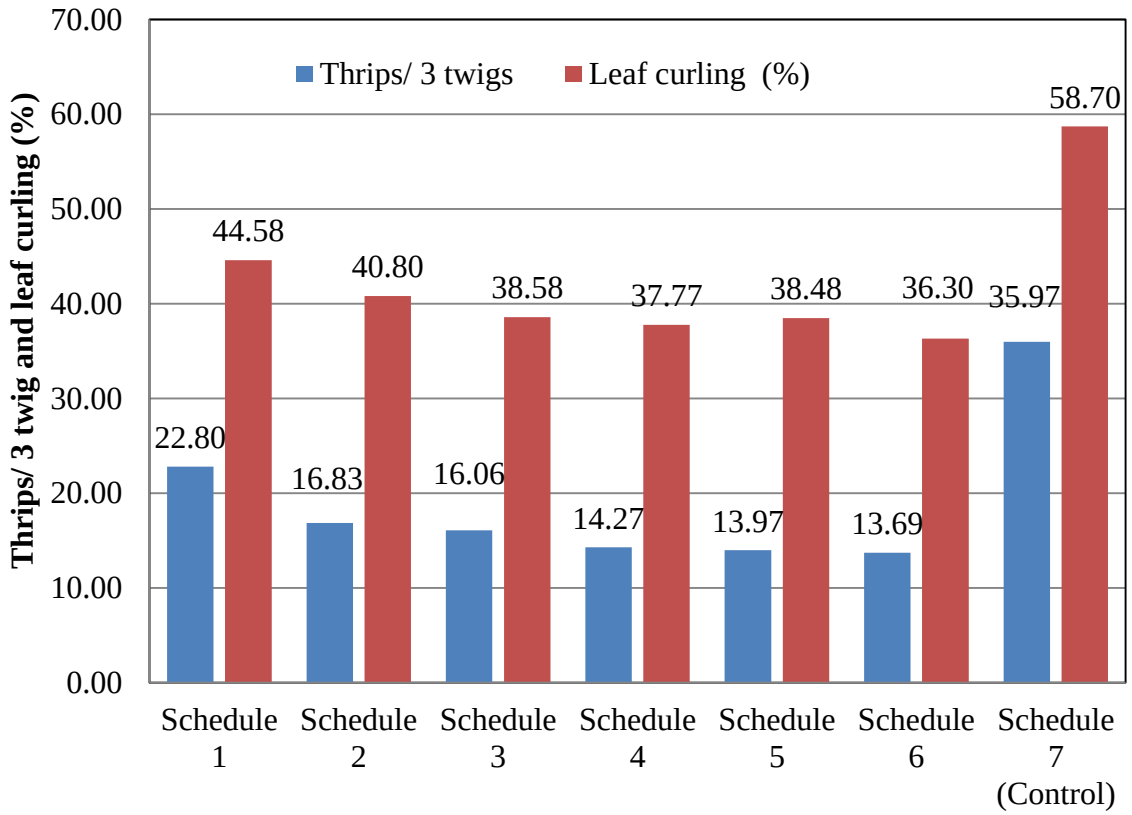

Fig. 4.13: Mean population of chilli thrips, *S. dorsalis* and leaf curling during *Kharif* - 2012 (pooled data of eight day after spray)

4.4.2 Yield and economics of different insecticidal spray schedule

4.4.2.1 Yield

The data on yield of green chilli obtained from the different spray schedule are summarized in Table 4.24 and depicted in Fig. 4.14.

The data revealed that the yield of green chilli in the different insecticidal spray schedule ranged from 7813 kg/ha to 10875 kg/ha was significantly higher over untreated control in which 3417 kg/ha recorded. However, significantly maximum yield of 10875 kg/ha with 218.29 per cent increased (over control) was obtained from spray schedule 6. The yield received from the schedule 5 (9271 kg/ha), schedule 4 (9354 kg/ha) and schedule 3 (8542 kg/ha) was statistically equal and was higher than rest of the schedules. Further, it was found that the maximum avoidable loss 68.58 per cent was from crop treated with schedule 6 followed by schedule 4 (63.47%), schedule 5 (63.15%), schedule 3 (60%), schedule 2 (57.40%) and schedule 1 (56.27%).

Table 4.24: Effect of insecticidal spray schedules on the yield of green chilli during *Kharif* - 2012

Sr. No.	Treatment	Yield of marketable green chilli (Kg/ha)	Increase in yield over control (%)	Avoidable yield loss (%)
1	Schedule 1	7813	128.66	56.27
2	Schedule 2	8021	134.76	57.40
3	Schedule 3	8542	150.00	60.00
4	Schedule 4	9354	173.78	63.47
5	Schedule 5	9271	171.34	63.15
6	Schedule 6	10875	218.29	68.58
7	Schedule 7 (Control)	3417	-	-
S.Em.±		281		
C.D. at 5 %		836		
C.V.%		10.16		

From the data (Table 4.24), it can be concluded that the insecticides (profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent spinosad 0.009 per cent, profenophos + cypermethrin 0.044 per cent,

acetamiprid 0.008 per cent, spinosad 0.009 per cent and imidacloprid 0.005 per cent) in the schedule 6 applied at eight day interval found most effective against thrips, *S. dorsalis* infesting chilli and malady of leaf curl caused by the thrips. Further it was found that maximum yield of green chilli (10875 kg/ha) with 68.58 per cent avoidable loss received from schedule 6.

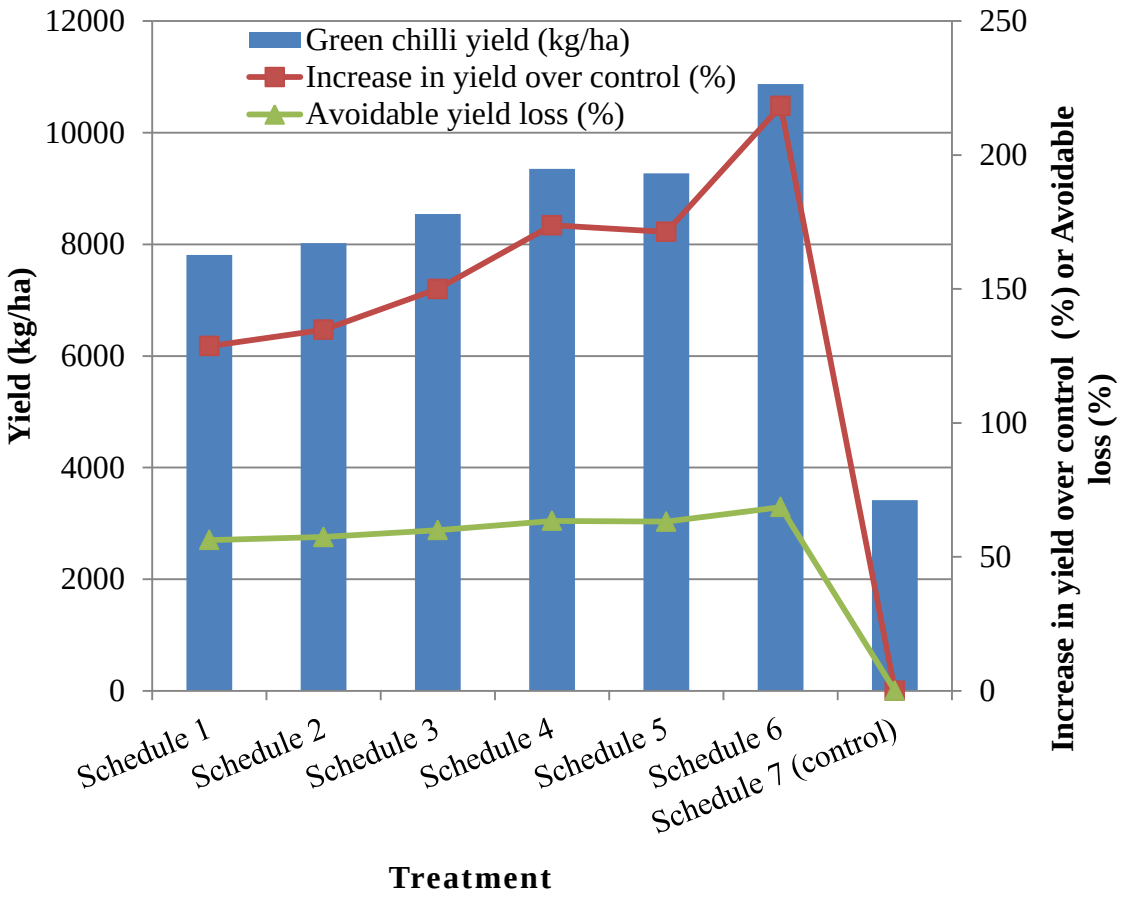

Fig. 4.14: Effect of insecticidal spray schedules on the yield of green chilli during *Kharif* - 2012

4.4.2.2 Economics of different insecticidal spray schedule

The data on economics of the different insecticidal spray schedules against thrips, *S. dorsalis* infesting chilli during *Kharif*-2012 are presented in Table 4.25 and depicted in Fig 4.15.

The maximum net return of ₹ 149160/ha with C:B ratio 16.06 was obtained from the spray schedule 6, followed by spray schedule 4 ₹ 118740/ha (C:B ratio1:15.29), spray schedule 5 ₹ 117080/ha (C:B ratio 1:13.32) and spray schedule 3 ₹ 102500/ha (C:B ratio 1:14.35).

The schedule 2 and schedule 1 gave relatively lower net return of ₹ 92080/ha (C:B ratio 1:14.18) and ₹ 87920/ha (C:B ratio 15.64), respectively.

From the results (Table 4.23, 4.24, 4.25 and Fig. 4.13, 4.14 and 4.15), it can be clearly concluded that seven insecticidal spray schedules were evaluated at Junagadh during *Kharif* -2012 of which schedule 6 was found most effective against chilli thrips, *S. dorsalis* and the leaf curling with maximum yield of green chilli (10875 kg/ha with 218.29% increased over control) and the highest monitoring return (₹ 149160/ha). The most effective spray schedule 6 included eight spray application at eight day interval with (i) profenophos + cypermethrin 0.044 per cent, (ii) abamectin 0.003 per cent, (iii) imidacloprid 0.005 per cent, (iv) spinosad 0.009 per cent, (v) profenophos + cypermethrin 0.044 per cent, (vi) acetamiprid 0.008 per cent, (vii) spinosad 0.009 per cent and (viii) imidacloprid 0.005 per cent, respectively.

Table 4.25: Economics of different spray schedule against thrips, *S. dorsalis* infesting chilli during *Kharif* - 2012

Sr. No.	Treatment	Cost of insecticide (₹/ha)	Total cost of control measure* (₹/ha)	Yiled (kg/ha)	Gross** realizati on (₹/ha)	Net realization (₹/ha)	C:B Ration (CBR)
1	Schedule 1	5020	5620	7813	156260	87920	15.64
2	Schedule 2	5694	6494	8021	160420	92080	14.18
3	Schedule 3	6144	7144	8542	170840	102500	14.35
4	Schedule 4	6564	7764	9354	187080	118740	15.29
5	Schedule 5	7388	8788	9271	185420	117080	13.32
6	Schedule 6	7688	9288	10875	217500	149160	16.06
7	Schedule 7 (Control)	-	1000	3417	68340	-	-

*Labour charges @ ₹ 200/ha/spray. ** Market value of chillies @ ₹ 20/kg.

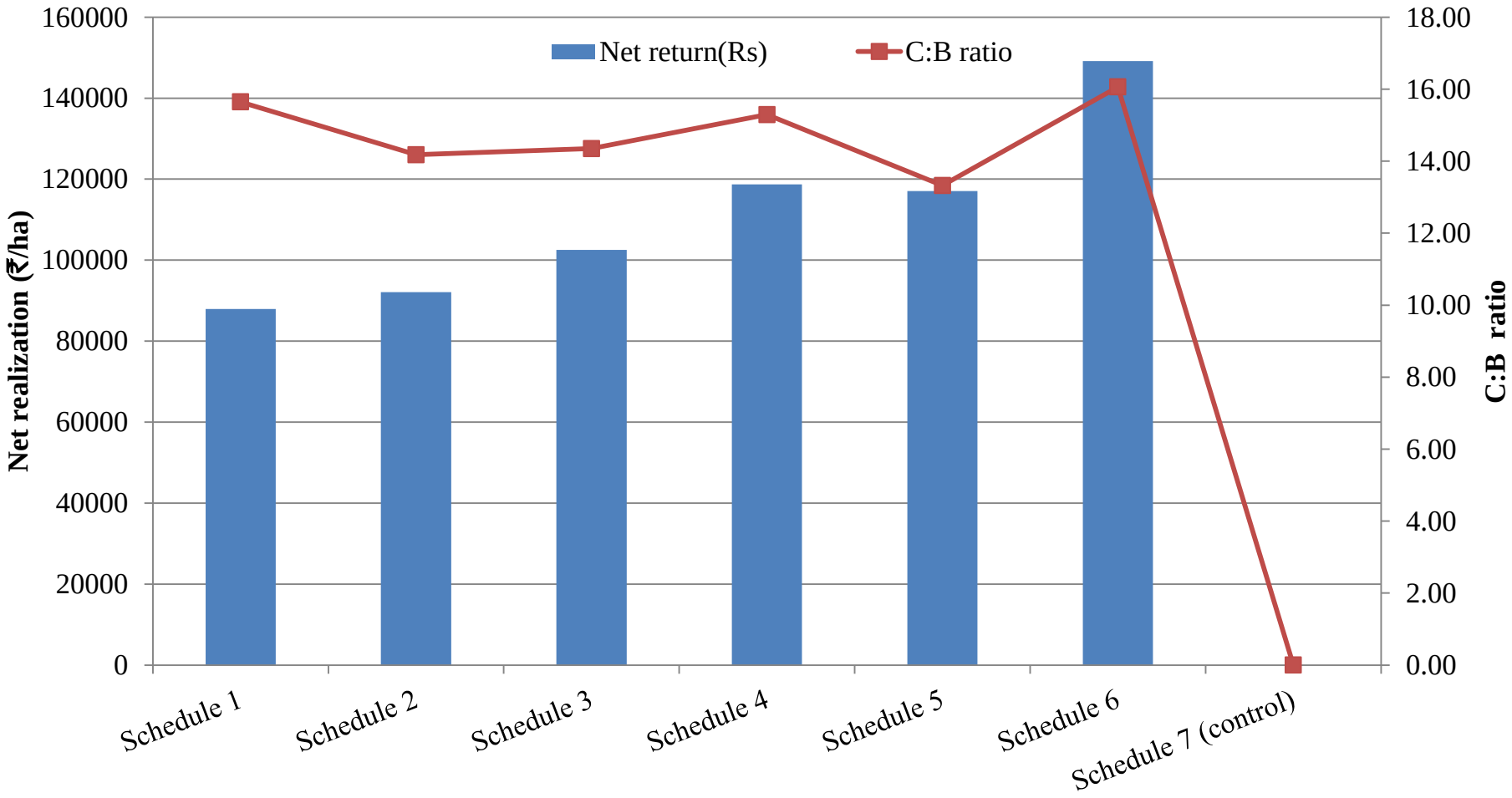

Fig. 4.15: Economics of different spray schedule against thrips, *S. dorsalis* infesting chilli during *Kharif* - 2012

4.5 Determination of the insecticides residue on/in chilli

Residue of the five insecticides *viz.*, spinosad 0.009 per cent, imidacloprid 0.005 per cent, abamectin 0.003 per cent, acetamiprid 0.008 per cent and ready mixture of profenophos + cypermethrin 0.044 per cent (Polytrin C 0.044%) was detected at 8 day after their application on chilli crop at Junagadh during fourth week of January 2013. The data given in Table 4.28 revealed that the residue of imidacloprid 0.005 per cent, abamectin 0.003 per cent and cypermethrin 0.004 per cent (Polytrin C 0.044%) was the maximum residue limit (MRL) and below determination limit (below limit quantitation). Further, it was found that the residue of spinosad 0.009 per cent and profenophos 0.04 per cent was also below maximum residue limit (MRL). But the residue of acetamiprid 0.008 per cent (0.346 mg/kg) was slightly above the maximum residue limit (0.20).

From the pesticide residue data it can be recommended that use of spinosad 0.009 per cent or imidacloprid 0.005 per cent or abamectin 0.003 per cent or Polytrin C 0.044 per cent (profenophos 40% + cypermethrin 4%) against chilli thrips, *S. dorsalis* infesting chilli and malady of leaf curling and the green chilli can be harvested safely for human consumption on the 8^{th} day after its application. Because, the residue of these insecticides was detect in/ on green chilli below its maximum residue limit (MRL).

Tatagar (2010) reported that the one week after in green chilli fruit residue were found imidacloprid 200 SL @ 0.25 ml/ℓ and vertimec 1.9 EC @ 0.5 ml below detectable level. Sarangdevot *et al.* (2010) sprayed ready mix insecticide Roket 44 per cent (Profenofos 40% + Cypermethrin 4%) @ 440 and 660 g a.i./ha and residue reached below detectable limit in 11 and 13 days after spraying in both respective doses. The safe waiting period and half-life value 2.75, 2.36, 2.70, 2.16, and 3.34, 2.47, 3.38, 2.52 days. Thus the present results were near about similar with previous report. And prove the insecticide were safe from the point of residue persistence in green chilli.

Table 4.28: Insecticides residue in/on green chilli harvested on 8th day after application at Junagadh (Gujarat) during January 2013

Sr. No.	Trade name	Name of Insecticide	Concentration (%)	Residue detected ug g^{-1} or mg/kg	*MRL mg/kg	**LOQ ug^{-1}	Waiting period day
1	Tracer	Spinosad 45% SC	0.009	0.282	0.30	0.1ppm	8 day
2	Sensex	Imidacloprid 17.8% SL	0.005	BDL	1.00	0.1ppm	8 day
3	Abacin	Abamectin 1.9% EC	0.003	BDL	0.02	0.01ppm	8 day
4	RaxaPRID	Acetamiprid 20% SP	0.008	0.364	Not available (2.00 in dry chilli and 0.20 in fruiting vegetables)	0.01ppm	8 day
5	Polytrin C 44% EC	Cypermethrin 4% EC	0.004	BDL	2.00	0.1ppm	8 day
6		Profenophos 40% EC	0.04	0.30	3.00	0.05ppm	8 day

BDL= Below determination limit

MRL= Maximum residue limit

Spray solution used @ 750 ℓ/ha.

* Joint FAO/ WTO food standards programme, CODEX COMMITTEE ON PESTICIDE RESIDUES, 44TH session Shanghai, P. R. China, 23-28 April 2012.

Drafts and proposed Draft of Maximum residue Limits in Foods and Feeds at steps 7 and 4 (CX PR12/44/5, March 2012).

** LOQ= Limit of Quantitation

CHAPTER-V

SUMMARY AND CONCLUSION

Chilli is one of the important commercial spices crop growing in all over India. The crop severely infested by the thrips and resulted malady of leaf curling throughout the India. Therefore, the efforts were made to study the population dynamics, yield losses and management of thrips, *Scirtothrips dorsalis* Hood infesting chilli at two different locations *i.e.* at farmer field in North Saurashtra Agroclimatic Zone during 2011 and at Junagadh in South Saurashtra Agroclimatic Zone during 2012. The aspect wise important conclusions emerged out from the investigation are summarized hereafter.

5.1 Population dynamics of chilli thrips, *S. dorsalis* and relationship with appearance of leaf curling symptoms

The activity of thrips, *S. dorsalis* commenced during 31st standard week (month of July) when the crop was at seedling stage during both year. From 33rd standard week, the pest population multiplied very fast and reached at first peak (22.28 thrips/ 3 twig) during 37th standard week. Thereafter, it was slightly decreased during next two weeks and again the thrips population was increased continuously from 41st standard week and reached at second (the highest) peak (84.13 thrips/ 3 twig) during 44th standard week. Thereafter, thrips population was decreased continuously during subsequent weeks.

The leaf curling symptoms on chilli seedling was appeared (4.17%) during 31st standard week (last week of July) *i.e.* third week after transplanting of chilli. The percentage of leaf curling was increased fast from 33rd to 45th standard week and produced maximum 81.25 per cent leaf curling intensity (Grade 4). Thereafter, the percentage of leaf curling decreased continuously in each subsequent week.

It was concluded that, when thrips population increased the percentage of leaf curling was also increased. The typical leaf curling symptoms were produced in chilli field at both the location. The thrips infested tender leaves started upward curling of leaf margin dorsally (adaxil) and the inter-veinal area getting raised up which appeared as buckled leaves and resulted in formation of narrow star (boat) shaped

leaves. The mechanical injury and some toxic substance introduced along with saliva into the leaves during feeding of thrips might have caused the upward type curling. Size of the leaf was reduced and malformed appetence observed on shoot (growing point) and plant growth was stunted. There was certain amount of intervienal buckling and the upper epidermis showed signs of irregular scraping by the thrips. The insect could also be seen within the curl affected leaves.

The weather condition during the higher activity period of thrips (32 to 82 thrips/3 twig) was maximum temperature 35.4℃ to 36.5℃, minimum temperature 19.0℃ to 25.5℃ with relative humidity maximum 64 to 71 per cent and minimum 28 to 37 per cent. The wind speed was to 2.4 to 5.4 km/h, bright sun shine hours was 6.4 to 9.2 h/day and evaporation rate was 4.7 to 5.9 mm/day with no rain.

The correlation between leaf curling severity and thrips population on chilli crop was found highly positive (r= 0.8719). The correlation between thrips population and maximum temperature was highly positive (r= 0.7230), while thrips population was exhibited significant positive correlation with evaporation rate (r= 0.4697) and bright sunshine hours (r= 0.5106). However, the correlation of thrips population with minimum relative humidity (r= -0.5484) and wind speed (r= -0.6891) were highly negative. Further, it was found that the thrips population significant negatively correlated with maximum relative humidity (r= -0.5336).

The correlation with thrips population and rainy days were highly negative (r= -0.5522).

The activity of thrips on chilli crop during entire growth period was found at both the location. The thrips activity on chilli was low during the rainy period July to August. The thrips population multiplied very high during the month of September and November being peak during October at both the location. The severity of leaf curling in chilli increased with increased population of the thrips and reach on grade-4 (75%) during the high activity period of thrips.

5.1.1 Relation of thrips density with leaf curling in chilli

Experiment were carried out to know whether the leaf curling produced in the field planted chilli was due to thrips feeding or due to virus transmission by the thrips.

The thrips were collected from the field plants of chilli severely infested and showing 4th grade leaf curling and released in variable numbers on different potted plants (45 day old). The commencement and severity of leaf curling was recorded daily up to 20 day.

The result revealed that the symptoms of leaf curling were first appeared on the top tender leaves by 12 days feeding of two thrips per plant. The number of thrips at the rate 3, 5, 8, 10 and 15 per plant resulted in production of leaf curling symptoms after 11, 10, 8, 7 and 3 days of release, respectively. Thus it was concluded that two or more thrips/ plant can produce leaf curling. As the number of thrips per plant increased the period for appearance of leaf curling symptoms was shorter. The coefficient of correlation between number of thrips and percentage of leaf curling was strongly positive (r= 0.9137). The leaf curling symptoms observed in potted plants were of similar type as observed in infested plants in the field. These result clearly indicated that the thrips, *S. dorsalis* was responsible to cause upward type of leaf curling symptoms in chillies.

The thrips was eliminated from chilli plants having 4th grade leaf curling using spinosad 0.009 per cent. After elimination of thrips from infested plants, the growth of plants was normal (without leaf curling) within 15 day. While the plants kept as control (untreated) were continued with thrips and pronounced leaf curling. It was concluded that the thrips in chilli was responsible for the leaf curling.

The cell sap of leaves showing severe and typical symptoms of leaf curling was inoculated on the healthy tender leaves of potted healthy plants.

The result showed that the leaf curl symptom was not produced up to one month in the sap inoculated plants but severe leaf curling (68.78%) produced on unprotected plants. This result indicated that thrips born virus was not responsible for producing the leaf curling in chilli, but thrips was responsible.

5.2 Estimation of qualitative and quantitative losses caused by chilli thrips, *S. dorsalis*

5.2.1 Qualitative losses

The percentage of leaf curling 48.47 to 65.97 per cent was recorded in unprotected crop as against 20.10 to 22.71 per cent in protected crop. Thus there was 58.53 to 65.57 per cent with on average of 62.58 per cent more leaf curl in unprotected crop was estimated.

The plant growth characters in protected crop and in unprotected crop were recorded at the two different location. The reduction (loss) in the plant growth character due to natural infestation of the thrips observed on protected crop against the thrips in chilli was estimated.

The loss in plant height was 25.93 to 26.76 per cent with an average of 26.34 per cent. Whereas, reduction in number of branches per plant was 26.93 to 29.98 per cent with an average of 28.50 per cent. The loss in length of leaves 60.84 to 84.86 per cent with an average 62.83 per cent and width of leaves was 63.16 to 64.86 per cent with an average 64.04 per cent, respectively. The loss in length and width of green marketable chilli fruit was 41.63 to 33.27 per cent with an average 33.39 per cent and 9.32 to 12.78 per cent with an average 11.01 per cent, respectively.

It was concluded that height of plant, number of branches/ plant, size of leaves and fruit were significantly reduced in unprotected crop over the protected chilli crop.

The damage caused by the thrips, on green chilli fruits was with scraping, crinkle, curved, colour become dark green and reduced size. Further quality of green chilli *i.e*. appearance, shape and luster of green chilli were detoriated.

5.2.2 Quantitative losses

The data of the year 2011 and 2012 revealed that the yield of green chilli produced 15244 kg/ha to 14556 kg/ha with an average of 14900 kg/ha obtained from protected crop was significantly higher over unprotected crop in which 3911 kg/ha to 3644 kg/ha with an average of 3778 kg/ha yield was recorded. The yield increased in protected crop over unprotected crop was 11333 to 10911 kg/ha with an average

11122 kg/ha. Thus 294.41 per cent green chilli yield was increased in crop protected against thrips. The avoidable loss of 74.65 per cent which can be saved by application of spinosad 0.009 per cent and abamectin 0.003 per cent alternatively at 10 day interval, starting 45 day after transplanting of chilli seedling.

5.3 Bioefficacy of insecticides against thrips, *S. dorsalis* infesting chilli

Twelve insecticide were evaluated against thrips, *S. dorsalis* infesting chilli crop at Farmer's Field (Village: Devlki, Tal: Vadia, Dist: Amreli) during *Kharif* 2011. Total three application of the various 13 insecticides was given at 15 day interval. The thrips population and percentage of leaf curling were recorded at 3, 7 and 14 day after each application.

The pooled result of three application of insecticides revealed that maximum reduction of chilli thrips was by treatment imidacloprid 0.005 per cent (3.13 thrips/3 twig) over control in which average 54.52 thrips/3 twig recorded. Further it was found that the reduction in thrips population due to profenophos + cypermethrin 0.044 per cent (3.22 thrips/3 twig), profenophos 0.05 per cent (3.35 thrips/3 twig), spinosad 0.009 per cent (3.47 thrips/3 twig) and abamectin 0.003 per cent (3.47 thrips/3 twig) was statistically equal with imidacloprid 0.005 per cent. Thus these five insecticides were found top most effective against chilli thrips at three day after their application on the crop. Further it was found the percentage of leaf curling was also reduced maximum by these insecticides. The similar trend was observed on seven and fourteen day after each spray application.

The significantly minimum thrips (7.33 thrips/3 twig with 16.65% leaf curling) was recorded on chilli plants treated with spinosad 0.009 per cent, found top most effective over rest of treatments at seven and fourteen day after applications. Treatment of profenophos + cypermethrin 0.044 per cent (11.76 thrips/3 twig with 20.18 % leaf curling), abamectin 0.003 per cent (12.02 thrips/3 twig with 21.69% leaf curling), imidacloprid 0.005 per cent (12.58 thrips/3 twig with 22.18% leaf curling), profenophos 0.05 per cent (13.44 thrips/3 twig with 20.18% leaf curling), acetamiprid 0.008 per cent (15.03 thrips/3 twig with 22.52% leaf curling), diafenthiuron 0.05 per cent (15.03 thrips/3 twig with 24.94% leaf curling) and indoxacarb 0.0145 per cent (16.32 thrips/3 twig with 27.46% leaf curling) were statistically equal in effective

against chilli thrips and leaf curling at seven and fourteen day after application formed second ranged effective group of insecticides.

The bioefficacy of biopesticides (*Beauveria, Verticillium* and *Metarhizium*) and the botanical pesticide (azadirachtin) was least effective as compared to the chemical pesticides against thrips. However, all the biopesticides and the botanical were significantly superior over control in reducing chilli thrips at three, seven and fourteen day after insecticidal spray.

However, it was found that the thrips population in all the insecticidal treatments increased two time or more on fourteen day compared to seventh day.

The result showed that the maximum reduction in leaf curling was recorded at the seven day after application of all the insecticides. But percentage of leaf curling increased at fourteen day after insecticides spray application.

The result clearly indicated that the chilli crop was severely infested with thrips, *S. dorsalis* (40 to 60 thrips/3 twig), which produced 39 to 65 per cent leaf curling in untreated (control) plots. Further, the leaf curling percentage reduced, where the thrips population reduced by application of the effective insecticides. Maximum reduction in thrips population and leaf curling was recorded in the chilli crop treated with spinosad 0.009 per cent, profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent, profenophos 0.05 per cent, acetamiprid 0.008 per cent and diafenthiuron 0.05 per cent.

The three application of the twelve insecticides were given at fifteen day interval against thrips infesting chilli and associated malady of leaf curling. The result clearly indicated that the highest yield of green chilli 15278 kg/ha with 229.34 per cent increased along with the highest monitoring return ₹ 212780/ha over control and 69.64 percent yield can be save due to treatment of spinosad 0.009 per cent. Further it was found that the green chilli yield received from the crop treated with profenophos + cypermethrin (Polytrin C 44%) 0.44 per cent (196.41% yield increased with 66.26% avoidable loss and net return ₹ 182220/ha) followed by abamectin 0.003 per cent (174.25% increased yield with 63.54% avoidable loss and net return ₹ 161660/ha) and imidacloprid 0.005 per cent (172.46 % increased yield with 63.3% avoidable loss and

net return ₹ 160000/ha) were statistically equal but significantly higher over rest of insecticidal treatment.

The botanical (azadirachtin 0.001 per cent) and microbial (*M. anisopliae, V. lecanii* and *B. bassiana*) found least economics compared to chemical insecticides for the control of chilli thrips and register the lower yield and net monitoring return.

5.4 Evaluation of insecticidal spray schedules against chilli thrips, *S. dorsalis*

The most effective insecticide spinosad 0.009 per cent, profenophos + cypermethrin 0.044 per cent, abamectin 0.003 per cent, imidacloprid 0.005 per cent, profenophos 0.05 per cent and acetamiprid 0.008 per cent were selected for the spray schedules. Total seven schedule were formed and in each schedule number of application of insecticide was 3 or 4 or 5 or 6 or 7 or 8 with interval of 30 or 20 or 15 or 12 or 10 and 8 day, respectively along with water spray (control).

The result showed that the maximum reduction of thrips population and the leaf curling was recorded in spray schedule 6 (13.69 thrips/3 twig and 36.30% leaf curling) and it was at par with schedule 5 (13.97 thrips/3 twig and 38.58% leaf curling), 4 (14.27 thrips/3 twig and 37.77% leaf curling), schedule 3 (16.06 thrips/3 twig and 38.58% leaf curling) and schedule 2 (16.83 thrips/3 twig and 40.80% leaf curling).

Spray schedule 1 found least effective against thrips and the leaf curling with 22.80 thrips/3 twig and 41.80%, respectively. But it was superior over schedule 7 (untreated). The maximum 35.97 thrips/3 twig with 58.70 per cent leaf curling was recorded in schedule 7 (untreated control).

The data revealed that the yield of green chilli in the different insecticidal spray schedule ranged from 7813 kg/ha to 10875 kg/ha was significantly higher over untreated control in which 3417 kg/ha recorded. However, significantly maximum yield of 10875 kg/ha with 218.29 per cent increased (over control along with the highest net monitoring return ₹ 149160/ha and C:B ratio 16.06) was obtained from spray schedule 6. The yield received from the schedule 5 (9271 kg/ha, 171.34% increased, net return ₹ 117080/ha and C:B ratio 1:13.32), schedule 4 (9354 kg/ha, 173.78% increased, net return ₹ 118740/ha and C:B ratio1:15.29) and schedule 3 (8542 kg/ha, 150.00% increased, net return ₹ 102500/ha and C:B ratio 1:14.35) were

statistically equal and higher than rest of the schedules. Further, it was found that the maximum avoidable loss 68.58 per cent was from crop treated with schedule 6 followed by schedule 4 (63.47%), schedule 5 (63.15%), schedule 3 (60%), schedule 2 (57.40%) and schedule 1 (56.27%).

From the results, it can be clearly concluded that the six insecticidal spray schedules were evaluated against thrips infesting chilli at Junagadh during *kharif* - 2012. The schedule 6 was found most effective in reducing chilli thrips, *S. dorsalis* and the malady of leaf curling, with the highest yield of green chilli and the highest monitoring return was received from schedule 6. The schedule 6 included eight spray application at eight day interval with insecticides (i) profenophos + cypermethrin (Polytrin C) 0.044 %, (ii) abamectin 0.003 per cent, (iii) imidacloprid 0.005 per cent, (iv) spinosad 0.009 per cent, (v) profenophos + cypermethrin 0.044 %, (vi) acetamiprid 0.008 per cent, (vii) spinosad 0.009 per cent and (viii) imidacloprid 0.005 per cent, respectively. The schedule 6 can be suggested to the farmer for management of chilli thrips, *S. dorsalis* causing leaf curling and getting more benefit during the *kharif* season from chilli crop.

5.5 Determination of the insecticides residue on/in chilli

The residue of the five insecticides was detected at 8 day after their application on chilli crop at Junagadh during the fourth week of January 2013. The residue of imidacloprid 0.005 per cent, abamectin 0.003 per cent and profenophos 0.04 per cent + cypermethrin 0.004 per cent (Polytrin c 0.044%) and spinosad 0.009 per cent was below maximum residue limit (MRL). But the residue of acetamiprid 0.008 per cent (0.346 mg/kg) was slightly above the maximum residue limit detected at 8 day after their application on chilli crop at Junagadh during week of January 2013.

It was concluded that the green chilli can harvest without harmful residue on 8 day after application of spinosad 0.009 per cent or imidacloprid 0.005 per cent or abamectin 0.003 per cent or polytrin C 0.044 per cent (profenophos 40% + cypermethrin 4%) against chilli thrips, *S. dorsalis* infesting chilli and malady of leaf curling .

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* Original not seen