Dynamics of Pest Complex on Potato Seed Crop in Punjab and its Integrated Management

A

Thesis

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IN

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By

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DECLARATION

I hereby declare that the thesis entitled **"Dynamics of Pest Complex on Potato Seed Crop in Punjab and its Integrated Management" submitted for Ph.D Zoology degree to the department of Zoology,** Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

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CERTIFICATE

This is to certify that **Mr. Kapil Kumar Sharma** has completed the Ph.D Zoology titled, **"Dynamics of Pest Complex on Potato Seed Crop in Punjab and its Integrated Management"** under my guidance and supervision. To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree or diploma.

The thesis is fit for the submission for the partial fulfillment of the condition for the award of degree of Ph.D in Zoology.

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ABSTRACT

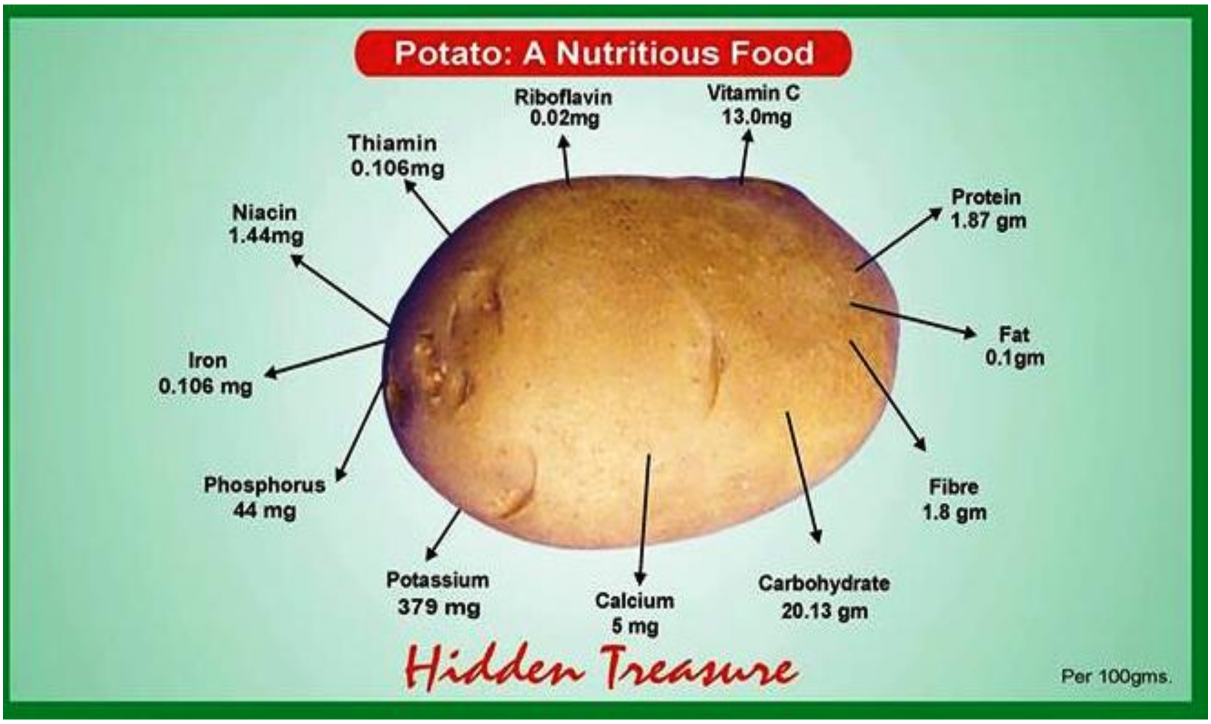
Agriculture is at the cross roads, by 2050 the world's population will reach 9.1 billion, 34 percent higher than today. Nearly all of this population increase will occur in developing countries. Urbanization will continue at an accelerated pace, and about 70 percent of the world's population will be urban (compared to 49 percent today). There will be hike in Income levels of what they are now. In order to feed this larger, more urban and richer population, food production must increase by 70 percent. Annual cereal production will need to rise to about 3 billion tonnes from 2.1 billion today and annual meat production will need to rise by over 200 million tonnes to reach 470 million tonnes. *(How to Feed the World in 2050, Food and Agriculture Organisation, united nation)*

Agriculture is the main pillar of the Indian economy. Agriculture and allied sectors contribute nearly 17.8 and 17.1 percent of Gross Domestic Product (GDP of India) during 2007-08 and 2008-09 respectively. The agricultural output, however, depends on monsoon as nearly 55.7 percent of area sown is dependent on rainfall.

Agriculture provides the principal means of livelihood for over 58.4% of India's population. It contributes approximately one-fifth of total gross domestic product (GDP). Agriculture accounts for about 10 percent of the total export earnings and provides raw material to a large number of industries. Low and volatile growth rates and the recent escalation of agrarian crisis in several parts of the Indian countryside, however, are a threat not only to national food security, but also to the economic well-being of the nation as a whole.

In recent years, many of the globe's major food crops have reached a "Yield plateau". global growth rate in yield of cereals has shown a decline,wheat slide from 2.92% per year from 1961to 1979 to 1.78% for the period from 1980 to 1997. For maize, the rate slipped from 2.88 to 1.29%. In India annual compound growth rate ranged between -2.83 to 1.14% during 1997-2004. India may need 300 million tonnes of cereals by 2020, but the productivity is estimated around 260 million tonnes by that time. this implies a cereal gap of 40 million tonnes or more by the year 2020. This situation may again revive the fear of Malthusian devil. To fill this gap of demand and production is either to import which will put an extra economic burden causing diversion of developmental funds to cope the situation. The other alternative would be to diversify from cereals to other nontraditional food crops. Potato can be one of the answer to this problem that is going to be faced by the world in future. Potato has been

idenified as the food for future by Food and Agriculture Organisation of the united nation (*Twenty steps towards hidden treasure, CPRI, Shimla*, Dec. 2008). Potato (*Solanum tuberosum* L.) belongs to the genus *Solanum* of family Solanaceae. Potato produces highest dry matter, carbohydrates, edible protein, minerals and vitamins C and B per unit area and time among major food crops. It is a low calorie food and its protein has a biological value almost equal to eggs or milk. It is a wholesome nutritious and versatile food which can come to rescue of the developing countries for alleviating hunger and malnutrition especially in the view of shrinking land resources. Dry matter production in potato is 47.6 kilogram/hectare/day, whereas in wheat and rice it is 18.1 and 12.4 kilogram/hectare/day respectively. Similarly, potato produces 3 kg of edible protein/day as compared to 2.5 and 1.0 kg in wheat and rice respectively (*Ezekiel et al., 1999*).



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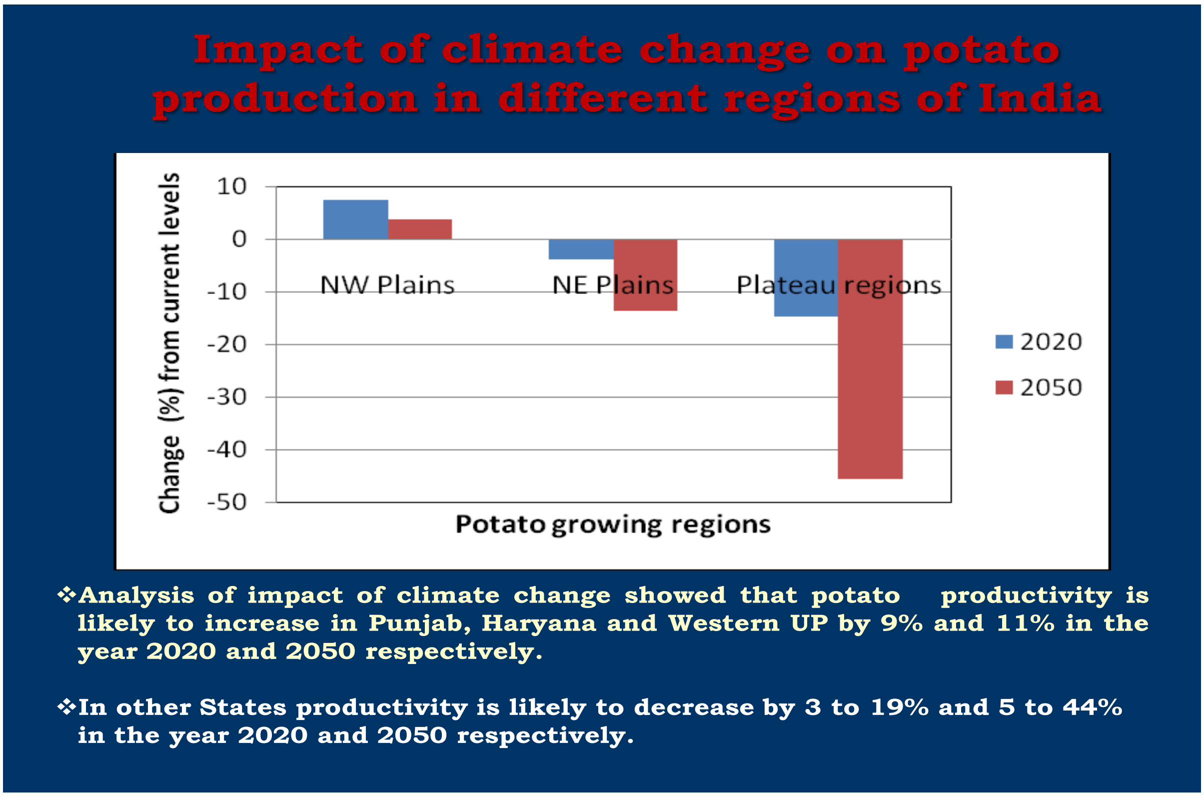
Impact of Global climate change on Potato production

The insects are ectothermic and sensitive to precipitation (Bale et.al. 2002). They have the tendency to fluctuate as a result of their inherent characteristics, influenced by the environment factors which effect their behaviour and physiology (Bale et al., 2002, Cannon 1998, parmesan 2007, Kumar, anthopod diversity, ICRISAT). The degree of influence of various Abiotic factors, determine the variation in the pest populations. Knowledge of population dynamics of pest complex is one of the foremost prerequisite for developing sustainable crop protection strategies and the developing long term/short term forecasting models to calculate the response of different taxonomic groups to weather patterns. Keeping in view of the global climate change and changing paradigm of insect- pest complex present study of population dynamics of insect pest complex on potato were undertaken at CPRS, Jalandhar as the region is the potato seed producing hub and 80% of the seed produced in this region is sent to other states like West Bengal, Karnataka, Maharashtra, UP, Bihar, Odisha and exported to neighboring countries. The change in dynamics of Insect pest complex of potato in this region is a matter of concern for farmer communities and the scientist.



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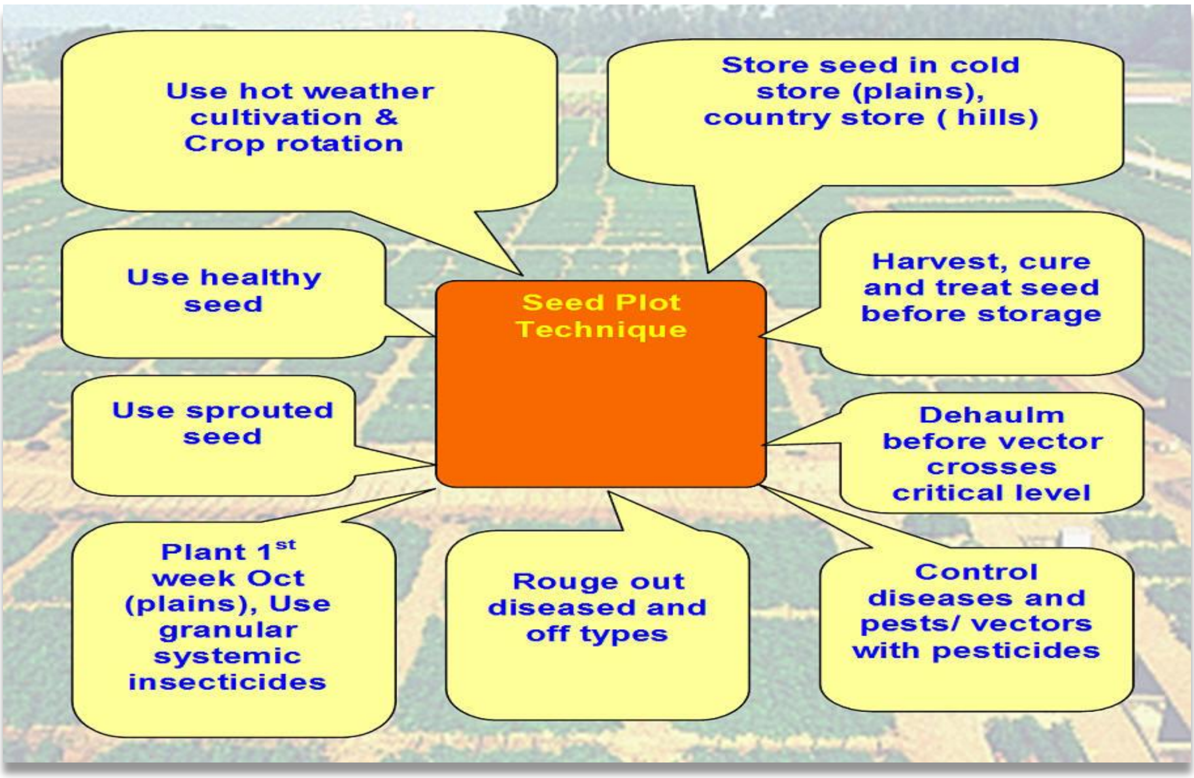
SEED PLOT TECHNIQUE

Central Potato Research Institute developed seed plot technique during 1959 which has revolutionized seed potato production in sub-tropical plains of India. The principle of seed plot technique is growing seed potato crop using healthy seed during low aphid period from October to first week of January coupled with integrated pest management, rouging and dehaulming the seed crop during the last week of January before aphids reach the critical limit.



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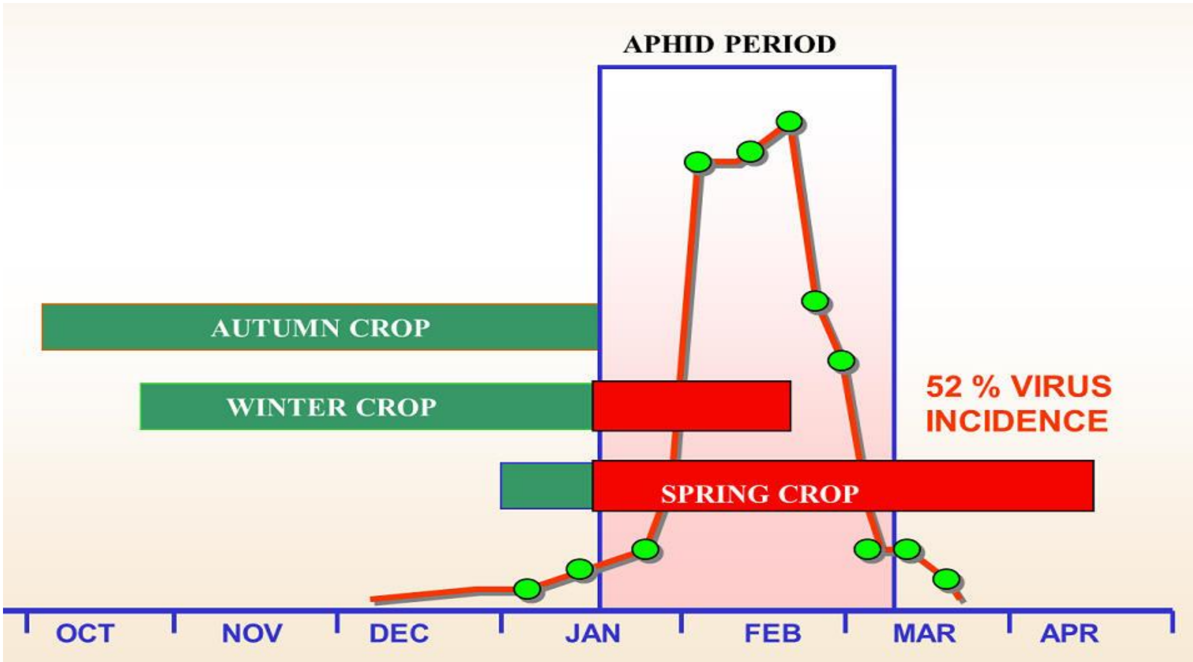

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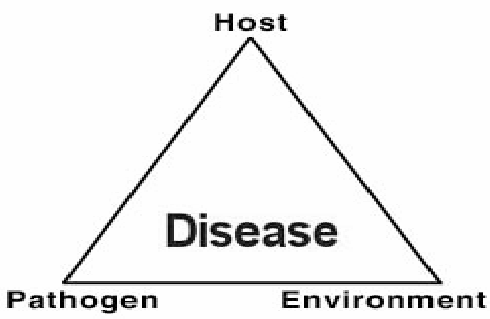
Changing world scenario of pest and diseases in agriculture

Potato is the only major food crop that suffers from largest number of viruses, many of which were transmitted by insect vectors. At least 37 viruses naturally infect cultivated potatoes, out of which 7 viruses are transmitted by aphids, one virus and almost all MLO (Mycoplasma like organism) are transmitted by leafhoppers, the newly emerging PALCV

(Potato apical leaf curl virus) caused by Gemini virus, is transmitted by white flies and potato stem necrosis virus caused by tospovirus is transmitted by thrips. It has been demonstrated that about 400 species of insects are involved in transmission of over 200 different plant viruses. Largest number of viruses is transmitted by aphids followed by leafhoppers and white flies.

Global warming and climate change will trigger major changes in diversity and abundance of arthropods, geographical distribution of insect pests, population dynamics, insect biotypes, herbivore plant interactions, activity and abundance of natural enemies, species extinction, and efficacy of crop protection technologies. Changes in geographical range and insect abundance will increase the extent of crop losses, and thus, will have a major bearing on crop production and food security. Distribution of insect pests will also be influenced by changes in the cropping patterns triggered by climate change. Major insect pests of potato crop such as aphids, leaf hoppers and white flies may move to temperate regions, leading to greater damage in potato crops. Global warming will also reduce the effectiveness of host plant resistance, transgenic plants, natural enemies, synthetic chemicals for pest management. Therefore, there is a need to generate information on the likely effects of climate change on insect pests to develop robust technologies that will be effective in future under global warming and climate change.

Extensive surveys on population dynamics of aphid were undertaken to search for areas suitable for healthy potato seed production and a sound technology named “Seed Plot Technique” had been carved out. The system still constitutes the backbone of healthy seed production in India. Seed production activity is now being extended to new areas with the objective of covering more and more area with healthy seed. The vector population is undergoing major change due to the influence of climate change. Now a complex of vectors is extending their services for the transmission of diseases.



Conditions are more favorable for the proliferation of insect pests in warmer climates. Longer growing seasons will enable insects such as grasshoppers to complete a greater number of reproductive cycles during the spring, summer, and autumn. Warmer winter temperatures may also allow larvae to winter-over in areas where they are now limited by cold, thus causing greater infestation during the following crop season. Altered wind patterns may change the spread of wind-borne pests, bacteria and fungi that are the agents of crop disease. Crop-pest interactions may shift as the timing of development stages in both hosts and pests is altered. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them, a situation that will require the further development and application of integrated pest management techniques.

With the outcomes of present investigation it concluded that, potato seed production is highly affected with the incidence of many pests in the Jalandhar region; however, aphids, leafhoppers and whiteflies are the major insect pests. These insects are much destructive since the carry many viruses with them. The incidence of such a virus namely potato leaf curl virus which is transported by whiteflies were also seen in the fields and had positive relation with whitefly population. These insects can be efficiently monitored with the help of yellow sticky traps, yellow water pan traps and pheromone traps. Further, it was also found that the population dynamics of insect pests get affected with environmental as well as biological factors. Therefore, adjusting the sowing date or the development of early or late sown varieties would definitely be fruitful in reducing the yield losses. With the outcomes of present investigation it concluded that, “THE HEAT IS ON” rising temperature, invasion of new pest species, turning up of minor pest like whiteflies into major pests and carrier of viruses like APCLV which is playing a havoc to the potato seed production.Survey of the two consecutive years have shown that pest population are ranging from moderate to high in the seed belt of Punjab which is supposed to be pest free or the pest population will remain below the ETL level during the crop season. Aphids, leafhoppers and whiteflies are the major insect pests reported in this area. These insects are much destructive since the carry many viruses with them. The incidence of such a virus namely potato apical leaf curl virus which is carried by whiteflies. A positive correlation between incidences of APCLV with whitefly population. These insects can be efficiently monitored with the help of yellow sticky traps, yellow water pan traps and pheromone traps. Further, it was also found that the population dynamics of insect pests get affected with environmental as well as biological factors. Therefore, adjusting the sowing date or the development of early or late sown varieties would definitely be fruitful in reducing the yield losses. Furthermore, the efficacy test of identified insecticides against

major sucking insect pests by means of rotating chemistry it was concluded that a combination of foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (2.5 ml /lit) (as second spray), Foliar spray of Imidacloprid 200SL (0.3 ml/lit) (as third spray) and Rogor 30EC (1.5ml/lit) (as fourth spray) would be useful in controlling the incidence of aphids, whiteflies and leafhoppers in the potato fields; new chemical molecule THYMOL (Derived from Ajwain) and KAOLIN (Sillicate based clay) are also tested and compared with NKE, and Immidacloprid 200SL at 0.03%. No doubt that the efficacy of imidacloprid is very good but the use of these alternative chemicals will open the ways to control pests when supplemented along with traditional chemicals will reduce the pressure these chemicals on crops. Furthermore, net houses can also be used as an option for controlling the infestation of insect pests on potato crop. The results showed that there was a significant decrease in the yield loss when the potatoes were grown under portable net houses. In future, a combination of net house traps and experiments chemical combination can be used as efficient IPM strategies for sustainable potato seed production.

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I am overwhelmed with rejoice to avail this opportunity to evince my profound sense of gratitude to my parents Lt. (Shri) Vidya Sagar and Mrs. Surjit Devi, my wife Praveen Lata and my daughters Priyanka Sagar and Varsha Sagar and all my well-wishers for their measureless prayers, everlasting love and constant encouragement throughout the period of my study.

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Place: Jalandhar, Punjab **(Kapil Kumar Sharma)**

Dated:

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Introduction

CHAPTER-I

INTRODUCTION

Potato (*Solanum tuberosum L.*) is an economically important crop prevailing all across the world with successful large-scale production, consumption and affordability with easy availability in the open market (Zaheer and Akhtar, 2016). It's a major source of carbohydrate in addition of several other mineral and vitamins for millions of people of the nation. The potato produces more dry weight (47.6 kg/ha/day) and edible protein (3 kg/ha/day) than the major cereal crops. Freshly harvested potato tubers contains almost 80% of water and 20% of dry weight of which 70% is starch. The biological value of its protein is almost similar to egg. The potato is low in fat (0.1%) and energy (80 k cal/100g edible portion). It is rich in vitamin C (17 mg/100 g edible portion) and a moderate source of Iron. It can supply at least part of the daily requirement of trace elements like Maganese, Molybdenum and Chromium. Thus this crop may play a major role in the need of food security of India. Beside this potato crop has proved as major cash crop and helps in improving the socio-economic status of farmers.

As a result of numerous scientific efforts the production of this crop has tremendously increased in India during past few decades.India produces 7.72% of the world's potatoes from 7.57 % of the total global potato-growing area, with productivity levels higher than the world's average (Rana 2011). The potato production has jumped from 1.54 mt in year 1949-50 to 41.5 mt in year 2013-14 and the productivity has increased by almost 27 times in these years (Anonymous, 2014). At present the crop stands third in total production after rice and wheat with only 0.8% of gross cropped area.

Increment in potato seed production at national level that has been achieved by the Indian agricultural scientists is highly appreciable; however, there are many abiotic and biotic factors rendering the production of this crop. Among these two, the biotic factors, especially the infestation of insect pest which further leads to the development of a number of serious viral diseases in potato, are major problem for potato seed production in India (Chandel *et al.*, 2007). India has a great diversity of insect pests attacking on the potato crop.These pests can damage potato plants by feeding on leaves, reducing photosynthetic area and efficiency by attacking stems, weakening plants and inhibiting nutrient transport, and by attacking potato tubers destined for consumption or use as seed (Chandel and Chandla, 2003). On an estimate various insect pest damages reduces the annual potato seed production by 20-30% which further leads to the annual loss of approximately 1.2 billion USD to Indian economy (Misra *et al.*, 2003).

Name of the Disease	**Name of Causing Agent**	**Economic Losses**	**Remarks**
FUNGAL DISEASES			
Late blight of potato	*Phytophthora infestans*	Up to 90%	Most widely studied disease of potato
Early blight of potato	*Alternaria solani*	Up to 20%	-
BACTERIAL DISEASES			
Bacterial diseases	*Ralstonia solanacearum*	Up to 75%	Zero tolerance in International seed certification system
Black leg or Soft rot	*Pectobacterium carotovorum*	Up to 100%	Effect from field to storage
Common Scab	*Streptomyces Spp.*	AT 5% level of incidence, seed lots rejected	Seed belt of Punjab, HP and UP are facing this disease
VIRAL DISEASES			
Potato Leaf Roll Virus(PLRV)	*Viron (Family Luteoviridae)*	Up to 80%	Phloem necrosis virus
Apical Leaf Curl Virus	*Gemini virus*	Up to 90%	Strain of tomato leaf curl New Delhi virus (TolCNDV)
Potato virus	*X,S,A and M*	Up to 30%	Show severe symptoms in association with other viruses.
Potato virus	Y, Y^{N}, Y^{NTN}	Up to 75%	Variants of Potato virus Y causes high rate of degeneration in potato seed tubers
Viroid	*Potato Spindle Tuber Viroid(PSTVD)*	Up to 75%	Shape deformation is also reported due to PSTVD

Conventionally, the infestation of insect pest in potato crop is done with the application of synthetic insecticides. It has been reported that potato is the heaviest user of chemical pesticides of all major food crops and often consumption up to 20% of its cost of production thus increasing the cost potato seed production (Anonymous 1992). Further, it has already been proven during many scientific studies that the use of chemical insecticides is not only hazardous for the human consumption but also disturb the flora and fauna. It has also been reported that since the chemical insecticides are not target specific they adversely affect the population of farmer friendly insects. In such conditions Integrated Pest Management (IPM) could be an approach for enhancing potato seed production in most eco-friendly ways.

Integrated pest management is a broad-based systematic approach to manage pests that combines a variety of techniques and strategies for reducing pest populations economy injury level (IJL). The major principles involved in IPM are monitoring, mechanical control, biological control and the responsive use of chemical pesticides. The first principle of IPM involves various strategies and the population dynamics is the basic one. Understanding the population dynamics is the foundation of IPM (Pedigo and Rice, 2016). The knowledge of seasonal pest dynamics enables to predict the time, type and the severity of insect pest infestation thus helps in deploying insecticide sprays and other control tactics in most effective ways, increasing their value and decreasing negative impacts on the environment (Nietschke *et al.*, 2007). Thus the study aimed with the understanding of seasonal insect pest dynamics may help not only in reducing the damage due to insect but also in saving environment by means of reducing the use of hazardous chemical insecticides, during the potato seed production.

Chapter-II

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.), is annual herbaceous food crop belonging to the family solanaceae. It has high nutritional values and contains water (70%), starch (18%), protein (2%) vitamins (1%), minerals and trace elements (Ahmad *et al.*, 2011) commonly known as "King of Vegetables", is one of the major food crops grown in over hundred countries and consumed by one billion peoples around the globe (Haase, 2008).

Total world potato production is approximately 368.096 million metric tons annually (FAO, 2015). The present area under potato in India is 1.99 million hectare and total production is 48 million tones with an average of 23.6 tones/hectare and stands second in production after China. In India, Punjab rank 6^{th} in potato production.It is worth mentioning that in 2011-12, potato was sown over 84, 114 hectares in Punjab, and per hectare yield was 25.01 metric tons a hectare with overall production was 2.10 million tones. Doaba region of Punjab caters the demand for potato seed to West Bengal, Gujarat, Uttar Pradesh, Assam, Bihar, Karnataka and Chattisgarh and also exporting to countries like Srilanka, Pakistan etc.

In past few decades the potato production has significantly increased; however, many biotic and abiotic factors limit it. Insects cause variable losses to potato production, worldwide. India has a great diversity of potato insect pest, these insect pests lead to a severe loss in potato seed production each year.The potato pests are grouped into soil pests, foliage feeders, sap feeders, and storage pests (Pathania *et al.*, 2013). To achieve the goal of higher production of potato crop it is necessary to control the damage due to the incidence of insect pests.

In this array understanding the dynamics of pest complex on potato seed crop and its integrated management would be a novel approach. However, a survey of literature for understanding the facts and logics is a prerequisite for conducting any research study therefore the present chapter includes a brief discussion on the previous studies relevant to the present investigation.

2.1 INSECT PEST COMPLEX OF POTATO

In 1918, Britton observed the attack of variety of chewing and leaf sucking insects on the potato crop at Connecticut (USA). He identified that among chewing pests Colorado potato beetle and potato flea beetle were major insect pests of that area whereas, three lined potato beetle, tortoise beetle, blister beetle, stalk borer, cutworm, wireworm, white grub and European corn borer were damaging occasionally. However, among sucking insects aphid species were severely damaging potato crop.

In a survey of potato growing hilly areas of Himachal Pradesh, Sharma and Bhalla (1964) observed insect pests of thirteen different species and orders, infesting on the potato.

Getzendaner (1966) observed a polyphagous insect namely European earwig feeding on potato and some other horticultural plants.

Members of *Liriomyza* species [*L. quadrata* (Mall.), *L. brasiliensis* (Frost)] were also observed as major destructing insect pest of potato tuber by Squire (1972) in the potato growing areas of Bolivia. He also reported some other major foliage feeders *Acordulecera* sp., *Empoasca fabialis* DeLong and *E. fabae* (Harris). Infestation of *Macrosiphum euphorbiae* (Solanifolii (Ashm.) which is a vector of potato mosaic virus and leaf-curl virus was also seen by him. The infestation of *E. adspersa* (Klug) and *E. vittata* (F.) was occasionally on both leaves and young shoots.

Further, Squire in the same year observed *Premnotrypes latithorax* (Pierce) and *Phthorimaea operculella* (Zell.) as major species attacking the potato tubers. He also reported that, in the humus soil the attack of *Cyclocephala melanocephala* (F.), *Bothynus* (Ligyrus) *burmeisteri* (Steinheil) and *Ontherus sulcator* (F.) larvae were quit damaging.

Saxena (1974) extensively worked on the identification of soil insect pests, defoliators, sap feeders and storage pests of potato in India and also suggested the measures for their control.

Dorozhkin *et al.* (1975) reported *L. decemlineata* (Say) and wireworms as major damaging insect pests of potato crop while working on combined protection of potatoes in Byelorussia. In addition to this he also reported at least 38 species of insect pests in potato cultivating areas of Cusco (Peru).

Butani and Verma (1976) demonstrated the attack of *Phthorimaea operculella* (Zell.), *Agrotis ipsilon* and other *Agrotis* species on above and underground parts of potato. He also demonstrated the attack of *Myzus persicae* (Sulz.) and twelve other species of aphids and *Gryllotalpa africana* leads to major damage in leaves and other parts of potato in fields. In addition to this, they also gave the management practices of identified insect pests.

Bacon *et al*. (1978) monitored the attack of *P. operculella* and *M. persicae* in California by means of water-pan traps baited with synthetic sex pheromone. He demonstrated that damage of potato tubers due to adult and larvae of *P. operculella* (Zell.) was substantially higher in insufficiently irrigated potato fields. Further, he indicated that being a vector of leaf-roll virus the damage due to *M. persicae* (Sulz.) in potato is more serious than that of *P. operculella* (Zell.). Bacon *et al.*, (1978) also demonstrated that the population of these two serious insect pests significantly declines due to use of weed management and insecticides.

Jensen *et al.* (1979) listed 67 species belonging from 24 genera of nematodes associated with potatoes. Among them the most damaging were the potato cyst nematode, *Globodera rostochiensis* and *G. pallida* causing tremendous losses in several countries. The other nematode species distributed worldwide causing significant losses including stubby root (*Trichodorus* and *Paratrichodorus* spp.), root lesion (*Pratylenchus* spp.), potato rot (*Ditylenchus* spp.) and *Basirolaminus indicus* (Waliullah, 1992).

Nagaich *et al.* (1979) collected 74 leaf hopper species from potato and other adjoining crops from different agro-climatic regions of India.

Tsendsuren (1979) identified eight different species of wireworms viz., *Selatosomus latus* (F.), *S. spretus* (Mannh.), *S. aeneus* (L.), *Agriotes obscures* (L.), *A. sputator* (L.), *A. lineatus* (L.), *A. meticulosus* (Cand.) and *A. dahuricus* (Cand.) severely damaging in potato fields. Further, over hundered species of scarabaeids were also seen in the potato fields among these, the most injurious was *Amphimallon solstitiale* (L.). Despite these few damaging beetles which include species of *Eodorcadion*, foliage feeding Lepidoptera viz., *Euxoa islandica* (Stgr.), *E. tritici* (L.) and *A. exclamationis* (L.) were also observed in potato crops.

A total of seven aphid species namely *A. craccivora* (Koch), *A. gossypii*, *A. fabae, M. persicae* (Sulz.), *Rhopalosiphum nymphaeae* (Linn.), *R. rufiabdominalis* and *Tetraneura nigriabdominalis* (Sasaki) infesting on the potato seed crops in Haryana (India) were reported by Kashyap and Verma (1982).

Radcliffe *et al.* (1982), in their review described five different types of insect pests attacking on the potato and causing severe damages to potato. They mainly discussed about the aphids (including aphid-transmitted potato viruses; aphid life-cycles and biology; aphids and virus transmission; population monitoring and modelling; insecticide resistance and biological control), leafhoppers, *Leptinotarsa decemlineata* (Say), *Phthorimaea operculella*

(Zell) and pests of tubers and roots. A short discussion on varietal resistance to insect pests was also made.

A study on the potato insect pests in Brazil by Hooker *et al.* (1983) demonstrated *M. persicae* (Sulz.), as major aphid species limiting the seed production by means of transmitting viruses. They also indicated that larvae and adults of *Diabrotica speciosa* (Germ.) and *Epitrix* spp., damage the crop by feeding on the foliage and tubers of seed and table crops, respectively. It was also reported that in some areas the infestation of *Liriomyza huidobrensis* (Blanch.) led to reduction in yield by 30 percent. In addition to the above mentioned major insect pests a considerable amount of damage had also been reported due to the infestation of *P. operculella* (Zell.), elaterids, *A. ipsilon* (Hufnagel.), *M. euphorbiae* (Thos.), *Nezara viridula* (L.) and *Epicauta* spp.

Velupillai and French (1986) reported the abundance of previously reported insect pest and disease in the potato farms of Sri Lanka; however, some new fungi (*Choanephora cucrditarum, Fusarium oxysporum*),aphids (*Rhopalosiphoninus latysiphon*)and mite (*Polyphagotarsenemus latus*) were also identified them.

Anwar *et al.* (1987) studied the insect pest complex of potato in the Multan region of Pakistan. They identified *Gryllus bimaculatus* and *Acrotylus humbertianus* as major insect pests. During the study on the population dynamics of insects in potato crop they recorded peak population of: *Bemisia tabaci* (2.25 individual plant^{-1}) in the first week of February, *Amrasca devastans* (1.22 plant^{-1}) in second week of January, *Myzus persicae* (1.68 aphid plant^{-1}) in the first week of December to (9.01 plant^{-1}) in the fourth week of January and the maximum attack of larvae of *Phthorimaea operculella* in February infesting approximately 13.5 percent of tubers.

Raodeo and Deshpande (1987) reported the severe attack of white grubs (Scarabaeidae) on the roots of various crops including wheat, ground nut, potato, tomato and sugarcane in fields of Marathwada region of Maharashtra.

Sharma *et al.* (1987) did a comparative study between the infestation under room temperature (20-25) and cold storage (2-3 ºC) and demonstrated that potatoes in cold storage were not infested with insect pests whereas a substantial infestation of tenebrionids (*Alphitobius laevigatus*), *Tribolium castaneum*, the trogossitid (*Tenebroides mauritanicus*)and the dermestid (*Trogoderma granarium*)could be seen on tubers stored at room temperature.

Tyagi and Misra (1987) surveyed (during 1984 and 1985) the extent of damage of potato crop done by white grub species in and around Shimla. The team reported that both *Lachnosterna coriacea* and *L. longipennis* were the major damaging species of white grub in certain pockets of Himachal Pradesh particularly at Shilaroo and its adjacent areas.

In Tripura region, Das (1988) identified a total of 23 species of insect pests infesting on potato; however among them only *Odontotermes obesus, Agrotis segetum, A. ipsilon, Aphis gossypii, A. fabae* and *M. persicae* were of economic importance. In addition to this, they also advised the control measures of these pests in the potato fields.

Das and Ram (1988) on the basis of their study of two successive years (1983-85) conducted in the potato growing regions of Bihar demonstrated that incidence and carry-over of the noctuid *A. ipsilon* led to on an average 12.76 and 4.26 percent damage to tubers during two successive years, respectively. They observed that the plant damage was first started during the 3rd week of December which subsequently increased till the 2nd week of January. However, the tuber damage was first observed during late December which continued till harvest. Interestingly no larvae were seen infesting on any part of potato crop; instead, larvae and pupae were found only on the alternative host plants *viz.*, *Chenopodium album, Solanum nigrum, Portulaca oleracea, Amaranthus viridis, Evolvulus alsinoides* and two unidentified weed species.

Misra and Agrawal (1988) in their report on the potato pests in India and their control, discussed about more than eighty different types of soil, sap-sucking, defoliators and storage insect pests of insects and several nematode pests in the potato fields. They also reported two major nematode *viz.*, root-knot and cyst forming infesting the crop.

Rai *et al.* (1988) observed the infestation of *Dioxyna sororcula* (Wiedmann) [Diptera: Tephritidae], *Creontiades* spp. [Hemiptera: Miridae] and *Taylorilygus pallidulus* (Walk) [Hemiptera: Miridae] during the survey of potato fields of R.A.R. Station Chhindwara, Madhya Pradesh.

Rajagopal and Trivedi (1989) reported *Epilachna vigintioctopunctata* as an important insect pest in Asia and widely distributed over South and East Asia, Australia, America and the East Indies. *E.* dodecastigma, E. *vigintioctopunctata*, *E. ocellata* and *E. sparsa* were some of the species commonly attacking on a number of plants belonging to *Solanaceae* plants and some of the cucurbits. They further reported that the peak period of infestation varies with region however in July-August the population of these insects remains at peak.

Sontakke *et al.* (1989) while studying the effect of climatic factors on the phenology of foliage pests of potato in Orissa (India) during the *Kharif* and *Rabi* seasons of 1983-84 and 1984-85, reported that potato crop was attacked by the aphids *A. gossypii* and *M. persicae*; *Chalaenosoma metallicum*, *Amrasca biguttula*, *Henosepilachna viginctioctopunctata*, *Thrips flavus*, *Polyphagotarsonemus latus* and *A. ipsilon*,in both seasons. However, the phenology of the pests and the intensity of their attack varied considerably with seasons and regions. The correlation analysis between various environmental factors and the incidence of the different pest species during *Kharif* season revealed that temperature might have a positive correlation with the incidence of most of the insect pests, except *A. ipsilon*. The population development of *A. ipsilon* had significant influence of day temperature during the *rabi*season.

Ewell *et al.* (1990) reported *Premnotrypes* spp., *Phthorimaea operculella*, *Symmetrischema* and *plaesiosema Liriomyza* as major insect pests of potato in the costal regions and highlands of Peruand Canete valley.

Lal (1990) reported the infestation of *Agrotis ipsilon* (Ratt), white grubs (*Lachnosterna coriacea* Hope), leaf-eating caterpillars (*Prodenia litura* Fab.), *Heliothis armigera* (Hubn.) and *Myzus persicae* (Sulzer) in the North-eastern regions of India. Further, the infestation of potato tuber moth (*Phthorimaea opercullela* Zeller) was observed exclusively in Meghalaya, where it damaged both plant (~50 percent) and indigenously stored tubers. Infestation of *Henosepilachna vigintioctopunctata* was severely damaging in Assam (~55 percent) and Arunachal Pradesh (~70%). In Tripura, the infestation mole cricket (*Gryllotalpa Africana*) led to 20-30 percent damage to young plants. In some parts of Meghalaya and Arunachal the infestation of red ants (*Dorylus orientalis*) was prevalent which caused about 37 percent and 20 percent damage in potato tubers, respectively.

Zaki and Masoodi (1990) reported a total of fifteen insect pests affecting both above and below ground parts of potato plant. They also reported that soil inhabiting insect pests is the major cause of damage in potato fields of the Kashmir valley.

In 1990, Learmonth and Matthiessen identified *Graphognathus leucoloma* and *Heteronychus arator* as major insect pests of potato in Western Australia. In addition to these, *Atrichonotus taeniatulus*, *Phlyctinus callosus*, *Otiorhynchus cribricollis* and *Pantomorus cervinus* were also identified as minor pests.

Singh (1990) reported the attack of aphids, jassids, cutworms, termites, white grubs, leaf eating caterpillars and beetles in potato fields and potato tuber moth larvae in storage, causing severe damage and loss in hilly regions of Uttar Pradesh.

In a population dynamics study of *Myzus persicae* at the different stages of potato crop, Trivedi and Verma (1990) reported that the population of *M. persicae* significantly differs at 27^{th}, 38^{th} and 50^{th} day whereas the difference in the population in a 63 and 69 day old potato crop was insignificant. Thus results indicated there could present a correlation between the stage of crop and landing, settling and population build-up of aphids on potato.

Tiwari *et al.* (1991) reported a total of 47 species of white grub in the hilly regions of Himachal Pradesh. Interestingly, nineteen species which also included *Brahmina coracea, Popillia cyanea* and *Xylotropes gideon* were reported for the first time.

Lloyd (1922) observed the occurrence of first adult of *T. vaporariorum* in chestnut in the beginning of July in Lea Valley and wondered if this species could survive mild winter outdoors. He further stated that eggs and adults could withstand in the considerable cold as compared to the intermediate stages. Further, during severe winters the eggs and feeding larvae dies causing reduction in whitefly population.

Misra *et al.* (1992) reported a positive correlation between the population of cutworm larvae and damage of potato tubers. Further, he reported that population of 2.5 larvae per plant might responsible for highest damage and yield losses. In a 10 m^2 plot economic threshold levels (ETLs) of *A. segetum* for table and seed crops were 2.88 and 1.20 larvae, respectively.

In a study Waliullah (1992) observed the infestation of several ecto- and endo-parasitic nematodes (*Basirolaimus indicus, Helicotylenchus* spp., *Pratylenchus* spp. *Trichodorus* spp., *Tylenchorhynchus* spp. and *Tylenchorhynchus mashhoodi*) in potato crops in different regions of Kashmir valley.

In Uttar Pradesh, Mishra and Singh (1993) reported that the adults of *H. longipennis* emerge began at the end of May peaking at the 2^{nd} week of June. The eggs and 1^{st} instar could be seen during June- July. The tuber damage due to 2^{nd} and 3^{rd} instar could be seen by the end of July and during mid-August, respectively.

Rodri *et al.* (1993) surveyed Costa Rica filed and identified a total of fifty insect pests' species infesting on potato crop. The major damage of potato crop was caused by

Phthorimaea operculella and *Scrobipalposis solanivora*. Further, *Phthorimaea* spp., followed by *Phyllophaga* spp. and *Epicaerus* species were found most destructive for potato tubers.

Parihar *et al.* (1994) demonstrated a severe damage in potato tubers due to the infestation of *Agriotes* spp., *Agrotis ipsilon* and *Lygus* spp. in Lahaul and Spiti region of Himachal Pradesh.

In north-western hills of Himachal Pradesh *Holotrichia coriacea* was identified as predominant insect pest among several other reported species insect pests of potato crop, by Mishra (1995). The damage to potato tubers was ranging from fifteen to eighty percent on the weight basis. In the same year Parihar *et al.* (1995) identified nine new species of insect pest damaging potato crop, in Himachal Pradesh.

Roux and Baumgärtner (1995), used pheromone traps to monitor the incidence of *Phthorimaea operculella* (Zeller) between 1986 and 1991 in the potato fields of Tunisia. With the help of time-series analysis they concluded that the coincidence of social events with harvest practices were responsible for the relatively high number caught in 1986. In the subsequent years, the pheromone catches gradually decreased. To eliminate this trend a linear model was used by them. A study of seasonality revealed a peak at the beginning of June and another increase in mid-June leading to high catches beyond the period of spring potato crops. By means of a spectral analysis, a four-week cycle, presumably influenced by the moon, and a ten week cycle, due to unknown causes, were identified. Furthermore, an annual cycle was found to be related with increasing population densities in spring *i.e.* the harvest time of the main-season potato crop.

Seyedoleslami and Naderi (1995) in Iran studied the populations of *Thrips tabaci*, *Empoasca decipiens* and *Trioza* spp. and common arthropod predators during 1985 and 1988. Cicadellids and psyllids had two distinct activity peak periods. The 1st one beings from early June to late July and the 2nd from late July to late September. The relative density of thrips was high from early June to late July and parasitism of adult cicadellids was synchronised with a peak in their activity. It was noted that predators were most abundant in June and July where *Trioza* spp. was more common on a few new potato varieties.

Chandel *et al.* (1996) identified white grubs (*H. longipennis*)as a major species of insect pests infesting potato in Lahaul valley of Himachal Pradesh.

To monitor and identify major insect pests of potato in the lowlands of Selangor (Malaysia) Fauziah and Siti (1996) conducted a series of field experiments in 1993-94. They observed the highest population of mite (>43,000/100 shoots/plot) followed by whiteflies, aphids and thrips. They furthermore demonstrated that yellow-sticky trap helps in the monitoring the greater number of whiteflies followed by leaf miner, leaf hopper, aphids and potato flea beetle.

A total of 34 species belonging to eight orders of insect pests which also included one mite species were reported by Nandhihalli *et al.* (1996) in Hassan, Karnataka. These all were associated to potato damage.

Pernal *et al.* (1996) observed that potato flea beetles exhibit preference for feeding in specific portions of potato plants. The pattern of feeding changes in response of metrological conditions. Thus counting, feeding and punctures would not be a reliable method of assessing whether control measures for potato flea beetles.

A total of eighteen insect and non-insect pests including nematodes were reported by Peter (1996). These pests were damaging both above and below ground parts of the potato crop. The insect pests included aphids, Andean potato weevil, blister beetle, cutworm, flea beetle, leaf miner flies, leaf beetles, leafhoppers, potato tuberworm, thrips, wireworm, white grub and whiteflies.

Min *et al.* (1997) while investigating the occurrence of major insect pests on seven recommended cultivars of potato from Korea observed *Myzus persicae*, *Macrosiphum euphorbiae* and *Spodoptera exigua* as major destructive insect pest of potato crops where as *Selatosomus puncticollis* was found destructive to tubers.

Verma *et al.* (1998) after field experiments at C.P.R.S. Modipuram, Meerut reported the appearance of *Myzus persicae* on the unprotected potato crop 35 days after planting. They also reported that *Myzus persicae* was not serving as an efficient vector of Potato Virus-Y (PVY) and Potato Leafroll Virus (PLRV).

Chandla *et al.* (2001) observed serious attack of various insect pests in the potato field of Fagu village of Shimla. They demonstrated that recorded that sandy loam soil with loose texture, lower elevation and rainy weather favoured activity of *Lachnosterna coriacea* in the potato fields leading to considerable damage to the crop.

Dharpure (2002a and b) conducted a survey in Madhya Pradesh and identified a total of 28 pest species attacking potato crops. Interestingly, attack of *Bagrada cruciferarum*, *Thrips palmi*, *Scirtothrips dorsalis* and *Haplothrips* spp. on potato crop was reported vary first time and among these *Bagrada cruciferarum* was serious insect pest damaging to the potato crop.

Konar and Mohasin (2002) reported the variations in the incidence of Epilachna beetle at different locations of West Bengal and concluded that incidence and damage of insect pests varies with the prevailing environmental factors.

Singh (2002) reported that in India the potato yield is adversely affected with the incidence of a number of insect pests which includes mainly: wireworms, white grub, aphids, potato tuber moth and cutworm. He further elaborated that in the spring crops incidence of cutworms and potato peach aphid was most devastating.

Chandel and Chandla (2003) reviewed that more than hundred insects attack on potato crop causing a considerable damage to potato production and various complex problems to farmers. The insect pests may damage potato plants by feeding on leaves, reducing photosynthetic area and efficiency by attacking stems, weakening plants and inhibiting nutrient transport and also by attacking potato tubers destined for consumption or use as seed. Among non-insect pests, snails, slugs and nematodes cause economic losses, the nematodes being more harmful than molluscs.

With a study on the population dynamics of potato white grub in the hills of Shimla district (Himachal Pradesh) Chandel *et al.* (2003) demonstrated the prevalence *Brahmina coriaceae*. During the month of July they observed pupae in the soil of potato fields whereas the adults and eggs were observed during the period of May to July. The larvae were observed after last week of July. The damaging stage (3^{rd} instar) was significantly prevalent between September and October months. After overwinter (in earthen cells up to April) the adults start emerging in May which sometimes continues up to the mid of June.

Chib and Malik (2003) identified the leaf hopper as a serious insect pest of potato crop, which, even with relatively low numbers could lead to substantial yield losses.

Garg *et al.* (2003) studied the impact of aphid population on the potato crops in the Leh and Ladakh region of Jammu & Kashmir. They reported heavy deterioration of potato crop which was marked with the foliar symptoms of mosaics, wavy leaf margins and leaf roll at majority of locations.

Mogahed (2003) with his field experiments at north Sinai Governorate (Egypt) demonstrated a considerable yield improvement in potato tubers and reduction in the incidence of cotton whitefly, cotton thrips, potato leaf aphids and potato leaf hoppers in the potato crops can be achived when intercropped with garlic and onion.

Singh *et al.* (2003) reported the copiousness of 33 species of white grub belonging to eight sub-families on 51 host plants including potato crop during 1996-97 in the Garhwal district of Uttranchal.

Kumar (2004) surveyed the insect pests of agricultural importance in high altitude arid temperate regions of north western Himalayas and identified several species of insect pests on almost all the crops. Most of these species commonly occurred in plains and low hilly areas as well. However, he reported that potato crops were mainly infested by cutworms (*Agrotis* spp.) and different species of white grubs.

Singh *et al.* (2004) conducted a study at sixteen different locations in Uttarakhand to access the nature and extent of damage on fifteen rainy season crops caused by insects. They reported that *H. longipennis* larvaefeed on live roots and cause stunted growth, yellowing and wilting. This insect pest severely damages the potato tubers even though the contrasting damage symptoms are not visible on the foliar parts. The extent of damage reported to be: 2.28-12.62, 5.67-65.16 and 4.96-62.92 percent in very high hills, high hills and mid hills, respectively.

Lakra (2005) monitored high and medium incidence of apical leaf curl, *Bemisia tabaciAmrasca biguttula* in October and November sown crops, respectively. Further, the incidence of *M. persicae*, early blight, leaf roll and mosaic virus was very serious that it led to almost 30 percent of yield loss.

Pandey (2007) reported that among various pests of potato crop such as cutworms, white grubs, potato tuber moth and cyst nematodes the incidence of aphids and leaf hoppers are most devastating since they are the vectors for number of viruses and mycoplasma. He further reported that cyst nematodes were curbed to the southern hills of Shimla (H.P.), only.

In the array of identifying the species complex of wireworms, timing of injury to potatoes and to evaluate the efficacy of various soil-applied insecticides alone or in combination for wireworm control Kuhar *et al.* (2008) conducted a study from 2002 to 2005 on the Eastern Shore of Virginia. It was reported that cornfield wireworm (*Melanotus communis* Gyllenhal), was the dominant species found in potato fields accounting for roughly eighty percent of individuals collected whereas *Conoderus lividus* (De Geer) and *Conoderus vespertinus* (Fabricius) comprised the remaining 20 percent of wireworm specimens found. Wireworms were most apparent on or near potato seed in late April and were detected less frequently near potato plants over time as the season advanced into July. Most wireworm damage to potato tubers, however, occurred late in the potato crop season (after mid-June). There was a reported significant positive relationship between tuber size and percentage of wireworm damage, by them.

Waliullah (2007) reported that field rats also lead to a substantial damage and yield loss in potato tubers and seed production.

Kamano and Mbata (2008) used diagonal 20-point observation method to check the incidence and abundance of insect pests of potatoes in the Fouta Djallon region of Guinea. They observed the infestation of mainly: potato tuber moth {*Phythorimmaea opercullele* (22.7%)}, variegated grasshopper {*Zonocerus variegatus* (14.8%)}, noctuid moths {*Agrotis ipsilon* (13.2%)}, *Helicoverpa* spp. (9.2%) and whiteflies {*Bemisia tabaci* (12.0%)}. In some plant key symptoms of viral infection were also been observed.

In Syria, during the year of 2006-07 Omar *et al.* (2008) studied the population dynamics of aphids and viral diseases on potatoes. They reported that the population of aphids increased in autumn which reached to peak in spring. During the autumn of 2006, in the potato fields of Aleppo and Hamma the population density tend to increase from mid of October to early November. Further, during spring 2007, the population was higher in the mid of April (just after sprouting) which later diminished by late May. The infection of virus could be seen in both of the seasons. They identified a total of thirteen genera of aphid species where *M. persicae*, *A. gossypii* and *A. fabae* were most severe among all.

Vallejo and Moron (2008) described the immature and adults of both sex stages of a white grub namely *Ancognatha scarabaeoides*. They found the association of 3^{rd} instar larva with higher potato crop damage.

Basavaraju *et al.* (2009) estimated yield losses of potato crop (cropping season 2004-2005) caused by the infestation of major insect and mite pests in the Madenur and Beekanahalli regions of Karnataka. They further, reported three and six percent yield loss led by the infestation of *M. persicae* at Madenur and Beekanahalli, respectively. *Spodoptera litura* headed to eight and four percent of yield loss at Madenur and Beekanahalli, respectively. Furthermore, at Madenur and Beekanahalli the yield loss due potato tuber moth(*Phthoremaea operculella*)were six to nine percent, respectively.

Khan *et al.* (2009) reported that spring tails (*Sinella curvista*), cutworm (*A. ipsilon*), white grub (*Brahmina coriacea* and *H. longipennis*), green peach aphid (*M. persicae*), root knot (*M. hapla*) and root lesion nematode (*Pratylenchus* spp.) lead to heavy yield losses in potato in Kashmir valley.

Khanal *et al.* (2012) studied the abundance and distribution of white grubs in three districts of Nepal namely Makawanpur, Tanahu and Chitwan, during June-July 2010. For assessing the activity of scarab beetles flight they installed two light traps for two nights in two locations of each of the districts and a season long light trap at Chitwan district from April to September 2010. They noted that the species composition of scarab beetles in these three districts were different. However, the most rampant species of scarab beetles in Chitwan were *Anomala dimidiata* (24%) *Maladera affinis* (23.75%), *A. varicolor* (23%), *Heteronychus lioderus* (14%) and *Holotrichia* spp.

Kumar *et al.* (2012) invested the influence of weather parameters on the efficiency of pheromone trap catches of *S. litura* in the Bengaluru district, Karnataka. The study shown that the efficiency of the pheromone traps, lures and the activity of the pest directly depends on several weather factors especially maximum and minimum temperatures, evaporation as well as wind speed. This exhibits a positive effect on the trap catches and percent defoliation caused by the pest. Furthermore it was observed that difference in trap catches was insignificant; however there was reported significant difference in moth catches during weeks and their interactions. It was also reported that trap catches lowered the damage caused by the insect.

Attack of more than hundered species of insect pests such as white grubs, cutworms, potato tuber moth, termites, red ants and mole crickets on potato tubers was identified by Chandel *et al.* (2013). Their study revealed that damage due to sap-feeding insects such as aphids, leafhoppers, thrips and white files was by directly feeding on different parts of a plant and acting as vectors of plant viruses. Being a vector of viruses such as PLRV, PVY and Gemini virus aphids and whiteflies constitute a major threat to the potato seed production. Order Lepidoptera and Coleoptera were the major foliar feeders those were damaging the potato plants. Among coleopterans, the most destructive pests are hadda beetle, flea beetle, blister beetle and chaffer beetles. Beside these *Spodoptera* spp., *H. armigera*, *Plusia orichalcea* and *Spilosoma obliqua* were the important leaf-feeding caterpillars of potato fields.

In the array of understanding the distribution and seasonal abundance potato tuber moth (PTM) in Nepal, Giri *et al.* (2014) conducted an annual monitoring of fifteen districts of Nepal during 2008-09. For this purpose they installed locally made pheromone traps and the observations were taken in every 24 hour intervals. The activity of PTM was observed in plains, mid hills and high hill districts. The population of PTM was found more in mid-hills than in plain whereas PTM was totally absent in high hill districts of Nepal. The highest average number of PTM was observed in May (480±238 moth/month) with no adult moths in October to December in plain whereas 522±174 moth/month was observed in July and 18±4 moth/month in December in mid-hills of Nepal. The seasonal abundance of PTM observed from March to July (74±63 to 126±100 moth/month) in Plain and March to October (191±157 to 104±60 moth/month) in mid-hills. The understanding of PTM population dynamics could be useful to make suitable management decision.

D'Auria *et al.* (2016) reported the incidence of potato tuberworm (*Phthorimaea operculella* Zeller), beet leafhopper (*Circulifer tenellus* Baker) and green peach aphid (*M. persicae*) on the potato crops at Washington State, USA. Each of these pests were responsible for the direct mutilated potato foliage and/or tubers. *C. tenellus* and *M. persicae* also transmitted the viruses that can significantly reduce potato yields.

Masetti *et al.* (2015) identified the *Phthorimaea operculella* (Zeller) as key pest of potato in tropical and subtropical regions of Italy and investigated its temporal and spatial dynamics. With the combination of geostatistical maps and georeferenced pheromone-baited traps they scrutinized the moth for over three years (2009–2011). Pheromone trapping, integrated with temperature-dependent developmental times, showed that PTW completed two generations throughout the potato-growing season; the remaining generations developed in the non-crop season. Maps showed a clumped distribution of PTW at the landscape scale. The hot spots of infestation corresponded to the area most intensively cropped with potato. Trap catches from hilling to harvesting were linearly and positively correlated with the percentage of damage in two out of three years and in the pooled data set. The present study demonstrated the widening of PTW areal to Northern Italy. They concluded that georeferenced pheromone traps could be a useful monitoring technique for describing the phenology and distribution of PTW, thus providing crucial knowledge for the rational management of this pest.

Castillo *et al.* (2016) demonstrated that bittersweet nightshade (*Solanum dulcamara* L.) is key non-crop host of the potato psyllid (*Bactericera cockerelli* Šulc) and could be a source of the psyllids that colonize potato (*Solanum tuberosum* L.) fields in the north-western United States. Furthermore, aphid, beetle, and thrips pests of potato also were collected on bittersweet nightshade by them.

2.2 MANAGEMENT STRATEGIES

2.2.1 Chemical Control

In New Jersey, Ginsburg *et al.* (1935) used completely refined petroleum distillate on a large number of greenhouse plants infested with several species of insects. He reported that the oils with pyrethrum extract equivalent to 1/2 lb flowers to 1 U.S. gallon killed *T. vaporariorum* on apple within 48 hours, surprisingly.

Mote (1978) used the agricultural spray oil (0.2 percent) alone and in combination with six insecticides against *B. tabaci*. The agricultural spray oil (0.2%) alone was found to give relatively good control on the *B. tabaci* rather than in combination with parathion (0.03%), malathion (0.05%), dimethoate (0.05%), monocrotophos (0.05%) and ambithion (a mixture of fenitrothion and malathion) (0.05%).

Semyanov *et al.* (1981) conducted an experiment for the control of insect pests of potato in Lithuania (USSR). The pests belonging to 3 groups, sucking pests, leaf eating pests and soil pests among which *Aphis naturtii* and *A. gossypii* were accounting more than 90 percent of aphid population. They demonstrated that Pre-sowing soil treatments with dust containing pirimicarb (Pirimor) and menazon (Sayfos) against these pests helped in increasing yield by eighteen percent over untreated check.

Blank (1987) worked out for estimating suitable threshold level of insecticides for the control of *T. vaporariorum* on tomarillos (*Cyphomandra betacea*) by spraying a mixture of deltamethrin (Decis 2.5 EC at 0.6 g a.i./100 lit) and mineral oil (Sunspray 96 EC, 300 g a.i./100 lit) and demonstrated that the threshold of 20 adults/ leaf would require twelve spray applications at an interval of eight days.

Baxendale and Johnson (1988) used three percent narrow range oil to control the whiteflies on New England aster and summer phlox.

Golberg *et al.* (1989) studied the efficiency of heptachlor with other insecticides in controlling the damages to potato crop caused by *Maladera matrida* in Besor region of southern part of Israel. The best outcomes were achieved with heptachlor (97.3 percent clean tubers) and with the synthetic pyrethroid namely Talstar (bifenthrin) (91.1 percent clean tubers).

Mimms and Vittum, (1990) demonstrated that narrow range oils (Sunspray 6E) on poinsettia reportedly produces phytotoxic symptoms on ‘Supjibi’ plants and did not reduce greenhouse whitefly numbers below marketable levels.

Larew and Locke (1990) investigated the efficiency of Sunspray 6E plus (a petroleum based horticultrural oil) against *T. vaporariorum* infested on glasshouse grown chrysanthemum. As a result they reported that two percent aqueous spray repel adults for at least eleven days after spraying and was toxic to newly hatched and 3rd instar larvae. Furthermore, no phototoxicity was reported when four weekly sprays of 1.2 and 4 percent oil were applied.

Impact of cotton seed oil (natural oil) against spider mites, aphids and whiteflies infesting on number of vegetable crops was investigated by Butler and Henneberry (1990) and reported some phytotoxicity on cucurbits and crucifers.

Blank *et al.* (1991) tested the effectiveness of buprofezin (6.25 g a.i./100 lit), deltamethrin plus oil (Decis 0.6 g a.i./ 100 lit) and Sunspray mineral oil (0.03 percent) against greenhouse whiteflies on tomarillo and got significantly positive results.

Liu *et al.* (1993) in their study reported that aldicarb was more space efficient as compare to bifenthrin and endosulfan and headed to more mortality of immature stages after four weeks of application.

Imidacloprid (Gaucho 70 WS and Gaucho 350) was tested by Pawinska and Turska (1995) for its efficiency of controlling aphids and colorado beetles (*Leptinotarsa decemlineata*) in the potato fields. As a result Imidacloprid was found highly effective against aphids and Colorado beetles (eggs, larvae and adults) in both dry and wet seasons. Furthermore, it also lowered the infection of potato leaf roll virus.

Riedl *et al.*, (1995) demonstrated that horticultural mineral oils works as ovicides against the codling moth [*Cydia pomonella* (L.)] when applied directly to the eggs. It was also reported that the susceptibility of eggs to the oil varies depending on the substrate on which eggs were laid. Furthermore, it was seen that topical treatment of neonates and adults caused no mortality at concentrations equivalent to field rates. Oil residue on the fruit surface did not inhibit neonates from entering fruit tissue. Interestingly, it was observed that female moths avoid fruit surface with oil residue for oviposition.

Angelini *et al.* (1997) reviewed that some new insecticides have been used by various workers for the control of whitefly. Imidacloprid, a new insecticide found to act on nervous system of insects with different mode of action than that of traditional neurotoxic products, has been reported to be effective against pests with piercing, sucking and chewing mouthparts.

Hernandez *et al.* (1999) demonstrate the outstanding performance of Confidor 200 SL (imidacloprid) against aleyerodids and aphids in vegetable crops and suggested that it can be useful during integrated pest control as the application (even *via* the irrigation system) and does not harm the bees used for pollination

Singh *et al.* (2000) compared the control of insect complex of tomato by conventional synthetic pesticides and petroleum spray oils. They found that one percent oil treatment is much more effective than that of conventional pesticide treatment for controlling budworm, *Helicoverpa* spp., aphid (*M. persicae* and *T. vaporariorum*) and spotted mite.

Zabel *et al.* (2001) compared the efficacy of Mospilan 20 SP with Lannate 90 SL (methomyl) and Applaud 25 WP (buprofezin) and found that all insecticides significantly decrease the number of whitefly nymphs.

Mishra (2001) determined the effectiveness of some insecticides against white grub (*H. longipennis*) on potato cv. Kufri jyoti and revealed that chlorpyrifos was the most effective followed by quinalphos and phorate.

CIPC (Isopropyl N-(3-chlorophenyl) carbamate) is a sprout suppressant commonly used on ware potatoes in Country stores. But beside suppression of sprouts. CIPC was found to reduce PTM infestation. Chandla *et al.* (2003) recorded only two to six percent tuber damage in the country stores after the period of sixty days of incubation.

Syed *et al.* (2005) conducted an experiment to uncover the efficacy of different chemical insecticides against *Myzus persicae* (Homoptera: Aphididae) on tobacco crop at Pakistan Tobacco research station, Khan Ghari, Mardan and NWFP-Pakistan. Results showed that lowest mean pupation of aphid/leaf was recorded with confidor (20 aphid/leaf) and actara

(18 aphid/leaf) treated plots, while highest mean population of aphid per leaf was recorded with methomyl (42 aphid/leaf) and tracer (39 aphid/leaf). Significant differences were not found in plant height (cm), number of leaves counted and fin leaf area (cm^2) among the different treatments. Yield of tobacco was highest (2253.0 kg/ha) with confidor application, while lowest (1732.0 kg/ha) in Sundaphos treatment.

Niroula and Vaidya (2004) reviewed that three plant species, viz. *Lantana camara*Linn.,*Eucalyptus globulus* L. Herit. and*Minthostachys* spp. either dried/shredded leaves or powder form are effective in preventing PTM damage to potatoes stored for four months in country stores. In India, out of the several plant species tested against PTM; *Lantana aculeata* L. provides the best protection by reducing PTM damage from seventy percent to below the five percent. Likewise, sprout damage can also be reduce from 45 percent to below 3 percent. They used three concentrations — 0.05 percent (w/w), 0.5 percent (w/w) and 5 percent (w/w) and all the concentrations of *L. neesiana* and *A. calamus* were found effective in PTM control. *L. neesiana* showed 66.7 percent, 70.0 percent and 83.3 percent and *A. calamus* showed 56.7 percent, 66.7 percent and 70 percent adult mortality.

Moawad and Ebadah (2007) tested four natural plant oils (Margorum, Cardamon, Rosemary and Terpintin) against different growth stages of PTM. The 0.02 and 0.05 percent concentrations of cardamon oils exhibited the best reduction in percentage of eggs hatchability (67.47 and 86.74 percent). Dusting potato tuber by 1.5 percent concentrations of cardamom and rosemary oils elicited the lowest percentage of larval penetration, pupation and adult emergence.

In the array of uncovering the efficacy of several conventional standard insecticide as well as several new IPM-compatible insecticides for control of lepidopteran pests in collards Cordero *et al.* (2006) conducted field efficacy tests during 2003 and 2004 at two different locations of Virginia. This experiment included acephate, emamectin benzoate, esfenvalerate, methomyl, methoxyfenozide, novaluron, indoxacarb and spinosad. Among these, acetamiprid, *Bacillus thuringiensis* subsp. *kurstaki*, and azadirachtin showed greater efficacy against lepidopteran pests. Further, indoxacarb, spinosad, novaluron, emamectin benzoate, and methoxyfenozide were identified as insecticide that may provide reliable control over lepidopteran pests that attack collards and are are relatively less toxic to natural enemies and thus can fit well into integrated pest management programs include.

Kuhar *et al.* (2008) with results from an experiment on several insecticide efficacy on insect pests of potatoes demonstrated that fipronil, imidacloprid, thiamethoxam, and bifenthrin applied to the soil at planting provide similar wireworm control (50–80 percent) to that of the organophosphate standards, phorate, and ethoprop. Combinations of imidacloprid or thiamethoxam with fipronil or bifenthrin did not enhance the efficacy of any one of them used alone. The aforementioned products provide much needed alternative insecticide modes of action for wireworm control in potatoes and perhaps other crops in the future.

Ahmad *et al.* (2009) suggested that mixture of insecticides can delay the development of resistance in *Spodoptera litura* (F.) more effectively than sequences or rotations. They assessed cypermethrin, deltamethrin, profenofos, chlorpyrifos and fipronil separately and in mixtures against laboratory susceptible *Spodoptera litura* and two field-collected populations. The field-collected population from Khanewal (KWL) was significantly more resistant to cypermethrin, deltamethrin, chlorpyrifos and profenofos than one collected from Muzaffar Garh (MGH). Mixtures of cypermethrin + chlorpyrifos or profenofos and of deltamethrin + chlorpyrifos or profenofos at 1:1, 1:10 and 1:20 ratios significantly increased ($P < 0.01$) toxicity to cypermethrin and deltamethrin in field populations. The combination indices of cypermethrin + chlorpyrifos at 1:1 and 1:10 ratios and cypermethrin + fipronil at 1:1, 1:10 and 1:20 ratios for the KWL strain and of cypermethrin + profenofos or fipronil at 1:1, 1:10 and 1:20 ratios for MGH were significantly below 1, suggesting synergistic interactions. The inhibitors DEF and PBO largely overcame resistance to deltamethrin, cypermethrin and profenofos, suggesting that resistance to the insecticides was associated with esterase and monooxygenase detoxification respectively. Chlorpyrifos, profenofos and fipronil could be used in mixtures to restore cypermethrin and deltamethrin susceptibility. These findings may have considerable practical implications for *S. litura* resistance management.

Saljoqi *et al*. (2009) studied integrated management of potato-peach aphid, *Myzus persicae* (Sulzer). Different treatments including, imidacloprid 25% WP, Tracer 240 EC, Acetamaprid 20 SP, potato berseem mixed cropping with or without yellow sticky plastic sheet and potato + yellow traps were evaluated for their effectiveness. Among all the treatments mixed cropping of potato and berseem together with or without yellow sticky plastic sheet traps was found most effective in reducing the population density of *M. persicae i.e.* 1.92 aphid per potato leaf and imidacloprid 25% WP, Acetamaprid 20 SP and Tracer 240 EC were ranked next to potato berseem mixed cropping (with or without yellow traps) in reducing the population density of *M. persicae* to 2.01, 2.01 and 2.07 aphid per potato leaf, respectively.

Zydenbos (2010) conducted a trial which included foliar applications of eleven insecticides and one soil-applied insecticide which were tested in potted plants targeting crawlers and young nymphs of Australian citrus whitefly. Ten weeks after application, diazinon, endosulfan and a soil application of imidacloprid had reduced infestations to nil. Other effective products after 12 weeks were bifenthrin, spirotetramat, pyrethrin, buprofezin, azadirachtin, maldison, pyriproxifen and mineral oil.

Sharma and Singh (2012) revealed that neem based formulations *viz.*, 1.5% Neem Gold, 1.5% Multineem, 1.0% Neem Gold and 1.5% Neemarin can be used successfully in managing the whitefly population. Among neem based tested formulations *viz.*, 1.5% Neem Gold (94.7%), 1.5% Multineema (91.8%), 1% Neem Gold (91.1%) and 1.5% neemarin (90.6%) led to significant reduction in the whiteflies', while other chemical except dicofol, provided moderate level of whitefly control.

Bhatnagar (2013) studied the effect of conventional insecticides on incidence and succession of thrips (*T. palmi*), potato aphid (*M. persicae*), leafhopper (*A. biguttula*), whitefly (*B. tabaci*) and cutworm (*A. epsilon*) associated with potato variety *Kufri Pukhraj* along with other yield attributes. The treatment, application of phorate 10G (15 kg ha^{-1}) at the time of planting followed by drenching of ridges with imidacloprid 17.8 SL (4 ml 10 lit^{-1} of water) at 45 and 55 days old potato crop proved highly effective in reducing the vector population on potato plants as compared to untreated plot.

More *et al*. (2015) observed that three foliar applications of spiromesifen 240 SC (8ml) as first spray at the time of plant emergence, followed by second spray of thiamethoxam 25 WG (3 g) and third spray of spiromesifen 240 SC (8 ml 10 lit^{-1}) of water at 15 days interval reduced the population of jassids and whitefly, while seed treatment with imidacloprid 200 SL (4ml/10 litre of water) for 10 minutes, first foliar spray with imidacloprid 17.8 SL (2.5ml) at emergence and second spray with thiamethoxam 25 WG (3 g/ 10 litre of water) after 15 days of first 19 spray reduced the population of aphids on potato.

2.2.2 Natural enemies

Broscus punctatus Dist. and *Liogryllus bimaculatus* Linn.were reported to be efficient larval parasitoids of cutworm by Fletcher (1916). He further suggested its use in the population control of cutworm.

Nair & Rao (1972), in Karnataka, reported indigenous parasitoids like *Chelonus curvimaculatus* Cameron, *Bracon gelechiae* Asheamd, *Apanteles* spp., *Pristomerus vulnerator* Panzer and several other braconids. These were reported to cause four to seventeen percent parasitisation of potato tuber moth (PTM) under field conditions.

Dalaya and Patil (1973) reported that *Copidosoma koehleri* Blanchard which is an exotic egg/larval parasitoid can parasitize 28.4-60.8 percent potato tuber moth. Thus may prove useful in controlling the population of PTM under field conditions.

Azam *et al.* (1974) reported a chalcid parasitoid, *Ugna menoni* Kerrich on *Helicoverpa vigintioctopuncta* from Andhra Pradesh.

Verma *et al.* (1976) identified the maximum (100%) capability of *Aphelinus* of parasitizing *Myzus persicae,* alone.

Diwakar and Pawar (1979), conducted a study on the efficacy of a larval parasitoid namely *Bracon hebator* Say against PTM and by releasing in field under natural conditions in Banglore. As a result they registered twelve percent parasitisation of the larvae under field conditions. Further, they recorded eleven important species of parasitoids from Bangalore on *Helicoverpa armigera*. Among ichnemonids, *Campoletis chlorideae* Uchida, Eriborus sp. and *Xanthopimia punctata* Fabr. ; In braconids, *Bracon hebetor* Say, *B. greeni* Ashm. and Apanteles spp. ; in bathylid *Goniozu* (*Parasierola*) spp., in trichogrammatid, *Trichogramma chilonis* Westwood; in tachinids, *Carcelia illota* Curq., *Palexorista laxa* Curr. and *Goniophthalmus halli* Mesnil and among mermithid *Hexmerimis* spp. were found to be most effective.

Saxena and Raj (1980) observed 2.5 to 5.0 percent parasitisation of PTM larvae with *Melanips* spp. and *Diadgma molliplum* (Holmgren) in Shimla hills.

Saxena and Singh (1982) identified three larval parasites (hymenopterons, *Chelones narayani* Gupta, *Horogene fenestralis* Opius and *Ecphoropsis* spp.) of *H. armigera* in Bihar. Further it was reported that the predators of *H. armigera* and *P. orichalcea* including Chrysopa spp. feed on the eggs, while *Micromius nilghiriousm* Novas, *Hemerabiuin* *onontanus* Kimmins, *Henricohania spinosa* Dist. and *Sphedanolestes variabillis* feed on the larvae.

Chaudhary *et al.*, (1983) tested the efficiency of four ovo-larval parasitoids (*Orgilus jennieae* Muesebeck, *Apanteles subandinus* Blanch, *Chelonus blackburni* Cameron and *C. kellieae* Cameron) in suppressing PTM population at Rajgurunagar (Maharashtra). They registered *O. jennieae* and *A. subandinus* as most effective ovo-larval parasitoids with 59.6 and 16.6 percent parasitization, respectively.

Singh (1988) identified over 24 predators and 22 parasitoids attacking on aphids (*M. persicae*). He further reported that among predoters: *Allograpta favana* (Wiedemnn), *Sphaerophoria indiana*(Bigot), *Leucopis fumidilarva* (Tanas) and *Episyerphus balteatus* (De Geer) and *Menochilus sexmaculatus* (Fabr) and among parasitoids: *Aphelinus* spp. and *Aphidius colemani* (Viereck) were most effective against the aphids. He also reported five entomopathogenic fungi against aphids in Shimla.

Trivedi (1988) conducted an intensive survey between 1984 and 1986 at ten locations of seven districts of Karnataka (Bangalore, Kolar, Hassan, Chickmagalur, Mercara, Dharwar and Belgaum), at monthly intervals. They collected various growth stages of the pests *viz.*, *Myzus persicae* (Sulzer) *Aphis* spp., *Phthorlmaea operculella* ZeU, *Heliothis armigera* Hubn., *Spodoptera litura* Guen., *Agrotis* spp., *Leucinodesorbonalis* Guen., and *Epilachna vigintioctopunctata* Fab. They identified a total of five parasites (*Aphidius colemani* Viereck; *Syrphophagus tachikawai* Hopper; *Apanteles* spp.; *Paraphylox* spp.; *Pedlobius foveolatus* Crawford) and four predators (*Menochflus Sexmaculatus* Fabricius; *Cocclnela septempunctata* Linnaeus; *Hannonia octomaculata* Fabricius; *Episyrphus balteatus* De Geer).

Lal (1993) reported that baculovirus remains effective up to a period of 120 days under storage condition and useful in reducing the damage due to PTM under storage conditions.

Mishra *et al.* (1995) recorded seven species of coccinellids, two of syrphids and a chryopid on potato around Farrukhabad, Agra and Meerut districts of Uttar Pradesh. However, the predominant one were Lady Bird beetle (*Cooccinella septempuncata* Linn.) and *M. sexmaculatus* Fabr.

Gupta *et al.* (1997) stated that the *C. septempunctata* is one of the most dominant enemies to reduce aphid population in the field.

Bacillus thuringiensis, a Gram positive, flagellated, rod-shaped bacterium, which produces a para sporal crystal during sporulation, has been reported to be effective in controlling PTM in Peru, Tunisia, and India (Ranjekaret *et al.*, 2003).

Mote and Bhavikatti (2003) tested biological control agents *Bacillus thuringiensis* (Bt; Delfin 85 WG) at 0.04% and *Trichogramma chilonis* at 60,000/ha and insecticides azadirachtin (Econeem) at 0.0006%, lufenuron (match 5 EC) at 0.005%, avermectin {vertimec (abamectin} at 0.0004%, monocrotophos 36 SL (monocil) at 0.05%, Spark 36 EC (deltamethrin+ triazophos 35) at 0.05%, bulldock star 262.5 EC (beta-cyfluthrin 12.5 + chlorpyrifos 250) at 0.05% and nurelle-D-505, 55 EC (cypermethrin 5 + chlorpyrifos 50) at 0.05% in Rahuri, Maharashtra, India, during the *kharif* season of 2000 against pest complex of aubergine. Treatments with spark and monocrotophos were most effective for controlling the sucking pest populations (including *Bemisia tabaci, Aphis gossypii, Amrasca biguttula biguttula* and *Scirtothrips dorsalis*) followed by Nurelle D-505 and Bulldock star. Treatments lufenuron, vertimec and azadirachtin were moderately effective against the sucking pests. Bt and spark were highly effective against the fruit borer (*Leucinodes orbonalis*) and increased fruit yield.

Yadav and Sharma (2005) conducted field studies to assess the efficacy of bioagents and neem products in relation to Malathion against shoot and fruit borer, *Leucinodes orbonalis* on aubergine. The bioagents and neem products were not superior to Malathion 50 EC (0.05percent), however, *Bacillus thuringiensis* subsp. *kurstaki* (2.5 ml/lit) water provided sufficient control of the pest.

Saljoqi (2009) who reported population dynamics of *C. septempunctata*, and concluded that the natural enemy effectively controls the population of *M. persicae*.

Harischandra *et al.* (2009) studied the bioefficacy of different entomopathogenic fungal formulations *viz.*, crude, wettable powder and oil based formulation of *Beauveria bassiana*, *Metarhizium anisopliae* and *Verticillium lecanii* against sucking pests of okra during *kharif* 2007-08. Oil based formulations of *M. anisopliae* was reported with minimum leaf hopper population of (5.25 leafhopper/3 leaves) followed by *B. bassiana* (6.88 leaf hopper/3leaves) and *V. lecanii* (7.75 leaf hopper/3leaves)

Mandal *et al.* (2010) conducted field experiment at Adisaptagram Block Seed Farm, Government of West Bengal, Hooghly, West Bengal during 2006-07 and 2007-08 to evaluate the efficacy of different doses of NSKE against whitefly (*Bemisia tabaci*) and shoot and fruit borer (*Leucinodes orbonalis*) on brinjal (*Solanum melongena* L.) at different spray schedule. NSKE was found to be the most effective treatment in minimizing the pest population and also recorded maximum yield of brinjal.

Mathur *et al.* (2012) evaluated the efficacy of neem oil (2%), iluppai oil (2%), pongamia oil (2%), combination of iluppai and pongamia oil (1:1) and microbial formulations *viz.*, *Beauveria bassiana* and *Verticillium lecanii* against brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee. The results revealed that oils of *iluppai* and pongamia oil were at par with standard check endosulfan and were found to be significantly superior to microbial formulations and also showed better efficiency than neem oil in the suppression of BSFB infestation. Maximum yield of marketable fruits was obtained using iluppai oil (202.75 q/ha); the percent gain over control was least with *V. lecanii* followed by *B. bassiana*, neem oil, combination of iluppai and pongamia oil, pongamia oil, iluppai oil (77.8%), and maximum with endosulfan (83.3%).

Chapter-III

Hypothesis

CHAPTER-III

HYPOTHESIS

Potato is the only major food crop that suffers from largest number of diseases. It can be affected by approximately 160 diseases and disorders of which 50 are caused by fungi, 10 by bacteria and other by non parasitic pathogens or due to unknown causes (Anon, 1960) and viruses, many of which were transmitted by insect vectors. at least 37 viruses naturally infect cultivated potatoes, out of which 7 viruses are transmitted by aphids, one virus and almost all MLO (Mycoplasma like organism) are transmitted by leaf hoppers, the newly emerging PALCV (Potato apical leaf curl virus) caused by Gemini virus, is transmitted by whiteflies and potato stem necrosis virus caused by tospovirus is transmitted by thrips. It has been demonstrated that about 400 species of insects are involved in transmission of over 200 different plant viruses. Largest number of viruses is transmitted by aphids followed by leaf hoppers and whiteflies.

Change of weather parameters triggered major changes in diversity and abundance of arthropods, geographical distribution of insect pests, population dynamics, insect biotypes, herbivore plant interactions, activity and abundance of natural enemies, species extinction, and efficacy of crop protection technologies. Changes in geographical range and insect abundance will increase the extent of crop losses, and thus, will have a major bearing on crop production and food security. Distribution of insect pests is also be influenced by changes in the cropping patterns triggered by climate change. Major insect pests of potato crop such as aphids, leaf hoppers and whiteflies may move to temperate regions, leading to greater damage in potato crops. Biotic and Abiotic factors will also affect the effectiveness of host plant resistance, natural enemies and synthetic chemicals for pest management. Extensive surveys on population dynamics of aphid were undertaken to search for areas suitable for healthy potato seed production and a sound technology named “Seed Plot Technique’’ had been carved out. The system still constitutes the backbone of healthy seed production in India. Seed production activity is now being extended to new areas with the objective of covering more and more area with healthy seed. The vector population is undergoing major change due to the influence of climate change. Now a complex of vectors is extending their services for the transmission of diseases

Conditions are more favorable for the proliferation of insect pests in warmer climates. Longer growing seasons will enable insects such as grasshoppers to complete a greater number of reproductive cycles during the spring, summer, and autumn. Warmer winter temperatures may also allow larvae to winter-over in areas where they are now limited by cold, thus causing greater infestation during the following crop season. Altered wind patterns may change the spread of wind-borne pests. Crop-pest interactions may shift as the timing of development stages in both hosts and pests is altered. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them, a situation that will require the further development and application of integrated pest management techniques

In the present study I will be able to complete the unfinished task. It will be environmentally safe as well as helpful to the farmers and state governments and those opting for integrated pest management.

Chapter-IV

Aims and Objectives

CHAPTER-IV

AIMS AND OBJECTIVES

4.1 BACKGROUND

Potato is one of the important vegetable crop all over the world. To get better crop, seed are very important gradient so potato seed production need much care and attention to avoid the pest and disease attack which deteriorate the quality and quantity of potato seed production. Insects pest of potato are very severe problem potato seed production which damage the crop directly and indirectly (act as vector of viral and other diseases). Aphids act as vector and spread most disease pathogens followed by Leafhopper and whitefly. Chemical and Biochemical use control the insect pest of crop effectively but also affect the useful insects, microbes and micro climate of crop adversely. Integrated pest management play important role in management of insect pest and facilitate the farmers to grow good quality cost effective potato seed crop. Keeping this view in mind, the current study was designed to evaluate the population dynamics of insect pests of potato in Jalandhar district of Punjab, India, use of various traps to monitor the population of insects and effective combination of chemical and biochemical for insect management in potato seed production crop.

4.2 EXPLANATION

According to the literature surveyed, it is clear that if no protection measure is used against insect pests that create favorable nutritional and environmental conditions for incident of pests in crop. Some of the insects not only damage the crop spread diseases too by serving as a vector for several pathogens. Considerable reduction in total yield with lower quality of potato seed occur in pest infected crop as compared to crop of same varieties/cultivars adopted integrated pest management. Knowledge of life cycle of insect, duration of their occurrence in season, alternate host in off-season and effect of macro and micro environment of region and field on activity, population of insects helps to manage the crop wisely to escape from infestation or incidence of pests. Several previous studies have supported the escape of crop from insect infestation by early or late sowing which is cost effective and ecofriendly mechanism to protect potato seed crop. Proficiently use of cultural practices, various traps, and chemical and biochemical combination improve the quality and yield of potato seed crop. It has been studied previously in many studies that efficacy of chemical and biochemical can be improved by using them in a proper combination. It has also been noticed and observed in past that continuous use of same chemical in a field or area forced insects to develop resistance against that and develop a new race biotype of insect which are difficult to control by contemporaneous chemical or biochemical. So use of chemical or biochemical in alternate manner and in accurate concentration is must to protect the crop as well as micro and macro climate of region.

4.3 AIM AND OBJECTIVES

After understanding the importance of potato seed production in food security and economy of India, impact of various chemical insecticides on both cost of production as well as environment and improving the potato seed production through the knowledge of insect pest population dynamics and IPM the present investigation has been designed with following major objectives:

(i) To study the population dynamics of potato pests with the help of light and pheromone insect traps.

(ii) To test the efficacy of earlier identified and new insect pathogens and plant extracts against potato pests.

(iii) To develop viable IPM schedule involving above components found effective against potato pest complex and demonstrate it in the fields.

(iv) To develop methodology for timely diagnosis and judicious use of insecticides with rotating chemistries.

(v) To study the impact of Climate change on the pest population build-up in potato crop.

Chapter-V

Material and Methods

CHAPTER-V

MATERIALS AND METHODS

The present investigation entitled, "Dynamics of pest complex on potato in Punjab and its integrated management" was carried out in the experimental field of Central Potato Research Station, during *Rabi* 2014-15 and 2015-16 cropping season of potato at Jalandhar, Punjab.

5.1 GEOGRAPHICAL LOCATION AND CLIMATE

Jalandhar is situated at altitude of 748 feet above mean sea level, between 31.32 North latitude and 75.57 East latitude.

Jalandhar has a humid subtropical climate with cool winters and long, hot summers. Out of six agro-climatic regions of Punjab the whole of the Jalandhar lies in the central plain regions. The land of the district is covered by the alluvial deposits of Indus- Ganga. Summers season last from April to June and winters from November to February. Temperatures in the summer vary from average highs of around 48 °C (118 °F) to average lows of around 25 °C (77 °F). Winter temperatures have highs of 19 °C (66 °F) to lows of −1 °C (30 °F). The climate is dry on the whole, except during the brief southwest monsoon season during July and August. The average annual rainfall is about 70 cm.

5.2 EXPERIMENTAL DETAILS

The present Experimental details were as follows for conducting studies on succession of insect complex on potato:

Crop	:	Potato
Variety	:	Kufri Jyoti, Kufri Badshah, Kufri Pukhraj, Kufri Khyati, Kufri Surya
Experimental design	:	Randomized Block Design (Figure: 3.1)
Plot size	:	5.00X4.00 mt.
No. of rows/plot	:	6
Row length	:	4 m
Spacing(Row X Plant)	:	65 cm X 20 cm

Figure 5.1(a): Layout of the experiment conducted to study the efficacy of tested insecticides, biopesticides and plant extract (NKE) during *Rabi* 2014 and 2015

R1	R2	R3
T5	T7	T2
T3	T1	T4
T7	T3	T1
T1	T6	T5
T4	T2	T7
T6	T5	T3
T2	T4	T5

R= Replication; T= Treatment

Figure 5.1(b): Layout of the experiment conducted to study the efficacy of new chemical molecule during *Rabi* 2014 and 2015

R1	R2	R3
T5	T5	T2
T3	T1	T4
T2	T3	T1
T1	T4	T5
T4	T2	T1

Potato Variety: - Kufri Khyati Experimental design:- Random Block Design
R= Replication; T= Treatment

5.3 MATERIAL AND METHODS

5.3.1 Succession of insect pest complex on potato

The observation were recorded periodically from 41st to 51st standard meteorological weeks. For observations, ten plants were randomly selected and different insect pests were recorded per 30 compound leaves. The crop was kept unprotected for this purpose. The sequence in which the insects appeared was also noted.

5.3.2 Pest population dynamics on five potato varieties of potato under net house and open field condition

Trials were conducted in randomized block design with three replications during 2014 and 2015 cropping seasons at CPRS, Jalandhar where healthy seeds of variety *Kufri Jyoti*, *Kufri Badshah*, *Kufri Pukhraj*, *Kufri Khyati* and *Kufri surya* (produced from Central Potato Research Station, Jalandhar) were planted under net house (25 X 20 metre) and in open field condition with same sowing dates and other agronomical practices. The observations were recorded on ten randomly selected plants thrice in a standard week, which were started from the first appearance of the pest and continued till their availability or maturity of the crop.

5.3.3 Relationship between insect pest population and abiotic factors

A Pearson's correlation coefficient was established to study the relationship between population dynamics of various insect pests of potato seeds and abiotic factors *viz.*, temperature, relative humidity, rainfall and duration of day light were recorded. The minimum and maximum temperatures at the experimental area were recorded with the help of a maximum and minimum thermometer. For recording relative humidity, wet and dry bulb thermometers (Pschrometer) were used.

5.3.4 Population monitoring with traps

The population of adults in crop fields was monitored by using pheromone traps, yellow sticky traps and yellow water pan traps. Two sticky traps (30x30 cm) coated with insect trapping adhesive (grease) were placed on an iron stand at one metre height and 10 metre apart in the crop field. In the same field two trays of same dimensions and height, filled 1/3 with water, were placed at 10 meter apart. Such traps were placed in tomato monitoring the adult population. Weekly counts of the trapped adults were taken. The sticky material as well as water was replaced after each count.

5.3.5 Efficacy of insecticides and bio-pesticides

A total of four chemical insecticides, one neem based oil and two microbial insecticides (Table 3.1) were used to test their efficacy by rotating chemistry on the insect pest of the potato seeds. For this a total of seven treatments (T1 to T7) including one control (water) were prepared (Table 3.2) .Every treatment was replicated thrice and the crop was sprayed by using knapsack sprayer. The control plants were sprayed with water. Before spraying, the pre-treatment counts were made by picking three leaflets per plant in a polythene bag from randomly selected ten plants per plot and counting the number of nymphs/larvae under light microscope in the laboratory. The leaflets were picked from the lower, middle and upper stratum of the plant. The post-treatment counts were made at 3^{rd}, 7^{th}

and 10th day after the treatment. The data was analysed statistically using randomized block design.

(A) Preparation of spray

The amount of spray fluid required was estimated each time by spraying water on control plots. The amount of insecticides required for preparing the solution was calculated for each insecticide. At the time of preparing spray fluid, the quantity of insecticide was calculated and mixed with 10 litre of water and then the solution was poured in knapsack sprayer. The application of insecticides was done during evening time

(B) Method of application of insecticidal sprays

The insecticides sprays were applied with the help of hand operated high volume knapsack sprayer. The entire treatment plots were treated with respective insecticide in all the three replication at a time for avoiding the drifts of spray fluid on neighbouring plots. Care had taken to wash thoroughly the spray pump with water before using for other insecticide. The first spray of different insecticides was made immediately after appearance of sucking pests on potato crop and application of second spray was given at 10 days interval after first spray. A total of four spray were given to crop in insect activity period.

Table 5.1: List of various insecticides/biopesticides/plant extracts(NKE)and new molecules used in the present investigation

S. No.	Name of the chemical	Trade name and formulation	Dose	Group	Source
1.	Chloropyriphos	Dursban 20EC	2.5ml/lit	Organophosphate	Dow Agro Science India Pvt. Ltd
2.	Dimethoate	Rogor30EC	1.5 ml/lit	Organophosphate	Cheminova Insectides ltd.
3.	Thiomethoxam	Actara25WG	0.3 gm/lit	Neonicotinoids	Syngenta India Ltd.
4.	Kaoline	Kaoline	24 gm/4lit	Sillicate	Basf Chemicals
5.	Thymol	Thymol	1.0 %	Monoterpene phenol	Loba Chemicals
6.	Imidacloprid	Tata mida 200SL	0.3 ml/lit (Foliar spray)	Neonicotinoids	Rallis India Ltd.
			0.4 ml/lit (Seed Treatment)		
7.	Neem oil	Neem Baan 1500 PPM	3 ml/lit	Botanical Insecticide	Pest Control of India
8.	*Metarrhizium anisopliae* $2X10^9$ CFU	Kalichakra	2 kg/ha	Entomopathogenic fungi	International Panaacea Ltd.
9.	*Beauveria bassiana* $2X10^9$ CFU	Daman	2 kg/ha	Entomopathogenic fungi	International Panaacea Ltd.

Table 5.2(a): Treatment detail of all chemicals combination for spray in IPM schedule for seed production in potato

Treatment	Treatment detail in IPM schedule for seed potato crop
T1	1st Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml) /lit; 3rd Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit); 4th Spray: Rogor 30EC (1.5ml/lit).
T2	1st Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml /lit); 3rd Spray: Foliar spray of Thiomethoxam 25WG (0.3 gm/lit); 4th Spray: Rogor 30EC (1.5ml/lit).
T3	1st Spray: Foliar spray of Imidacloprid200SL (0.3 ml/lit) + Neem Baan (3ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml /lit); 3rd Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit); 4th Spray: Rogor 30EC (1.5ml/lit).
T4	1st Spray: Seed treatment with Imidacloprid (0.4 ml/lit) + Metarrhizium anisopliae (2 Kg/ha) soil application + Foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance; 2nd Spray: Foliar spray of Thiomethoxam 25WG (0.3 ml/lit); 3rd Spray:Rogor 30EC (1.5ml/lit); 4th Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance.
T5	1st Spray: Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml /lit); 3rd Spray: Foliar spray of Imidacloprid200SL (0.3 ml/lit); 4th Spray: Rogor 30EC (1.5ml/lit) +Neem Baan (3ml/lit).
T6	1st Spray: Soil application of Beauvaria bassiana 2X109 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml /lit); 3rd Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit); 4th Spray: Rogor 30EC (1.5ml/lit).
T7	Untreated

Table 5.2(b): Treatment detail for checking efficacy of newer molecule against insect pests in potato seed production:

Treatments	Treatment detail
T1	KAOLIN (1.5%)
T2	Imidaclorpid (0.03%)
T3	Thymol (1.0%)
T4	NEEM BAAN 1500 PPM (3ml/Lit)
T5	Control

5.3.6 Meteorological Observations

Meteorological observations for temperature (T_{max} and T_{min}) in ºC, relative humidity (R_H) in percent, rainfall (RF) in mm and wind velocity in per meter recorded at meteorological observatory, ICAR–CPRS (Punjab). Pschrometer was used to record the mean temperature (T_{max} and T_{min}) and relative humidity (R_H %) in laboratory. The details of meteorological data are presented in Table 5.3.

Table 5.3: Meteorological observation recorded during *Rabi* 2014 and 2015

SMW	Tmax		Tmin		RHmin		RHmax		Rainfall		Sunshine hours	
	2014	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*
41st	17.40	20.00	30.40	32.00	58.70	65.83	74.77	75.50	4.12	0.00	4.85	5.53
42nd	15.00	18.20	27.60	30.00	58.40	66.00	74.00	75.80	0.00	0.00	6.06	4.58
43rd	14.80	15.25	29.60	26.96	59.40	64.96	72.60	73.46	0.00	3.87	5.44	5.27
44th	14.00	16.00	27.17	30.50	58.83	77.00	66.17	85.17	0.00	0.00	4.55	5.93
45th	13.01	13.47	27.30	24.87	58.99	62.63	74.13	64.90	0.00	0.00	5.60	3.63
46th	9.17	9.67	24.33	24.83	54.83	66.00	70.00	71.67	0.00	0.00	6.05	5.60
47th	8.00	9.80	23.43	24.40	52.71	66.80	75.71	72.40	0.00	0.00	5.86	4.78
48th	7.33	8.00	23.50	23.00	52.33	74.50	74.33	79.83	0.00	0.00	5.88	3.20
49th	5.33	7.20	20.33	18.60	54.17	64.00	77.17	76.20	6.44	0.00	3.77	5.33
50th	6.00	3.83	12.83	18.67	80.50	62.33	86.00	74.33	0.00	0.00	0.83	4.98
51st	4.17	3.81	11.50	20.28	79.83	61.89	85.00	79.22	0.00	0.00	0.00	4.65

5.3.7 Data Analysis

The statistical analysis of data generated with the present investigation was done with the help of XLSTAT™ and SPSS V.23.

Chapter-VI

Results and Discussion

<u>**CHAPTER-VI**</u>

RESULTS AND DISCUSSION

Results obtained from the present investigation entitled, "Dynamics of Pest Complex on Potato Seed crop in Punjab and Its integrated Management" have been presented and discussed in this chapter as follow:

6.1 SURVEY OF PEST COMPLEX ON POTATO

To identify the pest complex of potato in Jalandhar district of Punjab a total of twenty villages predominantly practising the potato seeds cultivation were randomly selected and surveyed during the cropping seasons of 2014 and 2015. A total of Seventeen pests were reported (Table 6.1 and 6.2). Further, these pests were characterized in six different categories:

a. **Foliage feeder:** Flea beetle (*Chaetocnema*spp. Stephans) and Semilooper (*Thysanoplusia orichalcea* Fabricus), Caterpillars (*Spodopteralitura,Helicoverpa armigera)*

b. **Foliage suckers:** *Aphis gossypii* and *Myzus persicae,whitefly,leaf hopper,Thrips*

c. **Collar feeder:** Cutworm *(Agrotis ipsilon* Hufnagel*).*

d. **Tuber feeder:** Wireworm (*Melanotus horticornis* Blyth).

e. **Nematodes:** Root Knot Nematode (Meloidogyne Spp.).

f. **Vertebrates:** Field rats

The survey revealed that the potato fields of Jalandhar district are not untouched with the incidence of the insects and pests; however, a survey of literature and previous findings confirmed that identified pests are common in potato and frequently occurs in the northern regions of India. Further, these findings are in accordance with the results of previous studies conducted by Birtton (1918), Eden and Garrett (1955), Sharma and Bhalla (1964), Dorozhkin *et al.* (1975), Escalante (1975), Menschoy (1975), Butani and Verma (1976), Das (1988), Misra and Agrawal (1988), Singh (1990), Parihar *et al.* (1995), Nandhihalli *et al.* (1996), Peter (1996), Dharpure (2002a), Sing (2002), Chandel and Chandla (2003), Pandey (2007) and Chandel *et al.* (2013) who reported that the crop is infested by number of insect pests and nematodes.

Morphological identification of different pest of Potato pest complex

Insect Vector	Name of the insect vector	Morphological Identification keys
Aphid	*Myzuspersicae Sulzer* (Aphididae, Hemiptera)	1. Adult apterae small to medium-sized, whitish green, pale yellow green, grey green, mid-green and uniformly coloured. 2. Alatae have a black central dorsal patch on the abdomen. 3. Apterae and alatae are 1.2 to 2.1 mm in length. 4. Siphunculi almost twice the length of cauda.
do	*Aphis gossypii* (Cotton aphid)	1. Aphids are dark green, almost black but adult produced in crowed colonies at high temperature are very pale yellow to almost white. 2. Apterae and alatae are less than 1 mm in length. 3. Siphunculi are dark and black in colour. 4. Cauda are pale or light in colour.
Whiteflies	*Bemisia tabaci* (Gennadius) (Aleyrodidae:Hemiptera)	1. Whiteflies are about less than 1mm in length and covered with white ,waxy powder on both wings and white to slightly yellowish in colour. 2. Two wings are distinct and separately attached to thorax which does not overlap each other. 3. Very active and fly away with a slight leaf movement.
Leaf hoppers	*Empoasca fabae* (Cicadellidae:Hemiptra)	1. The nymphs are green in colour and adults are pale green /greenish in colour. 2. Wedge shape bodies with heads slightly broader than the rest of the body. 3. Short antennae that ends with a bristle. 4. Hind legs are have enlarged hind legs that are used for jumping. 5. Nymphs and adult leafhoppers move diagonally or sidewise.
Thrips	*Scirthothrips dorsalis* (Thripidae:Thysanoptera)	1. Thrips are very tiny (1 to 2 mm long) with heavily fringed wings in adults. 2. Nymphs are dark in colour and feed in groups along the midrib and veins of older leaves, while adults dark in colour but feed along the midrib and veins of younger leaves. 3. Females have extremely slender wings with a fringe of long hairs around their margins. 4. Female members of suborder terebrantia possess the saw like ovipositor on the ante apical abdominal segments, while the females of suborder Tubulifera have tube shaped apical abdominal segments

Table 6.1: Pest complex of potato (*Solanum tuberosum* L.) at different locations of district Jalandhar during 2014 to 2015

S.No.	Name of the species	Family	Order	Damaging stage	Key symptom
1.	Whitefly	Aleyrodidae	Hemiptera	Nymph& adult	Sucking on foliage and vector of viruses
2.	Flea beetle	Chrysomelidae	Coleoptera	Grub and adult	Feeding on foliage and mainly on flowers
3.	Epilachna beetle	Coccinellidae	Coleoptera	Grub and adult	Feeding on foliage
4.	Weevil	Curculionidae	Coleoptera	Grub and adult	Feeding on the tender apical parts of potato plant
5.	Blister beetle	Meloidae	Coleoptera	Grub and adult	Feeding on potato foliage
6.	Tuber fly	Syrphidae	Diptera	Maggot	Feeding on tuber during rainy season
7.	Aphid	Aphididae	Homoptera	Grub and adult	Feeding on foliage part and vector for potato viruses
8.	Leaf hopper	Cicadellidae	Heteroptera	Larva and adult	Feeding on foliage and vector of mycoplasmal diseases
9.	Green bug	Pentatomidae	Heteroptera	Grub and adult	Feeding on foliage on potato
10.	Tuber moth	Gelechidae	Lepidoptera	Larvae	Feeding on tuber in field and storage
11.	Cutworm	Noctuidae	Lepidoptera	Larvae	Serious during early stage of crop growth during prolong dry and warm weather
12.	Gram pod Borer	Noctuidae	Lepidoptera	Larvae	Damage in early stages of potato crop
13.	Cabbage semiloopper	Noctuidae	Lepidoptera	Larvae	Damage on foliage parts of potato crop
14.	Grass hopper	Acrididae	Orthoptera	Grub and adult	Damage on foliage parts of potato crop
15.	Thrips palmi	Thripidae	Thysanoptera	Larva and adult	Sucking on foliage and vector of diseases
16.	Nematode	Heteroderidae	Nematoda	All Stages	Damage the root and tubers of potato
17.	Field rat	Muridae	Rodenta	All stage	Damage tubers in field and storage

Table 6.2: Village viz. occurrence of insect pests on potato crop (*Solanum tuberosum* L.) during the *Rabi* 2014 and 2015:

Sr. No.	Name of Village	1	2	3	4	5	6	7	8
1	Nangal Purdil	+	+	++	+	+	+	+	-
2	Phoolpur	+	+	+	+	-	-	+	-
3	Dhanal	+	-	++	-	+	+	-	-
4	Jamsher Khas	-	-	++++	+	+	+	+	+
5	Pratapra	+	+	++	+	+	+	+	+
6	Gokulpur	+	+	++	+	+	+	+	+
7	Lallian khurd	++	-	+	+	++	++	-	-
8	Uggi	++	-	+	+	+	++	-	-
9	Chitti	++	+	++	+	+	++	-	-
10	Talwandi	++	+	+	+	+	++	+	+
11	Kala sanghian	-	+	+	+	++	-	+	+
12	Apara	+	+	-	+	+	+	+	+
13	Abadan	+	+	+	+	+	+	+	-
14	Bajra	+	+	+	+	-	-	+	-
15	Sammipur	+	+	+	+	-	+	-	-
16	Pawar	++	+	++	+	+	++	-	-
17	Athola	++	+	++	+	+	++	-	-
18	Kohara	++++	++	++	+	+	+	-	-
19	Lambra	+	+	+	+	-	+	+	+
20	Khambra	++	+	+	+	+	+	+	+

1= white fly; 2 = Aphis gosypii; 3 = leaf hopper; 4 = Epilachna beetle; 5 = Defoliating caterpillar; 6 = M. persicae; 7 = Thrips; 8 = Mites
(-) = no incidence; (+) = low incidence; (++) = moderate incidence; (+++) = heavy incidence

While working on pest complex of potato in India and across the world which include flea beetle, blister beetle, potato tuber moth, cutworm, wireworm, white grub, leaf eating caterpillar, termites, earwig, aphids, thrips, jassids, whiteflies, root knot nematode, spiral nematode, stunt nematode, root lesion nematode and cyst nematode. They further concluded that these pests damage potato plant by feeding on leaves, reducing photosynthetic area and efficiency by attacking stems, weakening plants and inhibiting nutrient transport which ultimately affect the yield of crop and were classified into soil pests, sucking sap feeders, defoliators and storage pests.

6.2 POPULATION STATISTICS OF INSECT PESTS IN POTATO SEED CROP

To study the population statistics of various insect pests of potato seed crop an experiment was laid down in randomized block design during the cropping seasons of 2014 and 2015 at CPRS, Jalandhar. In order to achieve maximum infestation in the experimental plots, no synthetic or natural pesticide were sprayed. The data on the population statistics is furnished in Table 6.3. Further, a surface plot was developed to depict the overall population of insect pests during cropping season 2014 and 2015 (Figure 6.1). The population statistics of major insect pests reported during the experiment period are discussed as below:

6.2.1 Aphis gossypii

In the cropping season 2014, the population of *Aphis gossypii* was recorded between 1.00 and 5.80 adults per 10 plants with a mean population 3.60 adults 10 plants. The population was higher during 41^{st} to 48^{th} SMW and attained the peak (5.80 perten plants) in 42^{nd} SMW(s)

In the cropping season of 2015, the incidence of this insect pest was lower than that of the previous year. During the standard meteorological weeks 41^{st} to 51^{st} the insect population was recorded between 0.57 and 3.33 adults 10 plants with a mean population of 2.13 adults 10 plants. Figure 6.2(a) gives a comparative vision on the population statistics of the insect in both of the cropping seasons.

Myzus persicae

The incidence of *Myzus persicae* was first reported during 47^{th} SMW which continued up to 51^{st} SMW in cropping season 2014 and46^{th}SMW and continued to 51^{st} SMW IN 2015 of the cropping seasons. The population ranged from 6.5 to 24.50 and 7.00 to 26.29 adults per ten plants with a mean population of 7.29 and 8.77, in the cropping seasons of 2014 and 2015, respectively. In both of the years the population was minimum (6.5 and 7.00 adults per ten plants) during 47^{th} SMW and at peak (24.50 and 26.29 adults per 10 plants, respectively) during 51^{st} SMW. Figure 6.2(b) depicts the population of *M. persicae* during potato cropping seasons of 2014 and 2015.

Leafhoppers

During the cropping season of 2014 the occurrence of leafhopper adults was first noticed during the 41^{st} SMW which continued up to 51^{st} SMW. The population ranged between 1.33 and 12.40 adults per 10 plants with a mean population of 6.49 adults per hundred. The population was maximum (12-40) during the 42^{nd} SMW, 2014.

In cropping season of 2015 the population varied from 2.00 to 18.67 with a mean population of 9.55 adults per 10 plants during the 41^{st} to 51^{st} SMW. Unlike cropping season 2014 this year the peak population (18.67 adults per hundred leaves) was recorded in the 44^{th} SMW. Figure 6.2(c).

6.2.2 Whiteflies

The incidence of whiteflies was observed during 41^{st} to 51^{st} SMW in both cropping seasons. The population ranged between 3.83 and 9.40 adults per 10 plants in the cropping season of 2014; however, the mean population 5.94 adults per 10 plants. During the cropping season 2014, the population reached to the peak (9.40) during the 42^{nd} SMW.

The incidence of whiteflies was very high during the cropping season of 2015. The population ranged from 2.14 to 25.67 adults per 10 plants. The mean population in this cropping season was 9.83 adults per 10 plants. The population was higher during 41^{st} and 42^{nd} SMW(s); however, the peak population (25.67 adults per 10 plants) was recorded during the 41^{st} SMW. The Figure 6.2(d) depicts the incidence comparison of whiteflies between cropping season 2014 and 2015.

6.2.3 Mites

The incidence of mites was reported only during the 41^{st} and 42^{nd} MSW of 2014 which was very low. The mean population of mites in potato fields was 0.11 adults per 10 plants. Unlike 2014 the incidence was recorded from 41^{st} to 43^{rd} SMW during cropping season 2015. The mean population in 2015 was 0.23. Figure 6.2(e) depicts the incidence comparison between cropping season 2014 and 2015.

6.2.4 Thrips

The incidence of thrips was recorded in cropping season 2014 between 41^{st} and 42^{nd} SMW which was 0.33 to 2.00 adults per 10 plants; however, vary rarely insect was observed up to 47^{th} SMW with a mean population 0.38 adults per 10 plants. The similar pattern of thrips incidence was recorded during the cropping season of 2015 where the incidence ranged between 0.33 and 2.83 during 41^{st} and 42^{nd} SMW. The mean population 0.38 adults per 10 plants were reported during this cropping season. Figure 6.2(f) depicts the incidence comparison between cropping season 2014 and 2015.

Figure 6.1: Surface plot depicting the population of insect pest in the potato fields of Jalandhar during *Rabi* 2014 and 2015

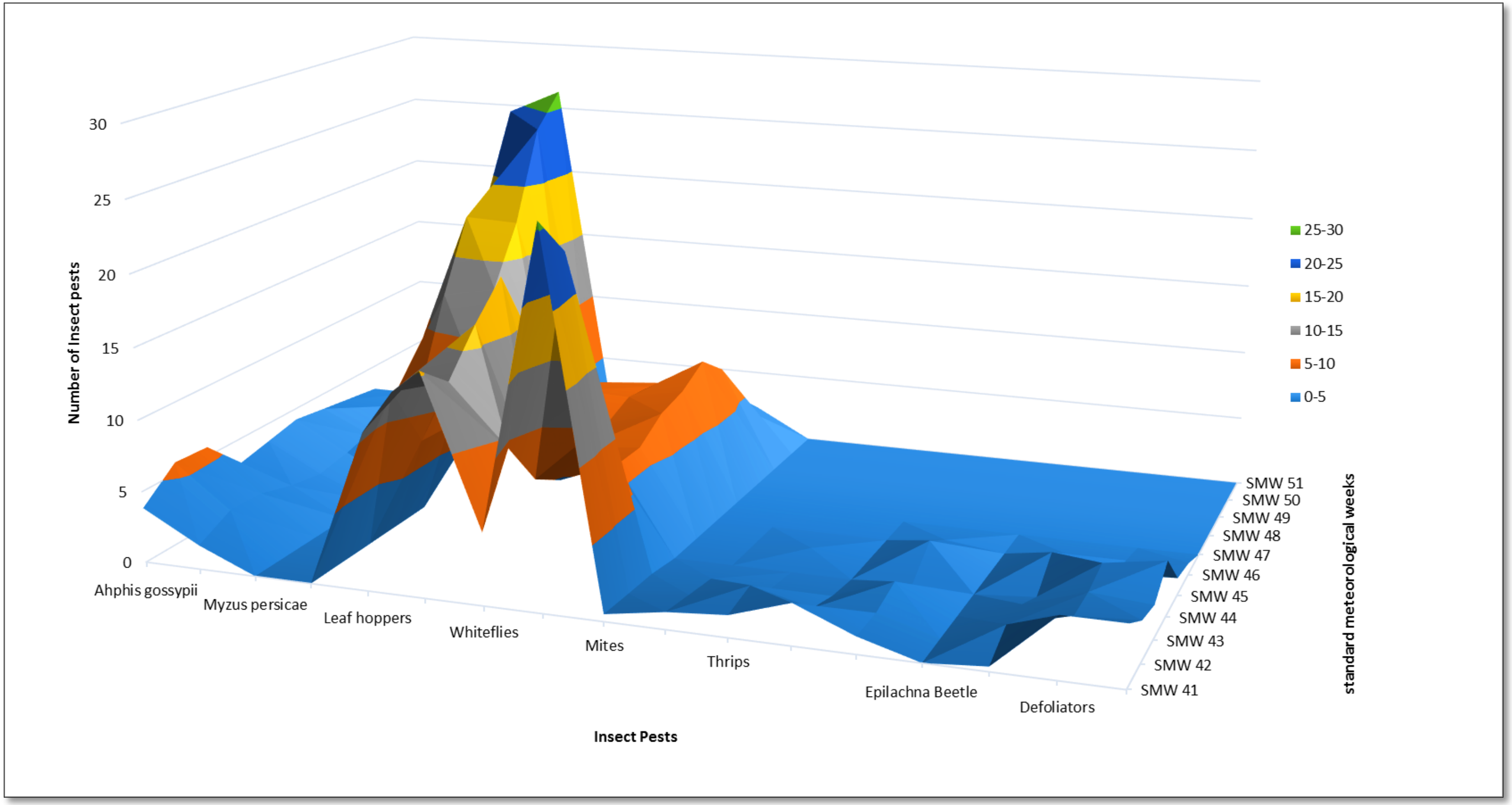
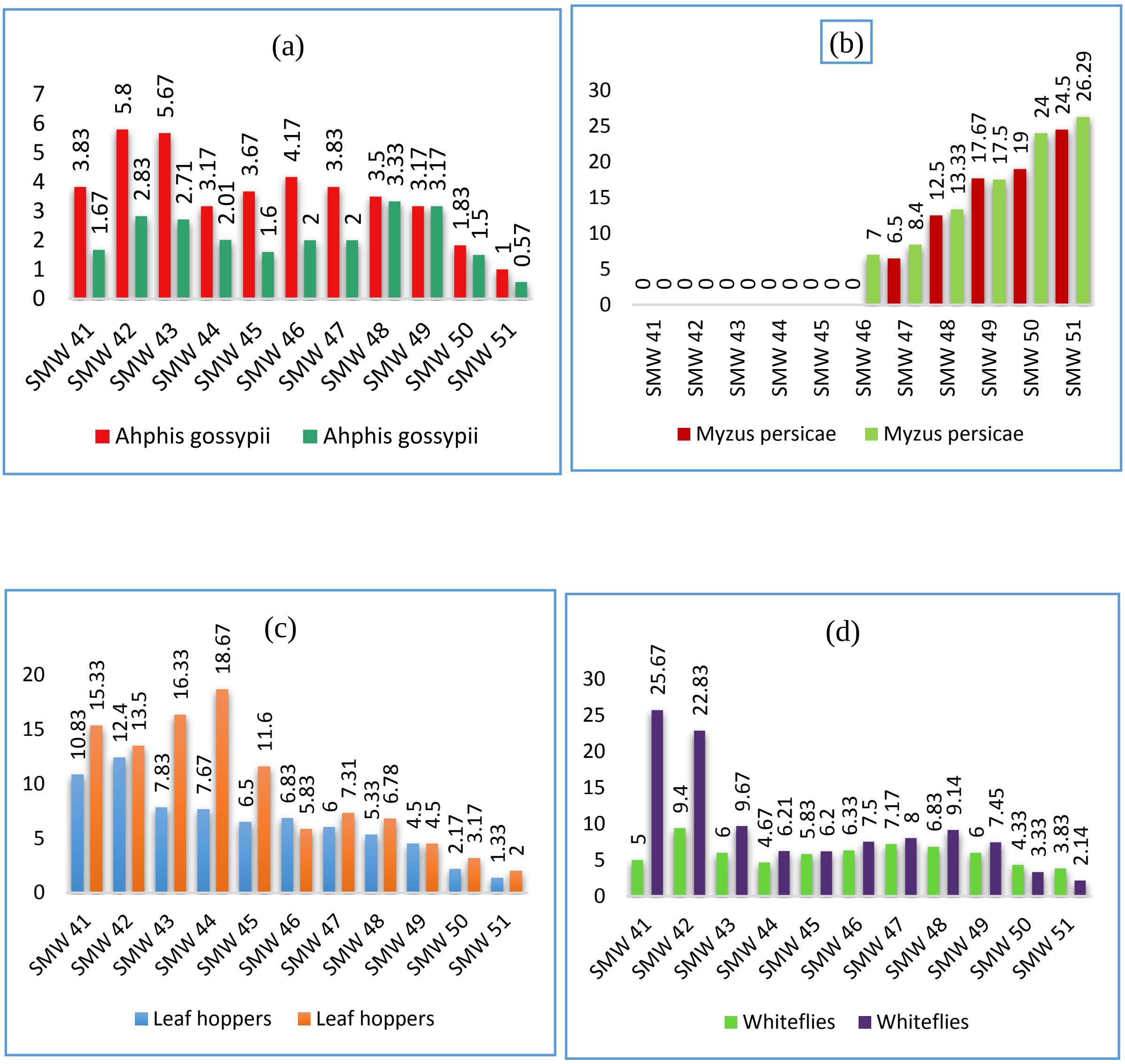
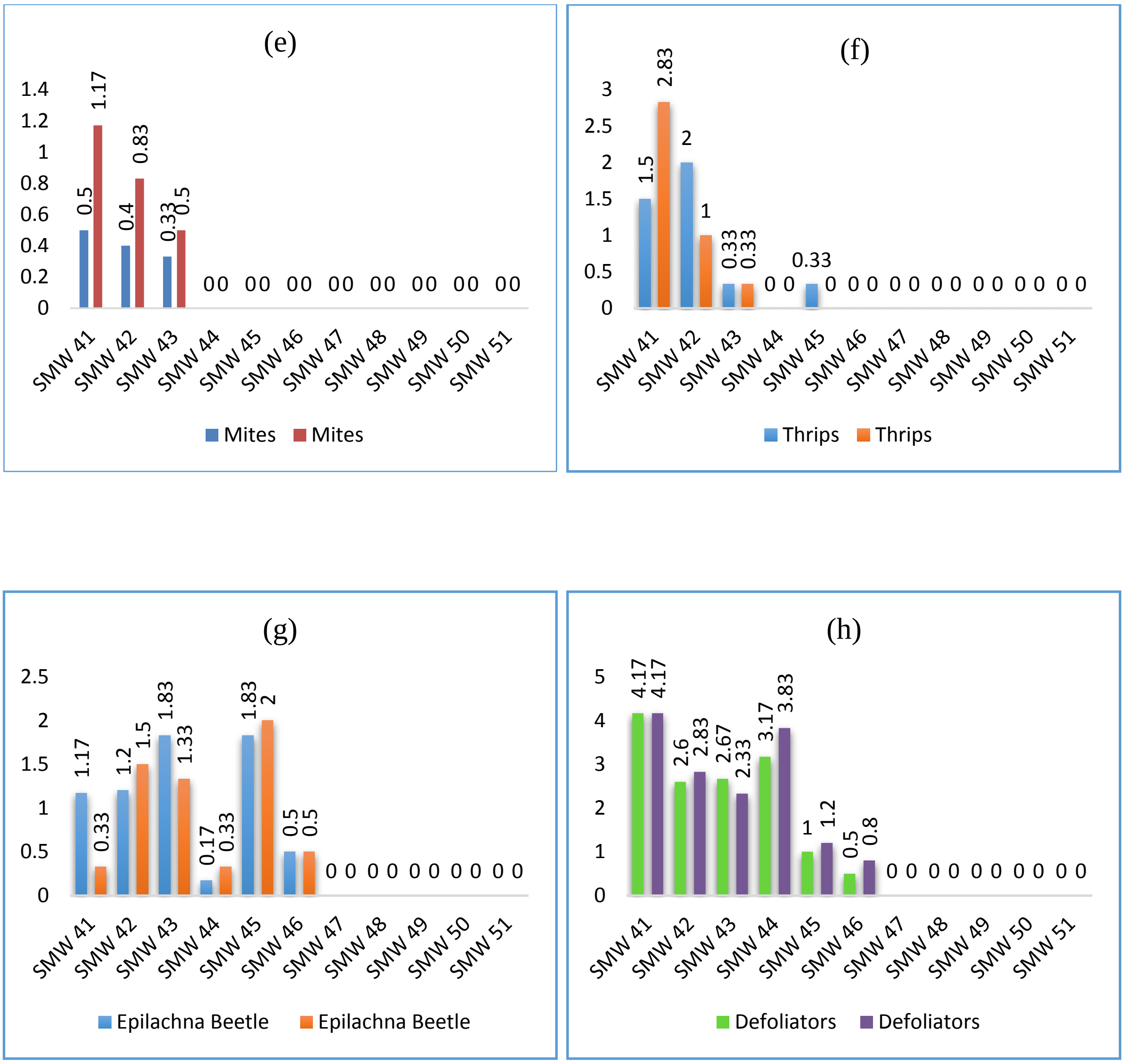


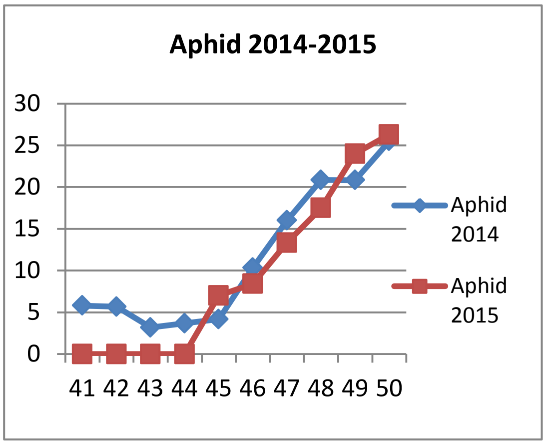
Figure 6.2 (a-n): **Depicting the incidence level of each insect pest of potato (*Solanum tuberosum* L.) at different locations of district Jalandhar during *Rabi* 2014 and 2015**



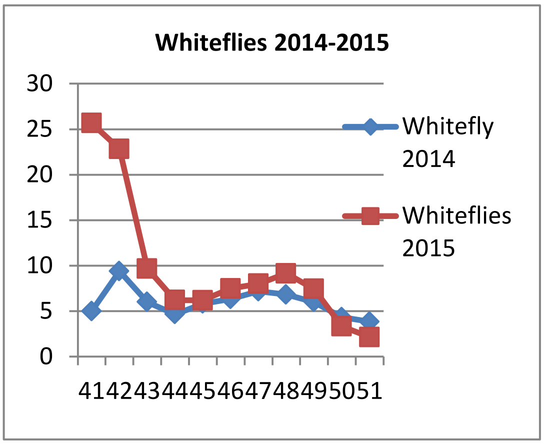

(e)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1.17
0.4
0.83
0.33
0.5
00 00 00 00 00 00 00 00
SMW 41 SMW 42 SMW 43 SMW 44 SMW 45 SMW 46 SMW 47 SMW 48 SMW 49 SMW 50 SMW 51
Mites Mites
(f)
3
2.5
2
1.5
1
0.5
0
1.5
2.83
2
1
0.33
0.33
0 0
0.33
0 0 0 0 0 0 0 0 0 0 0 0 0
SMW 41 SMW 42 SMW 43 SMW 44 SMW 45 SMW 46 SMW 47 SMW 48 SMW 49 SMW 50 SMW 51
Thrips Thrips
(g)
2.5
2
1.5
1
0.5
0
1.17
0.33
1.2
1.5
1.83
1.33
0.17
0.33
1.83
2
0.5
0.5
0 0 0 0 0 0 0 0 0 0
SMW 41 SMW 42 SMW 43 SMW 44 SMW 45 SMW 46 SMW 47 SMW 48 SMW 49 SMW 50 SMW 51
Epilachna Beetle Epilachna Beetle
(h)
5
4
3
2
1
0
4.17
4.17
2.6
2.83
2.67
2.33
3.17
3.83
1
1.2
0.5
0.8
0 0 0 0 0 0 0 0 0 0
SMW 41 SMW 42 SMW 43 SMW 44 SMW 45 SMW 46 SMW 47 SMW 48 SMW 49 SMW 50 SMW 51
Defoliators Defoliators

Comparative population dynamics for the crop season 2014 and 2015 at experimental plots at ICAR-CPRS, Jalandhar

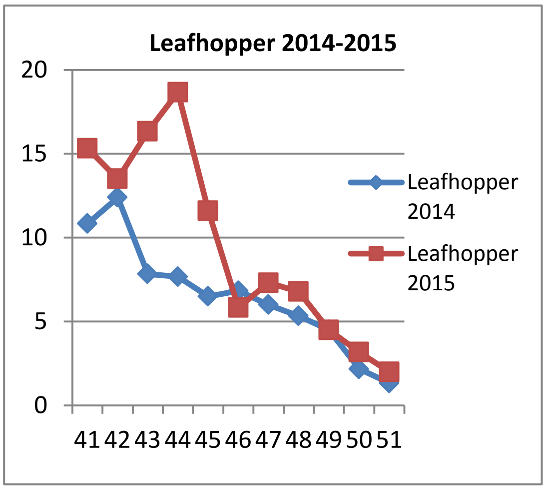
(i)



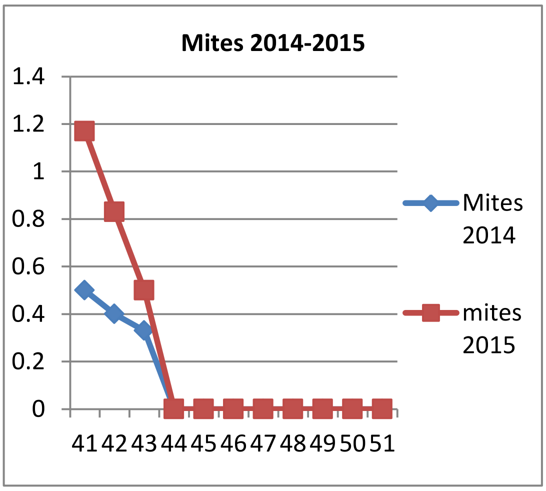
(j)



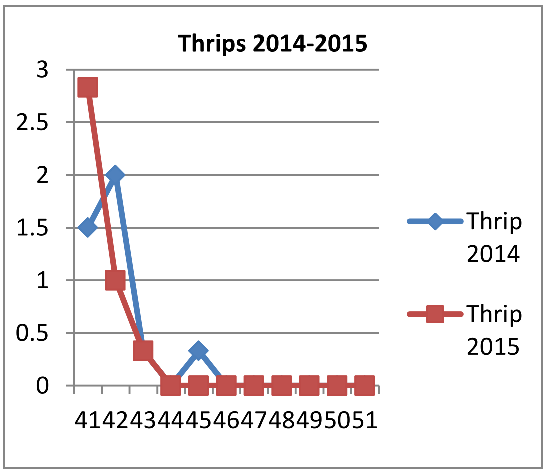
(k)



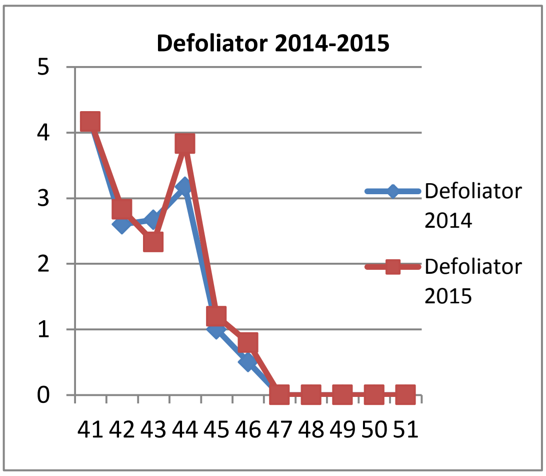
(l)



(m)



(n)



X axis – Standard meterological weeks, Y axis- Insect population

6.2.5 Epilachna Beetle

The incidence of this insect was recorded between 0.17 and 1.83 adults per 10 plants from 41st SMW to 46th SMW of 2014 and, in 2015 it was seen in the field during 41nd SMW to 46th SMW with a population ranged from 0.33 to 2.00 adults per 10 plants. The mean population in both the years was very low i.e. 0.61 and 0.54 adults per 10 plants, respectively. Figure 6.2(g) depicts the incidence comparison between cropping season 2014 and 2015.

6.2.6 Defoliators

In both of the cropping season the incidence of defoliators started from 41st SMW which continued up to 46th SMW. The population of defoliators in 2014 and 2015 ranged from 0.50 to 4.17 and 0.80 to 4.17 adults per hundred leaves, respectively. The population was at peak (4.17 adults per hundred leaves) during the 41st SMW of both years and was minimum (0.50 and 0.80 adult per 10 plants) during 46th SMW. The mean population 1.28 and 1.38 adult per 10 plants was recorded for cropping season 2014 and 2015, respectively. Figure 6.2(h) depicts the incidence comparison between cropping season 2014 and 2015.

Table 6.3: Population statistics of insect pest in the potato fields of Jalandhar during 2014 and 2015:

Insect pests		***Ahphis gossypii***		***Myzus persicae***		**Leaf hoppers**		**Whiteflies**		**Mites**		**Thrips**		**Epilachna Beetle**		**Defoliators**	
Months	**SMW**	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***	***2014***	***2015***
October	41	3.83	1.67	0.00	0.00	10.83	15.33	5.00	25.67	0.50	1.17	1.50	2.83	1.17	0.33	4.17	4.17
	42	5.80	2.83	0.00	0.00	12.40	13.50	9.40	22.83	0.40	0.83	2.00	1.00	1.20	1.50	2.60	2.83
	43	5.67	2.71	0.00	0.00	7.83	16.33	6.00	9.67	0.33	0.50	0.33	0.33	1.83	1.33	2.67	2.33
November	44	3.17	2.01	0.00	0.00	7.67	18.67	4.67	6.21	0.00	0.00	0.00	0.00	0.17	0.33	3.17	3.83
	45	3.67	1.60	0.00	0.00	6.50	11.60	5.83	6.20	0.00	0.00	0.33	0.00	1.83	2.00	1.00	1.20
	46	4.17	2.00	0.00	7.00	6.83	5.83	6.33	7.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.80
	47	3.83	2.00	6.50	8.40	6.00	7.31	7.17	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	48	3.50	3.33	12.50	13.33	5.33	6.78	6.83	9.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	49	3.17	3.17	17.67	17.50	4.50	4.50	6.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	1.83	1.50	19.00	24.00	2.17	3.17	4.33	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	51	1.00	0.57	24.50	26.29	1.33	2.00	3.83	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum		5.80	3.33	24.50	26.29	12.40	18.67	9.40	25.67	0.50	1.17	2.00	2.83	1.83	2.00	4.17	4.17
Minimum		1.00	0.57	0.00	0.00	1.33	2.00	3.83	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean		3.60	2.13	7.29	8.77	6.49	9.55	5.94	9.83	0.11	0.23	0.38	0.38	0.61	0.54	1.28	1.38

Various insect pests infesting on potato seeds were observed in the experimental plots at CPRS, Jalandhar, during the cropping seasons 2014 and 2015. However, among them only few were predominant. These included aphids (*Ahphis gossypii* and *Myzus persicae*), leafhoppers and whiteflies. The incidence of aphids, leafhoppers and whiteflies was reported from 41st SMW to 51st SMW i.e. starting from the mid of October to late December. It was interesting to know that in this region the *Aphis gossypii* was high in early development stage of potato plants (41st SMW) and tend to decrease continuously and finally vanished after 51st week *i.e.* in late December. In contrast to *Aphis gossypii* the *Myzus persicae* started to invade in the field 47th SMW and continued to increase in population till 51st SWM i.e. during the maturity period of potato crop. Potato is cultivated just after the harvesting of Rice in the Jalandhar region. These results advocate that the potato crop suffers severely, from the infestation of aphid spp., from its beginning to maturity and this might lead to lower quality seed production, if not managed.

Further, the infestation of leafhoppers was also recorded during the same period (mid-October to late December) in both the cropping seasons. In both seasons the leafhopper population followed the same trend. The incidence of this insect pest started in early October(41st SMW) with a high population which tend to decrease week by week up to late December (51st SMW).

The incidence of whiteflies was also recorded in both of the years from early Octobers to late December. The population was high during initial days which further declined week by week. Here, the interesting outcome is that in contrast to the potato cropping season 2014 the population of whiteflies was very much high in the potato cropping season 2015 where the incidence was very much high *i.e.* 25.00 adults per 10 plants. The reason behind this higher occurrence was that in *Kahrif*-2015 there was a severe incidence of whiteflies in cotton crop which harvested just fifteen to twenty days before the sowing dates of potato.

These results showed confirmatory with the earlier findings of Agarwal *et al.*, (2017), Kumar *et al.* (2017), Ali *et al.* (2015), Kumar and Gupta (2016), Mandali *et al.* (2016), Gupta (2014), Chandel *et al.* (2013), Parihar *et al.* (1994) and Misra and Agrawal (1987).

6.3 RELATIONSHIP BETWEEN INSECT PEST POPULATION AND ABIOTIC FACTORS

Correlation of population dynamics of different insect pests with meteorological data and cultivars were estimated to study the association between them and impact of meteorological factors and cultivars on the population dynamics of different insect pests of potato in the Jalandhar district.

6.3.1 Relationship between population dynamic and meteorological parameters

Pearson's correlation coefficient (r) was estimated to assess the relationship between population dynamics and meteorological parameters (Table 6.4 and 6.5).

The population of *Aphis gossypii* showed significant positive association with T_{min} (2014), T_{max} (2014) and sunshine hours (2014). But it showed a negative correlation with RH_{min} (2014) and RH_{max} (2014). Significant positive correlation was observed between *Myzuspersicae* population and RH_{min} (2014) and RH_{max} (2014). Significant negative correlation of *Myzuspersicae* population was found with T_{min} (2014 & 2015), T_{max} (2014) and sunshine hours (2014). T_{min} (2014 & 2015), T_{max} (2014) and sunshine hours (2014) showed positive correlation whereas only RH_{max} (2014) had negative correlation with population of leaf hoppers. In case of white flies, population showed positive correlation with sunshine hours (2014) and negative correlation with RH_{min} (2014). Population of mites and thrips were significantly interrelated with only T_{min} (2014 & 2015) among all the parameters. Population of Epilachna beetle was found to have significant positive association with T_{min} (2014) and T_{max} (2014). On the other hand, population of defoliators was positively associated with T_{min} (2014 & 2015) and T_{max} (2014).

Further, pooled data analysis of two years depicted that the population of *Aphisgossypii* was positively associated with T_{max} and sunshine hours whereas negatively with RH_{min}. *Myzuspersicae* population had positive association with RH_{max} and negatively with T_{min}, T_{max} and sunshine hours. Contradictorily, T_{min}, T_{max} and sunshine hours showed positive association with population of leaf hoppers. Population of white flies, mites, thrips and defoliators presented the same scenario being positively correlating with T_{min} and T_{max}. Epilachna beetle population had positive association with T_{min} and T_{max} but negative association with RH_{max}.

6.3.2 Relationship between population dynamics and potato cultivars

Correlation coefficients between pest population and potato cultivars *viz*. Kufri Jyoti (KJ), Kufri Badshah (KB), Kufri Pukhraj (KP), Kufri Khyati (KK) and Kufri Surya (KS) were also calculated (Table 6.6). However, there was present a valuable correlation between pest population and potato cultivars but some of the matrices were significant. In the year 2014, *Aphis gossypii* population showed non-significant positive correlation between KP: KJ; KP:KB and KS:KK. On the other hand, it showed non-significant negative correlation between KK:KJ; KK:KB; KK:KP; KS:KJ and KS:KP. White flies population had non-significant positive association between KK:KJ and non-significant negative between KP:KB; KS:KJ and KS:KB. Non-significant positive association was found between KS:KJ and negative between KP:KB; KS:KJ and KS:KB. *Myzus persicae* population was non-significantly and positively associated with KS:KJ and negatively with KP:KB and KK:KJ. But only leaf hoppers population showed highly significant positive correlation (significant at 1% level of significance) between KP:KJ (r = 0.991), non-significant positive correlation with KK:KJ; KK:KP; KS:KJ; KS:KP and KS:KK and non-significant negative with KS:KB.

There was slightly different scenario in 2015 where *Aphis gossypii* population had non-significant positive correlation with KP:KB; KK:KB; KS:KB and KS:KK and negative with KB:KJ and KS:KJ. In this study it had a positive and significant correlation (significant at 5% level of significance) with KK:KP(r = 0.998) and highly significant (significant at 1% level of significance) with KS:KB (r = 1.000). Population of white flies showed significant (significant at 5% level of significance) and positive correlation with KK:KP (r = 0.999), non-significant positive association between KP:KJ; KK:KJ; KS:KJ; KS:KP and KS:KK. It was further observed that no cultivar inhibited population of white flies in the field. There was a non-significant positive association of *Myzus persicae* population with KK:KB and negative with KP:KJ and KS:KB. Leaf hoppers population was non-significantly and positively associated with KP:KJ; KK:KB; KS:KB and KS:KK and negatively with KS:KJ.

6.3.3 Relationship between population dynamics, meteorological parameters and potato cultivars

A combined correlation study between population of economically important insect pests (*Aphis gossypii*, *Myzuspersicae*, leaf hoppers and whiteflies), meteorological parameters and potato cultivars (Table 6.7) revealed that the population of *Aphis gossypii* had a highly significant positive correlation r = 0.999* (at 5 percent) with T_{min} on *Kufri Khyati* cultivar during 2014. It also showed highly positive correlation r = 0.990* at 5 percent with sunshine hours on *Kufri Surya*, during 2014. The population of *Aphis gossypii* showed either non-significant or negative correlation with other meteorological parameters during 2014 or 2015 potato cropping season.

Further, during 2014 and 2015, no significantly positive correlation (at 5 percent) was observed between *Myzuspersicae* population and meteorological parameters on any of the five cultivars however, there were many significantly negative correlations (at 5 percent).

In the present investigation the leaf hoppers a highly positive correlation (at 5 percent) of leaf hoppers population with T_{min} and T_{max} was observed on Kufri badshah (r = 0.999* and 0.989*, respectively) and Kufri pukhraj (r = 0.999* and 0.989*, respectively) during 2015. The population showed a significantly positive correlation (at 5 percent) with rainfall on Kufri badshah (r = .990*). With rest of the parameters the leaf hopper population showed non-significant or negative association.

Population of whiteflies showed non-significant correlations with most of the meteorological parameters on all varieties however, at 5 percent a highly significantly positive correlation (r = .993*) was recorded with sunshine hours on Kufri badshah in 2015.

The impact of various biotic and abiotic factors on insects is already known. In the present investigation results from the correlation analysis uncovered valuable relationships between studied insect pests, abiotic factors and potato cultivars. These results further advocated that both abiotic and biotic factor affect the population dynamics of insect pests. The pooled data of two years revealed that with minimum and maximum temperature significantly affected the fluctuation in the population of the studied insect pests however, other factors viz., rainfall, sunshine hours and relative humidity also had some impact on this. These findings are in conformity with Karuppaiah and Sujayanad (2012) and Matilda *et al*. (2012) who studied the impact of abiotic factors and concluded that abiotic factors (especially temperature), significantly affect the ecology of insects by means of influencing their behaviour, distribution, development, survival and reproduction of insects. In addition to these, findings of Thakur *et al.* (2014) Kandakoor*et al*. (2012), More *et al*. (2012) further strengthen these outcomes of the present investigation.

Table 6.4: Pearson's correlation coefficient (r) between insect pest population and meteorological parameters of 2014 and 2015

Variables	T_{min}		T_{max}		RH_{min}		RH_{max}		RF		Sunshine Hours	
	2014	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*	*2014*	*2015*
Aphis gossypii	**0.693**	0.219	**0.831**	0.418	**-0.671**	0.123	**-0.644**	0.123	-0.060	0.236	**0.839**	-0.159
Myzus persicae	**-0.877**	**-0.930**	**-0.924**	-0.331	**0.605**	0.200	**0.831**	0.200	0.178	-0.288	**-0.812**	-0.147
Leaf hoppers	**0.886**	**0.920**	**0.875**	0.444	-0.570	0.130	**-0.659**	0.130	0.070	0.390	**0.730**	0.278
Whiteflies	0.261	0.370	0.466	0.126	**-0.623**	-0.219	-0.362	-0.219	-0.104	0.012	**0.724**	-0.295
Mites	**0.762**	**0.761**	0.581	-0.102	-0.127	-0.014	-0.164	-0.014	0.204	0.217	0.285	0.217
Thrips	**0.689**	**0.671**	0.499	-0.072	-0.129	0.009	-0.130	0.009	0.142	-0.018	0.307	0.242
Epilachna Beetle	**0.770**	0.572	**0.681**	-0.221	-0.193	-0.563	-0.330	-0.563	-0.097	0.360	0.447	-0.232
Defoliators	**0.929**	**0.913**	**0.732**	0.336	-0.191	0.238	-0.526	0.238	0.105	0.193	0.327	0.453

Values in bold are different from 0 with a significance level alpha=0.05

Table 6.5: Pooled Pearson's correlation coefficient (r) between insect pest population and meteorological parameters of 2014 and 2015

Variables	T_{min}	T_{max}	RH_{min}	RH_{max}	RF	Sunshine Hours
Ahphis gossypii	0.571	**0.661**	**-0.705**	-0.591	0.280	**0.800**
Myzus persicae	**-0.912**	**-0.957**	0.530	**0.820**	-0.011	**-0.860**
Leaf hoppers	**0.979**	**0.962**	-0.326	-0.536	0.138	**0.721**
Whiteflies	**0.737**	**0.705**	-0.461	-0.287	0.235	0.556
Mites	**0.764**	**0.648**	-0.201	-0.131	0.364	0.346
Thrips	**0.729**	**0.610**	-0.191	-0.110	0.273	0.296
Epilachna Beetle	**0.685**	**0.606**	-0.362	**-0.677**	0.052	0.391
Defoliators	**0.927**	**0.843**	-0.056	-0.283	0.205	0.494

Values in bold are different from 0 with a significance level alpha=0.05

Table 6.6: Pearson's correlation coefficient (r) between insect pest population and five cultivars of potato (*Solanum tuberosum*)

Insect pests	Year	2014					2015				
	Cultivar	*KJ*	*KB*	*KP*	*KK*	*KS*	*KJ*	*KB*	*KP*	*KK*	*KS*
Aphis gossyppi	*KJ*	1.000	0.693	0.971	-0.961	-0.922	1.000	-0.945	-0.655	-0.605	-0.945
	KB	0.693	1.000	0.500	-0.866	-0.359	-0.945	1.000	0.866	0.832	**1.000****
	KP	0.971	0.500	1.000	-0.866	-0.988	-0.655	0.866	1.000	**0.998***	0.866
	KK	-0.961	-0.866	-0.866	1.000	0.778	-0.605	0.832	**0.998***	1.000	0.832
	KS	-0.922	-0.359	-0.988	0.778	1.000	-0.945	**1.000****	0.866	0.832	1.000
White flies	*KJ*	1.000	0.410	-0.082	0.843	-0.803	1.000	0.592	0.922	0.908	0.971
	KB	0.410	1.000	-0.943	-0.145	-0.873	0.592	1.000	0.233	0.200	0.381
	KP	-0.082	-0.943	1.000	0.467	0.660	0.922	0.233	1.000	**0.999***	0.988
	KK	0.843	-0.145	0.467	1.000	-0.356	0.908	0.200	**0.999***	1.000	0.982
	KS	-0.803	-0.873	0.660	-0.356	1.000	0.971	0.381	0.988	0.982	1.000
Myzus persicae	*KJ*	1.000	-0.115	0.115	-0.803	0.918	1.000	-0.189	-0.866	0.115	0.655
	KB	-0.115	1.000	-0.997	-0.500	-0.500	-0.189	1.000	-0.327	0.954	-0.866
	KP	0.115	-0.997	1.000	0.500	0.500	-0.866	-0.327	1.000	-0.596	-0.189
	KK	-0.803	-0.500	0.500	1.000	-0.500	0.115	0.954	-0.596	1.000	-0.676
	KS	0.918	-0.500	0.500	-0.500	1.000	0.655	-0.866	-0.189	-0.676	1.000
Leaf hoppers	*KJ*	1.000	-0.500	**0.991****	0.971	0.866	1.000	-0.277	0.971	-0.500	-0.756
	KB	-0.500	1.000	-0.500	-0.693	-0.866	-0.277	1.000	-0.038	0.971	0.839
	KP	**0.991****	-0.500	1.000	0.971	0.866	0.971	-0.038	1.000	-0.277	-0.577
	KK	0.971	-0.693	0.971	1.000	0.961	-0.500	0.971	-0.277	1.000	0.945
	KS	0.866	-0.866	0.866	0.961	1.000	-0.756	0.839	-0.577	0.945	1.000

KJ= Kufri Jyoti, KB = Kufri Badshah, KP = Kufri Pukhraj, KK = Kufri Khyati, KS = Kufri Surya
*** = significant at 1% level of significance*
** = significant at 5% level of significance*

Table 6.7: Pearson's Correlation Coefficient (r) between insect pest population, meteorological parameters and five cultivars of potato (*Solanum tuberosum* L.)

Insect pests	Parameter	Min temp		Max temp		Min hum		Max hum		Rainfall		Sunshine hours	
	Variety	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Aphis gossypii	Kufri Jyoti	-0.970	0.687	**-0.999***	0.761	0.889	0.737	0.884	**-1.000****	0.407	0.189	-0.966	0.846
	Kufri Badshah	-0.847	-0.887	-0.731	-0.931	0.287	-0.476	0.277	0.935	-0.376	-0.500	-0.484	-0.974
	Kufri Pukhraj	-0.964	**-0.999***	**-0.997***	**-0.989***	0.900	0.028	0.895	0.633	0.429	-0.866	-0.972	-0.957
	Kufri Khyati	0.999*	**-0.994***	0.974	-0.977	-0.728	0.092	-0.720	0.582	-0.138	-0.896	0.857	-0.936
	Kufri Surya	0.800	-0.887	0.900	-0.931	**-0.997***	-0.476	**-0.996***	0.935	-0.730	-0.500	0.990*	-0.974
Myzus persicae	Kufri Jyoti	0.847	-0.934	0.731	-0.967	-0.287	-0.371	-0.277	0.888	0.376	-0.596	0.484	-0.993*
	Kufri Badshah	0.037	-0.944	0.226	-0.974	-0.686	-0.345	-0.694	0.875	-0.991	-0.619	0.516	-0.996*
	Kufri Pukhraj	0.037	-0.887	0.226	-0.931	-0.686	-0.476	-0.694	0.935	-0.990	-0.500	0.516	-0.974
	Kufri Khyati	0.532	-0.887	0.683	-0.931	-0.958	-0.476	-0.961	0.935	-0.927	-0.500	0.875	-0.974
	Kufri Surya	**-0.999***	-0.905	-0.974	-0.945	0.728	-0.440	0.720	0.920	0.138	-0.534	-0.857	-0.982
Leaf hoppers	Kufri Jyoti	-0.847	0.973	-0.731	0.942	0.287	-0.216	0.277	-0.475	-0.376	0.945	-0.484	0.885
	Kufri Badshah	-0.037	**0.999***	-0.226	**0.989***	0.686	-0.028	0.694	-0.633	0.990*	0.866	-0.516	0.957
	Kufri Pukhraj	-0.847	**0.999***	-0.731	**0.989***	0.287	-0.028	0.277	-0.633	-0.376	0.866	-0.484	0.957
	Kufri Khyati	-0.695	0.843	-0.545	0.781	0.049	-0.524	0.038	-0.161	-0.587	1.000**	-0.260	0.684
	Kufri Surya	-0.468	0.948	-0.292	0.908	-0.230	-0.304	-0.241	-0.393	-0.789	0.971	0.018	0.839
Whiteflies	Kufri Jyoti	0.037	-0.197	0.226	-0.091	-0.686	0.977	-0.694	-0.600	-0.990*	-0.693	0.516	0.052
	Kufri Badshah	0.927	-0.907	0.981	-0.856	-0.945	0.407	-0.941	0.289	-0.532	-0.991*	0.993*	-0.774
	Kufri Pukhraj	**-0.999***	0.199	**-0.989***	0.303	0.782	0.983	0.775	-0.864	0.219	-0.359	-0.896	0.436
	Kufri Khyati	-0.507	0.232	-0.334	0.335	-0.187	0.976	-0.198	-0.880	-0.761	-0.327	-0.026	0.466
	Kufri Surya	-0.625	0.044	-0.762	0.151	0.984	**1.000****	0.986	-0.775	0.878	-0.500	-0.925	0.290

*** = significant at 1% level of significance*

** = significant at 5% level of significance*

6.4 MONITORING OF POPULATION OF INSECT PESTS

The population of adult aphids (including *Aphis gossypii* and *Myzus persicae*), leafhoppers and whiteflies in potato was monitored with the help of yellow sticky trap and yellow water pan trap whereas the pheromone trap was used to monitor the *Spodoptera litura* during 2014 and 2015. Traps were placed in the experimental plots and observations were taken weekly. The data pertained with the yellow sticky trap, yellow pan water trap and pheromone trap are mentioned in Tables 6.8 and 6.9 respectively. Further, to depict the magnitude in change over time in the catches of insect pest with yellow sticky traps, yellow pan water traps and pheromone trap stacked area charts were used (Figure 6.3 to 6.5).

Both yellow sticky trap and yellow water pan trap played substantial role in monitoring the population of economically important insect pests in potato field *viz.*, aphids (including *Aphis gossypii* and *Myzus persicae*), leafhoppers and whiteflies in both potato cropping seasons.

In 2014, range of aphids, leafhoppers and whiteflies' trapped by yellow sticky trap was 2 to 17, 2 to 12 and 1 to 9 adults per yellow sticky trap, respectively. The least number of aphids (2), leaf hoppers (2) and whiteflies (1) were trapped during 41st, 49th and 50th standard meteorological weeks (SMW), respectively; however the maximum number(s) of adults of aphids (17), leafhoppers (12) and whiteflies (9) per yellow sticky trap were trapped during 51st, 43rd and 9th SMW(s), respectively. In the same cropping season i.e. *Rabi* 2014, the number of individuals trapped by yellow pan water traps ranged from 4 to 17, 2 to 13 and 0 to 7 for aphids, leafhoppers and whiteflies, respectively. The minimum number(s) of: aphids (4) were trapped during 41st SMW, leafhoppers (2) were trapped during 50th SMW and whiteflies (0) were recorded during 50th and 51st SMW(s).

In the cropping season of 2015, the range of number(s) of adults of aphid (*Aphis gossypii* and *Myzus persicae*), leafhoppers and whiteflies trapped per yellow sticky trap varied from 0 to 16, 0 to 4 and 0 to 28, respectively. No aphid, leafhopper and/or whitefly was trapped during 43rd, 50th& 51st and 51st SMW(s). However, the maximum number of adults of aphids (16), leafhoppers (16) and whiteflies (28) were trapped during 50th, 43rd to 44th and 41st SMW, respectively. The range of aphids, leafhoppers and whiteflies trapped with the yellow water pan trap ranged from 2 to 16, 0 to 15 and 0 to 25, respectively. The least and maximum number of aphids were trapped during 41st and 51st SMW(s), respectively. Further, no leafhopper was monitored during 50th and 51st SMW; however there were considerable numbers (3) of leafhoppers during 49th SMW; the maximum number of this insect were trapped during 43rd (15) and 44th (15) SMW followed by 42nd (12). Maximum (28) and minimum (1) numbers of whiteflies were monitored during 41st SMW and 50th SMW, respectively, with the help of yellow water pan trap; however during 51st SMW no whitefly was monitored.

Adults of whiteflies, thrips and leafhoppers are attracted to yellow colour and yellow traps have been used for trapping them. In the present studies, the yellow sticky trap and water trap were placed in potato of fields for monitoring the population of whiteflies, thrips and leafhoppers during 2014 and 2015. The idea behind the study was to replace the visual counting of the adults as the adults are mobile and leave the host on a little disturbance and to evaluate the method for management of these insect pests.

The data from this investigation reveal the weekly catch of adults in both the traps. Usually the adult catch per yellow water trap was more as compared to yellow sticky trap. So as an option the yellow water traps can also be used for monitoring whitefly population. These results are strengthen with the findings of Vučetić *et al.* (2014) who identified several new species of aphids with the help of yellow water pan traps. Further, findings of Tang et al. (2016), Do Bae *et al.* (2015), Lee *et al.* (2013) and Hall *et al.* (2009) also supports the findings on traps from the present investigation.

Pheromone traps played substantial role in monitoring the population of *Spodoptera litura* in potato field(s) for both years. The range of *Spodoptera litura* trapped by pheromone trap was 0 to 21 and 0 to 18 adults per week per pheromone trap for 2014 and 2015, respectively. For the year 2014, adult were captured only up to 48th SMW, Further no *Spodoptera* adult was captured by trap during 49th, 50th and 51st SMW while in year 2015 adult were captured upto 50th week. The maximum number of adult were monitored in 45th and 43rd week in 2014 and 2015, respectively.

These findings are in confirmatory with Kumar *et al.* (2009) who studied the correlation between the incidence of *S. litura* in potato filed and pheromone trap. Findings of Kalola *et al.* (2017) and Blassioli-Moraes *et al.* (2016) also strengthen these experimental findings.

Table 6.8: Number of insects trapped with yellow sticky trap and yellow water pan trap in the experimental fields of CPRS, Jalandhar during *Rabi* 2014 and 2015

SMW	Traps	Aphids			Leaf Hoppers			Whiteflies		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
41st	*YST*	2.00	3.00	2.50	5.00	11.00	8.00	5.00	28.00	16.50
	YWPT	4.00	2.00	3.00	9.00	10.00	9.50	3.00	25.00	14.00
42nd	*YST*	5.00	2.00	3.50	10.00	10.00	10.00	9.00	22.00	15.50
	YWPT	6.00	4.00	5.00	7.00	12.00	9.50	5.00	20.00	12.50
43rd	*YST*	5.00	0.00	2.50	12.00	16.00	14.00	6.00	19.00	12.50
	YWPT	4.00	5.00	4.50	6.00	15.00	10.50	6.00	20.00	13.00
44th	*YST*	3.00	6.00	4.50	8.00	16.00	12.00	5.00	9.00	7.00
	YWPT	5.00	6.00	5.50	8.00	15.00	11.50	5.00	11.00	8.00
45th	*YST*	7.00	3.00	5.00	8.00	11.00	9.50	7.00	10.00	8.50
	YWPT	7.00	8.00	7.50	10.00	10.00	10.00	7.00	8.00	7.50
46th	*YST*	10.00	6.00	8.00	6.00	5.00	5.50	4.00	8.00	6.00
	YWPT	8.00	9.00	8.50	12.00	4.00	8.00	3.00	8.00	5.50
47th	*YST*	10.00	9.00	9.50	5.00	7.00	6.00	5.00	6.00	5.50
	YWPT	10.00	4.00	7.00	13.00	8.00	10.50	3.00	6.00	4.50
48th	*YST*	13.00	8.00	10.50	3.00	5.00	4.00	4.00	4.00	4.00
	YWPT	13.00	10.00	11.50	6.00	6.00	6.00	3.00	5.00	4.00
49th	*YST*	11.00	13.00	12.00	2.00	4.00	3.00	4.00	2.00	3.00
	YWPT	11.00	14.00	12.50	5.00	3.00	4.00	4.00	1.00	2.50
50th	*YST*	14.00	16.00	15.00	0.00	0.00	0.00	1.00	1.00	1.00
	YWPT	14.00	14.00	14.00	2.00	0.00	1.00	0.00	1.00	0.50
51st	*YST*	17.00	10.00	13.50	0.00	0.00	0.00	0.00	0.00	0.00
	YWPT	17.00	16.00	16.50	3.00	0.00	1.50	0.00	0.00	0.00

YST: Yellow Sticky Trap: YWPT: Yellow Water Pan Traps

Table 6.9: Number of *Spodoptera litura* trapped with pheromone in the experimental fields of CPRS, Jalandhar during Rabi 2014 and 2015

SMW	*Spodoptera litura*		
	2014	2015	Pooled
41st	0.00	0.00	0.00
42nd	0.00	0.00	0.00
43rd	16.00	18.00	17.00
44th	20.00	15.00	17.50
45th	21.00	14.00	17.50
46th	13.00	16.00	14.50
47th	15.00	13.00	14.00
48th	10.00	12.00	11.00
49th	0.00	9.00	4.50
50th	0.00	5.00	2.50
51st	0.00	0.00	0.00

Figure: 6.3: Stacked area charts depicting the magnitude of change in catch of insect pest by yellow sticky trap during *Rabi* 2014 and 2015 at CPRS, Jalandhar

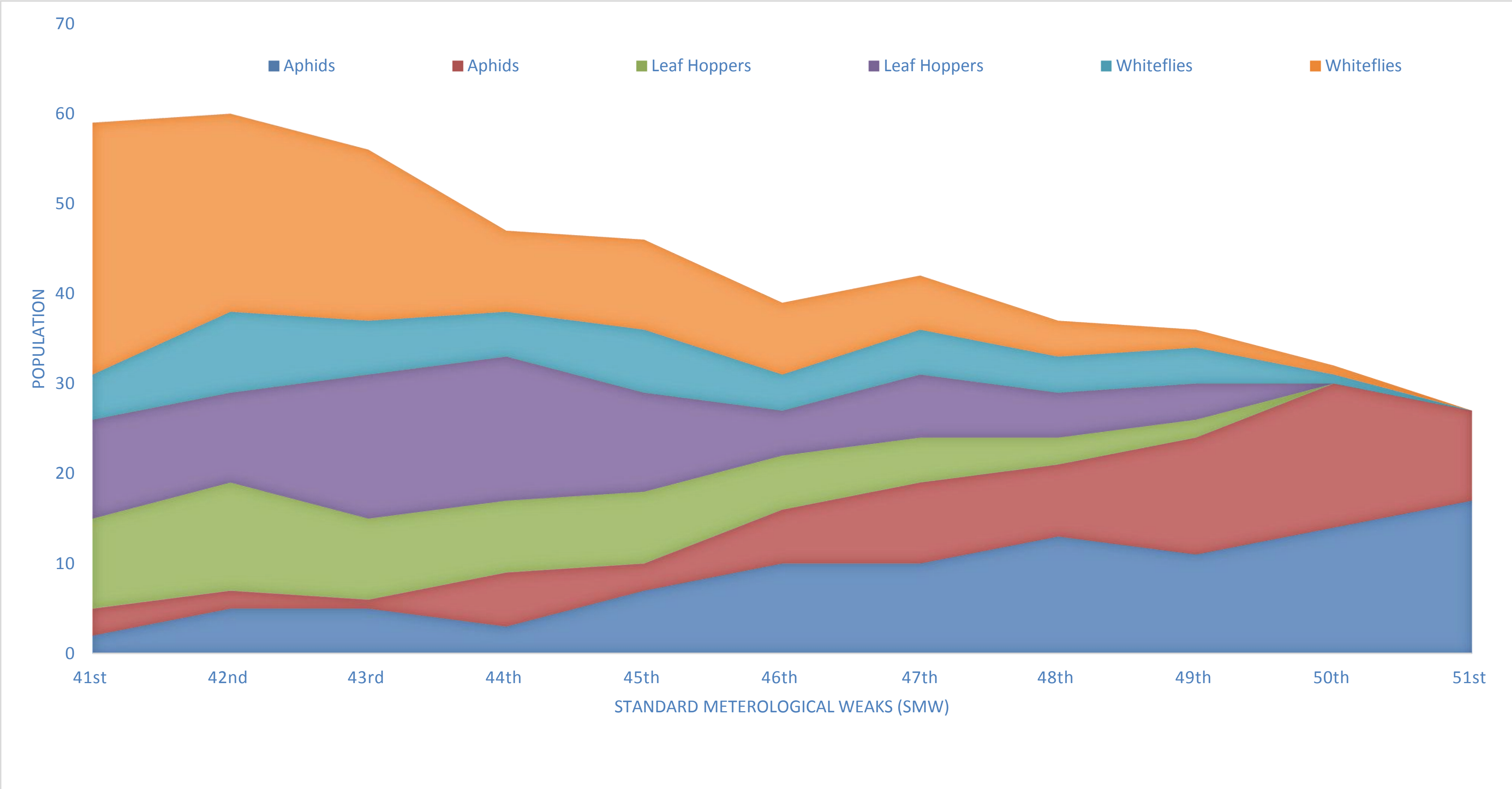


Figure: 6.4: Stacked area charts depicting the magnitude of change in catch of insect pest by yellow pan water trap during *Rabi* 2014 and 2015 at CPRS, Jalandhar

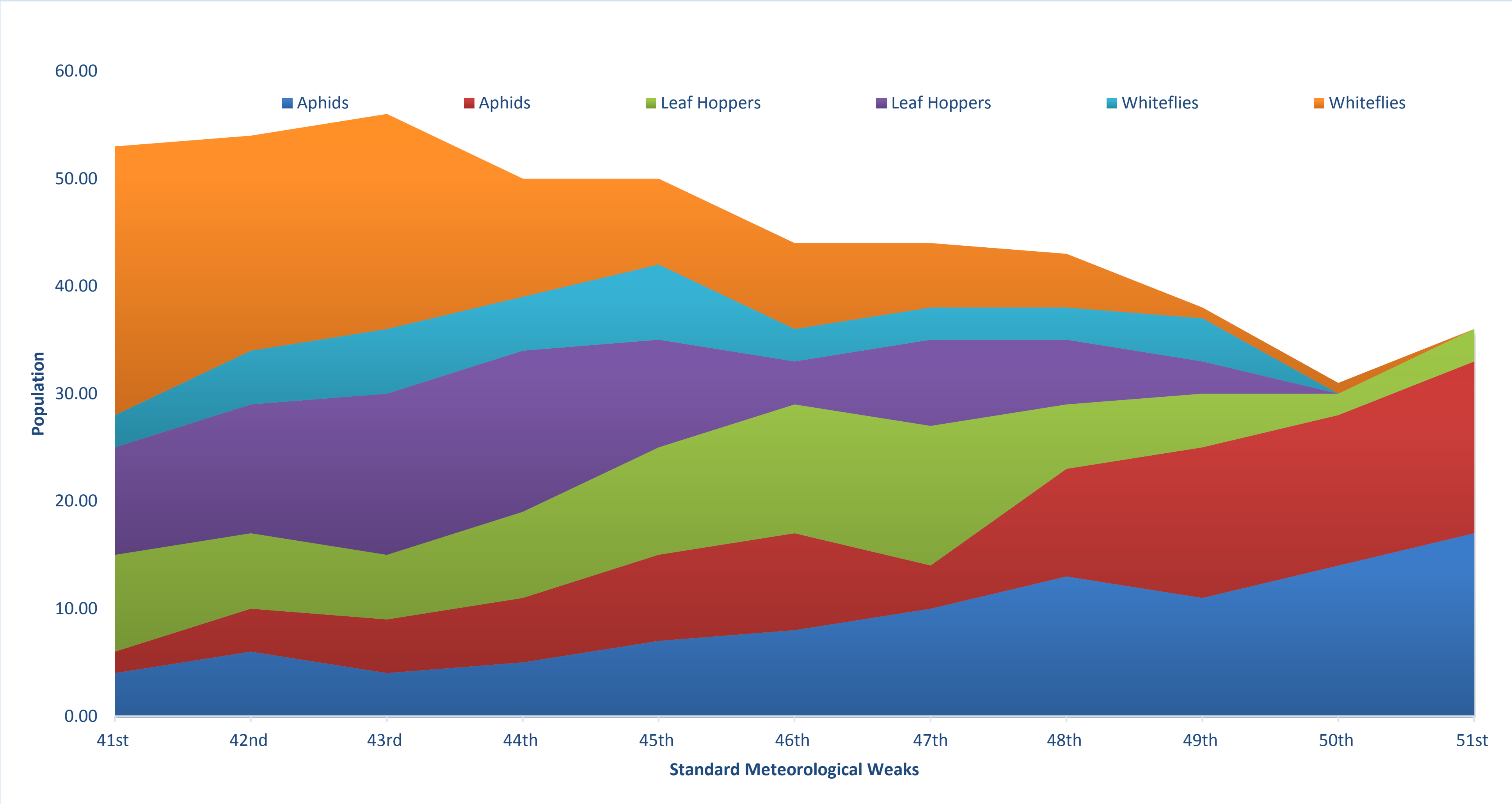
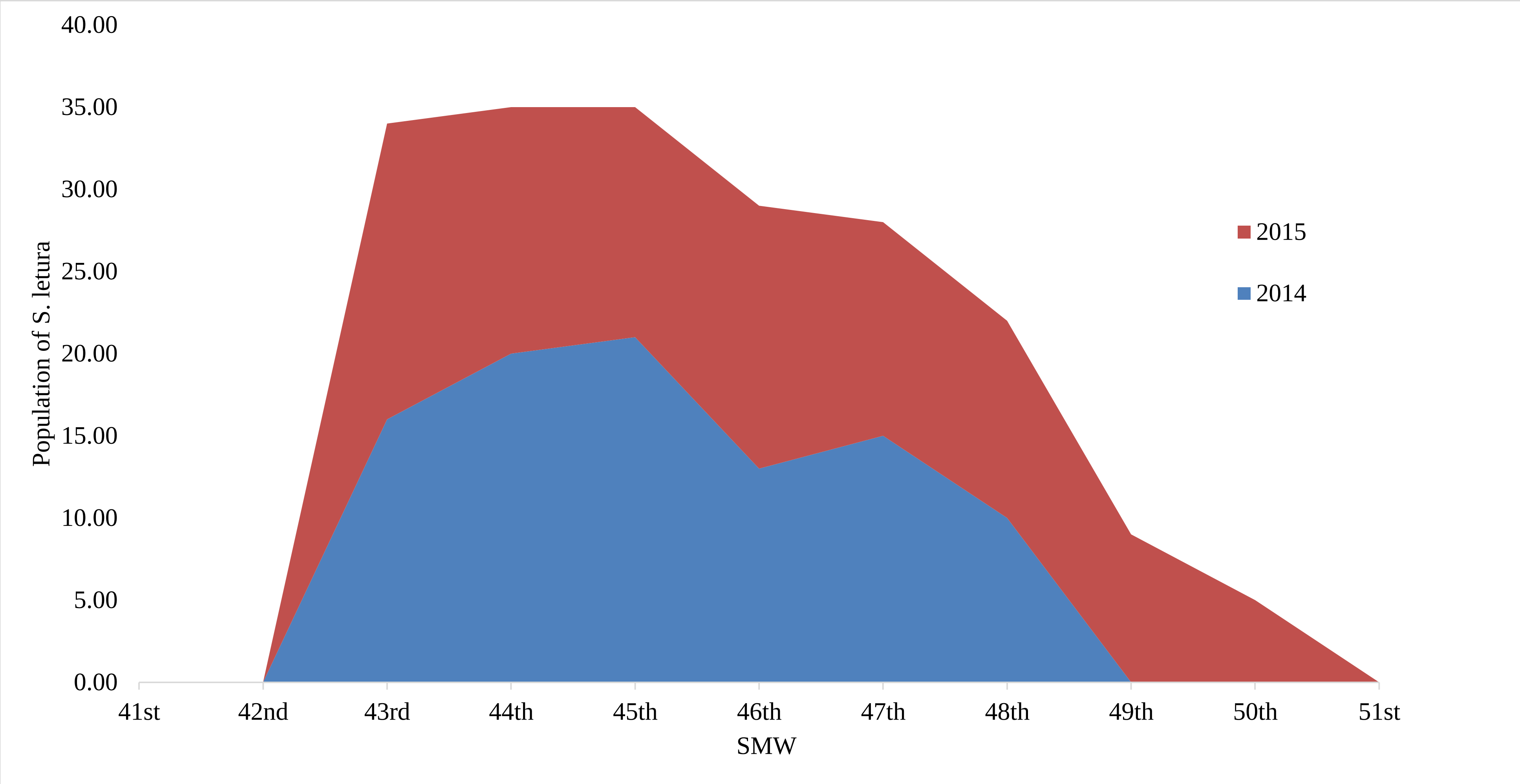


Figure 6.5: Stacked area charts depicting the magnitude of change in catch of *Spodoptera litura* by pheromone trap during *Rabi* 2014 and 2015 at CPRS, Jalandhar



6.5 Efficacy of chemical and bio insecticides and plant extract (NKE) by rotating chemistries against major sucking insect pests of potato (*Solanum tuberosum* L.)

Efficacy of a total of four chemical insecticides (Chloropyriphos, Dimethoate Thiomethoxam and Imidacloprid), one Neem based kernel extract (Neem Baan) and two bio pesticides (*Metarrhizium anisopliae* and *Beauveria bassiana*) was tested by means of rotating chemistry against major sucking insect pests of potato *viz.* aphids, leafhoppers and whiteflies during both cropping seasons 2014 and 2015.

6.5.1 Efficacy against aphids

The results obtained on the efficacy of above mentioned insecticides and bio-pesticides in reducing the aphid population by means of rotating chemistry after first, second, third and fourth spray is presented in Table 6.10 to 6.11 and depicted from Figure 6.6 to 6.8 of the cropping seasons 2014 and 2015.

6.5.1.1 Efficacy against aphids in cropping season 2014

In the cropping season 2014, the initial population (before spray) of aphids ranged from max 14.44 per ten plants to min 12.74 per ten plants in all the treatments and was significantly different at 5 percent CD.

(i) After first spray

After the 3rd day of first spray, the population of aphids was recorded between 2.93 and 4.99 aphids per ten plants in the treated plots; however, it was 17.24 in untreated (control) plot. The minimum number of aphids (2.93 aphids per ten plants) were recorded from the plot treated with T3 {foliar spray of Imidacloprid 200 SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} followed by T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* 2X10^{9} CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T5 { Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} the population was 3.74, 4.07, 4.66, 4.71 and 4.99 aphids per ten plants, respectively. The treatments T4, T5 and T6 were at par with each other; however, there were observed significant differences among all other treatments at

5 percent CD. There was reported a significant difference between all the treatments at 5 percent CD.

After 7th day of first spray the population of aphids was recorded between 3.28 and 5.60 aphids per ten plants while in control it was recorded 19.43 aphids per ten plants. The plot with treatment T3 had least population of aphids i.e. 3.28 aphids per ten plants. Further, 3.87, 4.34, 4.96, 5.13 and 5.60 aphids were recorded from the plots treated with treatments T2, T1, T4, T6 and T5, respectively.

In this array after 10th day of first spray the population in the untreated plot was recorded as 21.33 aphids per ten plants. The treatments followed the same trend of controlling aphid population as it was after 3rd and 7th. The plot with treatment T3 had least aphid population (3.54 aphids per ten plants) over the other six treatments. Population in plots treated with T2, T1, T4, T6, and T5 were 4.06, 4.72, 5.27, 5.27 and 5.96 aphids per ten plants, respectively. It was interesting to come to know that this time the results of T4 and T6 were at par with each other; however, there were observed significant differences among all other treatments at 5 percent CD

(ii) After second Spray

After 3rd day of second spray the highest population of aphids 23.56 aphids per ten plants. The data revealed that population of aphids was lowest (3.41 aphids per ten plants) in the plot treated with T3 {Chloropyriphos 20 EC (3ml /lit)} followed by T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)}. Population of aphids in these plots were recorded 3.92, 4.60, 5.21, 5.24 and 5.77 aphids per ten plants, respectively.

Further, after both 7th day and 10th day of second spray the highest population (26.49 and 28.34aphids per ten plants) were recorded from untreated plot whereas the least (3.53 and 3.88 aphids per ten plants, respectively) was noted down from the plot with T3 treatment. Further, after 7th and 10th day of second spray other treatments *viz.* T2, T1, T6, T4 and T5 were recorded with 4.12, 4.64, 5.36, 5.41 and 6.12 aphids per ten plants and 4.25, 4.95, 5.91, 5.84 and 6.34 aphids per ten plants respectively.

(iii) After third spray

The population in untreated plot was recorded 24.36 aphids per ten plants after 3rd day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was recorded with a population of 3.82 aphids per ten plants which was least among all. Followed to this the treatments namely T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T4 {Rogor 30EC (1.5ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} and T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} were recorded with 4.57, 5.24, 5.32, 6.17 and 6.62 aphids per ten plants, respectively in their respective plots.

After 7th day of third spray the population in the untreated plot was recorded 17.54 aphids per ten plants. Aphid population in the plot treated with T3 was recorded with minimum aphid population i.e. 3.08 aphids per ten plants. Other treatments *viz.*, T2, T1, T6, T4 and T5 were recorded with 3.76, 4.43, 4.63, 4.70 and 5.30 aphids per ten plants, respectively.

At 10th day of third spray the population in the untreated plot was recorded as 11.31 aphids per ten plants. The plot with T3 was having least number of aphids (3.01 aphids per ten plants) over the other six treatments *viz.*, T2, T1, T4, T6 and T5. These aphid population in the plots treated with these treatments was recorded 3.60, 3.93, 4.33, 4.47 and 4.80 aphids per ten plants, respectively.

(iv) After fourth spray

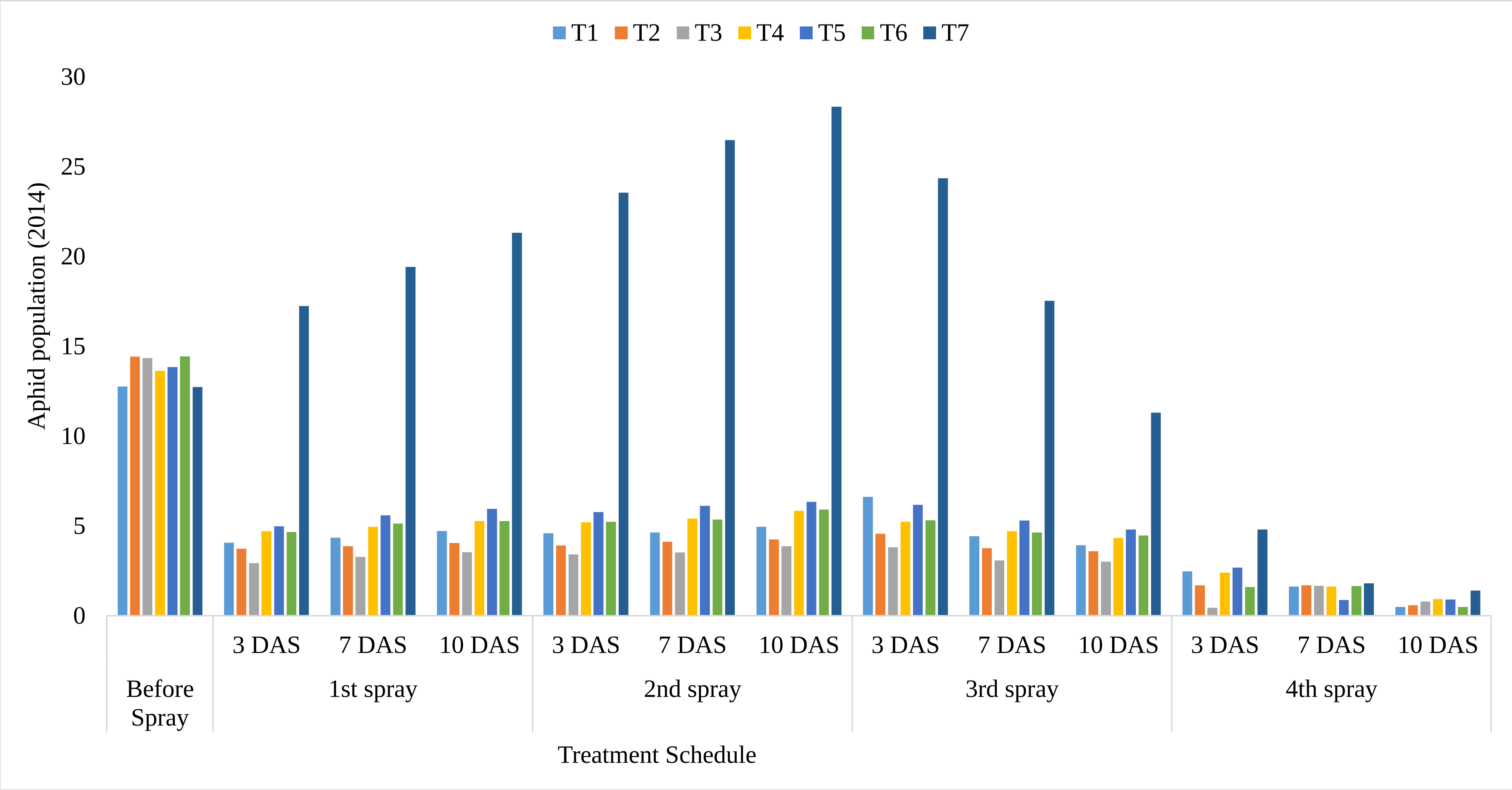
After the 3rd day of fourth spray, 4.80 in untreated (control) plot. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported with least aphid population (0.45 aphids per ten plants), significantly followed by T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, and T5 { Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance}. The population in these plots were recorded with 1.60, 1.70, 2.40, 2.47 and 2.68 aphids per ten plants, respectively.

Table 6.10: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2014:

Treatment	Before Spray	1st spray			2nd spray			3rd spray			4th spray			Percent Reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	12.77 (3.57)	4.07 (2.02)	4.34 (2.08)	4.72 (2.17)	4.60 (2.14)	4.64 (2.15)	4.95 (2.22)	6.62 (2.57)	4.43 (2.11)	3.93 (1.98)	2.47 (1.57)	1.63 (1.28)	0.49 (0.70)	76.27
T2	14.43 (3.80)	3.74 (1.93)	3.87 (1.97)	4.06 (2.02)	3.92 (1.98)	4.12 (2.03)	4.25 (2.06)	4.57 (2.14)	3.76 (1.94)	3.60 (1.90)	1.70 (1.30)	1.69 (1.30)	0.58 (0.76)	79.83
T3	14.35 (3.79)	**2.93 (1.71)**	3.28 (1.81)	3.54 (1.88)	3.41 (1.85)	3.53 (1.88)	3.88 (1.97)	3.82 (1.95)	3.08 (1.75)	3.01 (1.73)	0.45 (0.67)	1.67 (1.29)	0.79 (0.89)	83.11
T4	13.64 (3.69)	4.71 (2.17)	4.96 (2.23)	5.27 (2.30)	5.21 (2.28)	5.41 (2.33)	5.84 (2.42)	5.24 (2.29)	4.70 (2.17)	4.33 (2.08)	2.40 (1.55)	1.63 (1.28)	0.93 (0.97)	74.83
T5	13.85 (3.72)	**4.99 (2.23)**	5.60 (2.37)	5.96 (2.44)	5.77 (2.40)	6.12 (2.47)	6.34 (2.52)	6.17 (2.48)	5.30 (2.30)	4.80 (2.19)	2.68 (1.64)	0.88 (0.94)	0.90 (0.95)	71.90
T6	14.44 (3.80)	4.66 (2.16)	5.13 (2.26)	5.27 (2.30)	5.24 (2.29)	5.36 (2.32)	5.91 (2.43)	5.32 (2.31)	4.63 (2.15)	4.47 (2.12)	1.60 (1.26)	1.66 (1.29)	0.49 (0.70)	74.82
T7	12.74 (3.57)	17.24 (4.15)	19.43 (4.41)	21.33 (4.62)	23.56 (4.85)	26.49 (5.15)	28.34 (5.32)	24.36 (4.94)	17.54 (4.19)	11.31 (3.36)	4.80 (2.19)	1.80 (1.34)	1.40 (1.18)	
C.D.	0.07	0.056	0.073	0.087	0.073	0.075	0.116	0.052	0.072	0.082	0.556	N/A	N/A	
SE(m)	0.022	0.018	0.023	0.028	0.024	0.024	0.037	0.017	0.023	0.026	0.433	0.593	0.491	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.6: Efficacy of tested insecticides,Biopesticides and plant extracts (NKE) against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2014



After 7th day of fourth spray, highest aphid population 1.80 aphids per ten plants was recorded in untreated plot in contrast to this the plot with treatment T5 showed the least number of aphids i.e., 0.88 aphids per ten plants. Further, the treatments *viz.* T4, T1, T6, T3, and T2 treated plots had 1.63, 1.63, 1.66, 1.67 and 1.69 aphids per ten plants, respectively.

Further, after 10th day of fourth spray the population in the untreated plot was recorded as 1.40 aphids per ten plants. The T1 and T6 showed lowest aphid population (0.49 aphids per ten plants) over the other five treatments. T2, T3, T5 and T4 were recorded with 0.58, 0.79, 0.90 and 0.93 aphids per ten plants, respectively.

6.5.1.2 Efficacy against aphids in cropping season 2015

During the crop season 2015 the initial population of aphids before spray recorded between 14.59 per ten plants and 13.80 per ten plants in all the treatments.

(i) After first spray

In untreated plot the aphid population 17.93 aphids per ten plants was recorded Further, data recorded after the 3rd day of first spray plot treated with T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported with least aphid population (3.08 aphids per ten plants) followed by T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* 2X10^{9} CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T5 { Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} where 4.06, 4.54, 5.11, 5.31 and 6.09 aphids per ten plants, respectively were recorded . The treatment T4 was at par with T6; however, there was reported a significant difference between other treatments at 5 percent C.D.

At 7th day of first spray 19.51 aphids per ten plants recorded in the untreated plot. The treatment T3 was recorded with minimum (3.47 aphids per ten plants) numbers of aphid. The population in other treatments *viz.* T2, T1, T6, T4 and T5 was 4.20, 4.85, 5.51, 5.60 and 6.37 aphids per ten plants, respectively. There was reported a significant difference in all the treatments at 5 percent C.D.

Further, after 10th day of first spray the population in the untreated plot was recorded as 22.11 aphids per ten plants. Among all the treatments the lowest population 3.83 aphids per ten plants was recorded with the treatment T3 whereas T2, T1, T4, T6 and T5 were recorded with 4.13, 4.93, 6.04, 6.12 and 7.04 aphids per ten plants, respectively. Likewise cropping season of 2014 the treatments T4 and T6 were again at par to each other; however, there were observed significant differences among other treatments at 5 percent C.D.

(ii) After second Spray

Data recorded after 3rd day of second spray revealed that the number of aphids per ten plants were least (3.50) in the plot treated with T3 {Chloropyriphos 20 EC (3 ml /lit)} followed by the plots treated with treatment T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} which had 4.24, 4.91, 5.70, 5.87, and 6.60 aphids per ten plants, respectively.

Least number of aphids *viz.*, 3.91 and 4.07 aphids per ten plants, respectively were further recorded after both 7th day and 10th day of second spray in the plot with T3 treatment whereas the maximum number of aphids per ten plants (26.62 and28.76) were residing in untreated plot. Further, after 7th day of spray in other treatments *viz.* T2, T1, T6, T4 and T5 were recorded with 4.28, 4.97, 6.28, 6.23 and 6.92 aphids per ten plants, respectively whereas 5.57, 5.15, 6.81, 6.19 and 8.40 aphids were recorded with T1, T2, T6, T4 and T5, respectively after 10th day of spray. Further it was reported that after 7th day of spray results of treatments T4 and T6 were at par whereas after 10th day of spray results of treatments T1 were at par with T2.

(iii) After third spray

The population in untreated plot was recorded 25.18 aphids per ten plants after 3rd day of third spray. Further, the treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was recorded with least (4.05) number of aphids per ten plants. The treatment T6 {Rogor 30EC (1.5ml/lit)} had maximum (6.49) number of aphids. Further, 4.82, 5.24, 5.36 and 6.25 aphids per ten plants, respectively were reported in the plots treated with T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T5 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T4 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)}.

After 7th day of spray the population in the untreated plot was recorded 18.15 aphids per ten plants. Among treated plots the treatment namely T3 had minimum (3.44) number of aphids per ten plants where as T5 had maximum (5.75) number of aphids per ten plants. In T2, T1, T4 and T6 had 3.84, 4.43, 5.03 and 5.15 aphids per ten plants, respectively.

At 10th day of first spray the population in the untreated plot was recorded as 11.61 aphids per ten plants. Treatment T3 was found associated with least (3.34) number of aphids per ten plants whereas maximum (4.92 aphids per ten plants) was associated with T5. Plots with treatments T2, T1, T6 and T4 showed 3.61, 3.92, 4.72 and 4.74 aphids per ten plants, respectively. Further, the treatments T4, T5 and T6 were recorded at par with each other.

(iv) After fourth spray

After the 3rd day of fourth spray, the population of aphids varied between 1.21 and 2.13 aphids per ten plants in the treated plots however, it was 2.60 in untreated (control) plot. Plot with treatment T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}was reported with minimum aphid population (1.21 aphids per ten plants) in contrast to this plot with treatment T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} had maximum aphid density (2.13 aphids per ten plants). The other treatments *viz.*,T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}, T5 { Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance}, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance} had population of 1.45, 1.72, 1.82 and 2.0 aphids per ten plants, respectively.

In treated plots the range of aphid population after 7th day of fourth spray was recorded between 1.01 and 1.39 aphids per ten plants whereas 1.47 aphids per ten plants were recorded in untreated plot. Treatment T3 was recorded with minimum aphid population among all *i.e.* 1.01 aphids per ten plants in contrast maximum population was recorded in T4 (1.39 aphids per ten plants). Other treatments *viz.* T2, T5, T1 and T6 1.05, 1.14, 1.30 and 1.33 aphids per ten plants, respectively.

Further, after 10th day of fourth spray the population in the untreated plot was recorded as 1.04 aphids per ten plants. Treatment namely T2 was found associated with least aphid population (0.25 aphids per ten plants) among all others. Further, treatments *viz.*, T1, T3, T6, T4 and T5 were recorded with 0.65, 0.70, 0.83, 0.87 and 1.13 aphids per ten plants, respectively.

Figure 6.7: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2015

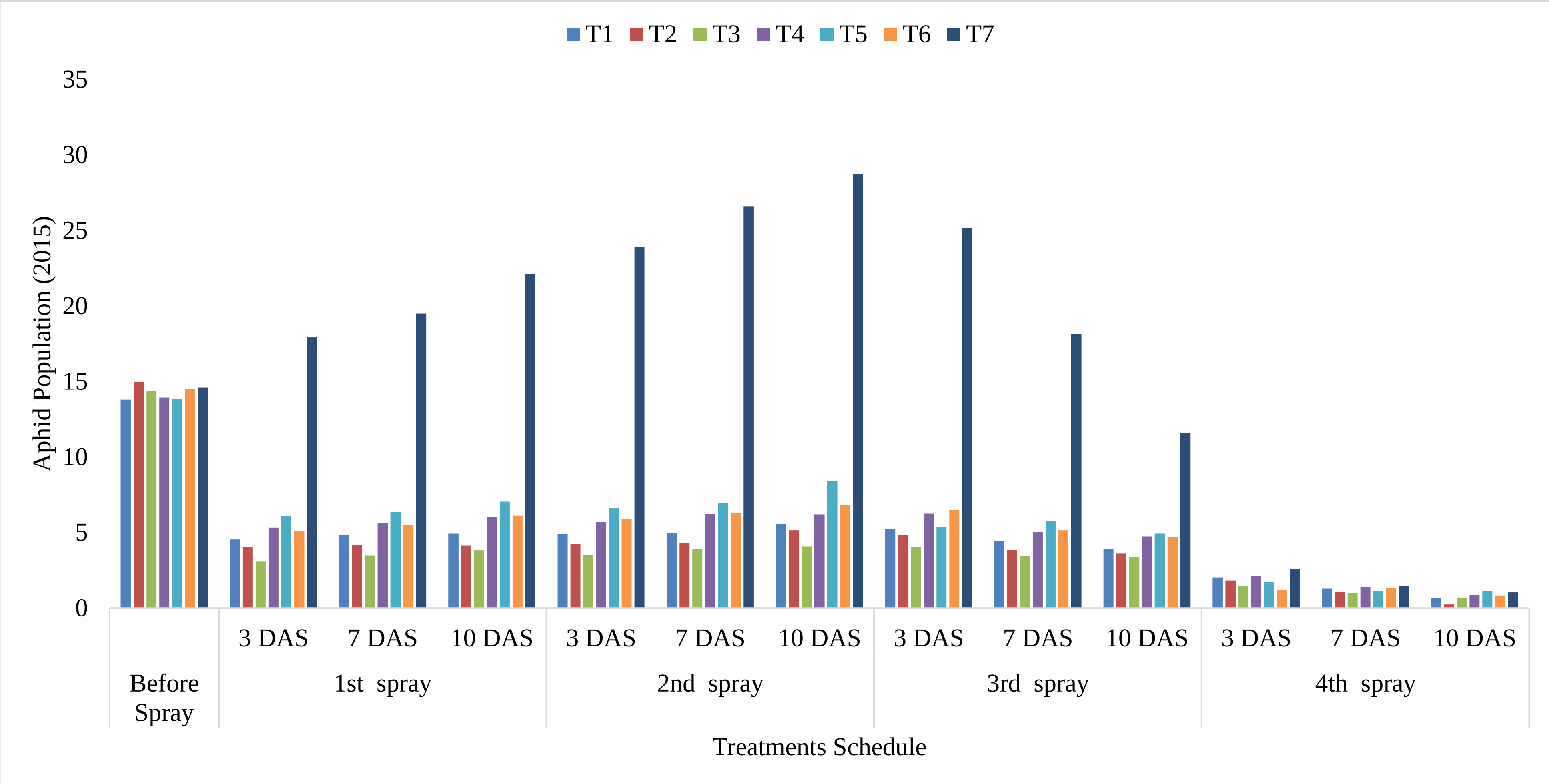


Table 6.11: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatments	**Before Spray**	**1st spray**			**2nd spray**			**3rd spray**			**4th spray**			**Percent Reduction**
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	13.80 (3.71)	4.54 (2.13)	4.85 (2.20)	4.93 (2.22)	4.91 (2.22)	4.97 (2.23)	5.57 (2.36)	5.24 (2.29)	4.43 (2.10)	3.92 (1.98)	2.0 (0.51)	1.30 (1.14)	0.65 (0.81)	79.27
T2	14.99 (3.87)	4.06 (2.01)	4.20 (2.05)	4.13 (2.03)	4.24 (2.06)	4.28 (2.07)	5.15 (2.27)	4.82 (2.20)	3.84 (1.96)	3.61 (1.90)	1.82 (0.21)	1.05 (1.02)	0.25 (0.50)	79.20
T3	14.40 (3.79)	3.08 (1.76)	3.47 (1.86)	3.83 (1.96)	3.50 (1.87)	3.91 (1.98)	4.07 (2.02)	4.05 (2.01)	3.44 (1.85)	3.34 (1.83)	1.45 (0.05)	1.01 (1.00)	0.70 (0.84)	82.01
T4	13.93 (3.73)	5.31 (2.30)	5.60 (2.37)	6.04 (2.46)	5.70 (2.39)	6.23 (2.50)	6.19 (2.49)	6.25 (2.50)	5.03 (2.24)	4.74 (2.18)	2.13 (0.09)	1.39 (1.18)	0.87 (0.93)	72.17
T5	13.81 (3.72)	6.09 (2.47)	6.37 (2.52)	7.04 (2.65)	6.60 (2.57)	6.92 (2.63)	8.40 (2.90)	5.36 (2.32)	5.75 (2.40)	4.92 (2.22)	1.72 (0.31)	1.14 (1.07)	1.13 (1.06)	69.17
T6	14.49 (3.81)	5.11 (2.26)	5.51 (2.35)	6.12 (2.47)	5.87 (2.42)	6.28 (2.51)	6.81 (2.61)	6.49 (2.55)	5.15 (2.27)	4.72 (2.17)	1.21 (0.55)	1.33 (1.15)	0.83 (0.91)	72.20
T7	14.59 (3.82)	17.93 (4.23)	19.51 (4.42)	22.11 (4.70)	23.93 (4.89)	26.62 (5.16)	28.76 (5.36)	25.18 (5.02)	18.15 (4.26)	11.61 (3.41)	2.6 (0.10	1.47 (1.21)	1.04 (1.02)	
C.D.	0.088	0.48	0.287	0.339	0.222	0.127	0.559	0.236	0.352	0.295	N/A	N/A	N/A	
SE(m)	0.028	0.154	0.092	0.109	0.071	0.041	0.179	0.076	0.113	0.095	0.266	0.655	0.366	

**Figures in parentheses are square root transformed values (x + 0.5)*

The outcomes from this experiment unveiled the efficacy of tested insecticides and pesticides of controlling the aphid population in the potato fields by means of rotating chemistry. The two season data generated during this investigation revealed that all the tested insecticides and pesticides were able to bring significant reduction in the aphid population over the control (untreated plot).

The data revealed that after 3^{rd}, 7^{th} and 10^{th} day of first, second and fourth spray the treatment namely T3 which included the foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (3 ml /lit), foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Rogor 30EC (1.5ml/lit), significantly reduced the aphid population in the treated plots during both season and found significantly superior over the other treatments.

6.5.1.3 Efficacy from pooled data of 2014 and 2015

The data of both cropping seasons were pooled and analysed to check the overall efficacy of different insecticides, biopesticides and plant extracts on controlling the aphid population in the potato crop. In the experimental fields the initial aphid population i.e. population before spray varied from 13.28 to 14.71 aphids per ten plants among all treatments; however, the difference between them at 5 percent C.D. was non-significant.

(i) After first spray

In the pooled data analysis, after 3^{rd} day of first spray, the population of aphids varied between 3.01 and 5.54 aphids per ten plants in the treated plots however, it was 17.58 in untreated (control) plot. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported as most promising treatment in reducing aphid population (3.01 aphids per ten plants), significantly. The other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} also helped in reducing the aphid population up to 3.90, 4.30, 4.89, 5.01 and 5.54

aphids per ten plants, respectively over the aphid population of untreated plot. The treatments T4 was at par with T5 and T6 in controlling aphid population; however, there were observed significant differences among all other treatments at 5 percent C.D.

After 7th day of first spray the population of aphids ranged between 3.37 and 5.99 aphids per ten plants and it was recorded 19.47 aphids per ten plants in the untreated plot. Treatment T3 was proved to be promising in controlling the aphid population by maintaining it to 3.37 aphids per ten plants in contrast to the population recorded in untreated plot. Further, the treatments namely T2, T1, T4, T6 and T5 also controlled the aphid population in the treated plots significantly while maintaining it to 4.04, 4.59, 5.28, 5.32 and 5.99, respectively. Further, treatments T4 and T6 were significantly similar.

After 10th day of first spray the population in the untreated plot was recorded as 21.72 aphids per ten plants. The treatments followed the same trend as it was after 3rd and 7th day i.e. the T3 promisingly controlled the aphid population (3.69 aphids per ten plants) over the other six treatments *viz.*, T2, T1, T4, T6 and T5 which maintained a population of 4.10, 4.83, 5.65, 5.69 and 6.50 aphids per ten plants, respectively which were significantly less than that of the aphid population of untreated plot. It was interesting to come to know results of T4 and T6 were at par with each other; however, there were observed significant differences among all other treatments at 5 percent C.D.

(ii) After second spray

23.74 aphids per ten plants were recorded in the untreated plot. Further, the data from this investigation revealed that after 3rd day of second spray the number of aphids per ten plants were least (3.46) in the plot with T3 {Chloropyriphos 20 EC (3 ml /lit)}. T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} maintained the aphid population at significantly lower than that of untreated plot 4.08, 4.76, 5.45, 5.56 and 6.19 aphids per ten plants, respectively which are significantly less than the aphid population of untreated plot.

After 7th day of first spray the population of aphids ranged between 3.72 and 6.52 aphids per ten plants and it was recorded 26.55 aphids per ten plants in the untreated plot. Treatment T3 promisingly controlled the aphid population and maintained it to 3.72 aphids per ten plants in contrast to the population recorded in untreated plot. Further, in contrast to untreated plot the aphid population was reported at significantly low level in the plots treated with the treatments T2 , T1 , T4 , T6 and T5 also controlled the aphid population in the treated plots significantly while maintaining it to 4.20, 4.80, 5.82, 5.82 and 6.52, respectively. Further, treatments T2 and T4 were found significantly similar with T3 and T6, respectively.

At 10th day of first spray the population in the untreated plot was recorded as 28.55 aphids per ten plants which was much higher than that of the previous one. The treatment T3 was found promising in controlling the aphid population (3.98 aphids per ten plants) over the other six treatments. Treatments T2 (4.70), T1 (5.26), T4 (6.02), T6 (6.36) and T5 (7.37) also showed considerable control on the aphid population.

(iii) After third spray

The population in untreated plot was recorded 24.77 aphids per ten plants after 3rd day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was found to be most promising for controlling the aphid population in the treated plot. This treatment significantly reduced the aphid population and maintained it to 3.94 aphids per ten plants which was significantly less than that of the untreated plot. The treatments namely T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T4 {Rogor 30EC (1.5ml/lit)}, T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} and T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} also controlled the aphid population significantly and maintained it to 4.70, 5.93, 5.74, 5.77 and 5.91, respectively. The treatment T1 was at par with T4, T5 and T6.

After 7th day of spray the population in the untreated plot was recorded 17.85 aphids per ten plants. The treatment namely T3 controlled the aphid population in the treated plot, most promisingly. This treatment significantly reduced the aphid population and maintained it to 3.26 aphids per ten plants which was significantly less than that of the untreated plot. Further, the treatments viz., T2, T1, T4, T6 and T5 also controlled the aphid population significantly and maintained it to 3.80, 4.43, 4.86, 4.89 and 5.53, respectively.

At 10th day of first spray the population in the untreated plot was recorded as 11.46 aphids per ten plants which was much higher than that of the previous one. Least population of aphids (3.17 aphids per ten plants) were reported in the plot treated with treatment number T3. Further, treatments T2 (3.60 aphids), T1 (3.93 aphids), T4 (4.54 aphids), T6 (4.60 aphids) and T5 (4.86 aphids) controlled the aphid population at significantly low level. Further, the treatments T4, T5 and T6 were found significantly similar.

(iv) After fourth spray

After the 3rd day of first spray, the population of aphids varied between 0.95 and 2.27 aphids per ten plants in the treated plots however, it was 3.70 in untreated (control) plot. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported as most promising treatment in reducing aphid population (0.95 aphids per ten plants), significantly. Beside this other treatments *viz.*, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T5 { Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance} and T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} also helped in reducing the aphid population up to1.41, 1.76, 2.20, 2.24 and 2.27 aphids per ten plants, respectively over the aphid population of untreated plot.

After 7th day of first spray the population of aphids ranged between 1.01 and 1.51 aphids per ten plants and it was recorded 1.63 aphids per ten plants in the untreated plot. The treatment T5 was proved most promising in controlling the aphid population by controlling it to 1.01 aphids per ten plants in contrast to the population recorded in untreated plot. Further, the treatments *viz.* T3, T2, T1, T6 and T4 also controlled the aphid population in the treated plots significantly while maintaining it to 1.34, 1.37, 1.47, 1.49 and 1.51, respectively.

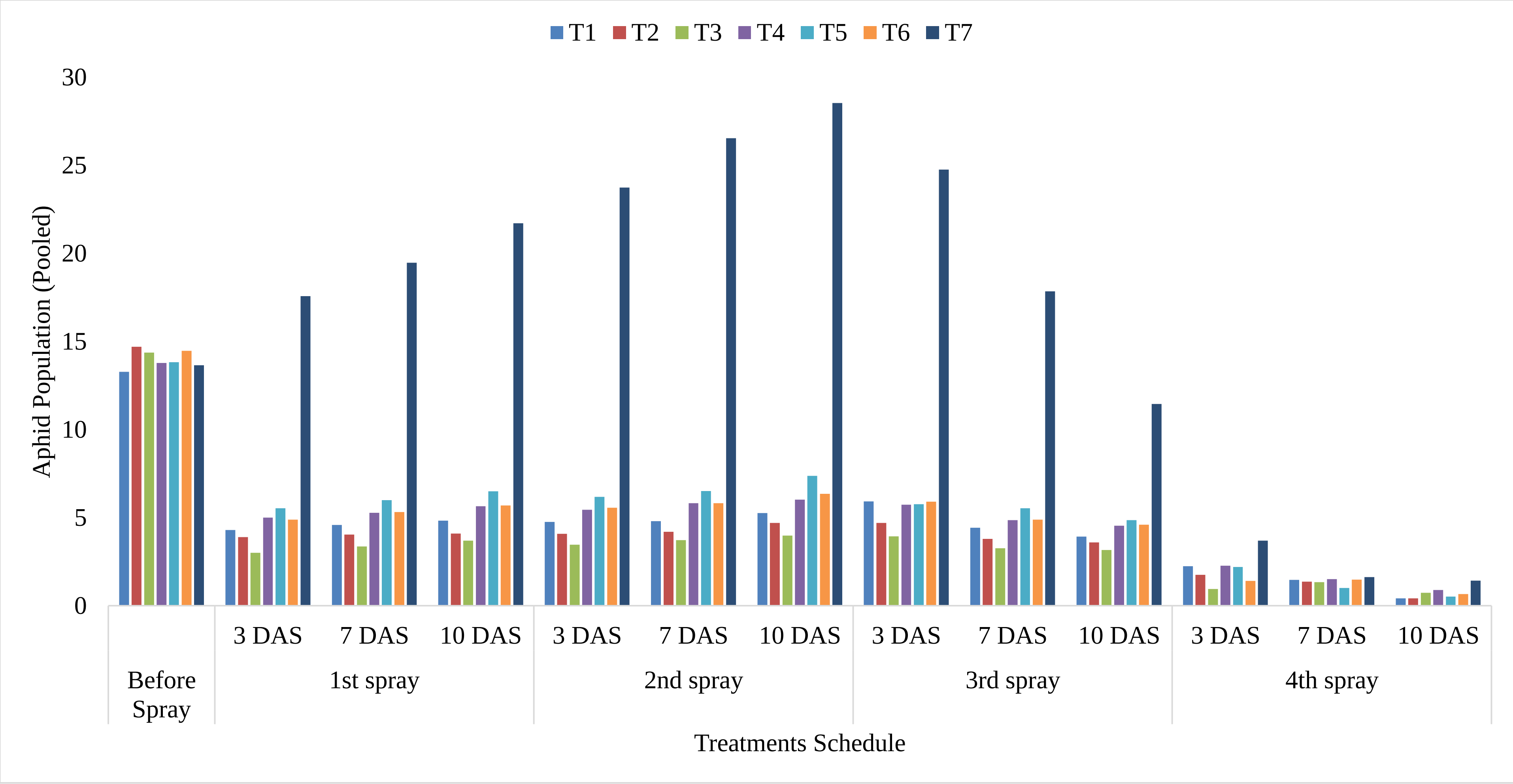
Further, after 10th day of first spray the population in the untreated plot was recorded as 1.43 aphids per ten plants which was much higher than that of the previous one. T2 promisingly controlled the aphid population (0.42 aphids per ten plants) over the other six treatments *viz.*, T1, T5, T6, T3, and T4 which maintained a population of 0.42, 0.52, 0.66, 0.74 and 0.90 aphids per ten plants, respectively.

Table 6.12: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against aphids at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	Before Spray	1st Spray			2nd Spray			3rd Spray			4th Spray			Percentage Reduction over control
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	13.28 (3.64)	4.30 (2.07)	4.59 (2.14)	4.83 (2.20)	4.76 (2.18)	4.80 (2.19)	5.26 (2.29)	5.93 (2.44)	4.43 (2.11	3.93 (1.98)	2.24 (1.49)	1.47 (1.21)	0.42 (0.65)	76.35
T2	14.71 (3.83)	3.90 (1.97)	4.04 (2.01)	4.10 (2.02)	4.08 (2.02)	4.20 (2.05)	4.70 (2.17)	4.70 (2.17)	3.80 (1.95	3.60 (1.90)	1.76 (1.33)	1.37 (1.17)	0.42 (0.65)	79.92
T3	14.38 (3.79)	3.01 (1.73)	3.37 (1.84)	3.69 (1.92)	3.46 (1.86)	3.72 (1.93)	3.98 (1.99)	3.94 (1.98)	3.26 (1.81	3.17 (1.78)	0.95 (0.97)	1.34 (1.16)	0.74 (0.86)	82.94
T4	13.78 (3.71)	5.01 (2.24)	5.28 (2.30)	5.65 (2.38)	5.45 (2.34)	5.82 (2.41)	6.02 (2.45)	5.74 (2.40)	4.86 (2.21	4.54 (2.13)	2.27 (1.56)	1.51 (1.23)	0.90 (0.95)	74.36
T5	13.83 (3.72)	5.54 (2.35)	5.99 (2.45)	6.50 (2.55)	6.19 (2.49)	6.52 (2.55)	7.37 (2.71)	5.77 (2.40)	5.53 (2.35)	4.86 (2.21)	2.20 (1.48)	1.01 (1.01)	0.52 (0.72)	72.10
T6	14.47 (3.80)	4.89 (2.21)	5.32 (2.31)	5.69 (2.39)	5.56 (2.36)	5.82 (2.41)	6.36 (2.52)	5.91 (2.43)	4.89 (2.21)	4.60 (2.14)	1.41 (1.19)	1.49 (1.22)	0.66 (0.81)	74.76
T7	13.66 (3.70)	17.58 (4.19)	19.47 (4.41)	21.72 (4.66)	23.74 (4.87)	26.55 (5.15)	28.55 (5.34)	24.77 (4.98)	17.85 (4.22)	11.46 (3.39)	3.70 (1.92)	1.63 (1.28)	1.43 (1.19)	
C.D.	N/A	0.532	0.434	0.676	0.429	0.586	1.105	1.689	0.392	0.288	N/A	N/A	0.602	
SE (m)	0.344	0.151	0.123	0.192	0.122	0.166	0.313	0.479	0.111	0.082	0.49	0.153	0.171	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.8: Efficacy of insecticides, Biopesticides and plant extracts (NKE)against aphids at experimental fields of CPRS, Jalandhar (Pooled)



The data from the efficacy test of above mentioned insecticides helped in identifying the superior insecticide combination against the aphids incidence. The data from a series of experiments conducted for two successive potato growing seasons (*Rabi* 2014 and 2015) and pooled analysis revealed that the a combination of foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (2.5 ml /lit) (as second spray), Foliar spray of Imidacloprid 200SL (0.3 ml/lit) (as third spray) and Rogor 30EC (1.5ml/lit) (as fourth spray) may prove useful in controlling the aphid population in potato fields. Further the persual of pooled data (Table 6.12) form both cropping season revealed that on overall bases all the treatments significantly controlled the aphid population in the potato fields; however, among the application treatment T3 { 1st Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit) + Neem Baan (3ml/lit) at the time of pest appearance; 2nd Spray: Chloropyriphos 20 EC (2.5 ml /lit); 3rd Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit); 4th Spray: Rogor 30EC (1.5ml/lit) was found most beneficial in controlling the aphids by means of bringing a reduction up to 82.94 percent over control, significantly. The treatments T2, T1, T4, T6 and T5 led up to 79.92, 76.35, 74.36, 74.76 and 72.10 percent of reduction over control, significantly. Further the Figure 6.8 depicted the over efficacy trend of treatments against aphid population i.e. T3 > T2 > T1 > T4 > T6 > T5.

6.5.2 Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against leafhoppers

6.5.2.1 Efficacy against leafhoppers in cropping season 2014

The results obtained from the efficacy test of above mentioned insecticides Biopesticides and plant extracts (NKE) against leafhoppers during the cropping season 2014, are presented in Table 6.13. And depicted in Figure 6.9. The population of leafhoppers before spray ranged from 12.57 to 14.75 leafhoppers per ten plants in all the treatments. The details of results from this investigation are as follow:

(i) After first spray

After the 3^{rd} day of first spray, the population of leafhoppers varied between 2.40 and 4.54 leafhoppers per ten plants in the treated plots however, it was 16.89 in untreated (control) plot. The treatment namely T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was found associated with minimum leafhoppers' population (2.40 leafhoppers per ten plants) among all treatments whereas the maximum population was found to be associated with treatment namely T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} (4.54 leafhopper per ten plants). The other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance} and T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} had 3.17, 3.37, 4.09 and 4.43 leafhoppers per ten plants, respectively. There was a significant difference among all the treatments at 5 percent C.D.

After 7th day of first spray the population of leafhoppers ranged between 3.07 and 5.07 leafhoppers per ten plants. The maximum leafhoppers population 18.78 leafhoppers per ten plants were recorded in the untreated plot. Further, plot treated with T5 showed least leafhoppers (3.07 leafhoppers per ten plants) in contrast to this plot treated with T6 had maximum (5.07 leafhoppers per ten plants) leafhoppers. Plots with treatments T2, T3, T1, T4 and T6 had 3.45, 3.55, 3.68 4.68, and 5.07 respectively.

Further, after 10th day of first spray the population in the untreated plot was recorded as 22.49 leafhoppers per ten plants. The treatment T2 promisingly controlled the leafhoppers population and maintained it to minimum (3.57 leafhoppers per ten plants). Further, 3.82, 4.06, 4.17, 4.93 and 5.00 leafhoppers were recorded from the plots treated with T3, T6, T1, T4 and T5, respectively.

(ii) After second Spray

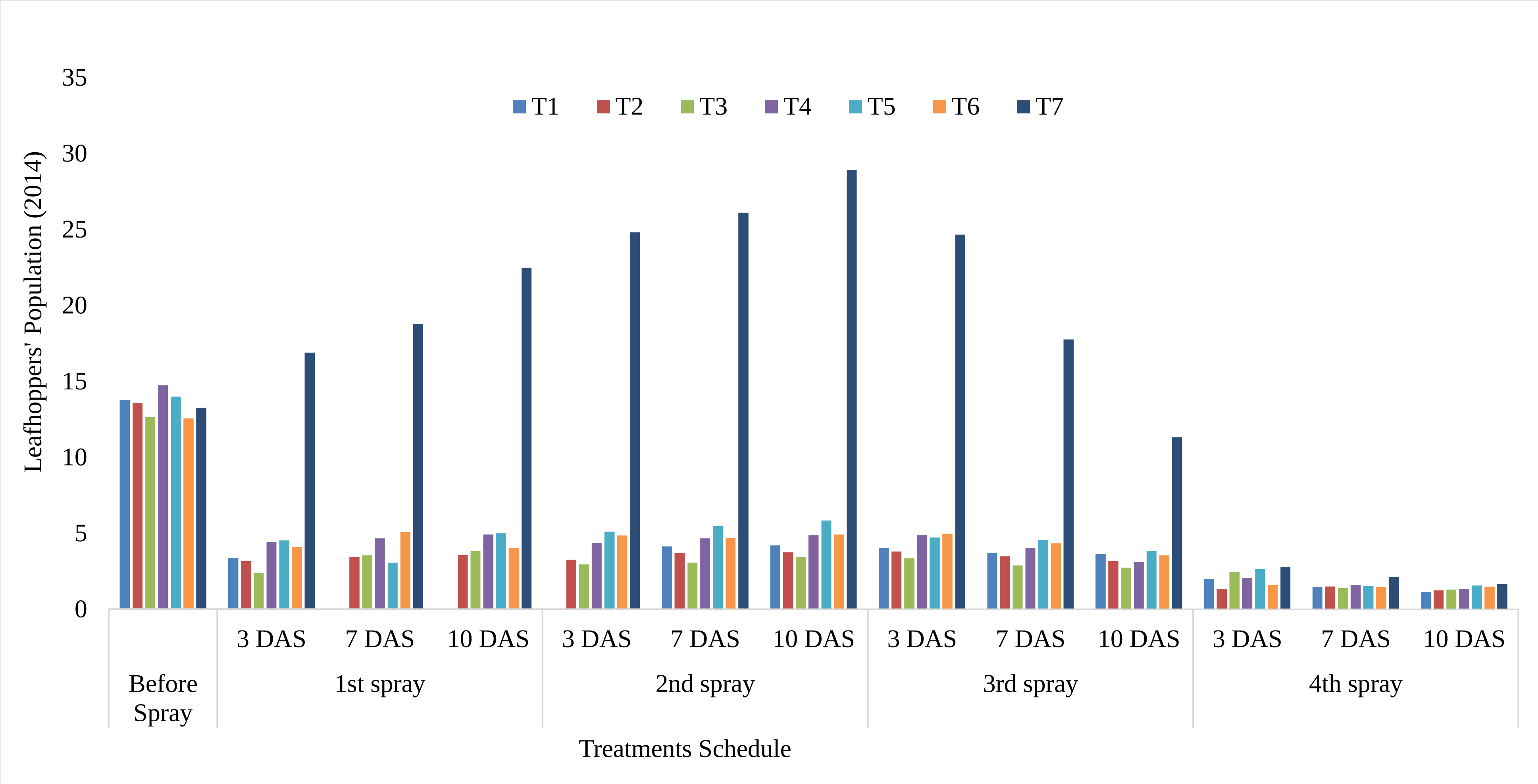
The data from this investigation revealed that treatments showed the same trend after 3rd, 7th and 10th day of second spray. The plots treated with T3 {Chloropyriphos 20 EC (3 ml /lit)} were having least number of leafhoppers per ten plants i.e. 2.95, 3.06 and 3.45 after 3rd , 7th and 10th days of second spray, respectively. Further, T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} were also proved to be important in controlling the leafhoppers population by maintaining it at significantly low level after, 3rd, 7th, and 10th days of second spray.

Table 6.13: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2014

Treatment	Before Spray	1st spray			2nd spray			3rd spray			4th spray			Percent reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	13.78 (3.71)	3.37 (1.84)	3.68 (1.92)	4.17 (2.04)	3.90 (1.97)	4.14 (2.03)	4.21 (2.05)	4.04 (2.01)	3.70 (1.92)	3.63 (1.91)	2.00 (1.41)	1.45 (1.20)	1.15 (1.07)	80.12
T2	13.59 (3.69)	3.17 (1.78)	3.45 (1.86)	3.57 (1.89)	3.25 (1.80)	3.70 (1.92)	3.76 (1.94)	3.80 (1.95)	3.48 (1.87)	3.17 (1.78)	1.33 (1.15)	1.50 (1.22)	1.25 (1.12)	82.14
T3	12.65 (3.56)	2.40 (1.55)	3.55 (1.89)	3.82 (1.95)	2.95 (1.72)	3.06 (1.75)	3.45 (1.86)	3.35 (1.83)	2.88 (1.70)	2.73 (1.65)	2.45 (1.57)	1.40 (1.18)	1.30 (1.14)	83.19
T4	14.75 (3.84)	4.43 (2.10)	4.68 (2.16)	4.93 (2.22)	4.35 (2.09)	4.68 (2.16)	4.88 (2.21)	4.89 (2.21)	4.03 (2.01)	3.12 (1.77)	2.07 (1.44)	1.60 (1.26)	1.33 (1.15)	77.32
T5	14.00 (3.74)	4.54 (2.13)	3.07 (1.75)	5.00 (2.24)	5.11 (2.26)	5.47 (2.34)	5.85 (2.42)	4.73 (2.17)	4.57 (2.14)	3.84 (1.96)	2.65 (1.63)	1.53 (1.23)	1.57 (1.25)	75.83
T6	12.57 (3.55)	4.09 (2.02)	5.07 (2.25)	4.06 (2.01)	4.86 (2.21)	4.69 (2.16)	4.93 (2.22)	4.98 (2.23)	4.33 (2.08)	3.55 (1.88)	1.60 (1.26)	1.46 (1.21)	1.48 (1.22)	77.26
T7	13.27 (3.64)	16.89 (4.11)	18.78 (4.33)	22.49 (4.74)	24.82 (4.98)	26.10 (5.11)	28.91 (5.38)	24.67 (4.97)	17.76 (4.21)	11.32 (3.37)	2.80 (1.67)	2.13 (1.46)	1.67 (1.29)	
CD (5%)	0.099	0.093	0.071	0.083	0.08	0.802	0.047	0.038	0.092	0.036	0.612	N/A	N/A	
SEm	0.032	0.03	0.023	0.027	0.026	0.257	0.015	0.012	0.029	0.011	0.197	0.502	0.19	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.9: **Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2014**



(iii) After third spray

The population in untreated plot was recorded 24.67 leafhoppers per ten plants after 3rd day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} found to be associated with minimum leafhoppers' population (3.35 leafhoppers per ten plants) followed by other treatments T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)}, T4 {Rogor 30EC (1.5ml/lit)} and T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} for which 3.80, 4.04, 4.73, 4.89 and 4.98 leafhoppers per ten plants were recorded, respectively.

After 7th day of spray the population in the untreated plot was recorded 17.76 leafhoppers per ten plants. Among treatments the T3 had minimum (2.88 leafhoppers per ten plants) in contrast to this the maximum leafhopper population was reported in the plot treated with T5 (4.57 leafhoppers per ten plants) Further, the treatments *viz.*, T2, T1, T4, T6 and T5 had 3.48, 3.70, 4.03 ,4.33 and 4.57 leafhoppers per ten plants, respectively in their respective plots.

At 10th day of first spray the maximum population in the untreated plot was recorded as 11.32 leafhoppers per ten plants. Among treated plots the plot treated with T3 was recorded with least population of leafhoppers i.e. 2.73 leafhoppers per ten plants. Further, the population of leafhoppers in the plots treated with T4, T2, T1, T6 and T5 was recorded 3.12, 3.17, 3.63, 3.55 and 3.84, respectively.

(iv) After fourth spray

After the 3rd day of fourth spray, the population of leafhoppers varied between 1.33 and 2.65 leafhoppers per ten plants in the treated plots; however, it was 2.80 in untreated (control) plot. The T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance} was reported with minimum 1.33 leafhoppers per ten plants, among all treatment whereas the maximum 2.65 leafhoppers per ten plants were recorded with treatment T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} significantly. Beside these, other treatments *viz.*, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance} , T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T3 {foliar spray of

Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} had population up to 1.60, 2.00, 2.07 and 2.45 leafhoppers per ten plants, respectively in their respective plots.

After 7th day of first spray the population of leafhoppers ranged between 1.40 and 1.60 leafhoppers per ten plants. The maximum population was recorded 2.13 leafhoppers per ten plants, in the untreated plot. Among treatments, plot with treatment T3 had minimum population which was 1.40 leafhoppers per ten plants in contrast to the population recorded in untreated plot. Followed by the plot with treatment T1 in which 1.45 leafhoppers per ten plants were recorded. Further, among treatments the maximum number of leafhoppers (1.60 leafhoppers per ten plants) were reported in the plot treated with T4. Other plots which were treated with T6, T2 and T5 were having 1.46, 1.50 and 1.53 leafhoppers per ten plants, respectively.

Further, after 10th day of first spray the population in the untreated plot was recorded as 1.67 leafhoppers per ten plants which was maximum among all. The treatment T1 was confounded with minimum number of leafhoppers (1.15 leafhoppers per ten plants) among all the treatments. Other treatments *viz.*, T2, T3, T4, T6 and T5 had 1.25, 1.3, 1.33, 1.48 and 1.57 leafhoppers per ten plants, respectively.

6.5.2.2 Efficacy against leafhoppers in cropping season 2015

The results obtained from the efficacy test of above mentioned insecticides, biopesticides and plant extracts (NKE)pesticides against leafhoppers during the cropping season 2015, are presented in Table 6.14. and depicted in figure 6.10. The population of leafhoppers before spray ranged from 12.95 to 14.65 leafhoppers per ten plants in all the treatments. The details of results from this investigation are as follow:

(i) After first spray

The population of leafhoppers varied between 3.23 to 5.06 leafhoppers per ten plants in the treated plots however, in untreated (control) plot it was recorded 17.14. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported minimum 2.15 leafhoppers per ten plants. Further, other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} had 3.23,3.55, 4.24, 4.56 and 5.06 leafhoppers per ten plants, respectively.

At 7th day of first spray the population of leafhoppers ranged between 2.32 and 5.26 leafhoppers per ten plants. The maximum number of leaf hoppers 18.22 leafhoppers per ten plants were recorded in the untreated plot. Among treatments, T3 was reported with minimum 2.32 leafhoppers per ten plants followed by treatments T2, T1, T6, T4 and T5 which were having 3.34, 3.69, 4.56, 4.60 and 5.26 leafhoppers per ten plants, respectively. There was reported a significant difference in among the treatments at 5 percent CD; however, treatments T4 and T6 were significantly similar.

Further, after 10th day of first spray the maximum population in the untreated plot was recorded as 22.39 leafhoppers per ten plants. The lowest number of leafhoppers 3.04 leafhoppers per ten plants were reported in the plot treated with T3 followed by T2, T1, T4, T6 and T5. The number(s) of leafhoppers reported with these treatments were 3.66, 4.29, 5.17, 5.19 and 6.03 leafhoppers per ten plants, respectively. Further, treatments T4 and T6 were at par to each other; however, there were observed significant differences among other treatments at 5 percent CD.

(ii) After second Spray

After 3rd, 7th, and 10th day of spray 24.62, 26.75 and 28.93 leafhoppers were recorded in untreated plot. The plot treated with treatment T3 {Chloropyriphos 20 EC (3 ml /lit)} reported with minimum leafhoppers' populations *viz.*, 3.00, 3.29 and 3.38 leafhoppers per ten plants, respectively. Further, after 3rd, 7th, and 10th day of spray the treatments T2 {Chloropyriphos 20 EC (2.5 ml /lit)} T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} also maintained significantly low leafhoppers' population than that of untreated plot. The treatment T4 was at par with T6 at 5 percent CD.

(iii) After third spray

The populations of leafhoppers in untreated plot were maximum and recorded as 25.14, 18.15 and 12.27 leafhoppers per ten plants after 3rd day, 7th, and 10th day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} showed minimum number of leafhoppers 3rd, 7th, and 10th day of spray. The plots treated with T3 were having 3.33, 3.15 and 3.21 leafhoppers per ten plants after 3rd, 7th and 10th day of spray, respectively. The treatments namely T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T4 {Rogor 30EC (1.5ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} and T5 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} also showed a significant control on the leafhoppers population after 3rd, 7th and 10th day.

(iv) After fourth spray

After the 3rd day of fourth spray, the population of leafhoppers varied between 1.18 and 2.78 leafhoppers per ten plants in the treated plots however, it was 2.80 in untreated (control) plot. The T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} was reported with least leafhopper population 1.18 leafhoppers per ten plants. The leafhopper population reported with other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T3 {foliar spray of Imidacloprid 20SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was 1.67, 2.27, 2.33, 2.40 and 2.78 leafhoppers per ten plants, respectively.

After 7th day of fourth spray the population of leafhoppers in treated plots ranged between 1.73 and 2.00 leafhoppers per ten plants. The highest population 2.47 leafhoppers per ten plants was recorded in the untreated plot whereas the T3 was recorded with minimum 1.78 leafhoppers per ten plants. The treatments *viz.* T1, T6, T5, T4 and T2 also controlled the leafhopper population in the treated plots significantly while maintaining it to 1.78, 1.79, 1.83, 1.93 and 2.00, respectively.

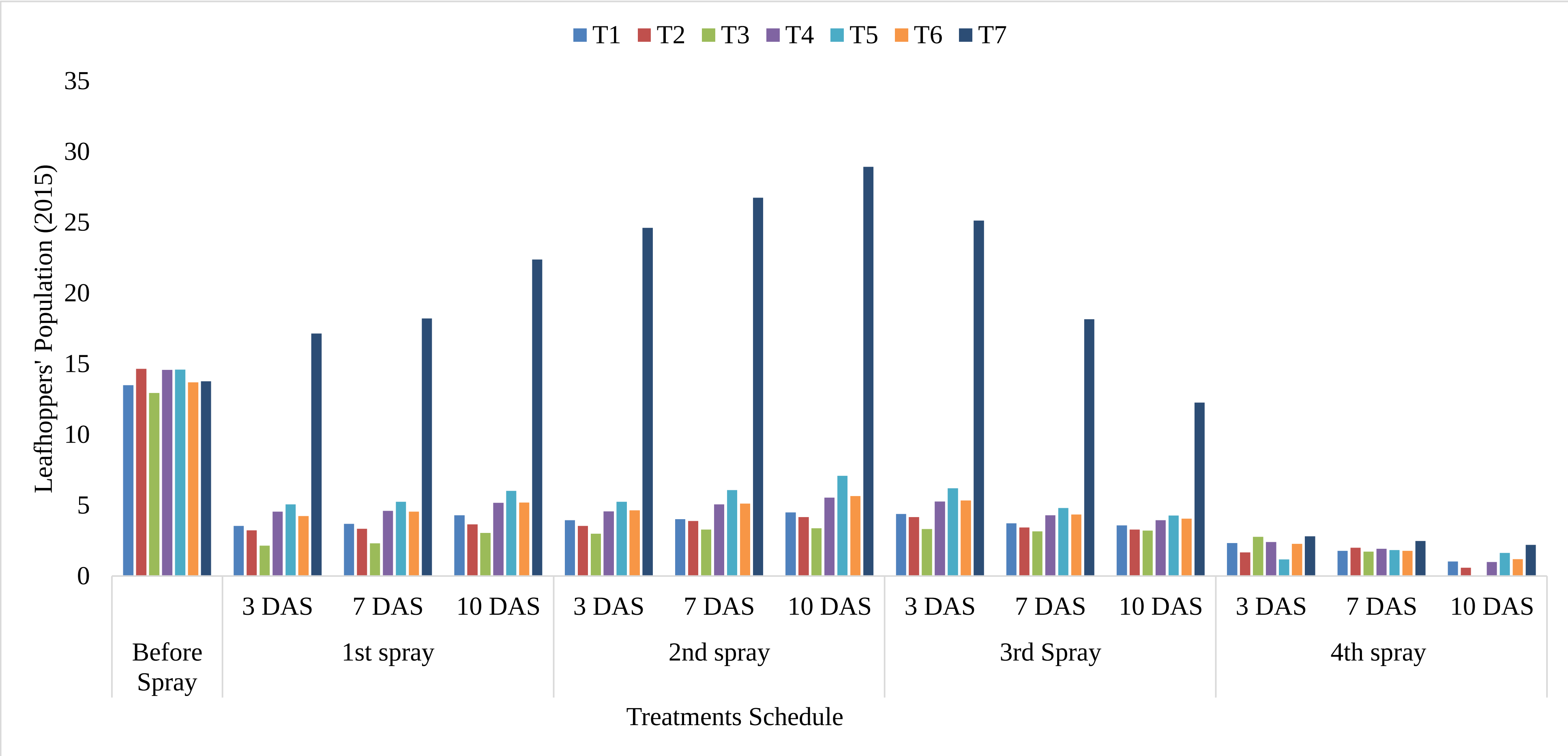
Further, after 10th day of fourth spray the population in the untreated plot was recorded as 2.20 leafhoppers per ten plants which was highest among all. Interestingly, no leafhopper was reported in the plots treated with the treatment T3. In contrast to this treatments *viz.*, T2, T4, T1, T6 and T5 had a population of 0.58, 1.00, 1.03, 1.20 and 1.63 leafhopper per ten plants, respectively, which were significantly less than that of the leafhoppers population of untreated plot.

Table 6.14: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatment	Before Spray	1st spray			2nd spray			3rd Spray			4th spray			Percent Reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	13.50 (3.67)	3.55 (1.88)	3.69 (1.92)	4.29 (2.07)	3.94 (1.98)	4.03 (2.01)	4.50 (2.12)	4.39 (2.10)	3.73 (1.93)	3.58 (1.89)	2.33 (1.53)	1.78 (1.34)	1.03 (1.02)	79.68
T2	14.65 (3.83)	3.23 (1.80)	3.34 (1.83)	3.66 (1.91)	3.55 (1.88)	3.89 (1.97)	4.16 (2.04)	4.16 (2.04)	3.44 (1.86)	3.28 (1.81)	1.67 (1.29)	2.00 (1.41)	0.58 (0.77)	81.62
T3	12.95 (3.60)	2.15 (1.47)	2.32 (1.52)	3.04 (1.74)	3.00 (1.73)	3.29 (1.81)	3.38 (1.84)	3.33 (1.83)	3.15 (1.78)	3.21 (1.79)	2.78 (1.67)	1.73 (1.32)	0 (0.00)	84.39
T4	14.57 (3.82)	4.56 (2.14)	4.60 (2.14)	5.17 (2.27)	4.58 (2.14)	5.07 (2.25)	5.55 (2.36)	5.27 (2.29)	4.30 (2.07)	3.95 (1.99)	2.40 (1.55)	1.93 (1.39)	1.00 (1.00)	75.94
T5	14.60 (3.82)	5.06 (2.25)	5.26 (2.29)	6.03 (2.46)	5.25 (2.29)	6.07 (2.46)	7.09 (2.66)	6.21 (2.49)	4.81 (2.19)	4.27 (2.07)	1.18 (1.09)	1.83 (1.35)	1.63 (1.28)	72.80
T6	13.70 (3.70)	4.24 (2.06)	4.56 (2.13)	5.19 (2.28)	4.64 (2.15)	5.13 (2.26)	5.66 (2.38)	5.34 (2.31)	4.35 (2.08)	4.06 (2.02)	2.27 (1.51)	1.79 (1.34)	1.20 (1.10)	75.92
T7	13.77 (3.71)	17.14 (4.14)	18.22 (4.27)	22.39 (4.73)	24.62 (4.96)	26.75 (5.17)	28.93 (5.38)	25.14 (5.01)	18.15 (4.26)	12.27 (3.50)	2.80 (1.67)	2.47 (1.57)	2.20 (1.48)	
CD (5%)	0.064	0.056	0.056	0.066	0.052	0.075	0.07	0.126	0.075	0.44	0.841	N/A	0.267	
SEm	0.021	0.018	0.018	0.021	0.017	0.024	0.022	0.04	0.024	0.141	0.27	0.498	0.086	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.10: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2015



6.5.2.3 Efficacy from pooled data of 2014 and 2015

The data of both cropping seasons were pooled and analysed to check the overall efficacy of different insecticides, biopesticides and plant extracts (NKE) on controlling the leafhoppers population in the potato crop. The data are presented in Table 6.15. and depicted in figure 6.11. In the experimental fields the initial leafhoppers population i.e. population before varied from 12.80 to 14.66 leafhoppers per ten plants among all treatments.

(i) After first spray

In the pooled data analysis, after 3rd day of first spray, the population of leafhoppers varied between 2.28 and 4.80 leafhoppers per ten plants in the treated plots; however, it was 17.02 in untreated (control) plot. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported as most promising treatment in reducing leafhoppers population (2.28 leafhoppers per ten plants), significantly. The other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} also helped in reducing the leafhoppers population up to 3.20, 3.46, 4.17, 4.49 and 4.80 leafhoppers per ten plants, respectively over the leafhoppers population of untreated plot. The treatments T4 was at par with T5 and T6 in controlling leafhoppers population; however, there were observed significant differences among all other treatments at 5 percent CD.

After 7th day of first spray the population of leafhoppers ranged between 2.94 and 4.81 leafhoppers per ten plants and it was recorded 18.50 leafhoppers per ten plants in the untreated plot. Treatment T3 was proved to be promising in controlling the leafhoppers population by maintaining it to 2.94 leafhoppers per ten plants in contrast to the population recorded in untreated plot. Further, the treatments namely T2, T1, T5, T4 and T6 also controlled the leafhoppers population in the treated plots significantly while maintaining it to 3.40, 3.68, 4.17, 4.64 and 4.81, respectively.

After 10th day of first spray the population in the untreated plot was recorded as 22.44 leafhoppers per ten plants. The treatments followed the same trend as it was after 3rd and 7thday i.e. the T3 promisingly controlled the leafhoppers population (3.43 leafhoppers per ten plants) over the other five treatments *viz.*, T2, T1, T6, T4 and T5 which maintained a population of 3.61, 4.23, 4.62, 5.05 and 5.52 leafhoppers per ten plants, respectively which were significantly less than that of the leafhoppers population of untreated plot.

(ii) After second spray

24.72 leafhoppers per ten plants were recorded in the untreated plot. Further, the data from this investigation revealed that after 3rd day of second spray the number of leafhoppers per ten plants were least (2.98) in the plot with T3 {Chloropyriphos 20 EC (3 ml /lit)}. T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} maintained the leafhoppers population at significantly lower than that of untreated plot 3.40, 3.92, 4.46, 4.75 and 5.18 leafhoppers per ten plants respectively which are significantly lower than the leafhoppers' population of untreated plot.

After 7th day of second spray the population of leafhoppers ranged between 3.17 and 5.77 leafhoppers per ten plants and it was recorded 26.43 leafhoppers per ten plants in the untreated plot. Treatment T3 promisingly controlled the leafhoppers population and maintained it to 3.17 leafhoppers per ten plants in contrast to the population recorded in untreated plot. Further, in contrast to untreated plot the leafhoppers population was reported at significantly low level in the plots treated with the treatments T2 (3.79), T1 (4.09), T4 (4.87), T6 (4.91) and T5 (5.77) also controlled the leafhoppers population in the treated plots

At 10th day of second spray the population in the untreated plot was recorded as 28.92 leafhoppers per ten plants. The treatment T3 was found promising in controlling the leafhoppers population (3.42 leafhoppers per ten plants) over the other five treatments. Treatments T2 (3.96), T1 (4.36), T4 (5.21), T6 (5.29) and T5 (6.47) also showed considerable control on the leafhoppers' population.

(iii) After third spray

The population in untreated plot was recorded 24.91 leafhoppers per ten plants after 3rd day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was found to be most promising for controlling the leafhoppers population in the treated plot. This treatment significantly reduced the leafhoppers population and maintained it to 3.34 leafhoppers per ten plants which was significantly less than that of the untreated plot.

The treatments namely T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T4 {Rogor 30EC (1.5ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} and T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} also controlled the leafhoppers population significantly and maintained it to 3.98, 4.22, 5.08, 5.16 and 5.47, respectively.

After 7th day of third spray the population in the untreated plot was recorded 17.96 leafhoppers per ten plants. The treatment namely T3 controlled the leafhoppers population in the treated plot, most promisingly. This treatment significantly reduced the leafhoppers population and maintained it to 3.02 leafhoppers per ten plants which was significantly less than that of the untreated plot. Further, the treatments viz., T2, T1, T4, T6 and T5 also controlled the leafhoppers population significantly and maintained it to 3.46, 3.72, 4.17, 4.34 and 4.69, respectively.

At 10th day of third spray the population in the untreated plot was recorded as 11.80 leafhoppers per ten plants. The Least population of leafhoppers (2.97 leafhoppers per ten plants) were reported in the plot treated with treatment number T3. Further, treatments T2 (3.23 leafhoppers), T1 (3.61 leafhoppers), T4 (3.54 leafhoppers), T6 (3.81 leafhoppers) and T5 (4.06 leafhoppers) also controlled the leafhoppers population at significantly low level.

(iv) After fourth spray

After the 3rd day of fourth spray, the population of leafhoppers varied between 1.50 and 2.62 leafhoppers per ten plants in the treated plots however, it was 2.80 in untreated (control) plot. The T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance was reported as most promising treatment in reducing aphid population (1.50 leafhoppers per ten plants), significantly. Beside this other treatments *viz.*, T5 at the time of pest appearance, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} and T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} also helped in reducing the aphid population up to 1.92, 1.93, 2.17, 2.23 and 2.62 leafhoppers per ten plants, respectively over the leafhopper population of untreated plot.

After 7th day of fourth spray the population of leafhoppers ranged between 1.57 and 1.77 leafhoppers per ten plants and it was recorded 2.30 leafhoppers per ten plants in the untreated plot. This time once again the T3 was proved most promising in controlling the leafhopper population by controlling it to 1.57 leafhoppers per ten plants in contrast to the population recorded in untreated plot. Further, the treatments *viz.* T1, T6, T5, T2 and T4 also controlled the aphid population in the treated plots significantly while maintaining it to 1.62, 1.63, 1.68, 1.75 and 1.77, respectively.

Further, after 10th day of fourth spray the population in the untreated plot was recorded as 1.93 leafhoppers per ten plants which was much higher than that of the previous one. T3 promisingly controlled the aphid population (0.65 leafhoppers per ten plants) over the other six treatments *viz.*, T2, T1, T4, T6 and T5 which maintained a population of 0.91, 1.09, 1.18, 1.34 and 1.60 leafhoppers per ten plants, respectively which were significantly less than that of the Leafhopper population of untreated plot.

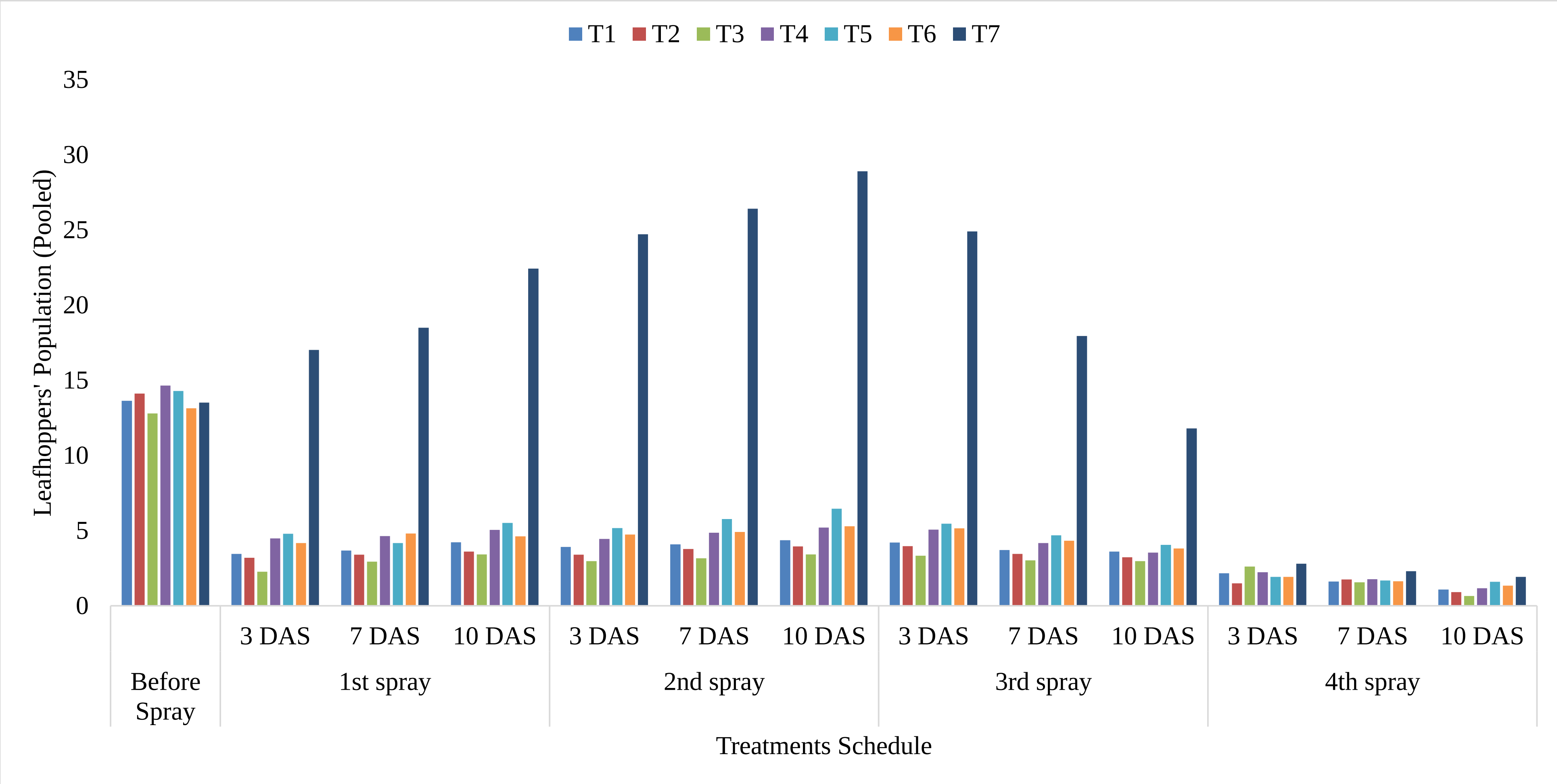
The above experiment revealed the efficacy of above mentioned insecticide combination against the leafhopper incidence in the potato fields of Jalandhar. The data from a series of experiments conducted for two successive potato growing seasons (*Rabi* 2014 and 2015) in *Rabi* 2014 the treatment with a combination of foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (2.5 ml /lit) (as second spray), Foliar spray of Imidacloprid 200SL (0.3 ml/lit) (as third spray) and Rogor 30EC (1.5ml/lit) (as fourth spray) efficiently controlled the leafhopper population. The persual of Table 6.13 revealed that the treatment T3 bought the maximum percent reduction over control. The trend of efficacy of treatments in this year was T3 (16.81%) > T2 (17.86%) > T1 (19.88%) > T4 (22.68%) > T6 (22.74%) > T5 (24.17%). The scenario on the trend of efficacy of treatments trend maintained in the *Rabi* 2015; however the performance of some of the treatments were better than that of previous year. The reason of this could be the biotic and abiotic factors. Table 6.14 revealed the trend of efficacy in 2015 which was T3 (16.15%) > T2 (18.68%) > T1 (20.35%) > T4 (24.09%) > T6 (24.13%) > T5 (28.14%). The pooled data further helped in identifying the overall efficacy of treatments. The Figure 6.11 clearly depicts the performance of all treatments by means of controlling the leafhopper population over the untreated one. Further the perusal of table 6.15 unveiled the trend of efficacy of treatments by means of percent reduction in leafhopper population over control. The overall trend of efficacy of treatments was T3 (83.76%) > T2 (81.88%) > T1 (79.90%) > T4 (76.63%) > T6 (76.59%) > T5 (74.31%).

Table 6.15: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against leafhoppers at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	Before Spray	1st spray			2nd spray			3rd spray			4th spray			Percent Reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	13.64 (3.69)	3.46 (1.86)	3.68 (1.92)	4.23 (2.06)	3.92 (1.98)	4.09 (2.02)	4.36 (2.09)	4.22 (2.05)	3.72 (1.93)	3.61 (1.90)	2.17 (1.47)	1.62 (1.27)	1.09 (1.05)	79.90
T2	14.12 (3.76)	3.20 (1.79)	3.40 (1.84)	3.61 (1.90)	3.40 (1.84)	3.79 (1.95)	3.96 (1.99)	3.98 (1.99)	3.46 (1.86)	3.23 (1.80)	1.50 (1.22)	1.75 (1.32)	0.91 (0.96)	81.88
T3	12.80 (3.58)	2.28 (1.51)	2.94 (1.71)	3.43 (1.85)	2.98 (1.72)	3.17 (1.78)	3.42 (1.85)	3.34 (1.83)	3.02 (1.74)	2.97 (1.72)	2.62 (1.62)	1.57 (1.25)	0.65 (0.81)	83.79
T4	14.66 (3.83)	4.49 (2.12)	4.64 (2.15)	5.05 (2.25)	4.46 (2.11)	4.87 (2.21)	5.21 (2.28)	5.08 (2.25)	4.17 (2.04)	3.54 (1.88)	2.23 (1.49)	1.77 (1.33)	1.18 (1.08)	76.63
T5	14.30 (3.78)	4.80 (2.19)	4.17 (2.04)	5.52 (2.35)	5.18 (2.28)	5.77 (2.40)	6.47 (2.54)	5.47 (2.34)	4.69 (2.17)	4.06 (2.01)	1.92 (1.71)	1.68 (1.30)	1.60 (1.27)	74.31
T6	13.14 (3.62)	4.17 (2.04)	4.81 (2.19)	4.62 (2.15)	4.75 (2.18)	4.91 (2.22)	5.29 (2.30)	5.16 (2.27)	4.34 (2.08)	3.81 (1.95)	1.93 (1.39)	1.63 (1.28)	1.34 (1.16)	76.59
T7	13.52 (3.68)	17.02 (4.13)	18.50 (4.30)	22.44 (4.74)	24.72 (4.97)	26.43 (5.14)	28.92 (5.38)	24.91 (4.99)	17.96 (4.24)	11.80 (3.43)	2.80 (1.67)	2.30 (1.52)	1.93 (1.39)	
C.D.	0.966	0.411	1.892	1.159	0.352	0.461	0.794	0.822	0.287	0.631	0.364	0.115	N/A	
SE(m)	0.274	0.116	0.536	0.329	6.100	0.131	0.225	0.233	0.081	0.179	0.103	0.033	0.288	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.11: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against leafhoppers at experimental fields of CPRS, Jalandhar (Pooled)



6.5.3 Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against whiteflies

6.5.3.1 Efficacy in cropping season 2014

The results obtained on the efficacy of tested insecticides and pesticide in reducing the whiteflies population by means of rotating chemistry after first, second, third and fourth spray during cropping season 2014 are presented in Table 6.16 and depicted from Figure 6.12. During this season the initial population (before spray) of whiteflies ranged from 14.47 to 16.27 whiteflies per ten plants in all the treatments.

(i) After first spray

After the 3rd day of first spray, the population of whiteflies varied between 0.82 and 3.70 whiteflies per ten plants in the treated plots however, it was 16.33 in untreated (control) plot. The treatment T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported lowest whitefly population i.e. 0.82 whiteflies per ten plants. In contrast to this the other treatments *viz.*, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance}, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}, T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance} and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} were reported with 1.40, 2.09, 3.00, 3.20 and 3.70 whiteflies per ten plants, respectively.

After 7th day of first spray the population of whiteflies ranged between 0.98 and 3.82 whiteflies per ten plants. The highest population of whiteflies 17.82 whiteflies per ten plants were recorded in the untreated plot in contrast to this plot treated with T3 was maintaining lowest whitefly population 0.98 whiteflies per ten plants. The other treatments *viz.*, T2, T1, T4, T6 and T5 were reported 1.71, 2.41, 3.14, 3.31 and 3.82 whiteflies per ten plants, respectively.

Further, after 10th day of first spray the population in the untreated plot was recorded with highest (18.11 whiteflies per ten plants) whitefly population whereas the treatment T3 was recorded with lowest whitefly population 1.22 whiteflies per ten plants. Further, 2.14, 2.68, 3.22, 3.51 and 4.07 whiteflies were recorded from the plots treated with T2, T1, T4, T6 and T5, respectively.

(ii) After second Spray

The data from this investigation revealed that after 3rd day of second spray the highest number whiteflies were in untreated plot (19.30 whiteflies per ten plants) whereas least (1.07) in the plot with T3 {Chloropyriphos 20 EC (3 ml /lit)} followed by T2 {Chloropyriphos 20 EC (2.5 ml /lit)} which had 1.72 whiteflies per ten plants. The other treatments *viz*. T1 {Chloropyriphos 20 EC (1.5 ml/lit), T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} were recorded with 2.42, 3.13, 3.47 and 3.93 whiteflies per ten plants, respectively.

After 7th day of second spray the untreated plot was recorded with richest whitefly population 20.49 whiteflies per ten plants whereas plot treated with the treatment namely T3 had poorest whitefly population 1.46 whiteflies per ten plants. Further, plots treated with treatments *viz.*, T2, T1, T4, T6 and T5 were recorded with 2.20, 2.80, 3.71, 3.80 and 4.14 whiteflies per ten plants, respectively.

At 10th day of second spray the population in the untreated plot was recorded as 12.31 whiteflies per ten plants. Further, the population of whiteflies in the plots treated with T3, T2, T1, T6, T4 and T5 was 1.71, 2.46, 3.30, 3.60, 3.76 and 5.80 whiteflies per ten plants, respectively.

(iii) After third spray

The population in untreated plot was recorded 8.51 whiteflies per ten plants after 3rd day of third spray. The treatment namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was having minimum whiteflies (1.53 whiteflies per ten plants). Further, the treatments namely T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T4 {Rogor 30EC (1.5ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} and T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} were recorded with a population of 2.27, 3.07, 3.73, 4.00 and 4.20 whiteflies per ten plants, respectively.

After 7th day of third spray the highest population of whitefly 5.32 whiteflies per ten plants was noted in the untreated plot. The treatment namely T2 had lowest population of whitefly i.e. 2.00 whiteflies per ten plants. Further, 2.10, 2.62, 3.31, 3.51 and 3.71 whiteflies per ten plants were recorded in the treatments *viz*., T4, T1, T3, T6 and T5, respectively.

At 10th day of third spray the population in the untreated plot was recorded as 2.71 whiteflies per ten plants in contrast to this the population whiteflies in the plots treated with T2, T4, T1, T3, T6 and T5 was 1.71, 1.80, 2.07, 2.31, 2.42 and 2.54 whiteflies per ten plants respectively .

(iv) After fourth spray

The data from this investigation revealed that after 3rd day of fourth spray no whitefly infestation was there in the plot treated with T4 {Foliar spray of Imidacloprid200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} where as in other plots treated with the treatments *viz.*, T3 {Rogor 30EC @1.5ml/lit)}, T2 {Rogor 30EC (1.5ml/lit)}, T5 {Rogor 30EC (1.5ml/lit) + Neem Baan (3ml/lit)}, T6 {Rogor 30EC (1.5ml/lit)} and T1 {Rogor 30EC (1.5ml/lit)} were characterized with 0.45, 1.00, 1.18, 1.27 and 1.33 whiteflies per ten plants, respectively which are significantly less than the aphid population of untreated plot (2.80) whiteflies per ten plants

After 7th day of fourth spray the maximum number of whiteflies 2.13 whiteflies per ten plants were recorded from the untreated plot. No whitefly was seen in the plot treated with treatment namely T4 however, the other treatments *viz.*, T3, T2, T1, T6 and T5 showed 0.40, 0.50, 0.78, 0.79 and 0.83 whiteflies per ten plants, respectively.

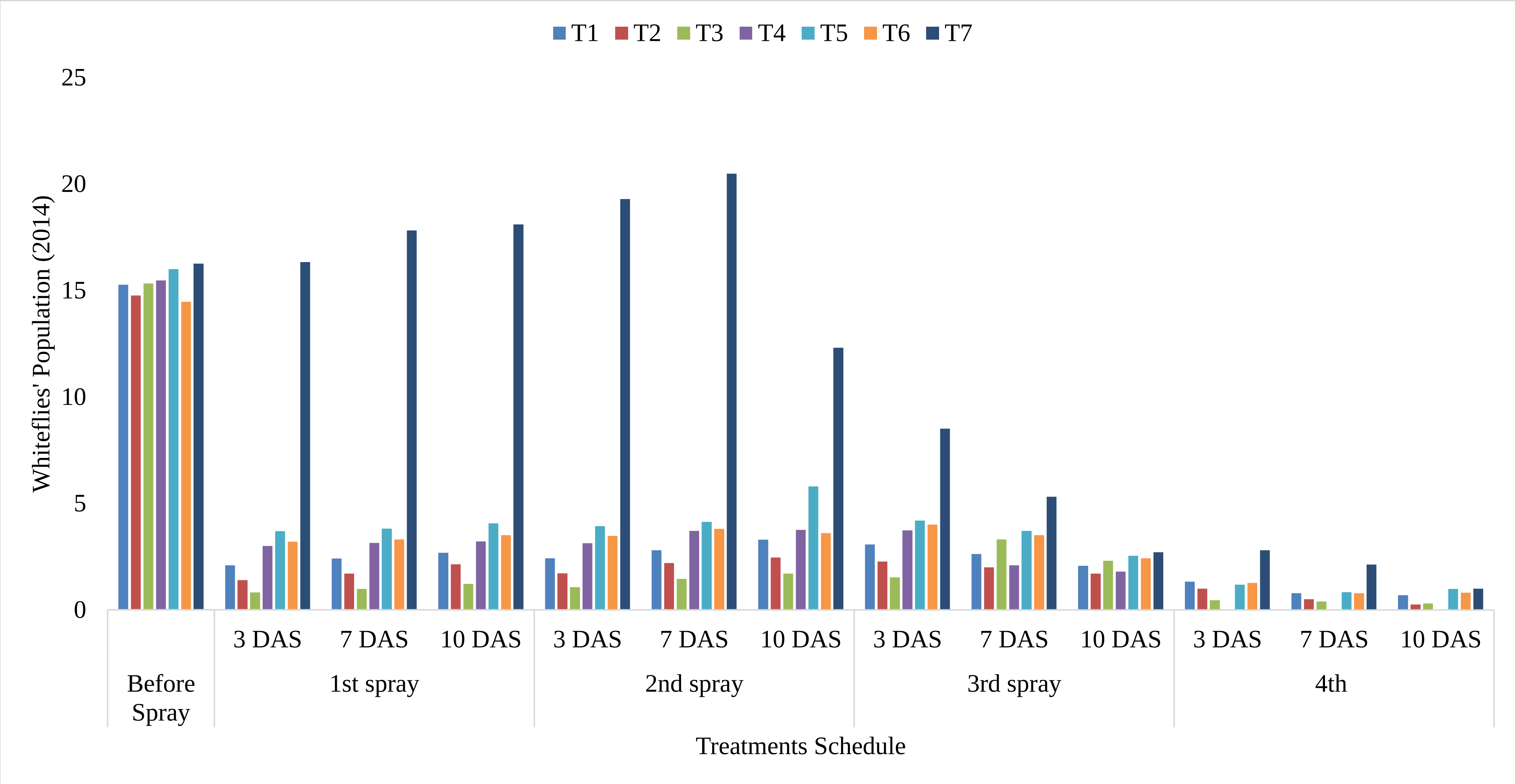
At 10th day of fourth spray the population in the untreated plot was recorded as 1.00 whiteflies per ten plants. No incidence was reported with treatment T4. Further, the population of whiteflies in the plots treated with T2, T3, T1, T6 and T5 was recorded 0.25, 0.30, 0.69, 0.81 and 0.98 whiteflies per ten plants, respectively.

Table 6.16: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2014

Treatments	Before Spray	1st spray			2nd spray			3rd spray			4th Spray			Percent Reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	15.27 (3.91)	2.09 (1.44)	2.41 (1.55)	2.68 (1.64)	2.42 (1.56)	2.80 (1.67)	3.30 (1.82)	3.07 (1.75)	2.62 (1.62)	2.07 (1.44)	1.33 (1.15)	0.78 (0.89)	0.69 (0.83)	79.29
T2	14.77 (3.84)	1.40 (1.18)	1.71 (1.31)	2.14 (1.46)	1.72 (1.31)	2.20 (1.48)	2.46 (1.57)	2.27 (1.51)	2.00 (1.41)	1.71 (1.31)	1.00 (1.00)	0.50 (0.71)	0.25 (0.50)	84.72
T3	15.33 (3.91)	0.82 (0.91)	0.98 (0.99)	1.22 (1.11)	1.07 (1.03)	1.46 (1.21)	1.71 (1.31)	1.53 (1.24)	3.31 (1.82)	2.31 (1.52)	0.45 (0.67)	0.40 (0.63)	0.30 (0.55)	87.73
T4	15.48 (3.93)	3.00 (1.73)	3.14 (1.77)	3.22 (1.80)	3.13 (1.77)	3.71 (1.93)	3.76 (1.94)	3.73 (1.93)	2.10 (1.45)	1.80 (1.34)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	78.24
T5	16.00 (4.00)	3.70 (1.92)	3.82 (1.96)	4.07 (2.02)	3.93 (1.98)	4.14 (2.04)	5.80 (2.41)	4.20 (2.05)	3.71 (1.93)	2.54 (1.59)	1.18 (1.09)	0.83 (0.91)	0.98 (0.99)	69.31
T6	14.47 (3.80)	3.20 (1.79)	3.31 (1.82)	3.51 (1.87)	3.47 (1.86)	3.80 (1.95)	3.60 (1.90)	4.00 (2.00)	3.51 (1.87)	2.42 (1.56)	1.27 (1.13)	0.79 (0.89)	0.81 (0.90)	73.43
T7	16.27 (4.03)	16.33 (4.04)	17.82 (4.22)	18.11 (4.26)	19.30 (4.39)	20.49 (4.53)	12.31 (3.51)	8.51 (2.92)	5.32 (2.31)	2.71 (1.65)	2.80 (1.67)	2.13 (1.46)	1.00 (1.00)	
C.D.	0.141	0.48	0.287	0.339	0.222	0.127	0.559	0.236	0.352	0.295	0.736	N/A	N/A	
SE(m)	0.045	0.154	0.092	0.109	0.071	0.041	0.179	0.076	0.113	0.095	0.236	0.655	0.366	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.12: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2014



6.5.3.2 Efficacy in cropping season 2015

The results obtained on the efficacy of tested insecticides, Biopesticides and plant extracts (NKE) in reducing the whiteflies population by means of rotating chemistry after first, second, third and fourth spray during cropping season 2015 are presented in Table 6.17 and depicted from Figure 6.13. During this season the initial population (before spray) of whiteflies ranged between 22.46 and 25.64 whiteflies per ten plants in all the treatments. The details of the results are as follows:

(i) After first spray

After the 3rd day of first spray, the population of whiteflies varied between 2.33 and 6.50 whiteflies per ten plants in the treated plots however, it was 18.27 in untreated (control) plot. The least, 2.33 whiteflies per ten plants, were reported in the plot T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}. The number of whiteflies per ten plants in other treatments *viz.*, T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance},T6 {soil application of *Beauvaria bassiana* 2X10^9 CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance}, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} were 3.00, 4.75, 5.00, 5.25 and 6.50 whiteflies per ten plants, respectively over the whiteflies population of untreated plot(18.27) whiteflies per ten plants.

After 7th day of first spray the population of whiteflies ranged between 0.50 and 5.25 whiteflies per ten plants. The maximum whiteflies per ten plants were recorded in the untreated plot where the maximum whiteflies per ten plants (21.00 whiteflies) was recorded in treatment T4. Further, significant performance of the treatments T3, T1, T2, T6 and T5 was also reported. These treatments maintained the whiteflies’ population to 2.20, 3.00, 4.25, 4.75 and 5.25 whiteflies per ten plants, respectively.

Further, after 10th day of first spray the population in the untreated plot was recorded as 20.70 whiteflies per ten plants. T4 promisingly controlled the whiteflies population (1.00

whiteflies per ten plants). Further, 2.00, 3.25, 3.50, 4.02 and 5.00 whiteflies were recorded from the plots treated with T3, T1, T6, T2 and T5, respectively.

(ii) After second Spray

The data from this investigation revealed that after 3rd day of second spray there was no incidence of whiteflies in the plot treated with T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}; however in other treatments *viz.*,T3 {Chloropyriphos 20 EC (3 ml /lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), Chloropyriphos 20 EC @ 2.5 ml /lit },T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} the whitefly populations were 2.00, 3.00, 3.01, 3.75 and 4.50 whiteflies per ten plants, respectively which is significantly less than T7 (16.00) whiteflies per ten plants .

After 7th day of second spray no incidence of whiteflies in the plot treated with T4; however, in untreated plot it was 14.75 whiteflies per ten plants and in other the treatments *viz.*, T3, T6, T1, T2 and T5 it was to 1.75, 1.76, 3.00, 3.00 and 3.20, whiteflies per ten plants respectively.

At 10th day of second spray the population in the untreated plot was recorded as 14.00 whiteflies per ten plants. The treatment T4 controlled the hundred percent population. Further, the population whiteflies in the plots treated with T3, T6, T5, T2 and T1 was 2.00, 2.21, 2.75, 3.00 and 3.75, respectively which were significantly less than that of the whiteflies' population recorded in untreated plot.

(iii) After third spray

The population in untreated plot was recorded 15.00 whiteflies per ten plants after 3rd day of third spray. No incidence was reported with T4 {Rogor 30EC (1.5ml/lit)}. The treatments namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} and T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} also controlled the aphid population significantly and maintained it to 1.00, 1.70, 1.75, 2.00 and 2.50, respectively.

After 7th day of third spray the population in the untreated plot was recorded 14.70 whiteflies per ten plants. No incidence was reported with T4 {Rogor 30EC (1.5ml/lit)}. The treatments namely T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} and T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} also controlled the aphid population significantly and maintained it to 1.00, 1.00, 1.10, 1.10 and 2.50, respectively.

At 10th day of third spray the population in the untreated plot was recorded as 19.06 whiteflies per ten plants. No incidence of whiteflies were reported in the plot treated with T4, however, in T5, T3, T2, T6 and T1 the incidence was 0.48, 1.00, 1.00, 1.20 and 2.20 whiteflies per ten plants, respectively.

(iv) After fourth spray

The data recorded after fourth spray revealed that after 3rd day, the maximum population of whiteflies, 19.00 whiteflies per ten plants, occurred in untreated plot. The plot treated with T4 {Foliar spray of Imidacloprid200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} showed no incidence; however, T3 {Rogor 30EC @1.5ml/lit)}, T5 {Rogor 30EC (1.5ml/lit) + Neem Baan (3ml/lit)}, T6 {Rogor 30EC (1.5ml/lit)}, T2 {Rogor 30EC (1.5ml/lit)}, and T1 {Rogor 30EC (1.5ml/lit)} showed incidence of 0.45, 0.85, 1.00, 1.00 and 1.00 whiteflies per ten plants, respectively in their respective plots

After 7th day of fourth spray the population in the untreated plot was recorded 13.00 whiteflies per ten plants whereas no incidence was reported in the plot treated with T4. Further, the other plots with treatments *viz.*, T3, T1, T5, T2 and T6 the incidence was 0.40, 0.45, 0.50, 0.50 and 0.56, whiteflies per ten plants, respectively.

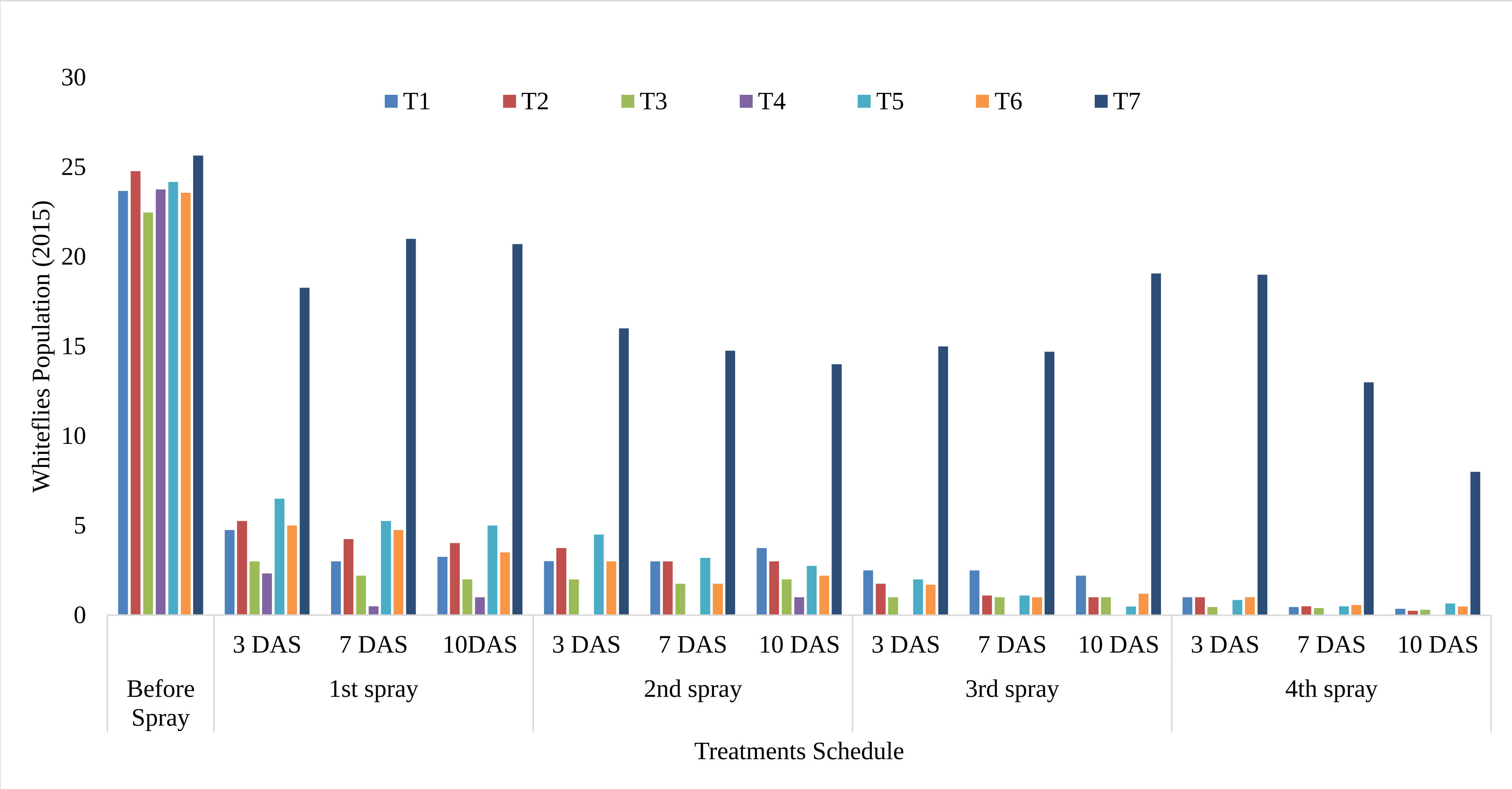
No incidence was reported in the plot treated with T4 after 10th day of fourth spray. The untreated plot was recorded with maximum 8.00 whiteflies per ten plants. Further, the population of whiteflies in the plots treated with T2, T3, T1, T6 and T5 was 0.25, 0.30, 0.35, 0.48 and 0.65 whitefly per ten plants, respectively.

Table 6.17: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatment	Before Spray	1st spray			2nd spray			3rd spray			4th spray			Percent Reduction
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	23.67 (4.87)	4.75 (2.18)	3.00 (1.73)	3.25 (1.8)	3.01 (1.73)	3.00 (1.73)	3.75 (1.94)	2.50 (1.58)	2.50 (1.58)	2.20 (1.48)	1.00 (1.00)	0.45 (0.67)	0.35 (0.59)	84.62
T2	24.77 (4.98)	5.25 (2.29)	4.25 (2.06)	4.02 (2.00)	3.75 (1.94)	3.00 (1.73)	3.00 (1.73)	1.75 (1.32)	1.10 (1.05)	1.00 (1.00)	1.00 (1.00)	0.50 (0.71)	0.25 (0.50)	85.08
T3	22.46 (4.74)	3.00 (1.73)	2.20 (1.48)	2.00 (1.41)	2.00 (1.41)	1.75 (1.32)	2.00 (1.41)	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)	0.45 (0.67)	0.40 (0.63)	0.30 (0.55)	91.16
T4	23.76 (4.87)	2.33 (1.53)	0.50 (0.71)	1.00 (1.00)	0.00 (0.00)	0.00 (0.00)	1.00 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	97.50
T5	24.17 (4.92)	6.50 (2.55)	5.25 (2.29)	5.00 (2.24)	4.50 (2.12)	3.20 (1.79)	2.75 (1.66)	2.00 (1.41)	1.10 (1.05)	0.48 (0.69)	0.85 (0.92)	0.50 (0.71)	0.65 (0.81)	83.05
T6	23.57 (4.85)	5.00 (2.24)	4.75 (2.18)	3.50 (1.87)	3.00 (1.73)	1.76 (1.33)	2.21 (1.49)	1.70 (1.30)	1.00 (1.00)	1.20 (1.10)	1.00 (1.00)	0.56 (0.75)	0.48 (0.69)	86.47
T7	25.64 (5.06)	18.27 (4.27)	21.00 (4.58)	20.70 (4.55)	16.00 (4.00)	14.75 (3.84)	14.00 (3.74)	15.00 (3.87)	14.70 (3.83)	19.06 (4.37)	19.00 (4.36)	13.00 (3.61)	8.00 (2.83)	
C.D.	0.458	0.499	0.133	0.136	0.177	0.187	0.109	0.148	0.484	0.116	0.647	5.019	N/A	
SE(m)	0.147	0.16	0.043	0.044	0.057	0.06	0.035	0.047	0.155	0.037	0.208	1.611	2.024	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.13: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2015



6.5.3.3 Efficacy from pooled data

The data of both cropping seasons were pooled and analysed to check the overall efficacy of different insecticides, biopesticides and plant extracts (NKE) on controlling the whiteflies population in the potato crop. In the experimental fields the initial whiteflies population i.e. Meanpopulation stands at 20.97 whiteflies per ten plants among all treatments.

(i) After first spray

After the 3rd day of first spray, the population of whiteflies varied between 1.91 and 5.10 whiteflies per ten plants in the treated plots however, it was 17.30 in untreated (control) plot. The T3 {foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} was reported as most promising treatment in reducing whiteflies population (1.91 whiteflies per ten plants), significantly. Beside this other treatments *viz.*, T4 {seed treatment with Imidacloprid (0.4 ml/lit) + *Metarrhizium anisopliae* (2 Kg/ha) soil application + foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance}, T2 {Foliar spray of Imidacloprid 200 SL (0.3 ml/lit) at the time of pest appearance}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit) at the time of pest appearance},T6 {soil application of *Beauvaria bassiana* $2X10^9$ CFU (2.00 Kg/ha) + Foliar spray of Thiomethoxam 25WG (0.3 gm/lit) + Neem Baan (3ml/lit) at the time of pest appearance} and T5 {Foliar spray of Thiomethoxam 25WG (0.3 ml/lit) at the time of pest appearance} also helped in reducing the aphid population up to 2.67, 3.33, 3.42, 4.10 and 5.10 whiteflies per ten plants, respectively over the whiteflies population of untreated plot.

After 7th day of first spray the population of whiteflies ranged between 1.59 and 4.54 whiteflies per ten plants and 19.41 whiteflies per ten plants were recorded in the untreated plot. T3 performed most efficiently in controlling the whiteflies population by maintaining it to 1.59 whiteflies per ten plants in contrast to the population recorded in untreated plot. Further, significant performance of the treatments T4, T1, T2, T6 and T5 was also reported. These treatments maintained the whiteflies population to 1.82, 2.71, 2.98, 4.03 and 4.54, respectively.

Further, after 10th day of first spray the population in the untreated plot was recorded as 19.41 whiteflies per ten plants. T3 promisingly controlled the whiteflies population (1.61 whiteflies per ten plants). Further, 2.11, 2.96, 3.08, 3.51 and 4.54 whiteflies were recorded from the plots treated with T4, T1, T2, T6 and T5, respectively.

(ii) After second Spray

17.65 whiteflies per ten plants were recorded in the untreated plot. Further, the data from this investigation revealed that after 3rd day of second spray the number of whiteflies per ten plants were least (1.54) in the plot with T3 {Chloropyriphos 20 EC (3 ml /lit)}. T4 {foliar spray of Thiomethoxam 25WG (0.3 ml/lit)}, T1 {Chloropyriphos 20 EC (1.5 ml/lit), T2 {Chloropyriphos 20 EC (2.5 ml /lit)}, T6 {Chloropyriphos 20 EC (1 ml /lit)} and T5 {Chloropyriphos 20 EC (0.5 ml /lit)} maintained the whiteflies population at significantly lower than that of untreated plot 1.57, 2.72, 2.74, 3.24 and 4.22 whiteflies per ten plants, respectively which are significantly lower than thewhiteflies' population of untreated plot.

After 7th day of second spray the population of whiteflies ranged between 1.60 and 3.67 whiteflies per ten plants and it was recorded 17.62 whiteflies per ten plants in the untreated plot. Treatment T3 promisingly controlled the whiteflies population and maintained it to 1.60 whiteflies per ten plants in contrast to the population recorded in untreated plot. Further, in contrast to untreated plot the whiteflies population was reported at significantly low level in the plots treated with the treatments T4 (1.86), T2 (2.60), T6 (2.78), T1 (2.90) and T5 (3.67) also controlled the whiteflies population in the treated plots, significantly.

At 10th day of second spray the population in the untreated plot was recorded as 13.16 whiteflies per ten plants. The treatment T3 was found promising in controlling the whiteflies population (1.86 whiteflies per ten plants) over the other five treatments. Treatments T4 (2.38), T2 (2.73), T6 (2.91), T1 (3.53) and T5 (4.28) also showed considerable control on the whiteflies population.

(iii) After third spray

The population in untreated plot was recorded 11.76 whiteflies per ten plants after 3rd day of third spray. T3 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} was found promising by reducing whitefly population up to 1.27 whiteflies per ten plants in the treated plot. Further, T4 {Rogor 30EC (1.5ml/lit)}, T2 {foliar spray of Thiomethoxam 25WG (0.3 gm/lit)}, T1 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)}, T6 {Foliar spray of Imidacloprid 200SL (0.3 ml/lit)} and T5 {Foliar spray of Imidacloprid200SL (0.3 ml/lit)} also controlled the aphid population significantly and maintained it to 1.87, 2.01, 2.79, 2.85 and 3.10, respectively.

After 7th day of third spray the population of whiteflies ranged between 1.05 and 2.56 whiteflies per ten plants and it was recorded 10.01 whiteflies per ten plants in the untreated plot. Treatment T4 promisingly controlled the whiteflies population and maintained it to 1.05

whiteflies per ten plants in contrast to the population recorded in untreated plot. Further, in contrast to untreated plot the whiteflies population was reported at significantly low level in the plots treated with the treatments T2 (1.55), T3 (2.16), T6 (2.26), T5 (2.41) and T1 (2.56) also controlled the whiteflies population in the treated plots, significantly.

At 10th day of third spray the population in the untreated plot was recorded as 10.89 whiteflies per ten plants. Treatment T4 promisingly controlled the whiteflies population and maintained it to 0.90 whiteflies per ten plants in contrast to the population recorded in untreated plot. Further, the population whiteflies in the plots treated with T2, T5, T3, T6 and T1 was 1.36, 1.51, 1.66, 1.81 and 2.14 respectively which were significantly less than that of the whiteflies population recorded in untreated plot.

(iv) After fourth spray

The data from this investigation revealed that after 3rd day of fourth spray the incidence in untreated plot was 10.90 whiteflies per ten plants whereas no whitefly infestation was there in the plot treated with T4 {Foliar spray of Imidacloprid200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance} thus proved to be the most promising among all other treatments. Further, T3 {Rogor 30EC @1.5ml/lit)}, T2 {Rogor 30EC (1.5ml/lit)}, T5 {Rogor 30EC (1.5ml/lit) + Neem Baan (3ml/lit)}, T6 {Rogor 30EC (1.5ml/lit)} and T1 {Rogor 30EC (1.5ml/lit)} were also proved to be important in controlling the whitefly population by maintaining it 0.45, 1.00, 1.02, 1.13 and 1.17 whiteflies per ten plants, respectively which are significantly less than the whiteflies population of untreated plot.

After 7th day of fourth spray the population in the untreated plot was recorded 7.57 whiteflies per ten plants. The treatment namely T4 fully controlled the whiteflies population in the treated plot and found most promising. Further, the other treatments *viz.*, T3, T2, T1, T5 and T6 also controlled the aphid population significantly over untreated plot and maintained it to 0.40, 0.50, 0.62, 0.67 and 0.68, respectively.

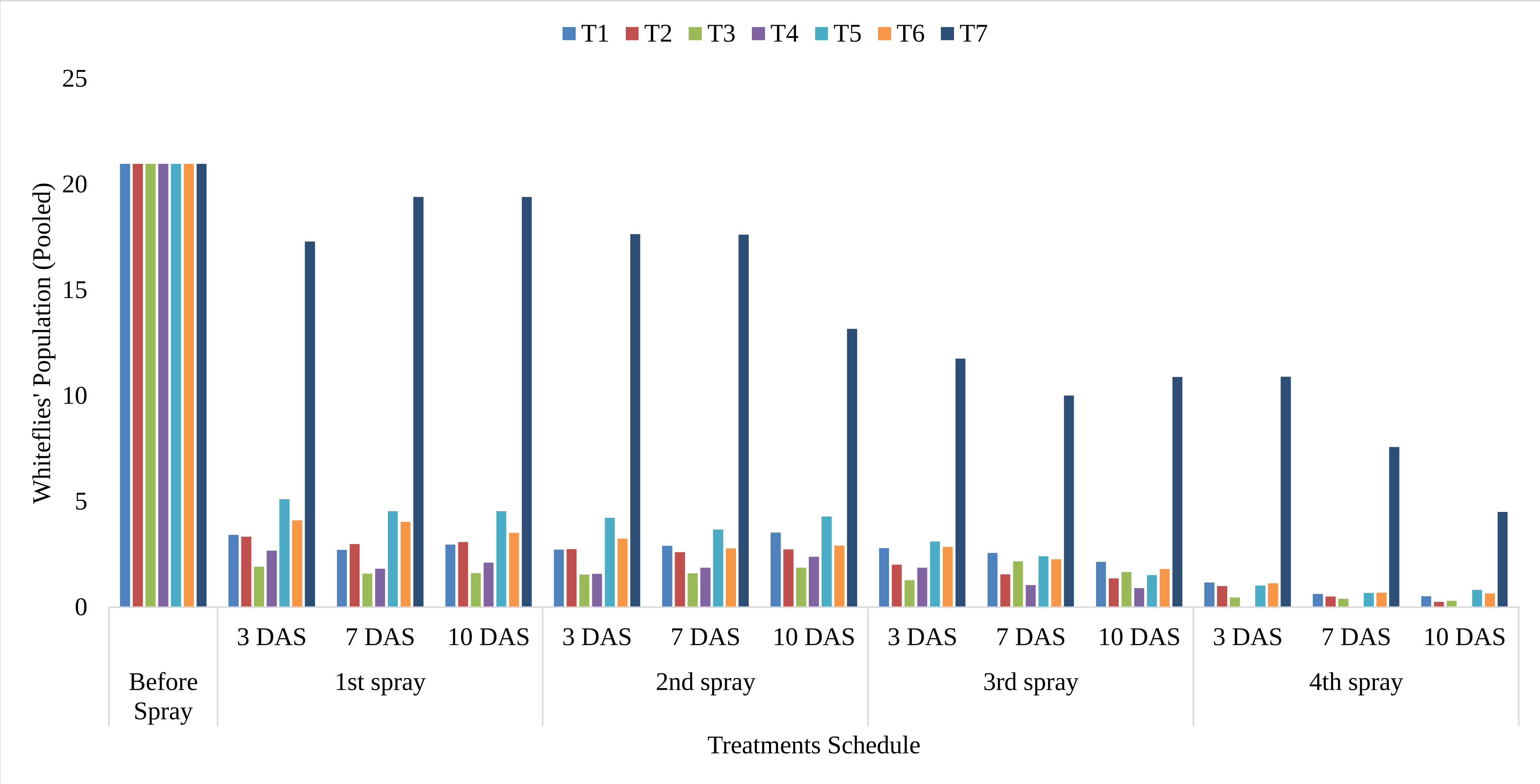
At 10th day of fourth spray the population in the untreated plot was recorded as 4.50 whiteflies per ten plants. T4 was promisingly controlled the whiteflies population (no incidence). Further, the population of whiteflies in the plots treated with T2, T3, T1, T6 and T5 was 0.25, 0.30, 0.52, 0.65 and 0.82, respectively, which were significantly less than that of the whiteflies' population recorded in untreated plot.

Table 6.18: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE)against whiteflies at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	Before Spray	1st spray			2nd spray			3rd spray			4th spray			Percentage reduction over control
		3 DAS	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	*3 DAS*	*7 DAS*	*10 DAS*	
T1	20.97 4.58	3.42 (1.85)	2.71 (1.64)	2.96 (1.72)	2.72 (1.65)	2.90 (1.70)	3.53 (1.88)	2.79 (1.67)	2.56 (1.60)	2.14 (1.46)	1.17 (1.08)	0.62 (0.79)	0.52 (0.72)	82.51
T2	20.97 4.58	3.33 (1.82)	2.98 (1.73)	3.08 (1.76)	2.74 (1.65)	2.60 (1.61)	2.73 (1.65)	2.01 (1.42)	1.55 (1.24)	1.36 (1.16)	1.00 (1.00)	0.50 (0.71)	0.25 (0.50)	84.94
T3	20.97 4.58	1.91 (1.38)	1.59 (1.26)	1.61 (1.27)	1.54 (1.24)	1.60 (1.27)	1.86 (1.36)	1.27 (1.12)	2.16 (1.47)	1.66 (1.29)	0.45 (0.67)	0.40 (0.63)	0.30 (0.55)	89.80
T4	20.97 4.58	2.67 (1.63)	1.82 (1.35)	2.11 (1.45)	1.57 (1.25)	1.86 (1.36)	2.38 (1.54)	1.87 (1.37)	1.05 (1.02)	0.90 (0.95)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	89.87
T5	20.97 4.58	5.10 (2.26)	4.54 (2.13)	4.54 (2.13)	4.22 (2.05)	3.67 (1.92)	4.28 (2.07)	3.10 (1.76)	2.41 (1.55)	1.51 (1.23)	1.02 (1.01)	0.67 (0.82)	0.82 (0.90)	77.61
T6	20.97 4.58	4.10 (2.02)	4.03 (2.01)	3.51 (1.87)	3.24 (1.80)	2.78 (1.67)	2.91 (1.70)	2.85 (1.69)	2.26 (1.50)	1.81 (1.35)	1.13 (1.06)	0.68 (0.82)	0.65 (0.80)	81.31
T7	20.97 4.58	17.30 (4.16)	19.41 (4.41)	19.41 (4.41)	17.65 (4.20)	17.62 (4.20)	13.16 (3.63)	11.76 (3.43)	10.01 (3.16)	10.89 (3.30)	10.90 (3.30)	7.57 (2.75)	4.50 (2.12)	
C.D.	N/A	2.459	3.291	2.699	3.634	4.247	3.199	5.825	N/A	N/A	N/A	N/A	N/A	
SE(m)	0.471	0.697	0.933	0.765	1.03	1.204	0.907	1.651	2.155	3.329	3.092	2.084	1.357	

**Figures in parentheses are square root transformed values (x + 0.5)*

Figure 6.14: Efficacy of tested insecticides, Biopesticides and plant extracts (NKE) against whiteflies at experimental fields of CPRS, Jalandhar (Pooled)



The data from a series of experiments conducted for two successive potato growing seasons (*Rabi* 2014 and 2015) helped in identifying an efficient combinations of tested insecticides against the incidence of whiteflies in potato fields at CPRS, Jalandhar. Figures 6.12 and 6.13 clearly depicts the performance of various treatments by means of controlling the whitefly population over the untreated plots, during *2014* and 2015, respectively. On pursuing Table 6.16 it was reported that in *Rabi* 2014 the combination of foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (2.5 ml /lit) (as second spray), Foliar spray of Imidacloprid 200SL (0.3 ml/lit) (as third spray) and Rogor 30EC (1.5ml/lit) (as fourth spray) efficiently controlled the whitefly population. Furthermore, the Table 6.16 revealed that the trend of efficacy of treatments in this year was quite similar with the efficacy against aphids and leafhoppers i.e. T3 (87.73%) > T2 (84.72%) > T1 (79.29%) > T4 (78.24%) > T6 (73.43%) > T5 (69.31%). The scenario on the trend of efficacy of treatments in the *Rabi* 2015 was quite different than that of the reported earlier. In this year the application of treatment T4 {1st Spray: Seed treatment with Imidacloprid (0.4 ml/lit) + Metarrhizium anisopliae (2 Kg/ha) soil application + Foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit) at the time of pest appearance; 2nd Spray: Foliar spray of Thiomethoxam 25WG (0.3 ml/lit); 3rd Spray:Rogor 30EC (1.5ml/lit); 4th Spray: Foliar spray of Imidacloprid 200SL (0.3 ml/lit) and Neem Baan (3ml/lit)} was found most efficient in controlling the whitefly population. The reason for this could be the environmental factors or the difference in the biotypes from the previous year. Further, Table 6.17 revealed the trend of efficacy in 2015 which was T4 (97.50%) > T3 (91.16%) > T6 (86.47%) > T2 (85.08%) > T1 (84.62%) > T5 (83.05%). The pooled data further helped in identifying the overall efficacy of treatments. The Figure 6.14 clearly depicts the overall performance of treatments by means of controlling the whitefly population over the untreated one. The pursuance of table 6.18 unveiled the overall trend of efficacy of treatments by means of percentage reduction in whitefly population over control. The overall trend of efficacy of treatments against whitefly in potato fields of CPRS, Jalandhar was T4 (89.87%) > T3 (89.80%) > T2 (84.94%) > T1 (82.51%) > T6 (81.31%) > T5 (77.61%).

The experimental findings on the efficacy of insecticides, bio-pesticides and plant extracts (NKE) against insect pests of potato by means of rotating chemistry provided valuable outcomes. In the present investigation most of the treatments performed efficiently and significantly controlled the population of aphids, leafhoppers and whiteflies against the untreated plots. According to these findings the treatment T3 may efficiently control all three insect pests in the potato fields; however, as an option other treatments can also be used. For controlling the whiteflies alone, the application of treatment T4 and T3 are at par as per pooled data results .

These findings are in conformity with the study of Kahar *et al.* (2016) who studied the efficacy of imidaclorpid, chlorpyriphos, phorat and hydrochloride by means of rotating chemistry against *Myzus pericae* and *Aphis gossypii* on potato. Further, Golmohammadi *et al.* (2014) who assessed and evaluated the efficacy of imidaclorpid in different combination with other synthetic insecticides against whitefly and reported significant results also favours the present experimental findings. Further, findings of More *et al.* (2015), Khan *et al*. (2011), Bhatnagar (2012), Chandel *et al.* (2010) and Bhatnagar and Thakur (2008) strengthen the present results.

6.6 Efficacy of newer molecule against sucking insect pest of potato

In the array of identifying efficacy of newer molecules (Table 5.3) an experiment was conducted at ICAR-CPRS, Jalandhar during *Rabi* 2014 and 2015. The results are discussed as below:

6.6.1 Efficacy of newer molecule against aphids

The data from table 6.19 revealed that in 2014, treatment namely T2 (Imidacloprid 17.8 SL @0.03%) significantly controlled the aphid population in contrast to control (T5) after 3^{rd}, 7^{th} and 10^{th}day of first spray. The population of aphids after 3^{rd}, 7^{th} and 10^{th} day of first spray in the plots treated with T2 was 1.67, 3.33 and 2.33 aphids per ten plants, respectively. The performance was maintained by T2 even after the 2^{nd} and 3^{rd} spray. On the basis of percent reduction in the aphid population over the control one the efficacy trend was T2 {Imidacloprid 17.8 SL @0.03%}(78.33 %) > T3 (48.68 %) {Thymol @ 1.0%}>T4{Neem Baan 1500 Ppm @ 3ml/Lit}(55.88%) > T1 (19.41 %){Kaolin @ 1.5%}.

The scenario in 2015 was at par with the previous year the plots treated with T2 were recorded with lowest number of aphids per ten plant after 1^{st}, 2^{nd} and 3^{rd} spray. The overall efficacy trend on the basis of percent reduction over control was T2 (77.10 %) > T4 (61.28 %) > T3 (60.89) > T1 (42.32%). However, the treatment T3 was at par with T4 at 5% C.D (Table 6.20).

Further, the pooled data analysis (Table 6.21 and Figure 6.15) revealed the overall performance of the tested molecules against the aphids. The treatment T2 efficiently controlled the aphid population; however on the basis of percent reduction the trend was T2 (77.70%) > T4 (58.51 %) > T3 (54.65 %) > T1 (30.63 %).

6.6.2 Efficacy of newer molecule against leafhoppers

The initial leafhopper population ranged between 11.00 and13.00 leafhopper per ten plants in all the treatments. Further the data from Table 6.22 and Figure 6.16 revealed that in 2014, treatment Imidacloprid 17.8 SL @ 0.03% controlled the leafhopper population most efficiently after first, second and third spray. On the basis of percent reduction in the leafhopper population over the control one the efficacy trend was T3 {Thymol @ 1.0%} (61.16 %) > T4 {Neem Baan 1500 Ppm @ 3ml/Lit} (48.06%) > T2 {Imidacloprid 17.8 SL @0.03%} (45.63%) > T1 (45.14 %) {Kaolin @ 1.5%}.

The scenario was little bit different in *Rabi* 2015 than that of 2014. The results for the efficacy of newer molecules in *Rabi* 2015 are facilitated in Table 6.23 and depicted in Figure 6.16. The plots treated with T2 were recorded with lowest number of leafhoppers per ten plants after first, second and third spray. The overall efficacy trend on the basis of percent reduction over control was T2 (52.52 %) > T3 (45.14) > T4 (36.96 %) > T1 (30.35%).

Further, the pooled data analysis (Table 6.24 and Figure 6.16) revealed the overall performance of the tested molecules against the aphids. The treatment T2 efficiently controlled the aphid population; however on the basis of percent reduction the trend was T2 (55.51%) > T4 (47.95 %) > T3 (42.55 %) > T1 (34.34 %).

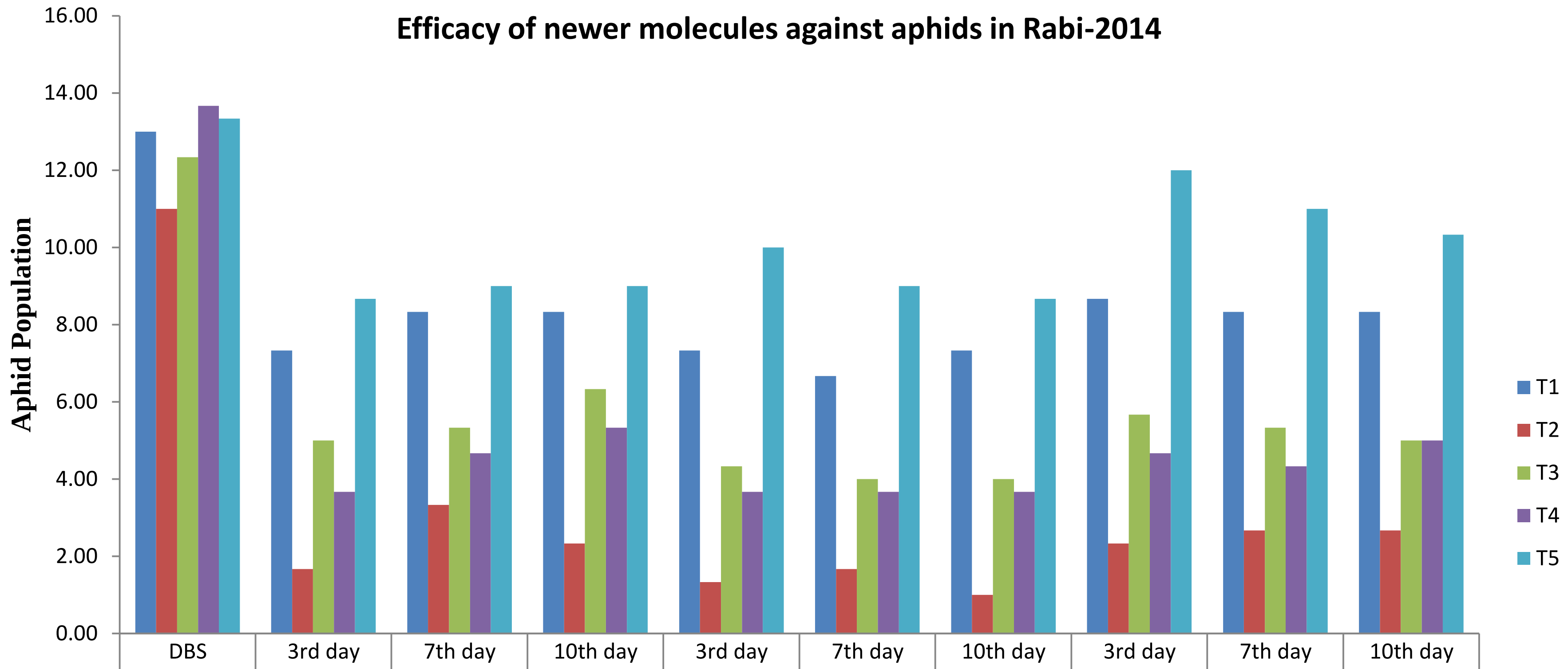
6.6.3 Efficacy of newer molecule against whiteflies

In *Rabi* 2014, the initial whiteflies population ranged between 13.33 and 16.00 whiteflies per ten plants in all the treatments. Further the data from Table 6.25 and Figure 6.17 revealed that in 2014, treatment Imidacloprid 17.8 SL @ 0.03% controlled the whitefly population most efficiently after 1st, 2nd and 3rd spray. On the basis of percent reduction in the white population over the control one the efficacy trend was T2 {Imidacloprid 17.8 SL @0.03%} (68.71 %) > T4 {Neem Baan 1500 Ppm @ 3ml/Lit} (67.07%) > T3 {Thymol @ 1.0%}(60.50 %) > T1 (35.82 %) {Kaolin @ 1.5%}.

Table 6.19: Efficacy of newer molecules against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2014

Treatments	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13 (3.61)	7.33 (2.71)	8.33 (2.89)	8.33 (2.89)	7.33 (2.71)	6.67 (2.58)	7.33 (2.71)	8.67 (2.94)	8.33 (2.89)	8.33 (2.89)	19.41
T2	11 (3.32)	1.67 (1.29)	3.33 (1.83)	2.33 (1.53)	1.33 (1.15)	1.67 (1.29)	1.00 (1.00)	2.33 (1.53)	2.67 (1.63)	2.67 (1.63)	78.33
T3	12.333 (3.51)	5.00 (2.24)	5.33 (2.31)	6.33 (2.52)	4.33 (2.08)	4.00 (2.00)	4.00 (2.00)	5.67 (2.38)	5.33 (2.31)	5.00 (2.24)	48.68
T4	13.667 (3.70)	3.67 (1.91)	4.67 (2.16)	5.33 (2.31)	3.67 (1.91)	3.67 (1.91)	3.67 (1.91)	4.67 (2.16)	4.33 (2.08)	5.00 (2.24)	55.88
T5	13.333 (3.65)	8.67 (2.94)	9.00 (3.00)	9.00 (3.00)	10.00 (3.16)	9.00 (3.00)	8.67 (2.94)	12.00 (3.46)	11.00 (3.32)	10.33 (3.21)	
C.D.	1.637	1.78	0.89	1.076	0.987	0.855	0.819	1.158	0.89	1.896	
SE(m)	0.494	0.537	0.269	0.325	0.298	0.258	0.247	0.35	0.269	0.573	

**Figures in parentheses are square root transformed values (x + 0.5)*



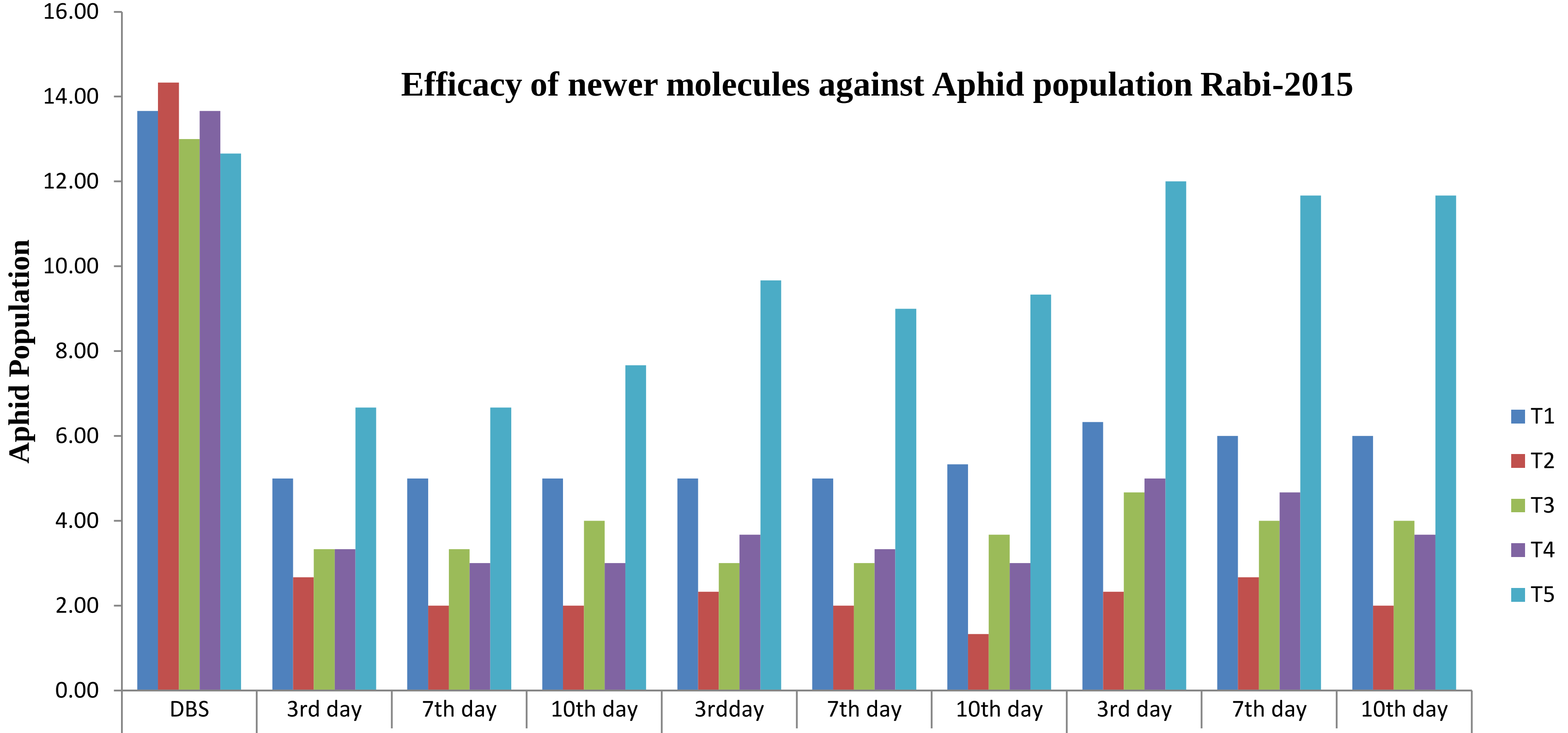
	DBS	1st spray 3rd day	1st spray 7th day	1st spray 10th day	2nd spray 3rd day	2nd spray 7th day	2nd spray 10th day	3rd spray 3rd day	3rd spray 7th day	3rd spray 10th day
T1	13.00	7.33	8.33	8.33	7.33	6.67	7.33	8.67	8.33	8.33
T2	11.00	1.67	3.33	2.33	1.33	1.67	1.00	2.33	2.67	2.67
T3	12.33	5.00	5.33	6.33	4.33	4.00	4.00	5.67	5.33	5.00
T4	13.67	3.67	4.67	5.33	3.67	3.67	3.67	4.67	4.33	5.00
T5	13.33	8.67	9.00	9.00	10.00	9.00	8.67	12.00	11.00	10.33

Treatment Schdule

Table 6.20: Efficacy of newer molecules against aphids at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13.66 (3.70)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	5.33 (2.31)	6.33 (2.52)	6.00 (2.45)	6.00 (2.45)	42.32
T2	14.33 (3.79)	2.67 (1.63)	2.00 (1.41)	2.00 (1.41)	2.33 (1.53)	2.00 (1.41)	1.33 (1.15)	2.33 (1.53)	2.67 (1.63)	2.00 (1.41)	77.10
T3	13 (3.61)	3.33 (1.83)	3.33 (1.83)	4.00 (2.00)	3.00 (1.73)	3.00 (1.73)	3.67 (1.91)	4.67 (2.16)	4.00 (2.00)	4.00 (2.00)	60.89
T4	13.66 (3.70)	3.33 (1.83)	3.00 (1.73)	3.00 (1.73)	3.67 (1.91)	3.33 (1.83)	3.00 (1.73)	5.00 (2.24)	4.67 (2.16)	3.67 (1.91)	61.28
T5	12.66 (3.54)	6.67 (2.58)	6.67 (2.58)	7.67 (2.77)	9.67 (3.11)	9.00 (3.00)	9.33 (3.05)	12.00 (3.46)	11.67 (3.42)	11.67 (3.42)	
C.D.	N/A	1.018	0.781	0.89	1.896	0.987	0.89	1.329	0.855	1.418	
SE(m)	0.489	0.307	0.236	0.269	0.573	0.298	0.269	0.401	0.258	0.428	

**Figures in parentheses are square root transformed values (x + 0.5)*



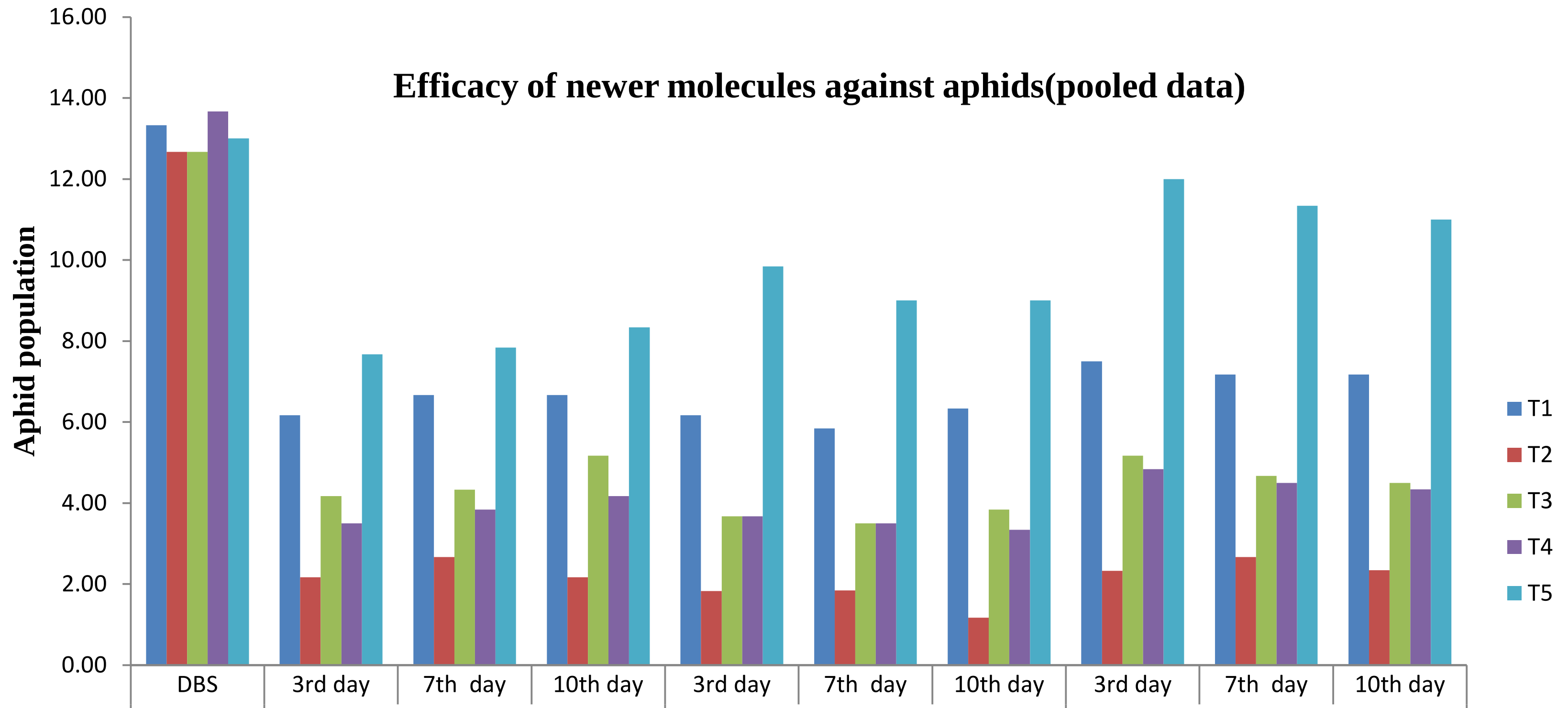
	DBS	1st spray			2nd spray			3rd spray		
		3rd day	7th day	10th day	3rdday	7th day	10th day	3rd day	7th day	10th day
T1	13.66	5.00	5.00	5.00	5.00	5.00	5.33	6.33	6.00	6.00
T2	14.33	2.67	2.00	2.00	2.33	2.00	1.33	2.33	2.67	2.00
T3	13.00	3.33	3.33	4.00	3.00	3.00	3.67	4.67	4.00	4.00
T4	13.66	3.33	3.00	3.00	3.67	3.33	3.00	5.00	4.67	3.67
T5	12.66	6.67	6.67	7.67	9.67	9.00	9.33	12.00	11.67	11.67

Treatment Schdule

Table 6.21: Efficacy of newer molecules against aphids at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13.33 (3.65)	6.17 (2.48)	6.67 (2.58)	6.67 (2.58)	6.17 (2.48)	5.84 (2.41)	6.33 (2.51)	7.50 (2.74)	7.17 (2.68)	7.17 (2.68)	30.63
T2	12.67 (3.55)	2.17 (1.47)	2.67 (1.63)	2.17 (1.47)	1.83 (1.35)	1.84 (1.35)	1.17 (1.08)	2.33 (1.52)	2.67 (1.63)	2.34 (1.52)	77.70
T3	12.67 (3.55)	4.17 (2.04)	4.33 (2.08)	5.17 (2.27)	3.67 (1.91)	3.50 (1.87)	3.84 (1.95)	5.17 (2.27)	4.67 (2.15)	4.50 (2.12)	54.65
T4	13.67 (3.69)	3.50 (1.87)	3.84 (1.95)	4.17 (2.04)	3.67 (1.91)	3.50 (1.87)	3.34 (1.82)	4.84 (2.20)	4.50 (2.12)	4.34 (2.08)	58.51
T5	13.00 (3.60)	7.67 (2.77)	7.84 (2.79)	8.34 (2.88)	9.84 (3.14)	9.00 (3.00)	9.00 (3.00)	12.00 (3.46)	11.34 (3.37)	11.00 (3.32)	
C.D.	N/A	2.784	1.545	2.298	2.573	1.618	2.089	2.202	2.541	2.715	
SE(m)	0.76	0.691	0.383	0.57	0.638	0.401	0.518	0.546	0.63	0.674	

**Figures in parentheses are square root transformed values (x + 0.5)*



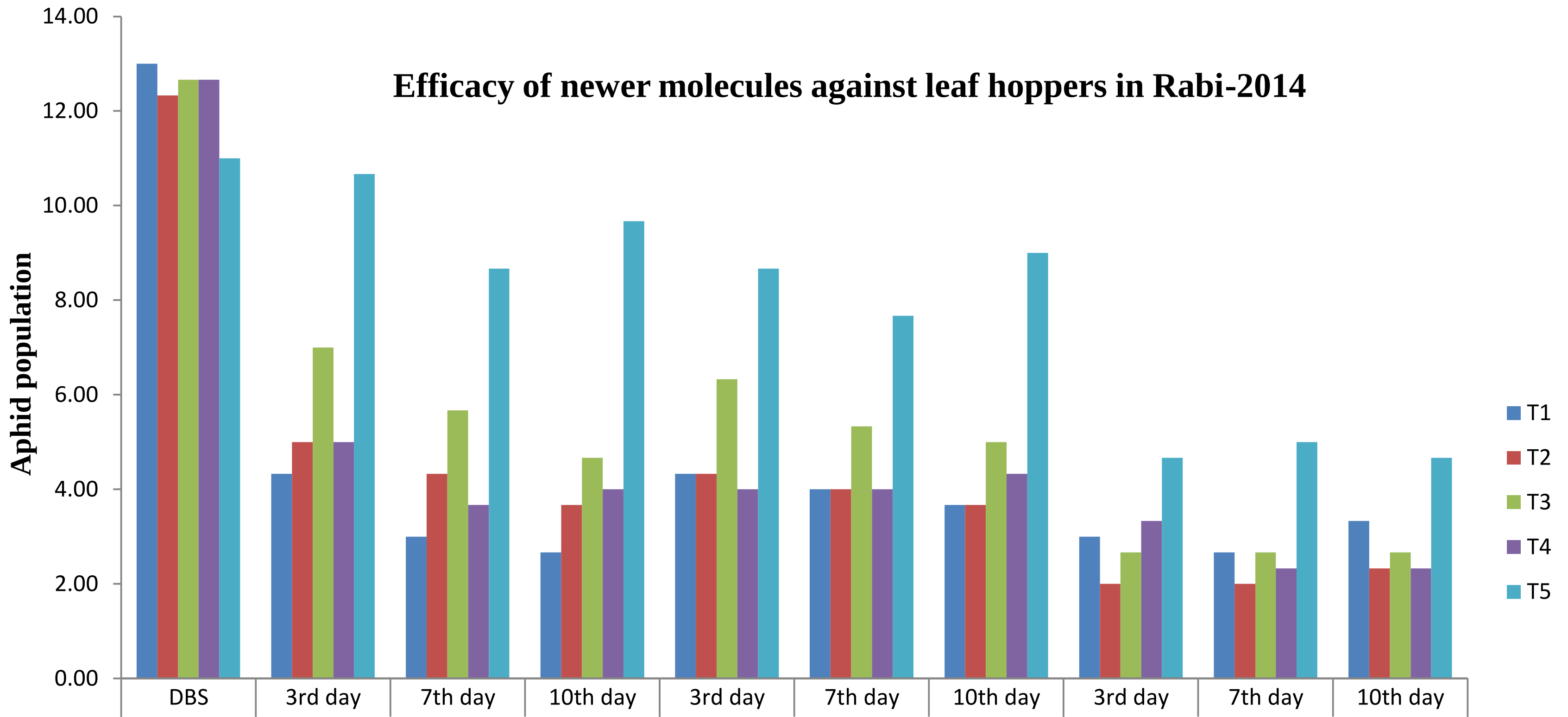
	DBS	1st spray 3rd day	1st spray 7th day	1st spray 10th day	2nd spray 3rd day	2nd spray 7th day	2nd spray 10th day	3rd spray 3rd day	3rd spray 7th day	3rd spray 10th day
T1	13.33	6.17	6.67	6.67	6.17	5.84	6.33	7.50	7.17	7.17
T2	12.67	2.17	2.67	2.17	1.83	1.84	1.17	2.33	2.67	2.34
T3	12.67	4.17	4.33	5.17	3.67	3.50	3.84	5.17	4.67	4.50
T4	13.67	3.50	3.84	4.17	3.67	3.50	3.34	4.84	4.50	4.34
T5	13.00	7.67	7.84	8.34	9.84	9.00	9.00	12.00	11.34	11.00

Treatment Schdule

Table 6.22: Efficacy of newer molecules against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2014

Treatment		1st spray			2nd spray			3rd spray			Percent reduction
	DBS	3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13.00 (3.61)	4.33 (2.08)	3.00 (1.73)	2.67 (1.63)	4.33 (2.08)	4.00 (2.00)	3.67 (1.91)	3.00 (1.73)	2.67 (1.63)	3.33 (1.83)	45.14
T2	12.33 (3.51)	5.00 (2.24)	4.33 (2.08)	3.67 (1.91)	4.33 (2.08)	4.00 (2.00)	3.67 (1.91)	2.00 (1.41)	2.00 (1.41)	2.33 (1.53)	45.63
T3	12.66 (3.56)	7.00 (2.65)	5.67 (2.38)	4.67 (2.16)	6.33 (2.52)	5.33 (2.31)	5.00 (2.24)	2.67 (1.63)	2.67 (1.63)	2.67 (1.63)	61.16
T4	12.66 (3.56)	5.00 (2.24)	3.67 (1.91)	4.00 (2.00)	4.00 (2.00)	4.00 (2.00)	4.33 (2.08)	3.33 (1.83)	2.33 (1.53)	2.33 (1.73)	48.06
T5	11.00 (3.32)	10.67 (3.67)	8.67 (2.94)	9.67 (3.11)	8.67 (2.94)	7.67 (2.77)	9.00 (3.00)	4.67 (2.16)	5.00 (2.24)	4.67 (2.16)	
C.D.	N/A	1.158	1.501	1.076	0.89	1.158	1.329	1.329	1.018	1.131	
SE(m)	0.628	0.35	0.453	0.325	0.269	0.35	0.401	0.401	0.307	0.342	

**Figures in parentheses are square root transformed values (x + 0.5)*



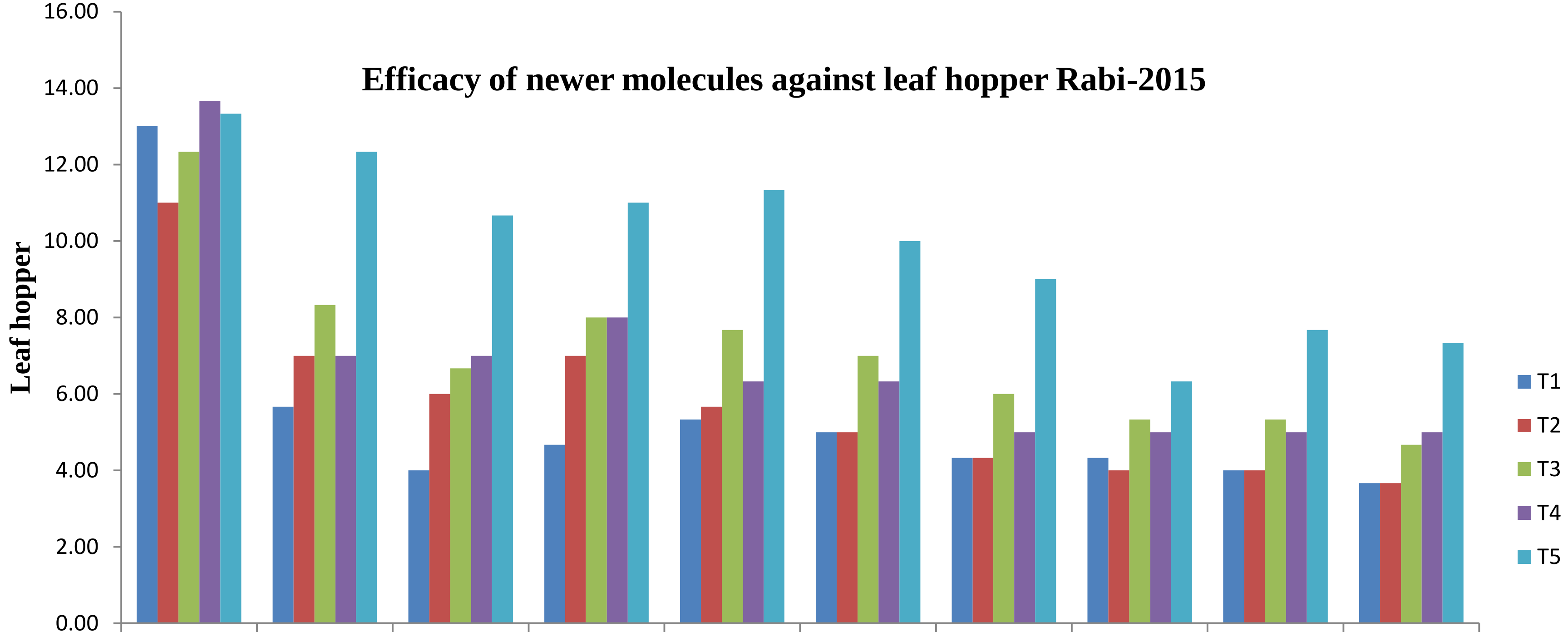
	DBS	1st spray 3rd day	1st spray 7th day	1st spray 10th day	2nd spray 3rd day	2nd spray 7th day	2nd spray 10th day	3rd spray 3rd day	3rd spray 7th day	3rd spray 10th day
T1	13.00	4.33	3.00	2.67	4.33	4.00	3.67	3.00	2.67	3.33
T2	12.33	5.00	4.33	3.67	4.33	4.00	3.67	2.00	2.00	2.33
T3	12.66	7.00	5.67	4.67	6.33	5.33	5.00	2.67	2.67	2.67
T4	12.66	5.00	3.67	4.00	4.00	4.00	4.33	3.33	2.33	2.33
T5	11.00	10.67	8.67	9.67	8.67	7.67	9.00	4.67	5.00	4.67

Treatment Schdule

Table 6.23: Efficacy of newer molecules against leafhoppers at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13.00 (3.61)	5.67 (2.38)	4.00 (2.00)	4.67 (2.16)	5.33 (2.31)	5.00 (2.24)	4.33 (2.08)	4.33 (2.08)	4.00 (2.00)	3.67 (1.91)	30.35
T2	11.00 (3.32)	7.00 (2.65)	6.00 (2.45)	7.00 (2.65)	5.67 (2.38)	5.00 (2.24)	4.33 (2.08)	4.00 (2.00)	4.00 (2.00)	3.67 (1.91)	52.53
T3	12.33 (3.51)	8.33 (2.89)	6.67 (2.58)	8.00 (2.83)	7.67 (2.77)	7.00 (2.65)	6.00 (2.45)	5.33 (2.31)	5.33 (2.31)	4.67 (2.16)	45.14
T4	13.66 (3.70)	7.00 (2.65)	7.00 (2.65)	8.00 (2,83)	6.33 (2.52)	6.33 (2.52)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	36.96
T5	13.33 (3.65)	12.33 (2.51)	10.67 (3.27)	11.00 (3.32)	11.33 (3.37)	10.00 (3.16)	9.00 (3.00)	6.33 (2.52)	7.67 (2.77)	7.33 (2.71)	
C.D.	1.637	1.329	1.209	1.306	1.6	1.076	0.605	0.855	0.653	0.89	
SE(m)	0.494	0.401	0.365	0.394	0.483	0.325	0.183	0.258	0.197	0.269	

**Figures in parentheses are square root transformed values (x + 0.5)*



	DBS	3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day
		1st spray			2nd spray			3rd spray		
T1	13.00	5.67	4.00	4.67	5.33	5.00	4.33	4.33	4.00	3.67
T2	11.00	7.00	6.00	7.00	5.67	5.00	4.33	4.00	4.00	3.67
T3	12.33	8.33	6.67	8.00	7.67	7.00	6.00	5.33	5.33	4.67
T4	13.66	7.00	7.00	8.00	6.33	6.33	5.00	5.00	5.00	5.00
T5	13.33	12.33	10.67	11.00	11.33	10.00	9.00	6.33	7.67	7.33

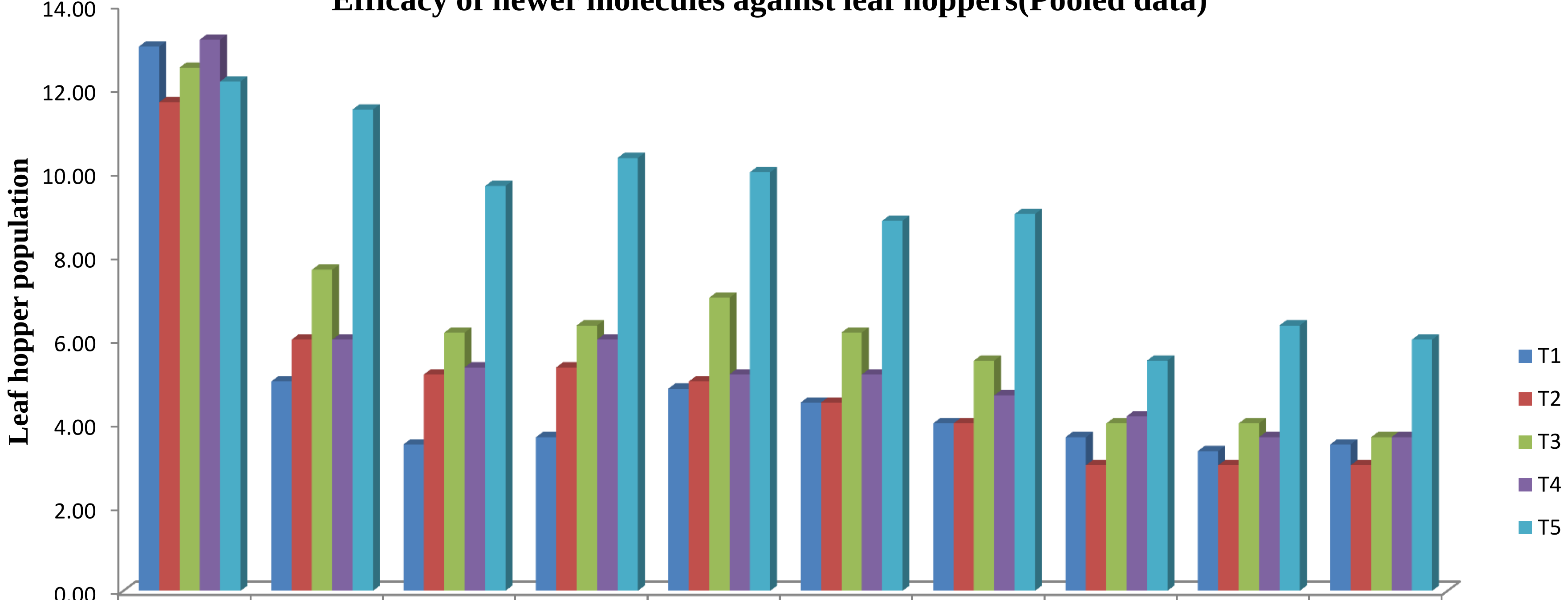
Treatment Schdule

Table 6.24: Efficacy of newer molecules against leafhoppers at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	13.00 (3.60)	5.00 (2.24)	3.50 (1.87)	3.67 (1.92)	4.83 (2.19)	4.50 (2.12)	4.00 (2.00)	3.67 (1.91)	3.34 (1.82)	3.50 (1.87)	34.34
T2	11.67 (3.41)	6.00 (2.45)	5.17 (2.27)	5.34 (2.30)	5.00 (2.23)	4.50 (2.12)	4.00 (2.00)	3.00 (1.73)	3.00 (1.73)	3.00 (1.73)	55.51
T3	12.50 (3.53)	7.67 (2.77)	6.17 (2.48)	6.34 (2.51)	7.00 (2.64)	6.17 (2.48)	5.50 (5.50)	4.00 (2.00)	4.00 (2.00)	3.67 (1.91)	47.95
T4	13.17 (3.62)	6.00 (2.45)	5.34 (2.30)	6.00 (2.44)	5.17 (2.27)	5.17 (2.27)	4.67 (4.66)	4.17 (2.04)	3.67 (1.91)	3.67 (1.91)	42.55
T5	12.17 (3.48)	11.50 (3.40)	9.67 (3.11)	10.34 (3.21)	10.00 (3.16)	8.84 (2.97)	9.00 (3.00)	5.50 (2.34)	6.34 (2.52)	6.00 (2.44)	
C.D.	N/A	0.67	1.933	2.209	1.447	1.341	0.735	1.016	1.205	N/A	
SE(m)	0.697	0.166	0.479	0.548	0.359	0.333	0.182	0.252	0.299	0.492	

**Figures in parentheses are square root transformed values (x + 0.5)*

Efficacy of newer molecules against leaf hoppers(Pooled data)



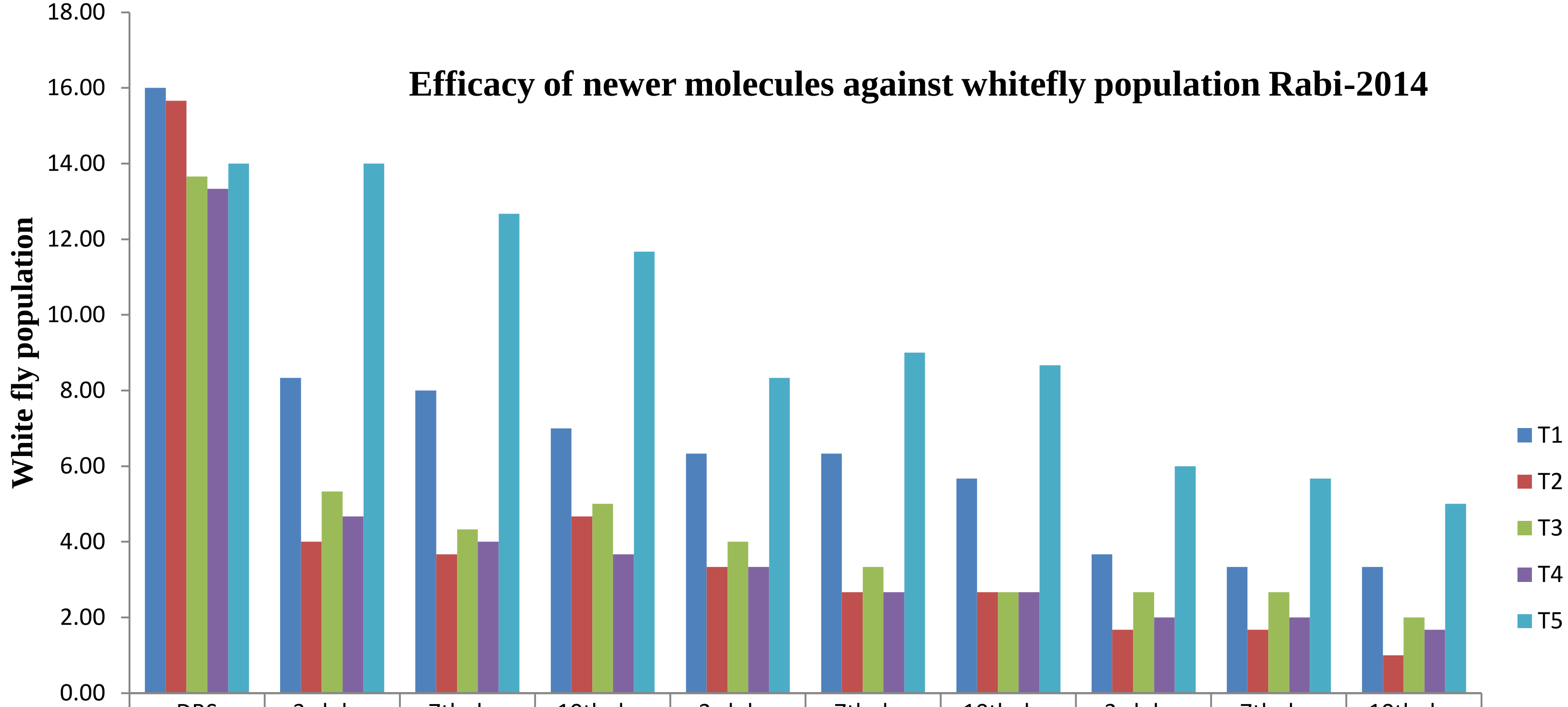
	DBS	3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day
		1st spray			2nd spray			3rd spray		
T1	13.00	5.00	3.50	3.67	4.83	4.50	4.00	3.67	3.34	3.50
T2	11.67	6.00	5.17	5.34	5.00	4.50	4.00	3.00	3.00	3.00
T3	12.50	7.67	6.17	6.34	7.00	6.17	5.50	4.00	4.00	3.67
T4	13.17	6.00	5.34	6.00	5.17	5.17	4.67	4.17	3.67	3.67
T5	12.17	11.50	9.67	10.34	10.00	8.84	9.00	5.50	6.34	6.00

Treatment Schdule

Table 6.25: Efficacy of newer molecules against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2014

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	16 (4.00)	8.33 (2.89)	8.00 (2.83)	7.00 (2.64)	6.33 (2.51)	6.33 (2.51)	5.67 (2.38)	3.67 (1.92)	3.33 (1.82)	3.33 (1.82)	35.82
T2	15.66 (3.96)	4.00 (2.00)	3.67 (1.91)	4.67 (2.16)	3.33 (1.82)	2.67 (1.63)	2.67 (1.63)	1.67 (1.29)	1.67 (1.29)	1.00 (1.00)	68.71
T3	13.66 (3.70)	5.33 (2.31)	4.33 (2.08)	5.00 (2.23)	4.00 (2.00)	3.33 (1.82)	2.67 (1.63)	2.67 (1.63)	2.67 (1.63)	2.00 (1.41)	60.50
T4	13.33 (3.65)	4.67 (2.16)	4.00 (2.00)	3.67 (1.91)	3.33 (1.82)	2.67 (1.63)	2.67 (1.67)	2.00 (1.41)	2.00 (1.41)	1.67 (1.29)	67.07
T5	14 (3.74)	14.00 (3.74)	12.67 (3.56)	11.67 (3.41)	8.33 (2.89)	9.00 (3.00)	8.67 (2.94)	6.00 (2.44)	5.67 (2.38)	5.00 (2.23)	
C.D.	1.847	2.329	2.080	1.418	0.494	0.924	1.131	1.047	0.987	0.890	
SE(m)	0.558	0.703	0.628	0.428	0.149	0.279	0.342	0.316	0.298	0.269	

**Figures in parentheses are square root transformed values (x + 0.5)*



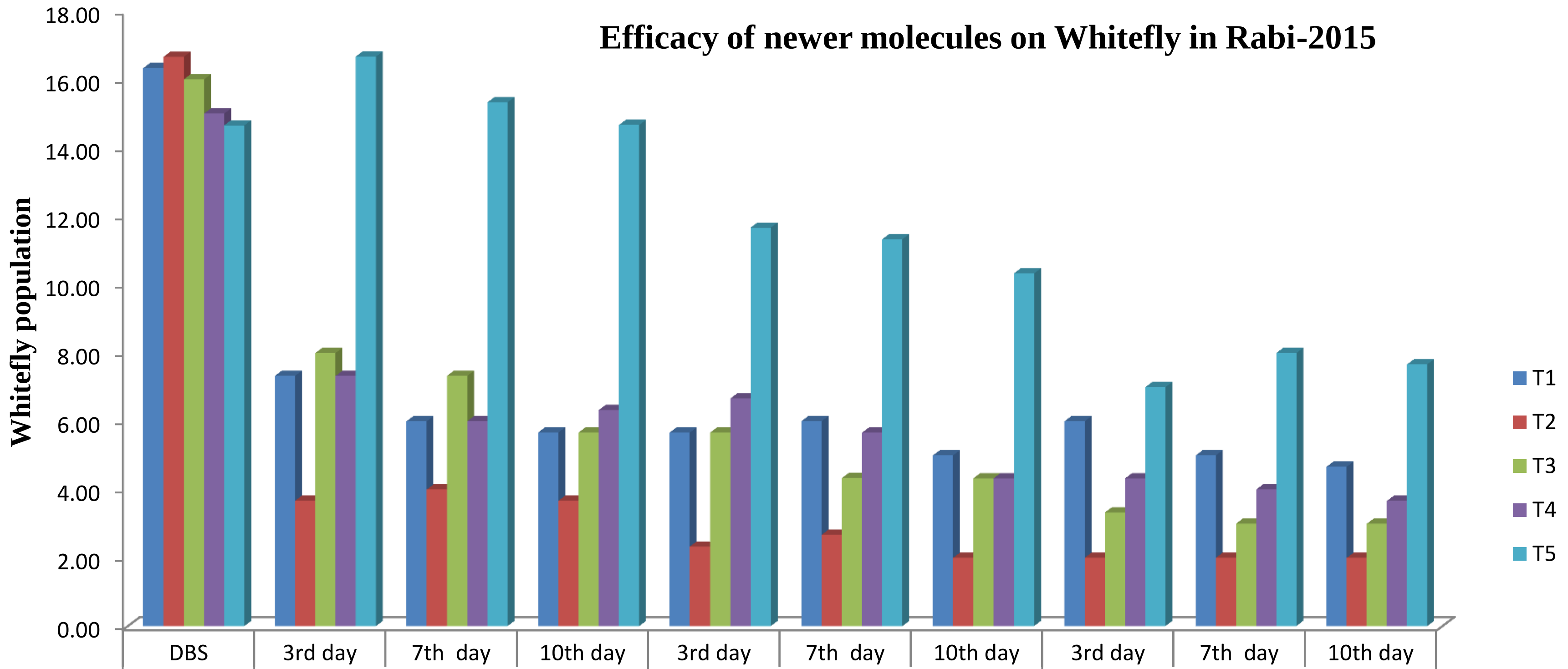
	DBS	1st spray 3rd day	1st spray 7th day	1st spray 10th day	2nd spray 3rd day	2nd spray 7th day	2nd spray 10th day	3rd spray 3rd day	3rd spray 7th day	3rd spray 10th day
T1	16.00	8.33	8.00	7.00	6.33	6.33	5.67	3.67	3.33	3.33
T2	15.66	4.00	3.67	4.67	3.33	2.67	2.67	1.67	1.67	1.00
T3	13.66	5.33	4.33	5.00	4.00	3.33	2.67	2.67	2.67	2.00
T4	13.33	4.67	4.00	3.67	3.33	2.67	2.67	2.00	2.00	1.67
T5	14.00	14.00	12.67	11.67	8.33	9.00	8.67	6.00	5.67	5.00

Treatment Schdule

Table 6.26: Efficacy of newer molecules against whiteflies at experimental fields of CPRS, Jalandhar during *Rabi* 2015

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	16.33 (4.04)	7.33 (2.71)	6.00 (2.45)	5.67 (2.38)	5.67 (2.38)	6 (2.45)	5 (2.24)	6.00 (2.45)	5.00 (2,24	4.67 (2.16)	50.00
T2	16.66 (4.08)	3.67 (1.91)	4.00 (2.00)	3.67 (1.91)	2.33 (1.53)	2.67 (1.63)	2 (1.41)	2.00 (1.41)	2.00 (1.41)	2.00 (1.41)	76.30
T3	16 (4.00)	8.00 (2.83)	7.33 (2.71)	5.67 (2.38)	5.67 (2.38)	4.333 (2.08)	4.33 (2.08)	3.33 (1.83)	3.00 (1.73)	3.00 (1.73)	56.51
T4	15 (3.87)	7.33 (2.71)	6.00 (2.45)	6.33 (2.52)	6.67 (2.58)	5.667 (2.38)	4.33 (2.08)	4.33 (2.08)	4.00 (2.00)	3.67 (1.91)	52.94
T5	14.66 (3.83)	16.67 (4.08)	15.33 (3.92)	14.67 (3.83)	11.67 (3.41)	11.33 (3.41)	10.33 (3.21)	7.00 (2.65)	8.00 (2.83)	7.67 (2.77)	
C.D.	N/A	1.184	0.855	0.494	3.003	1.259	1.047	1.6	1.047	0.605	
SE(m)	1.108	0.357	0.258	0.149	0.907	0.38	0.316	0.483	0.316	0.183	

**Figures in parentheses are square root transformed values (x + 0.5)*



	DBS	1st spray 3rd day	1st spray 7th day	1st spray 10th day	2nd spray 3rd day	2nd spray 7th day	2nd spray 10th day	3rd spray 3rd day	3rd spray 7th day	3rd spray 10th day
T1	16.33	7.33	6.00	5.67	5.67	6.00	5.00	6.00	5.00	4.67
T2	16.66	3.67	4.00	3.67	2.33	2.67	2.00	2.00	2.00	2.00
T3	16.00	8.00	7.33	5.67	5.67	4.33	4.33	3.33	3.00	3.00
T4	15.00	7.33	6.00	6.33	6.67	5.67	4.33	4.33	4.00	3.67
T5	14.66	16.67	15.33	14.67	11.67	11.33	10.33	7.00	8.00	7.67

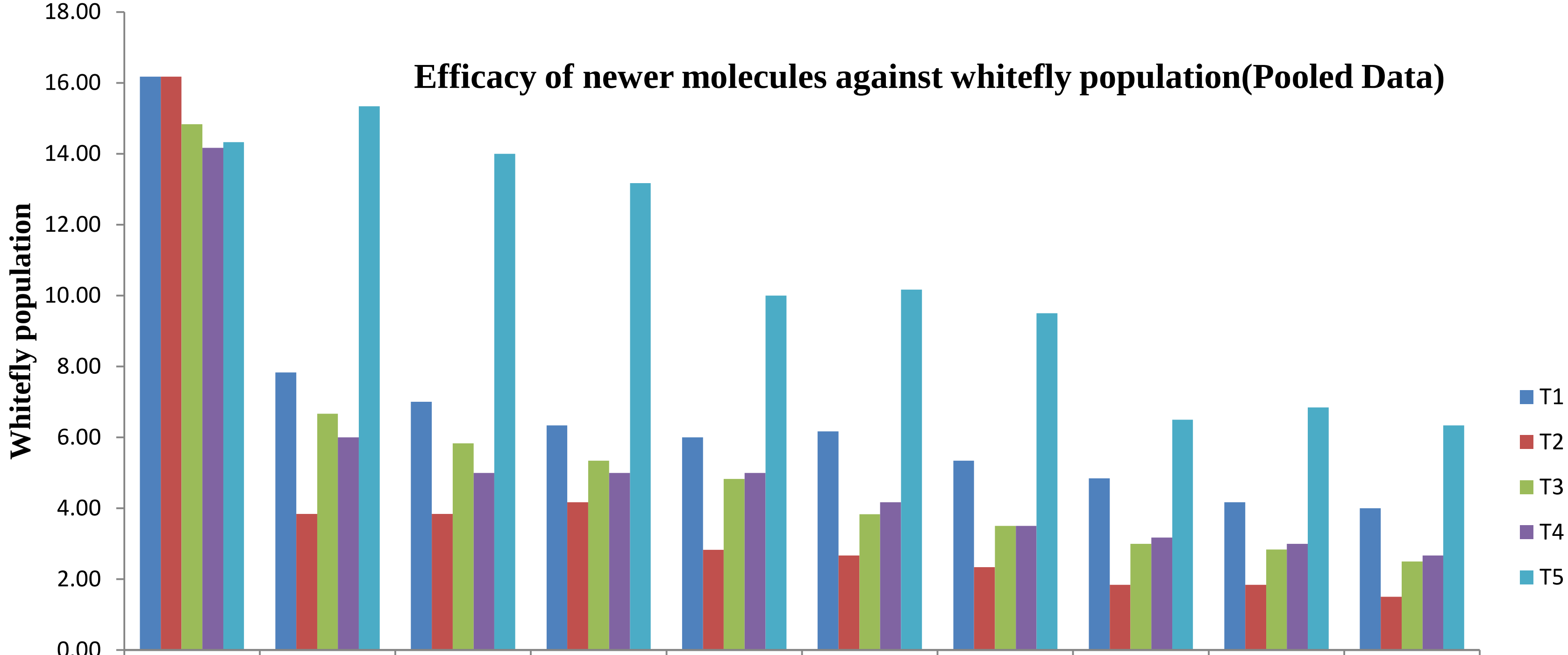
Treatment Schdule

Table 6.27: Efficacy of newer molecules against whiteflies at experimental fields of CPRS, Jalandhar (Pooled)

Treatment	DBS	1st spray			2nd spray			3rd spray			Percent reduction
		3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day	
T1	16.17 (4.02)	7.83 (2.79)	7.00 (2.64)	6.34 (2.52)	6.00 (2.45)	6.17 (2.48)	5.34 (2.30)	4.84 (2.20)	4.17 (2.04)	4.00 (2.00)	43.73
T2	16.17 (4.02)	3.84 (1.95)	3.84 (1.95)	4.17 (2.04)	2.83 (1.68)	2.67 (1.63)	2.34 (1.53)	1.84 (1.35)	1.84 (1.35)	1.50 (1.22)	72.92
T3	14.83 (3.85)	6.67 (2.58)	5.83 (2.41)	5.34 (2.31)	4.83 (2.19)	3.83 (1.95)	3.50 (1.87)	3.00 (1.73)	2.84 (1.68)	2.50 (1.58)	58.26
T4	14.17 (3.76)	6.00 (2.44)	5.00 (2.24)	5.00 (2.24)	5.00 (2.24)	4.17 (2.04)	3.50 (1.87)	3.17 (1.78)	3.00 (1.73)	2.67 (1.63)	59.16
T5	14.33 (3.78)	15.34 (3.92)	14.00 (3.74)	13.17 (3.63)	10.00 (3.16)	10.17 (3.19)	9.50 (3.08)	6.50 (2.54)	6.84 (2.61)	6.34 (2.52)	
C.D.	N/A	3.709	4.157	4.043	N/A	2.911	2.576	1.901	1.903	1.458	
SE(m)	0.401	0.92	1.031	1.003	1.048	0.722	0.639	0.472	0.472	0.362	

**Figures in parentheses are square root transformed values (x + 0.5)*

Efficacy of newer molecules against whitefly population(Pooled Data)



	DBS	3rd day	7th day	10th day	3rd day	7th day	10th day	3rd day	7th day	10th day
		1st spray			2nd spray			3rd spray		
T1	16.17	7.83	7.00	6.34	6.00	6.17	5.34	4.84	4.17	4.00
T2	16.17	3.84	3.84	4.17	2.83	2.67	2.34	1.84	1.84	1.50
T3	14.83	6.67	5.83	5.34	4.83	3.83	3.50	3.00	2.84	2.50
T4	14.17	6.00	5.00	5.00	5.00	4.17	3.50	3.17	3.00	2.67
T5	14.33	15.34	14.00	13.17	10.00	10.17	9.50	6.50	6.84	6.34

Treatment Schdule

The results for the efficacy of newer molecules in *Rabi* 2015 are facilitated in Table 6.26 and depicted in Figure 6.17. The plots treated with T2 were recorded with lowest number of whiteflies per ten plant after first, second and third spray. The overall efficacy trend on the basis of percent reduction over control was T2 (76.30 %)> T3 (56.51) > T4 (52.94 %) > T1 (50.00%).

Further, the pooled data analysis (Table 6.27 and Figure 6.17) revealed the overall performance of the tested molecules against the whitefly. The treatment T2 efficiently controlled the whitefly population; however on the basis of percent reduction the trend was T2 (72.92%) > T4 (59.16 %) > T3 (58.26 %) > T1 (43.73 %).

6.7 Incidence of potato apical leaf curl virus

The data on percent incidence of (PALCV) in experimental trial after sowing the potato crop was collected periodically at meteorological week. The whitefly as a vector is responsible for the transmission of PALCV which cause the poor health and yield of crop.

During 2014, in 44^{th} SMW i.e. in early stage of crop, population of whitefly 5.0 and percent incidence of PALCV (0.030) was observed less as compare to same week of 2015 which is 19.39 and 0.192, respectively. However, pooled data showed that 44^{th} week had maximum population of whitefly and percent incidence of PALCV. During 45^{th} SMW i.e. 25 DAS whitefly showed increase in population and percent incidence of PALCV in 2014 while in 2015, sudden decrease in population of whitefly and percent incidence of PALCV is observed. Pooled data of both the year also showed decrease in population of whitefly correlated with decrease in percentage incidence of PALCV.

Pearson’s correlation coefficient (r) was estimated to access the association between incidences of apical leaf curl virus disease and whitefly population dynamics. (Table 6.19) which has showed positive correlation in between PALCV and population of whitefly in 2014 and 2015 as well as in Pooled data of both the years.

These results are in confirmatory with Maan *et al.* (2017) who reported a significantly positive correlation between PALCVand whitefly population in potato fields. Further, Borah and Bordoloi (1998) reported similar results for tomato leaf curl virus and whitefly population.

Table 6.28: Incidence of apical leaf curl virus in potato crop and relationship with population of whitefly during *Rabi* 2014 and 2015

Months	SMW	2014		2015		Pooled	
		Incidence of PALCV (%)	*Whitefly*	*Incidence of PALCV (%)*	*Whitefly*	*Incidence of PALCV (%)*	*Whitefly*
October	44th	0.03	5.0	0.192	19.39	0.111	12.20
November	45th	0.068	9.4	0.048	6.21	0.058	7.81
	46th	0.045	6	0.045	6.20	0.045	6.10
	47th	0.037	4.67	0.051	7.50	0.044	6.09
	48th	0.048	5.83	0.067	8.00	0.057	6.92
December	49th	0.06	6.33	0.076	9.14	0.068	7.74
	50th	0.043	5.17	0.053	7.45	0.048	6.31
	51st	0.057	8	0.027	3.33	0.042	5.67
	52nd	0.061	8.83	0.011	2.14	0.036	5.50
Pearson's Correlation (r)		0.888**		0.992**		0.990*	

6.8 Assessment of yield loss in potato due to sucking insect pests

The infestation of sucking insect pests lead to a severe yield loss in potato fields. An experiment was conducted to estimate the yield loss in five varieties of potato *viz.*, Kufri Jyoti, Kufri Phukhraj, Kufri Badshah, Kufri Khyati and Kufri Surya, due to the incidence of major sucking insect pests. For this a comparison between the yield obtained from the unprotected plots and yield obtained from the plots protected with portable net houses (25 X 20 m^2) was made. In order to eliminate the error the data were firstly recorded for two years for both of the conditions and was then pooled to analyse.

The data revealed that there was a considerable difference between net house and open field for the incidence insect pests (Table 6.20). The mean population of *Aphis gosyppii, Myzus persicae*, whiteflies and leafhoppers in open fields (unprotected cultivation) was 1.88, 7.25, 1.75 and 3.06, respectively in contrast to this the protected plots were recorded with lower incidence of these insect pests i.e.,1.13, 1.19, 0.50 and 0.25, respectively.

Further, the yield data (Table 6.20) of two successive cropping seasons revealed that the yield loss in potato seeds in all five varieties was considerably high under portable net house than that of the open fields. The mean yield under portable net house was 29.70 tons/hectare whereas 27.26 tons/hectare mean yield was obtained from open fields.

Thus the investigation as an option uncovers the importance of net house cultivation in crop protection and may prove useful in reducing the insecticides use and in the integrated pest management strategies. The present findings are supported by the findings of Mukul *et al.* (2017) who studied the influence of insect proof net-house and open field conditions on vegetative growth and flowering behaviour of parental lines of cucumber cv. Pant Sankarkhira-1 during hybrid seed production. Further, findings of Kaur *et al.* (2009) who used the net house cultivation for the management of brinjal shoot and fruit borer, *leucinodes orbonalis* Guenee and reported significant results in damage reduction, strengthen the outcomes of this experiment.

Table 6.29: Incidence of sucking insect pests in open fields and portable net houses for the *Rabi* 2014 and 2015

SMW	Net house				Open Field			
	Aphis gossipy	*Myzus persicae*	*White flies*	*Leaf hopper*	*Aphis gossipy*	*Myzus persicae*	*White flies*	*Leaf hopper*
44th	2.00	1.50	0.00	0.50	4.00	2.50	4.50	13.00
45th	1.00	2.00	0.50	1.00	1.00	6.00	3.00	3.50
46th	1.00	3.00	1.50	0.50	4.50	2.00	2.50	3.00
47th	5.00	0.50	1.50	0.00	3.00	22.00	1.50	2.00
48th	0.00	0.00	0.50	0.00	0.50	13.50	2.50	3.00
49th	0.00	0.50	0.00	0.00	0.00	3.50	0.00	0.00
50th	0.00	2.00	0.00	0.00	0.00	6.50	0.00	0.00
51st	0.00	0.00	0.00	0.00	2.00	2.00	0.00	0.00
Mean	**1.13**	**1.19**	**0.50**	**0.25**	**1.88**	**7.25**	**1.75**	**3.06**

Table 6.30: Yield performance of potato cultivars under net house and open field cultivation for the *Rabi* 2014 and 2015

Variety	Yield (t/ha)	
	Net house	*Open field*
Kufri Jyoti	22.30	20.70
Kufri Phukhraj	36.40	31.00
Kufri Badshah	31.80	32.60
Kufri Khyati	26.10	24.50
Kufri Surya	31.90	27.50
Mean	**29.70**	**27.26**

Chapter-VII

Summary and Conclusion

CHAPTER-VII

SUMMARY AND CONCLUSIONS

The present study entitled "**Dynamics of Pest Complex on Potato Seed crop in Punjab and its integrated Management**" was conducted with the purpose to study population dynamics of the major insect pests of potato and efficacy of some known synthetic insecticides and bio-pesticides against them, in the array of sustainable potato seed production, mainly. The major objectives of present investigation were:

(i) To study the population dynamics of potato pests with the help of light and pheromone insect traps.

(ii) To test the efficacy of earlier identified and new insect pathogens and plant extracts against potato pests.

(iii) To develop viable IPM schedule involving above components found effective against potato pest complex and demonstrate it in the fields.

(iv) To develop methodology for timely diagnosis and judicious use of insecticides with rotating chemistries.

(v) To study the impact of Climate change on the pest population build-up in potato crop.

The present investigation was conducted at the experimental fields of ICAR CPRS, Jalandhar for the two successive potato growing seasons *Rabi* 2014 and 2015. The experiment was laid down in the randomized block design and the analysis was done on the basis of mean values. The major outcomes from this experiment have been summarized as follow:

7.1 SUMMARY

- Initially a total of twenty villages of Jalandhar district, which leads in potato cultivation, were randomly selected for the survey of pests of potato crop. In the survey a total of eighteen pests were reported which included fifteen insects of thirteen families belonging to six orders, one mollusc, one nematode and one vertebrate. However, the incidence of aphids (*Aphis gossypii* and *Myzus persicae)*, leafhoppers and whiteflies was high.
- The mean population of *Aphis gossypii*, *Myzus persicae*, leafhoppers and whiteflies in 2014 were 3.60, 7.29 and 6.49 per ten plants respectively and in 2015 it was recorded

7.29, 6.49 and 5.94 per ten plants. Whereas, the mean population of some other insect pests *viz*., mites, thrips, epilachna beetle and defoliators were, 0.11 and 0.23; 0.38 and 0.38; 0.61 and 0.54, and 1.28 and 1.38, respectively in 2014 and 2015.

- Further, yellow sticky traps, yellow water traps and pheromone traps were used to monitor adults the insect pests of potato in the experimental fields of CPRS Jalandhar.
- In correlation study between population of major insects, meteorological parameters and five different potato varieties many significant positive correlations were obtained.
- Efficacy of tested Insecticides, biopesticides, plant extract (NKE) was tested in Rabi 2014 and Rabi 2015, in a schedule of set of sprays and it is found that rotating chemistries and supplementation of biopesticides and plant extract enhances the efficacy of the insecticides.
- New molecule Thymol(derived from AJWAIN seeds) and Kaolin (Sillicate based clay)along with Neem Kernel extract and compared with Immidacloprid 200SL as standard insecticide were also tested in the Rabi 2014 and 2015.

7.2 CONCLUSION

With the outcomes of present investigation it concluded that, **"THE HEAT IS ON"** rising temperature, invasion of new pest species, turning up of minor pest like whiteflies into major pests and carrier of viruses like APCLV which is playing a havoc to the potato seed production. Survey of the two consecutive years have shown that pest population are ranging from moderate to high in the seed belt of Punjab which is supposed to be pest free or the pest population will remain below the ETL level during the crop season. Aphids, leafhoppers and whiteflies are the major insect pests reported in this area. These insects are much destructive since they carry many viruses with them. A positive correlation between incidences of APCLV with whitefly population. These insects can be efficiently monitored with the help of yellow sticky traps, yellow water pan traps and pheromone traps. Further, it was also found that the population dynamics of insect pests get affected with environmental as well as biological factors. Therefore, adjusting the sowing date or the development of early or late sown varieties would definitely be fruitful in reducing the yield losses. Furthermore, the efficacy test of identified insecticides against major sucking insect pests by means of rotating chemistry it was concluded that a combination of foliar spray of Imidacloprid 200SL (0.3 ml/lit) plus Neem Baan (3ml/lit) at the time of pest appearance followed by Chloropyriphos 20 EC (2.5 ml /lit) (as second spray), Foliar spray of Imidacloprid 200SL (0.3 ml/lit) (as third spray) and Rogor 30EC (1.5ml/lit) (as fourth spray) would be useful in controlling the incidence of aphids, whiteflies and leafhoppers in the potato fields; new chemical molecule THYMOL(Derived from Ajwain) and KAOLIN (Sillicate based clay) are also tested and compared with NKE, and Immidacloprid200SL at 0.03%. No doubt that the efficacy of imidacloprid is very good but the use of these alternative chemicals will open the ways to control pests when supplemented along with traditional chemicals will reduce the pressure these chemicals on crops. Furthermore, net houses can also be used as an option for controlling the infestation of insect pests on potato crop. The results showed that there was a significant decrease in pest population when the potatoes were grown under portable net houses. In future, a combination of net house, traps and biocontrol agents and chemical combination can be used as efficient IPM strategies for sustainable potato seed production.

Plate 1: Potato Experimental Filed at ICAR CPRS, Jalandhar

Plate 2: Monitoring of Insect Pest and Net House Cultivation of Potato at Potato Experimental Fields at ICAR CPRS, Jalandhar

Plate 3: Whiteflies

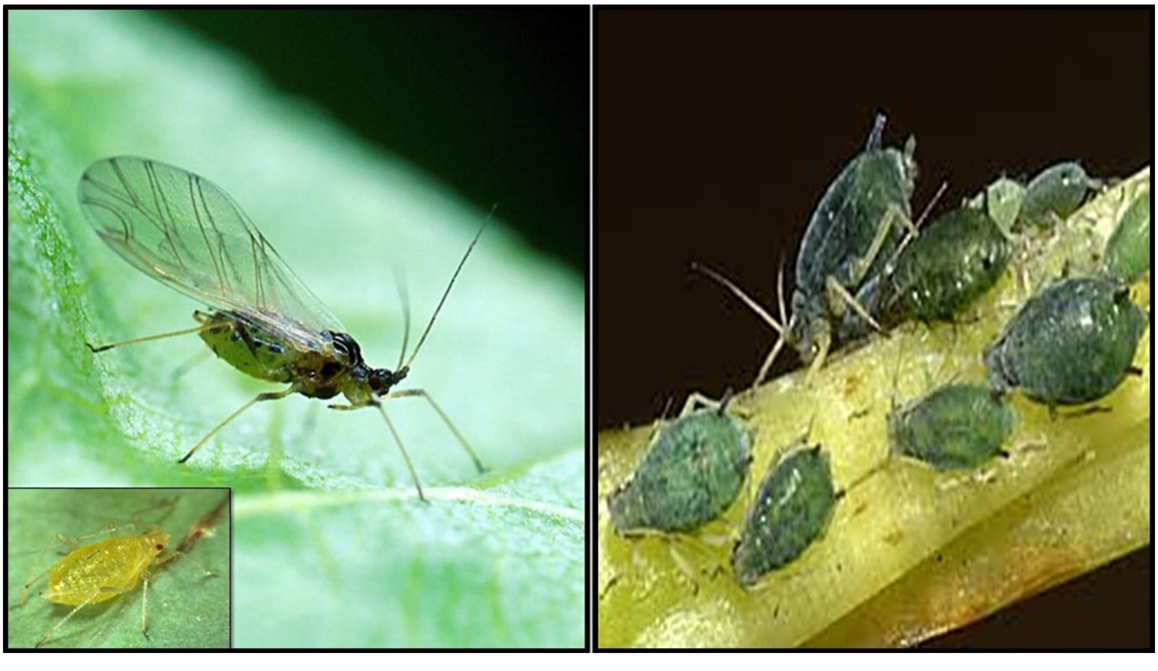


Plate 4: Aphid

Plate 5: Leafhoppers

Plate 6: Jassids

Plate 7: Defoliator

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Appendices

APPENDIX-I

LIST OF ABBREVIATIONS

a.i.	–	Active ingredient
Av.	–	Average
B.t.	–	Bacillus thuringiensis
C.D.	–	Critical Difference
Cfu	–	Colony forming unit
cm	–	Centimeter (s)
DAP	–	Days after planting
DAS	–	Days after spraying
EC	–	Emulsifiable Concentrate
ETL	–	Economic Threshold Level
et al.	–	Et alli (and others)
etc.	–	Et cetera (and others)
F.	–	Flowable
Fig.	–	Figure
g	–	Gram(s)
ha	–	Hectare
hrs.	–	Hours
i.e.	–	Id est (That is)
kg.	–	Kilogram
lit.	–	Litre
MT	–	Metric Tonne
mg	–	Milligram
ml	–	Millilitre
MW	–	Meteorological week
N.S.	–	Non Significant
N.S.K.E.	–	Neem seed kernel extract
No.	–	Number
ppm	–	Parts per million

q	–	Quintal
RH-I	–	Morning relative humidity
RH-II	–	Evening relative humidity
SEm	–	Standard Error mean
SC	–	Soluble Concentrate
SL	–	Soluble Liquid
SP	–	Soluble Powder
SMW	–	Standard meteorological week
T	–	Tonne (s)
$T_{max.}$	–	Maximum temperature
$T_{min.}$	–	Minimum temperature
viz.	–	Videlicet (namely)
WG	–	Wettable Granules
WP	–	Wettable Powder
%	–	Per cent
/	–	Per
@	–	At the rate of
<	–	Less than
>	–	Greater than
^0C	–	Degree celcius

APPENDIX-II

Dissemination and demonstration of temporary net house technology for quality seed potato production at farmer's field

J S Minhas, Kapil Kumar Sharma, R K Arora and Prince Kumar

Potato is a vegetatively/clonally propagated crop commercially due to which the requirement of the quality seed potato is tremendous in the north Indian indo-gangetic plains. In the present changing climate scenario, huge vector load in entire growing period have alarmed the frequency of clone degeneration and ultimately seed potato quality. Production potential of a crop is directly proportional to the quality of the seed material used. Therefore, Alternative approaches of protected conditions are required to maintain the quality of clone.

Central Potato Research Institute and its substations are dedicated to the production of disease-free basic seed potato to fulfil its seed requirement of the country. The seed production programme involves multiplication of seed potato in field under goes four stages/ generations following stringent control and consistent monitoring of the crop before its final supply for distribution to farmers through designated government agencies. Central Potato Research Station, Jalandhar of CPRI, Shimla has developed the low-cost portable net house technology to prevent the exposure of the crop to insects transmitted viruses. In the crop season 2013-14, the portable net houses were erected over the stage I of varieties *viz.* Kufri Jyoti and Kufri Pukhraj. Perusal of data observed that virus incidence reduced drastically. Besides this ten-fold reduction in roughing based on visual viral symptoms was also observed in stage I crop under portable net house as compared to the crop of open field conditions.

These net houses can be easily constructed by using locally available material due to which it is not only economical to install but also does not require much expertise for the construction. The development of net houses technology is a significant innovative step toward combating changing climatic scenario and increasing vector pressure affecting the quality of the potato breeder seed crop in the country.

Fig. 1: Stage 1 potato plants under the net house

Fig. 2: Dissemination of net house technology at farmer’s field

USE OF LOW COST PORTABLE NET HOUSES AND INSECT TRAPS FOR CONTROLLING SUCKING PEST POPULATION ON SEED CROP

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State of Punjab is a hub of high quality Potato seed production. Present study was designed to determine the effectiveness of low cost portable net houses and low cost reusable insect traps to control sucking pest complex on potato seed crop in context to the changing environmental conditions and invasion of new pest species. Potato crop is attacked by more than 8o insects and pests. They can be broadly classified into sucking pests, sap feeders, defoliators, soil pests and storage pests. Sucking insects and sap feeder are the main insects to control because of their severity in spreading virus infection in the crop. Growing crop under insect proof net is a safe and environment friendly option to keep out vectors from the seed crop and using insect traps to catch up the flying populations which are the major cause of spread. White fly is a vector for potato apical leaf curl virus (PACLV) and spacio-temporal spread and persistence of this pest is posing a serious threat to production of quality seed in this region. A combination of net and insect traps was, therefore, evaluated for production of seed from indexed tubers in stage-I. Indexed tubers of Kufri Jyoti were planted in Stage-I under the insect proof net along with mulch at ridges and compared with the normal crop grown without net. The crop was grown following recommended dose fertilizers and plant protection measures. Data was recorded for pest population inside the net house and normal crop grown without net. Virus incidence on the plants grown under net revealed the mosaics incidence of 0.3% as compared to 0.48% in open field. The study revealed that growing crop under insect proof net Stage-1 of breeder seed production is beneficial in reducing virus incidence. Other variables recorded during the study has also shown the increase in number and weight of tubers, reducing cracking in tubers and saving on irrigation.

By sampling from the crop (per 100 compound leaves), from insect traps and funnel traps has revealed Appearance of insects like white fly, aphid species like Myzus persicae & Aphis gossypii has shown deviation from the earlier trends and the persistence of these insects throughout the season has made an alert to the research community to start integrated pest management to control these insects. Meteorological data and comparative insect data are analyzed by using different statistical and computing models. Now it is a time to take a multipronged strategy using chemical methods (By rotating Chemistries), biological methods and field level mechanical methods by using net houses, insect traps to counter the insect insurgency Various methods of insect collection viz by using insect traps at different locations in potato fields.