Succession and Population Dynamics of Insect Pest Complex of Onion and Management of Thrips

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfilment of the requirements for the Degree of

MASTER OF SCIENCE

In

AGRICULTURE
(Entomology)

By

KOMMIREDDY NARESH

Department of Entomology
College of Agriculture, Jabalpur 482004
Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, Madhya Pradesh

2016

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*This is to certify that the thesis entitled “**Studies on succession and population dynamics of insect pest complex of onion and management of thrips**” submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURE (Entomology)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by Mr./Mrs./Ms. **Kommireddy Naresh** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.*

All the assistance and help received during the course of the investigation has been acknowledged by him/her.

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Committee	**Name**	**Signature**
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Member	Dr. S.K. Sengupta	....
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Head of the Department/Section	Dr. A. K. Bhowmick	....
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*I, **Kommireddy Naresh** S/o **Shri** K. China Nageswarao certify the work embodied in the thesis entitled "**Studies on succession and population dynamics of insect pest complex of onion and management of thrips**" is my own first time bonafide work carried out by me under the guidance of **Dr. A.K. Saxena** at **Department of Entomology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2015-2016**.*

The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

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(Major advisor) — **(Student)**

ACKNOWLEDGEMENT

While travelling on the path of life and education many hands pushed me forward, enlighten by their knowledge and experience, present acknowledgement is many more than what I am expressing here.

It is my great privilege and immense pleasure in availing this golden opportunity to express my deepest sense of gratitude and humble indebtedness towards my respected chairperson **Dr. A. K. Saxena** (Associate Professor) Department of Entomology, J.N.K.V.V., Jabalpur for his kind, generous and valuable guidance, intellectual inspiration, keen interest, constant encouragement, unlimited patience and parental affection with cheerful smiling gesture. I consider myself fortunate in having guided by him.

I equally and ineffably cheered to place on record my obligation and gratitude to my Advisory Committee Member **Dr. S.B. Das** (Professor, Department of Entomology), **Dr. S.K. Sengupta** (Sr. Scientist and Professor, Department of Horticulture) and **Dr. H.L. Sharma** (Professor and Head), Department of Mathematics & Statistics, JNKVV, Jabalpur whose rationale, keen and continued interest, encouragement-inspiring, advice and generous help in carrying out the relevant experiment required for my research work.

I also take the opportunity to thank **Pro. V. S. Tomar** Hon'ble Vice Chancellor, JNKVV, Jabalpur, **Dr. P.K. Mishra** Dean Faculty of Agriculture, **Dr. D. Khare**, Director of Instruction, **Dr. (Smt.) OM Gupta**, Dean, College of Agriculture, JNKVV, Jabalpur and **Dr. A. K. Bhoumick**, Professor & Head Department of Entomology for providing necessary facilities during the course of investigation.

I owe my sincere thanks to all my teachers , Professor Head; **Dr. A. K. Bhoumick**, Professor; **Dr. R. Pachori**, Professor; **Dr. A. Shukla**, Professor; **Dr. Moni Thomas**, Senior Scientist, **Dr. A. S. Thakur**, Associate Professor; **Dr. A. K. Sharma**, Assistant Professor, Department of Entomology, College of Agriculture, JNKVV, Jabalpur, **Dr. A. K. Pandey**, (Scientist) for their infinite favour with which they encouraged me during the period of research work.

I express my sincere and special thanks to all the laboratory attendants and field workers for their constant and timely help during the investigation.

I am extremely thankful to my Seniors P. Swathi, Nithin K, Anil kurmi, Narendra tank, Sai reddy, Shanker rao, Miss. Jagrati Upadhyay, Harioam, Annapura and Swetha for the help renderd during the time of this investigation.

My appreciation and thanks goes to my colleagues and friends V.V. Jyothi, Virendra deharia, Ravi, Shailendra sahu, Mishra, Raju, B. Ajay, Aajay, Leelesh, Miss. Divya sri, Miss. preethi, Miss. Varsha, Miss. Niketa and Miss. Piyali

I thank Words fail me to express my gratitude from the deepest core of my heart to my father ***Shri. China Nageswarao*** *and mother* ***Smt. Anantha Lakshmi****, whose selfless love, constant encouragement, obstinate sacrifices, sincere prayer, expectation, and blessing have always been the most vital source of inspiration in my life.*

Finally, I am thankful to the Almighty God for his heavenly blessings which has enabled me to achieve this seemingly invincible.

I would beg pardon and vendor my apologies to all those names which have not been included through oversight in the acknowledgement, they would kindly excuse me for this blunder.

Place : Jabalpur

Date: / / ***Kommireddy Naresh***

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List of Symbols

Symbol	Stand for
@	At the rate of
±	Plus or minus
%	Percentage
^0C	Degree celsius
Abbreviation	
CD	Critical difference
ha	Hectare
hr	Hour
Kg	Kilogram
l	Litre
m	Meter
g	Gram
Max	Maximum
Min	Minimum
NS	Non significant
RH	Relative humidity
SEm ±	Standard error of mean
SW	Standard Week
Temp	Temperature
WG	Wettable granules
G	Granules
EC	Emulsifiable concentration
SL	Soluble liquid
et al.	(And other or co-worker)
Fig.	Figure

INTRODUCTION

Onion, (*Allium cepa* Linnaeus) belongs to the family Amarylidaceae (Alliaceae) is an important commercial vegetable crop grown all over the world. It is of South West Asia or Mediterranean region origin and has got considerable amount of carbohydrates, proteins, vitamin B and C (Selvaraj, 1976). Onion is also having many medicinal values and used for preparation of various Homeopathic, Unani, Ayurvedic medicines and has been used as domestic remedy for scurvy. It is used in dehydrated form or preserved food products and hence, there is an increasing demand for onion in food industries.

The major onion producing countries are China, India, Japan, Spain, Turkey and Brazil. India is the second largest onion growing country in the world with approximately 11.70 lakh ha area with an annual production of 189.20 lakh MT during 2014-15 (Anonymous, 2015). It is grown over an area of 8.34 lakh ha which is 10.40 percent of total vegetable area (www.nhb.gov.in). Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Bihar are the major onion growing states in the country. Madhya Pradesh is the 3^{rd} largest onion growing state in India with approximately 1.1 lakh ha area with an annual production of 28.4 lakh MT during 2014-15 (Anonymous, 2015).

Onion crop suffers severely by various insect pests like thrips (*Thrips tabaci* Lindeman), fruit borer (*Helicoverpa armigera* Hubner), cut worm (*Agrotis ipsilon* Hufnagel), onion maggot (*Delia antique* Meigen) and non insect pest like red spider mite (*Tetranychus telarius* Linnaeus).

Thrips is the most important insect pest of onion. Out of these insect pests attacking onion, thrips, *Thrips tabaci* Lindeman has been identified as a pest of national importance. It was originally prevalent only in warmer parts of Paleoarctic and Neoarctic regions, but now spread to all parts of the world and also has became cosmopolitan in its distribution. It is a regular and potential pest of onion in tropical areas (Liu, 2004 and Schmutterer et al. 1969). The pest is active throughout the year and found on onion and garlic from November to May. Numerous nymphs and adults are observed between leaf sheath and stem lacerating the epidermis of leaves and sucking the exuding cell sap (Lewis 1997). Thrips attack onion at all the stages of crop growth, but their number increase from bulb initiation (Ibrahim and Adesiyun, 2009).

The early bulb enlargement stage of onion growth is the most sensitive to thrips feeding and caused indirect damage as vector of viral diseases *viz.,* Iris yellow spot virus. The affected leaves show silvery blotches which later turn into brownish colour. Leaves get distorted from tips downwards and plant ultimately wilt and dry. (Childres, 1997 and Jenser et al. 2003). The crop may suffer heavy losses even up to 50 per cent in onion (Montano 2011) and Fournier et al. (1995). Due to thrips infestation 34-43 percent loss in yield was reported by Kumar et al. (2001). Yield losses due to thrips may range from 18 to 60 percent (Waiganjo, 2004).

The fruit borer is a serious pest of onion seed crop in Northern India. The larva of this insect cuts the pedicel of the flower and feeds on the stalk. Single larva damages many flower stalks. Cutworm is apolyphagous pest. Young larva feeds on tender foliage and grown up larva cuts the stem at collar region. Red spider mite causes direct damage in terms of loss of chlorophyll, stunting of growth, stippling, webbing, leaf yellowing, defoliation, leaf burning, reduction in size and quality of bulbs, appearance of various types of plant deformities, followed by death etc. The larvae of onion maggot enter into soil and damage disc portion of onion bulb. Infested plants turn yellowish brown and finally dry up. The affected bulbs rot in storage. However it is not present in Madhya Pradesh.

So far, the chemical insecticides have been the primary tactics for their management, however, repeated applications often led to resistance in the thrips population, suppression of natural enemies and unsustainable management. Besides the increased cost and environmental pollution, it is difficult to control this pest with insecticides because of its small size and cryptic habits (Lewis, 1997). Insecticides should be persistent enough to control the pest effectively. But longer persistence of insecticides may affect natural enemies and also result in pest resurgence.

Today, newer safer molecules like insect growth regulators, synthetic pyrethroids, oxadiazenes, etc. based on natural products are commercially available in market. Moreover, the increasing concern for environmental safety and global demand for pesticide residue free commodities have evolved a keen interest and necessitated a deep insight into issue of safer products in pest management.

Since onion is the most essential ingredient in many dishes, it is necessary to make use of safer insecticides for controlling the damage caused by thrips and avoid the yield losses as well as to make available residue free food in the global market. Also, the use of safer insecticides helps to protect the natural enemies of thrips which aid in reducing the cost of insecticide application. Keeping in view the above facts, the studies were planned with following objectives:

1. To study the succession of insect pest complex on onion
2. To study the population dynamics of major insect pests of onion
3. Management of onion thrips :

    a) To study the effect of planting dates on thrips incidence

    b) To study the efficacy of insecticides and NSKE against onion thrips

REVIEW OF LITERATURE

2.1 Succession of insect pest complex on onion

Schmutterer et al. (1969) described onion thrips as a polyphagous pest attacking a great number of wild plants and crops like radish, pigeon pea, pumpkin, tomato, onion and cabbage. They reported that adults and nymphs of *T. tabaci* feed mainly near the base of the inner and intermediate leaves of onion bulbs, feeding on the outer leaves was less. The feeding resulted in sunken silvery patches on which the excrement of the pests can be observed as dark and shiny droplets.

Lorini et al. (1986) studied the seasonal trends in the population levels of *Thrips tabaci* on the onion cultivars in 1986 at Ituporanga in Santa Catarina, Brazil. Population levels increased from early October, when the amount of rainfall was decreased and the temperature was increased, to a peak in early November. Yield reduction was greater on cv. Norte 14, which was transplanted in September, than in cv. EMPASC 351, which was transplanted in August and which was in turn greater than in cv. Baia Periforme, transplanted in July.

Waterhouse and Norris (1989) reported that thrips species are attacked by several groups of generalist predators including Coleoptera, Diptera, Neuroptera, Hemiptera and Acari.

Gupta et al. (1994) reported that the diseases and insect pests play an important role in the production of onion in India. In the past decade, both prevalence and distribution of various diseases and insect pests have increased with devastating effect yield losses vary from 10 to 15 percent annually, depending upon the season and the prevalence of diseases and insect pests.. Thrips infestation was observed in both seasons (rainy and winter) but was more severe in the winter/summer crop.

Fournier et al. (1995) reported that if the thrips is not controlled, onion yield reductions can reach levels from 34 percet to nearly 50 percentage.

Childers (1997) reported that the *T. tabaci* feeding caused silvery leaf spots that turn into white blotches and silvery patches along the leaves, which reduced photosynthesis.

Legutowska (1997) studied the population dynamics of *Thrips tabaci* on leek in central Poland in 1993-95. Infestation began during the 3rd-5th week after planting, i.e., at the 3-5 leaf phase of plants (from early to late June). At the beginning, the pest occurred in small numbers, but all plants were infested from late July to the time of harvest. The maximum density of thrips was found on plants in August and September. Adults and larvae of *Thrips tabaci* were most numerous on the middle leaves of leek (at the 5 to 8 leaf growth stage).

Gendi (1998) reported that *Thrips tabaci* on onion varieties at Fayoum, Egypt, was evident from mid-December to mid-May with two peaks. The first peak of infestation occurred at the end of December, with 8.5 and 9.8 nymphs per plant during 1995/96 and 1996/97 seasons, respectively. The second peak occurred in mid-March with 39.0 and 56.5 nymphs per plant during the preceding seasons. The major weather factors (max. temperature and RH) had little effect on population density. Delayed planting to late November decreased infestation rate and gave the highest yield. Also, cv. Giza 20 was relatively more susceptible to thrips infestation than cv. Giza 6 cv. Behiri was the least susceptible.

Jimenez et al. (1998) studied the damage caused by *Thrips tabaci* on onion by describing the sequence of damage development at different phonological phases of the crop. The incidence and seasonal abundance of the pest on crops with different sowing dates was also recorded in Cuba. The extent of damage caused by different levels of artificial thrips infestations on plants of two ages was quantified. The symptoms of attack generally began to be visible after production of the fifth leaf. The largest yield reductions were identified when young plants were attacked by 10 or more thrips, and when 60-days-old plants were infested by large pest densities.

Kirk (2000) quantified the impact of future climate change on the developmental dynamics of onion thrips. It is resulted that the rainfall had negative effect on the population of *T. tabaci* because heavy precipitation events can kill larvae and suppress dispersal of adult.

Kumar et al. (2001) repeated cultivation of onion crop on the same land, season after season and year after year and water stress has increased the pest problem which was one of the important factors responsible for low yield. Among the insect pests, onion thrips, *Thrips tabaci* was most serious inflicting 34 - 43 percent loss in yield.

Steene et al. (2001) studied the biology of *T. tabaci* during winter 1999-2000 and 2000-2001 in winter leek crop at Kruishoutem and Sint Katelijne-Waver, Belgium. The number of larvae decreased starting November while the numbers of adults increased. Only over wintering adults were found during January, February and March on the leek plants. From the beginning of April, larvae were again observed in the winter leek crop. Weather permitted the adults of these “spring generation” immigrates into the leek seed beds or early leek crop.

Anonymous (2003) A field experiment was conducted to determine the seasonal incidence of *Thrips tabaci* on onion cv. bellary Red (transplanted from the first week of June 2002 until the first week of May 2003). The mean thrips population per plant ranged from 17.29 to 46.88 on the crop transplanted in different months. There was a gradual increase in thrips population on the crop transplanted from June 2002 to May 2003. However, a maximum of 46.88 thrips per plant was recorded on May transplanted crop followed by April (45.00) and March 2003 (39.90). Significantly high bulb yield of 8.65 t/ha was recorded from the crop transplanted during the first week of October 2002 which was at par with that of the crop transplanted in November 2002 (8.21 t/ha). Significantly low yield of 4.91 t/ha was observed from the crop transplanted during March 2003 followed by May (6.00 t/ha), February (6.13 t/ha) and April 2003 transplanted crop (6.58 t/ha).

Jenser et al. (2003) reported that the empty cells on attacked plants create silvery-white spots, referred to as silver damage, that make the plants less marketable. Onion thrips were also an important vector of several plant viruses such as tomato spotted wilt virus. The affected leaves show silvery blotches which later turn into brownish colour. Leaves got distorted from tips downwards and plant ultimately wilted and dried.

Liu (2004) reported that more than 90 percent of thrips collected from onion plants were onion thrips. The percentage increased up to 99 percent in medium-aged and mature plants. The seasonal patterns appeared unimodal. From onion emergence to harvest, the adult populations stayed at non detection levels (0.1/plant) for 9-13 week and gradually increased for 7-9 week before declining. The onset of the population increase period occurred in the early half of September and population decline began between late October and mid- November. Larval populations first appeared and peaked in onion later than adult population. Peak density varied from 4 to 59 per plant for adults and from 11 to 190 per plant for larvae.

Shahnawaz and Goud (2005) conducted a survey from October 2002 to February 2003 In Dharwad, Gadag and Haveri taluks of Karnataka, India, to determine the population of thrips, coccinellids and chrysopids. In general, Haveritaluk recorded maximum of 43.59 thrips per plant followed by Dharwad (38.58), whereas Gadag taluk recorded a minimum of 30.91 thrips per plant. The mean population of coccinellid, *Menochilus sexmaculatus (Cheilomenes sexmaculata)* in 3 different taluks ranged from 0.73 to 2.47 per plant. The maximum mean population of 2.47 coccinellids per plant was recorded in Dharwad taluk followed by Gadag taluk (1.58); however, Haveri taluk recorded minimum activity of coccinellids (0.73 per plant). The population of *Chrysoperla carne* arranged from 0.74 to 1.90 per plant. Gadag taluk recorded a maximum of 1.90 per plant followed by Haveri taluk (1.68), as where Dharwad taluk recorded minimum of 0.74 chrysopids per plant.

Pandey and Ahmed (2007) observed the population of thrips, *Thrips tabaci* on timely transplanted and late transplanted onion at Leh, Ladakh located at 11300 feet AMSL. Transplantation time and weather parameters (Temperature, humidity and rainfall) had significant correlation with the thrips population on onion. Timely transplanted onion had more thrips (1.62-39.08 thrips/leaf) than late transplanted (0.35-32.44 thrips/leaf).

Montano et al. (2011) studied that in past two decades, onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), has become a global pest of increasing concern in commercial onion (*Allium cepa* L.), because of its development of resistance to insecticides, ability to transmit plant pathogens, and frequency of producing more generations at high temperatures. *T. tabaci* feeds directly on leaves, causing blotches and premature senescence as well as distorted and undersized bulbs. *T. tabaci* can cause yield loss > 50 percent but can be even more problematic when it transmits Iris yellow spot virus (family Bunyaviridae, genus Tospovirus, IYSV). IYSV was identified in 1981 in Brazil and has spread too many important onion-producing regions of the world, including several U.S. states. IYSV symptoms include straw-colored, dry, tan, spindle-or diamond-shaped lesions on the leaves and scrapes of onion plants and can cause yield loss up to 100 percent.

Mallinath et al. (2014) seasonal incidence studies indicated the prevalence of high population of thrips in the kharif season especially during August to October. Roving survey indicated that maximum population of spiders and coccinellid beetles were recorded in Basavanabagewadi and Bijapur talukas, respectively whereas, minimum number of spiders and coccinellid beetles were recorded in Muddebihal and Sindagi talukas, respectively.

2.2 Population dynamics of major insect pests of onion

Raheja (1973) conducted field experiments on *Thrips tabaci* in Zaria (Sub-humid zone of Nigeria) and found that population of thrips gradually built up and reached a peak 50 days after transplanting.

Kranzet et al. (1977) reported that the number of thrips on a crop increased rapidly in dry weather and decreased rapidly after rain.

Lorini and Dezordi (1990) reported that the population density of *T. tabaci* increased with temperature and non-significant positive association with wind velocity was observed.

Lowry et al. (1992) found that the temperature and precipitation have varying effects on thrips population. With increasing temperature throughout the spring, there was increased thrips activity, development, and population growth up to the point when winter hosts began to senesce and thrips flights declined.

Domiciano et al. (1993) reported the negative correlation between thrips population and relative humidity on onion.

Kirk (1997) reported that rainfall produced to negative affect on thrips populations because heavy precipitation events killed larvae and suppressed dispersal of adult. Population during rainy and cool season was significantly lower than those during dry and hot seasons, presumably because of high larval mortality and slower population growth rates.

Waiganjo et al. (2008) conducted field trials in four seasons at Kenya Agricultural Research Institute (KARI) Mwea-Tebere farm in Kirinyaga District. Yield losses due to thrips ranged from 18 to 60 percent. Onion plants were planted periodically and thrips populations monitored weekly from onion plant samples and blue sticky traps for a full year under natural field conditions. The purpose of the trials was to assess the effect of weather on thrips population in onions with the aim of predicting thrips control requirements for a given climatic trend. Weather variables monitored included: rainfall, temperature, relative humidity and wind. Thrips occurred in the onion field and infested onions in all the crop seasons. However, there was significant (*P*=0.05) variation in thrips numbers between the crop seasons. Dry weather (30.3 mm rainfall) with moderately high temperatures (15.6-28.2°C) increased seasonal thrips numbers, while wet season (391mm rainfall) with moderately high relative humidity was negatively correlated with thrips numbers. Regression analysis (step-wise selection model) showed that minimum relative humidity was the only significant weather factor for predicting thrips infestation in the onion crop (R2=0.15; y = 60.342-0.1022x). The results suggest that climatic trends can be used to determine the potential thrips control needs in onion production.

Ullah et al. (2010) conducted population dynamic studies at Peshawar, Pakistan and showed that the activity of onion thirps (*Thrips tabaci* L.) was first recorded on 3rd February (1.20 thrips/plant) and reached to its peak (100 thrips per plant) during the last week of April. Later, the population declined to 3.85 thrips per plant towards the end of May as the crop started to mature. Population model using the meteorological data indicated that linear and quadratic components of average air temperature were important in predicting the population development of *T. tabaci.* However, the model accounted only for 44 percent of total population variability.

Tripathy (2012) conducted field experiments at Odisha. to study the population dynamics and seasonal incidence of Thrips in onion during Rabi season of 2010-11. The onion variety Agrifound Light Red was planted at 15 days intervals with treatments consisted of 14 dates of planting (1st July, 2010 to 15th January, 2011 at 15 days intervals). Each date of planting again consisted of four treatments with three replications in a Randomized block design. The injury rating was done at 75 days after transplanting using 5-point scale. Under Odisha condition, transplanting of Rabi onion should be completed within 1^{st} week of November, preferably to obtain higher bulb yield with lower incidence of pests. Irrespective of planting dates, the yield loss was more by thrips infestation (2.5 % to 68.7%).

Verma et al. (2012) have studied the seasonal incidence of *T. tabaci* infesting the garlic cultivar, Bikaner. The population density of *T. tabaci* increased with temperature. Minimum temperature negatively correlated with thrips population.

Haider et al. (2014) conducted the studies during 2008-2010, and reported that thrips colonization showed negative correlation with heavy rainfall and low temperature. Stage specific thrips abundance survey revealed that thrips were high on crop when it was at 5-7 and 8-12 leaf stages as well as bulb initiation stage 1, as compared to other leaf and bulb developmental stages on all other genotypes.

Hossain et al. (2015) the field experiment was conducted at Shibganj, Bogra to study the population dynamics and to evaluate the effectiveness of inter cropping of carrot, tomato and french bean with onion for the management of thrips attacking onion. Infestation of onion thrips was started from the first week of February and it became gradually increased up to first week of April then it was declined. Thrips population was positively correlated with temperature and negatively with relative humidity and rainfall. Thrips incidence and damage severity were determined at 7 days interval with damage severity also estimated on scale of 1 to 5. This study showed that carrot or tomato intercrop may be utilized as inter crop for the management of onion thrips.

Sathe and pranothi (2015) reported that *Thrips tabaci* Lind. (Thysanoptera: Thripidae) was destructive, polyphagus pest of agricultural and other economically important crop plants. *T. tabaci* scrape its mouth parts on tender parts of the crop and feed on oozing sap, resulted white / brown specks / stricks on leaves / flowers and fruits and affected the growth of plant and quality of fruits. Results recorded that on onion and garlic incidence of thrips was started from November and steadily increased during the hot months.

2.3 Management of onion thrips:

a) To study the effect of planting dates on thrips incidence

Kisha (1977) stated that early transplanted onions were usually well established before attack began in mid- February of 1971.

Edelson et al. (1989) managed the population of *Thrips tabaci* on onion by using insecticides to achieve differential levels of infestation. Yields of onion bulbs from the plots were evaluated using regression analysis to determine impact of thrips feeding on bulb size. The results were used to quantify the economic impact of managing thrips with insecticides. The results indicated that in years with favourable weather for onion production, growers have increased profit by controlling thrips population. Additionally, the results indicated that in years with unfavourable weather conditions for production of onion, the lack of thrips management resulted in net losses to growers.

Lewis (1997) reported that the impact of thrips infestation on a crop depends on many factors: the size of the thrips population, the plant growth stage, the duration of the infestation, and the suitability of weather for population growth. He also observed that time of sowing and harvesting crops have also reduced the severity of injury. The pest was active throughout the year have found on onion and garlic from November to May. Numerous nymphs and adults were observed between leaf sheath and stem lacerating the epidermis of leaves and sucking the exuding cell sap.

Ibrahim and Adesiyun (2009) reported that 13 week old onion crop was transplanted from December to April in 2001-2002 and November to March in 2002-2003 growing seasons to highest level of thrips damage and its effect on onion bulb yield. Thrips attacked onion at all the stages of crop growth, but their number increased from bulb initiation. Results revealed that thrips started appearing from January but the number was very low until end of February, when the population reached at 12 thrips/plant. November transplanted was free of thrips up to 9 weeks after transplanting (WAT), December transplanted up to 8 WAT, January transplanted up to 6 WAT, while February, March and April transplanted had population of >5 thrips/plant at 4 WAT. There was a significant difference between plantings from 4-14 WAT. The peak of thrips incidence in the various transplants were as follows: November at 13 WAT (90), December at 12.5 WAT (234), January at 9.5 WAT (373), February at 8.5 WAT (217), March at 6 WAT (41.2) and April at 5 WAT (20). Onion bulb yields were also found to differ in descending order as follows: November (48 t/ha), December (42 t/ha), January (13.5 t/ha), February (5.5 t/ha) and March (1.5 t/ha).

Ibrahim and Adesiyun (2010) transplanted the onion seedlings from November to March to study the population dynamics of onion thrips, *Thrips tabaci.* There were four transplants in 2001/2002 and five in 2002/2003 seasons. In 2000/2001 season onion plants were grown in exploratory trials and in 2003/2004, water traps were used to confirm results of the previous experiments. Results indicated that November transplanted had a peak population of onion thrips in late February (176 thrips/plant); December (416 thrips/plant) and January (608 thrips/plant) transplants peaked in March, February (148 thrips/plant) and March (86 thrips/plant) transplants had peaks in April. Water traps indicated that the peak population of adult thrips was at the time of harvest in April, similar to November transplant. The early transplant (November) had peak thrips population at maturity and middle transplant recorded the peak population in middle of the season and late transplant had their peaks at early part of the growing season. The findings of this work revealed that onion thrips in Sokoto, Nigeria, breed from January to May with peak in March.

Tripathy et al. (2012) conducted field experiments at Odisha to study the population dynamics and seasonal incidence of thrips in onion during Rabi season of 2010-11. The onion variety Agrifound Light Red was planted at 15 days interval with treatments consisted of 14 dates of planting (1st July, 2010 to 15th January, 2011 at 15 days intervals). Each date of planting again consisted of four treatments with three replications in a Randomized block design. The injury rating was done at 75 days after transplanting using 5-point scale. Transplanting of Rabi onion should be completed upto 1st week of November, preferably to obtain higher bulb yield with lower incidence of disease and pests. Irrespective of planting dates, the yield loss was more by thrips infestation (2.5 % to 68.7%).

Dharmatti et al. (2013) conducted an experiment was conducted at University of Agricultural Sciences, Dharwad, Karnataka, India during 2009-2010, 2010- 2011 and 2011- 2012 to find out the thrips population attacking onion sown at different dates to determine the optimum dates of sowing. There were twelve transplants in 2009-2010, sixteen transplants in 2010-2011 and 2011- 2012. Results indicated that in 2009-10, November 1st transplanted seedlings had a peak population of onion thrips in protected (8.95 thrips/plant) as well as in unprotected plots (53.30 thips/plant). Where as in 2010-11 and 2011-12, December 1st transplanted seedlings had a peak population of thrips *i.e.* 10.75 thrips/plant in protected plot and 55.49 thrips/plant in unprotected plant (2010-11) and 11.58 thrips/plant in protected plot and 57.83 thrips/plant in unprotected plant (2011-12). The seedlings transplanted in Rabi season had peak thrips population compared to Kharif season transplanting dates. Therefore, the findings of this work revealed that onion thrips in Dharwad, Karnataka breed from November 1st to January 1st with a peak in December.

b) To study the efficacy of insecticides and NSKE against onion thrips

The bio efficacy of different insecticides carried out in India and abroad against onion thrips (*Thrips tabaci*, Lindeman) have generated quite substantial information, which has been reviewed thoroughly and presented under the respective heading below.

Bhardwaj and Gupta (1992) reported that an aqueous extracts of garlic leaves or cloves or neem *(Azadiracta indica)* bark or leaves had no effect on *Thrips tabaci,* while neem oil caused considerable mortality.

Sinha et al. (1992) conducted a field study during 1982-83 to determine the efficacy of sprays of the Pyrethroid insecticides Deltamethrin, Permethin, Cypermethrin and Fenvalerate, and the Organophosphorus insecticides Fenitrothion, Methyl-demeton (Demeton-methyl) and Dimethoate to control infestation of *Thrips tabaci* on onion. Cypermethrin applied at 60 and 120 g/ha, and Deltamethrin applied at 24 g/ha reduced pest numbers effectively for up to 8 days after application. Fenitrothion applied at 600 g/ha was as effective as the Pyrethroid insecticides. None of the chemicals had any effect after 15 days. There were no phytotoxic effects on onions and no residues were detected.

Vijayalakshmi (1995) from Indian Institute of Horticultural Research, Bengaluru has developed pulverized neem seed powder extract (NSPE) and neem soap (NS) as an alternative to NSKE, for the management of insect pests such as onion thrips. Neem has been found to be a very good alternative to synthetic insecticides and neem seed kernel extract (NSKE) has been found effective against this pest.

Gonclaves (1998) tested different dosages of insecticides *viz.,* Deltamethrin + Triazophos (EC) at 3.0 + 105.0, 4.5 + 157.5 and 6.0 + 210.0 g a.i./ha, Cypermethrin (EC) at 150.0, 120.0 and 50 g a.i./ha, Lamda Cyhalothrin (WP) @ 15.00 g a.i./ha along with Cypermethrin and an untreated control against *T. tabaci* on onion. The treatments with Lamda Cyhalothrin and Cypermethrin were effective, but only Cypermethrin @ 150 g a.i. /ha increased the yield of onion bulbs.

Ascher et al. (1996) conducted extensive experiments with *T. tabaci* and studied the insect growth and development; effect and persistence of industrial neem formulation applied as sprays or drenches and found that Neem Seed Kernel Extract showed better results.

Hussain et al. (1997) tested different insecticides against *T. tabaci* on garlic and found that Methamidophos was the most effective insecticide for the control of thrips, followed by Dicrotophos and Endosulfan. While, Cypermethrin and Monocrotophos were the least effective.

Gupta and Sharma (1998) conducted studies at Karnal, India, during the Rabi seasons of 1996-98 to record the efficacy of insecticides/bio pesticides for the control of onion thrips *(Thrips tabaci).* Treatments (4 sprays) were Cartap hydrochloride (50 SP) at 250 and 500 g a.i. /ha, Fluvalinate 25 EC at 50 g a.i. /ha, Deltamethrin 2.8 EC at 7.5 g a. i./ha, Profenofos 50 EC at 500 and 750 g a.i./ha and *Azadirachtin* (0.03 EC) at 0.1%, *Calotropis* leaf extract at 250 leaves crushed in 100 ml water and the extract diluted 20 times, and a control consisting of water and triton. Sprays were applied fortnightly started from 30 days after transplanting. Deltamethrin (2.8 EC) at 7.5 g a.i. /ha significantly reduced *T. tabaci* populations and increased onion yield, whereas botanical insecticides were ineffective.

Hazara et al. (1999) evaluated the efficacy of lamda Cyhalothrin, Endosulfan, Imidacloprid and Profenophos against thrips and recorded 61.6, 86.6, 51.2 and 97.6 percent mortality of the pest respectively, after three days of insecticidal application.

Altaf et al. (1999) reported that chemical and neem-based botanicals had reduced thrips population significantly over control.

Patel et al. (2001) and Noor (2001) reported that Profenophos was effective against many sap feeding insects including onion and chilli thrips.

Gupta et al. (2002) found that Chlorpyriphos (500 g a.i./ha) + Deltamethrin (20 g a.i. /ha) was better in controlling thrips population, with higher yield and gave more profit than neem based bio pesticides. They also endorsed effect of neem based bio-pesticides in controlling thrips. Moreover, uses of natural plant products or plant-based insecticides were found to be effective in controlling the insect pests in many vegetable crops. Neem was found to be a very good alternative to synthetic insecticides.

Shitole et al. (2002) evaluated the performance of certain chemicals for the management of onion thrips and found that Carbosulfan @ 200 and 250 g a.i. /ha, Acephate @ 600 g a.i./ha and Koranda (premix of Fenvalerate + Acephate) @ 420 g a.i. /ha were superior followed by cypermethrin @ 75 g a.i./ha and Imidacloprid @ 20 g a.i. /ha for the control of thrips. Systemic Organophosphates and Pyrethroids are commonly used for thrips control, however, their repeated usage led to the development of resistance in thrips. The new formulation of fipronil showed promising results and it can be employed for better management of thrips.

Jadhav (2003) evaluated the efficacy of fipronil 5 SC at different concentrations against the sucking pest complex of chilli in comparison with Imidacloprid 17.8 SL @ 20 g a.i. /ha and found that fipronil 5 SC @ 100 g a.i./ha recorded lowest thrips population and higher yield.

Praveen and ragupathy (2003) collected *T. tabaci* from cotton and studied susceptibility to Thiamethoxam, Imidacloprid and Dimethoate. *T. tabaci* was more susceptible to Imidacloprid and Thiamethoxam than to Dimethoate. The resistance factor at LC95 varied from 1.36 to 2.28, 1.21 to 2.84, and 1.91 to 4.82 for Thiamethoxam, Imidacloprid and Dimethoate, respectively. They concluded that the populations of *T. tabaci* exhibited low level of resistance to these insecticides.

Sallam and Hosseny (2003) Tested the insecticides Profenofos (Selecron 75% EC at 750 cm3/fed), Pirimiphos-methyl (Actelllc 50% EC at 500 m13/100 lit), Carbosulfan (Marshal 25% w.p. at 300 g/100 lit), Methomyl (Lannate 90% SP at 150 g/1 00 lit) and mineral oil (Capl-2 96.6% v.v. at 1.5%) to control *T. tabaci* infesting onion cultivars Giza 6 and South Valley in a field experiment in Sohag, Egypt, during 2000-01 and 2001-02. The insecticides were sprayed using a ground spray motor on 20^{th} February and 11^{th} March 2001 in the first season, and on 26^{th} February and 18^{th} March 2002. All the insecticides reduced the pest population. Carbosulfan was the most effective, followed by Profenofos, Methomyl and Pirimiphos-methy, while mineral oil was the least effective in controlling the pest of onion.

Kadri and Goud (2006) evaluated newer molecules of insecticides viz: Imidacloprid, Emamectin benzoate and Acetamiprid against onion thrips and reported that these insecticides have significantly reduced thrips populations.

Suresh et al. (2006) conducted an experiment, to evaluate the efficacy of various botanicals against thrips and cutworm of onion. The highest percent reduction of thrips population was recorded in Dimethoate 30 EC at 1 ml/lit. The yield was highest (12.33 t/ha) in the standard control treatment (Dimethoate 30 EC at 1 ml/lit or Chlorpyrifos 20 EC at 2 ml/lit) followed by neem oil 3% (11.33 t/ha) and neem gold at 2 ml/lit (11.10 t/ha).

Mishra et al. (2007) stated that among the several factors attributed to low productivity of onion, damage of crop due to onion thrips is substantially important. Farmers were using parathion dust 2% to control the menace. However, neem based bio-pesticides *i.e.,* neem seed extract (NSE) neem leaf extract (NLE) or neem oil constitute the recommendation for managing onion thrips. The recommended practice of using neem oil to manage thrips was feasible and economically viable over farmers practice. In order to overcome the drudgery involved in preparation and lack of free availability of neem leaf or neem seed for making bio-pesticide, the neem oil, which was easily available in local market and better option to adopt for controlling onion thrips using eco-friendly management.

Pandy and Ahmed (2007) developed an Integrated Pest Management package for thrips in onion Agrifound Light Red at Nasik and Karnal during Rabi 2005-08. The pooled analysis of data revealed that two foliar spray of Spinosad 45% SC @ 1 ml/lit., Neem oil @ 2 ml/lit., Acetamiprid 10 WP @ 1 ml/lit. at fortnightly intervals proved effective in controlling thrips population and gave higher yield at both the places.

Ambekar and Nayakwadi (2008) found that Acetamiprid was moderately effective, while the treatments of Azadirachtin and NSKE were observed as less effective against onion thrips.

Bhatnagar (2009) reported that among indigenous materials, the least count was noticed in NSKE treatment and all other treatments showed no difference compared to untreated control. Neem Seed Kernel Extract (NSKE) was found effective against *T. tabaci* on onion.

Ullah et al. (2010) reported that except Thiamethoxam, all insecticides were significantly effective against thrips as compared to control with maximum cost-benefit ratio for Imidacloprid and least for Thiamethoxam treated plots.

Jagadish and Purnima (2011) reported that half opened flower stage of rose was superior to control *S. dorsalis*. Among different botanicals, NSKE. two percent recorded 74.37 per cent mortality of thrips. Among different entomopathogens, *Heterorhabditis indica* @ 2000 IJs/ml was found next best to botanicals by recording 72.08 per cent mortality of thrips.

Pokharkar et al. (2011) evaluated nine insecticidal treatments *viz.*, Cypermethrin 10 EC 0.01 percent, Fipronil 5 SC 0.075 percent, Imidacloprid 17.8 SL 0.071 percent, Spinosad 45 SC 0.0025 percent, Carbosulfan 25 EC 0.025 percent, Deltamethrin 1 percent + Triazophos 35 percent 0.07 percent, Profenophos 50 EC 0.05 percent, Novaluron 10 EC 0.005 percent and NSKE 4 percent against onion thrips, and reported that Profenophos 50 EC 0.05 percent was found to be most effective in suppressing the thrips population at 3, 7 and 14 days after each of three sprays. It was, however, followed by Deltamethrin 1 percent + Triazophos 35 percent @ 0.07 percent and Fipronil 5 SC 0.075 percent.

Sreekanth and Reddy (2011) evaluated six new insecticides viz., Imidacloprid 200 SL, Acetamaprid 20 SP, Thiamethoxam 25 WG, Diafenthiuron 500 SC, Triazophos 40 SC and Fipronil 5% SC for their efficacy against the sucking insect pests viz., aphid, leafhopper, whitefly and thrips in cotton. The results revealed that the most effective insecticides for aphids and leafhoppers up to seven days were Imidacloprid and Acetamiprid whereas, the insecticide Triazophos was ineffective in controlling aphids. Thiomethoxam and Fipronil were found to be most effective insecticides against thrips.

Mallinath and Biradar (2013) have conducted field experiment to evaluate organic and inorganic chemical molecules against onion thrips, *Thrips tabaci* Lindeman under field condition during 2012-13 at the Regional Agricultural Research Station, Vijayapur. Among different insecticides tested, the lowest thrips population and highest bulb yield was recorded in the treatment imidacloprid 70 WG @ 0.33 g/l and thiamethoxam 25 WG @ 0.2 g/l.

Abdul et al. (2014) Tested the effectiveness of three botanical insecticides (Neem, Datura and bitter apple), and three new chemical synthetic insecticides (Acephate, Spirotetramat and Spinetoram) against onion thrips (*Thrips tabaci*) in experimental field plots in Pakistan. All the botanicals and chemical insecticides tested caused significant reductions (45–70%) in thrips populations; the botanicals gave more than 60% control of thrips, while among chemical insecticides, Acephate was found to be the most effective followed by Spirotetramat and Spinetoram. These insecticides gave better control than the botanicals. The adverse effects of the botanicals on predator populations were negligible compared to the chemical insecticides. All chemical treatments resulted in a significantly higher yield compared to the untreated control.

Eijaz et al. (2014) evaluated the efficacy and residual persistence of synthetic insecticides *viz.,* Profenophos, Dimethoate, Chlorpyriphos and Trichlorfon against thrips on okra, and reported that Dimethoate proved best against thrips by providing maximum mortality and it was next to Profenophos.

Tadele and Mulugeta (2014) evaluated the effect of insecticides and botanicals (*Azadirachta indica* L. and *Dodon aeangustifolia* L.) on onion thrips, and revealed that the botanicals, *A. indica* and *D. angustifolia* fresh leaf extracts with foliar application gave promising mortality rate when used as alternative control measures for onion thrips, while the combination of two botanicals was found less effective as compared with other treatments but significantly differed from untreated check. The study concluded that botanicals are better option and eco-friendly for controlling onion thrips.

Ali et al. (2015) conducted field experiments in Pakistan to study the population fluctuation and toxicity of some insecticides against thrips on onion bulb crop. Four insecticides Endosulphan 35 EC @ 800 ml/acre, Imidacloprid 20% SL @ 80 ml/acre, Profenophos 500 EC @ 500 ml/acre and Thiamethoxam 25 WG @ 50 g/acre were tested. They reported that Imidacloprid and Endosulphan were found best among the four insecticides. Minimum infestation was recorded in plot treated with Endosulphan and Imidacloprid as compared to control. However Thiamethoxam 25 WG was not effective in reducing the pest population.

Naik et al. (2015) reported that the lowest population of thrips was recorded from the plots treated with Abamectin 0.002 percent. Whereas, Malathion 0.04 percent, Dimethoate 0.05 percent, Triazophos 0.06 percent, Profenophos 0.05 percent and Dichlorovos 0.05 percent were found to be next effective treatments in reducing thrips population. While, NSKE 5 percent was least effective in reducing thrips population as compared to chemical insecticides.

MATERIAL AND METHODS

The field experiments on the succession of insect pest complex on onion, population dynamics of major insect pest of onion and management of onion thrips. a) Effect of planting dates on thrips incidence. b) Efficacy of insecticides and NSKE against onion thrips were conducted at the experimental field of Department of Horticulture, JNKVV, Jabalpur (M.P) during the year 2015-16. The materials required and methodology adopted for conducting both the experiments are described below.

3.1 Geographical location and climate:

Jabalpur is situated at 23.09° N latitude and 79.58° E longitude at an altitude of 411.78 meter above the mean sea level. Jabalpur is under the agro-climatic zone-IV Kymore Plateau and Satpura Hills and lies in rice-wheat crop zone of the state. It falls under subtropical climatic conditions, which is characterized by the features of hot dry summers and cool dry winters. The average (10-years mean basis) annual rainfall of the area is about 1350 mm, and nearly 90% of the total annual rainfall is mostly received during the period between end of June to end of September. The rainfall is often most erratic and ill-distributed along with an occasional long dry spells or frequent heavy rainy days during rainy season.

There is occasional and little rainfall during the rest period of the year. The maximum and minimum temperature ranges between 24^oC to 45^oC and 2^oC to 32^oC, respectively within a year. In some of the years, maximum temperature reaches as high as 45^oC in the month of May or June, while minimum temperature falls down to a limit of 2^oC during end of December or January months. The relative humidity varies from season to season. It ranges between 80 to 90% during rainy season, which reduces as 60 to 70% during rainy season, which reduces as 60 to 70% during winter season, and 30 to 40% during summer season.

3.2 Materials:

The materials such as onion seeds, insecticides, sprayer, measuring cylinder and weighing balance, magnifying lens, thread, wooden pegs were required to conduct the experiment. Besides these, other materials such as card sheet paper, butter paper bags, rubber band, fine camel brush, earthen pots were required during the course of investigation.

3.2.1 Objective1: To study the succession of insect pest complex on onion

1.	Crop		:	Onion
2.	Variety		:	Bhema super
3.	Replications		:	3
4.	Spacing		:	15 cm x 10 cm
5.	Plot size :	Gross	:	3.0 m x 2.0 m
		Net	:	2.5 m x 1.5 m
6.	Fertilizer dose		:	N:P:K @ 100:50:50 kg/ha
7.	Planting date		:	1st November 2015

3.2.2 Objective 2: To study the population dynamics of major insect pest of onion

1.	Crop		:	Onion
2.	Variety		:	Bhema super
3.	Replications		:	3
4.	Spacing		:	15 cm x 10 cm
5.	Plot size :	Gross	:	3.0 m x 2.0 m
		Net	:	2.5 m x 1.5 m
6.	Fertilizer dose		:	N:P:K @ 100:50:50 kg/ha
7.	Planting date		:	1st November 2015

3.2.3. Objective3: Management of onion thrips

a) To study the effect of planting dates on thrips incidence

1.	Crop	**:**	Onion
2.	Variety	:	Bhema super
3.	Design	:	Slit Plot Design
4.	Treatment details		
a.	Main treatments	:	8 (date of planting)
			1/09/2015, 15/09/2015, 1/10/2015, 15/10/2015, 1/11/205, 15/11/2015, 1/12/2015, 15/12/2015.
b.	Sub treatments	:	2 (protected and unprotected)
5.	Replications	:	3
6.	Spacing	:	15 cm x 10 cm
7.	Plot size : Gross	:	3.0 m x 2.0 m
	Net	:	2.5 m x 1.5 m
8.	Fertilizer dose	:	N:P:K @ 100:50:50 kg/ha

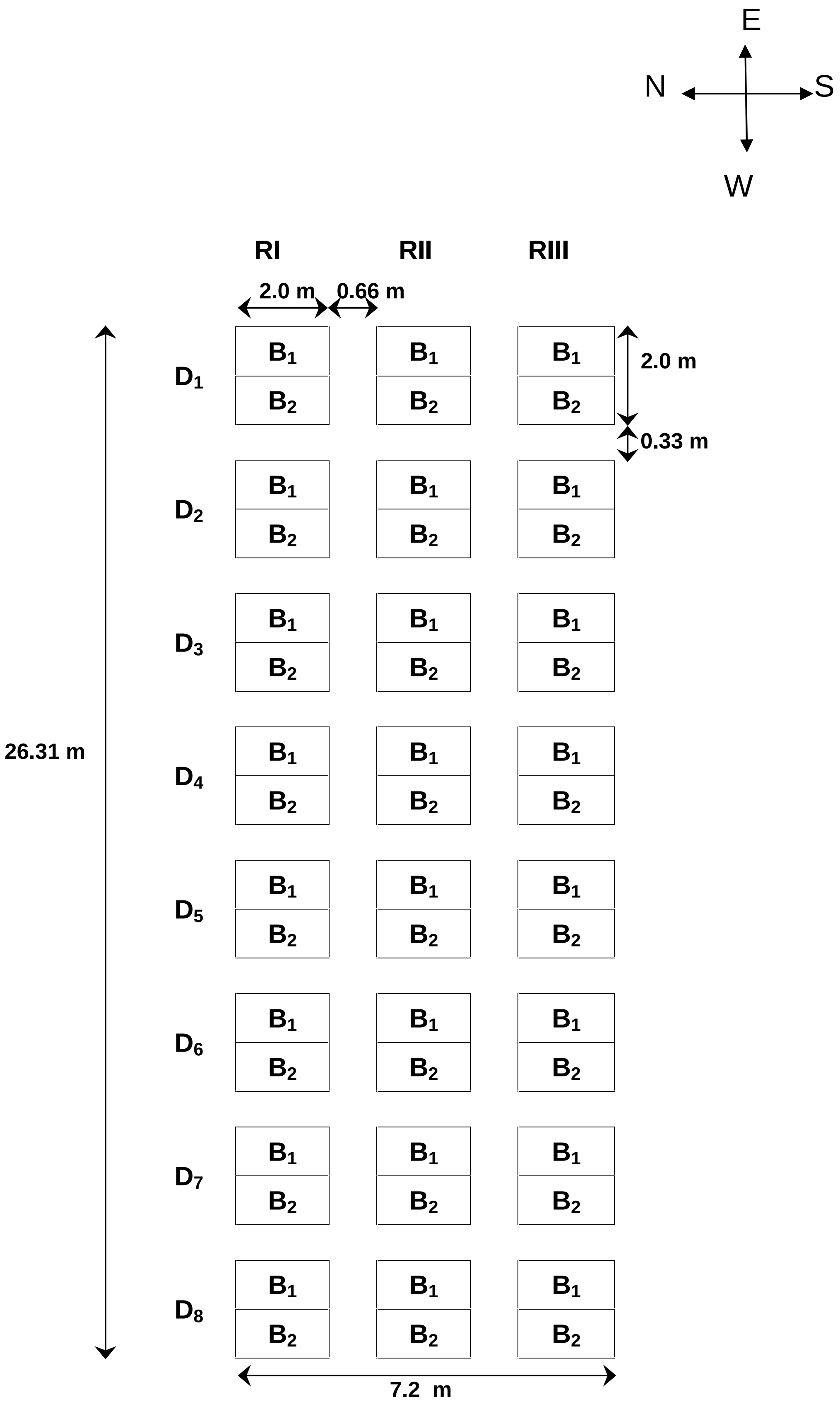


Fig.1. Layout plan of experimental trial (objective: 3.a)

3.2.4 Objective3: Management of onion thrips

b) To study the efficacy of insecticides and NSKE against onion thrips.

1.	Crop	:	Onion
2.	Variety	:	Bhema super
3.	Design	:	RBD
4.	Treatments	:	7
5.	Replications	:	3
6.	Spacing	:	15 cm x 10 cm
7.	Plot size : Gross	:	3.0 m x 2.0 m
	Net	:	2.5 m x 1.5 m
8.	Fertilizer dose	:	N:P:K @ 100:50:50 kg/ha
9.	Planting date	:	1st November 2015

Table 1: Details of treatment

S.No.	Treatment	Dose g.a.i./ha.	Chemical dose/ lit of water
T_1	Profenophos 50% EC	500ml	2ml/l
T_2	Cypermethrin 10% EC	100ml	2ml/l
T_3	Imidacloprid 17.8% SL	29.37ml	0.33ml/l
T_4	Chlorpyrifos 20% EC	200ml	2ml/l
T_5	Triazophos 40% EC	400ml	2ml/l
T_6	Neem Seed Kernel Extract 5%	1250g	50ml/l
T_7	Check	-	-

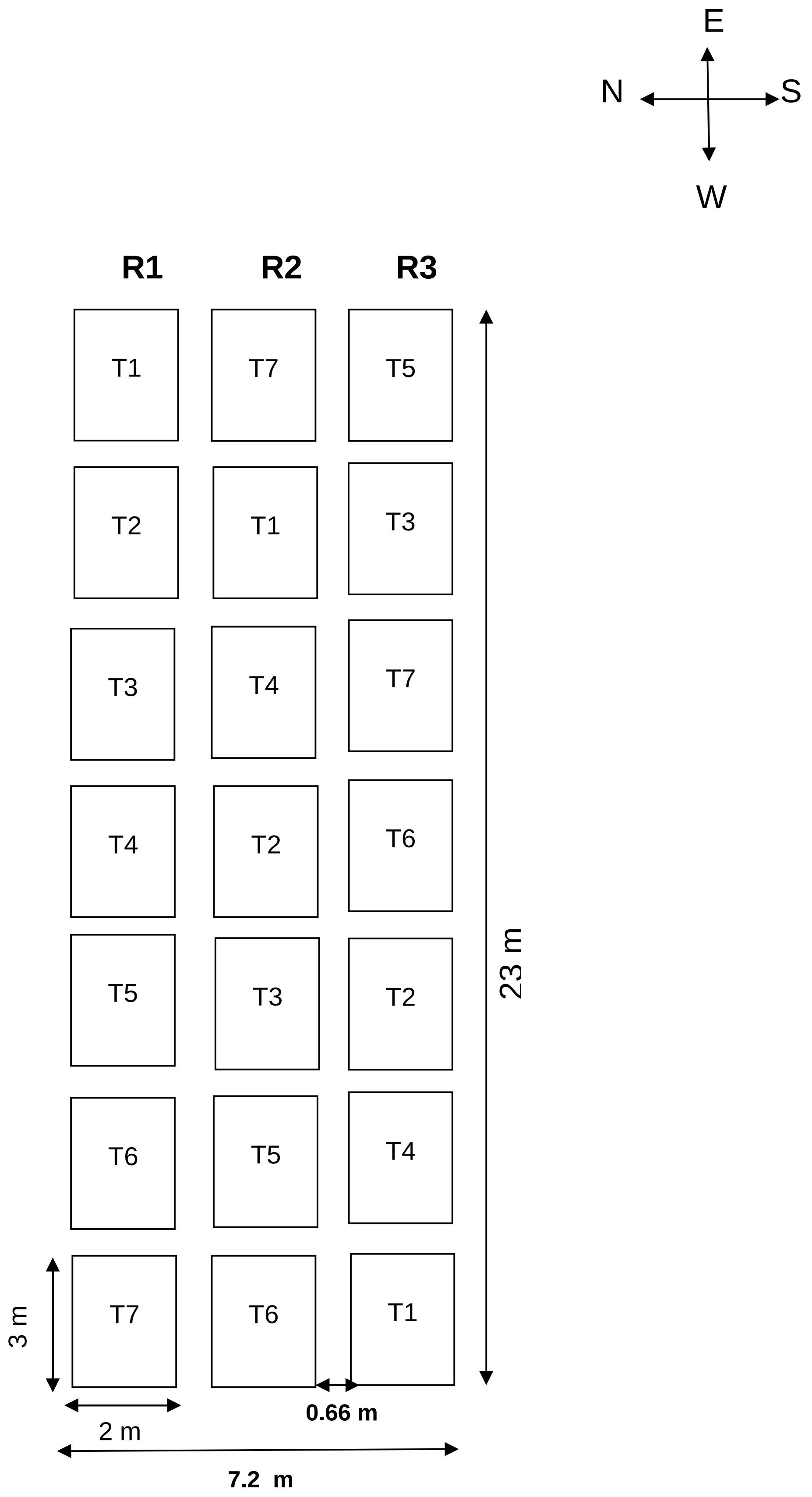


Fig.2. Layout plan of experimental trial (objective: 3.b)

3.2.5 Preparatory tillage

The experimental land was thoroughly ploughed by tractor drawn mould board plough followed by two harrowing. The field was cleaned by collecting and burning of stubbles. At the time of harrowing, the manures @ 30 t/ha and fertilizers N:P:K @ 100:50:50 kg/ha was applied to experimental field and the trial was laid out as given in plan of layout.

3.2.6 Raising of onion crop

The onion seeds were grown on raised beds prepared with well cultivated soil. Farm yard manure and fertilizers were mixed in the beds as per recommendations and the beds were irrigated timely to maintain healthy seedlings. About seven weeks old seedlings were transplanted in flat beds at 15 cm x 10 cm distance. All the crop management practices including FYM, fertilizers application, irrigation, interculturing operations etc. were carried out as per recommendations. The treatments were allotted randomly to each plot.

3.2.7 Intercultural operations

Weeding was carried out from time to time to remove weeds to improve soil aeration and conserve soil moisture. Irrigations were given as per the requirement of the crop to avoid moisture stress.

3.2.8 Spraying interval and number of sprays

Insecticides were sprayed early in the morning. In this experiment (objective 3.b) first spray was given at 41 days after transplanting. However, second spray was given at 56 days after transplanting. In all, four sprays were given at an interval of 15 days during 2015-16. Application of insecticides was carried out by using hand operated knapsack sprayer (ASPEE make) using required quantity of water.

3.2.9 Preparation of spray solution

In all, four foliar sprays for each treatment were given at an interval of 15 days with the help of Knapsack sprayer. The quantity of spray fluid required for spraying in each plot was calculated by spraying untreated control plot of 3m x 2m with water. The quantity of insecticide required was computed by using following formula and measured volume of the insecticide was dissolved in small quantity of water, mixed well and required concentration of spray solution was prepared by adding requisite quantity of clean water to it.

The sticker (Sandovit @ 0.5 ml/lit.) was added in spray fluid in spray tank to ensure wetting and spreading of insecticides on leaves at the time of application of insecticide. In case of oils, soap was used as emulsifier. During care was taken to wash the spray pump thoroughly prior to spraying and after spraying of each insecticide.

$$\text{Quantity of Insecticidal Formulation required} = \frac{\text{Desired strength} \times \text{Quantity of spray}}{\text{\% of insecticidal formulation material required}}$$

3.2.10 Preparation of Neem Seed Extract

The pulverized neem seed powder 40g was soaked in 200 ml water over night, filtered through double layered muslin cloth to prevent the powdered neem seed powder from clogging the nozzle and volume was made to one litre to prepare 5 percent solution for spraying. It was noted to prepare fresh NSKE before each spray.

3.3 Method of recording observations

In order to study the field efficacy of test insecticides against onion thrips, five plants from each plot were selected randomly for recording the observations. Numbers of thrips (nymphs & adults) present on inner i.e. middle sheath of onion plants were recorded. The observations were recorded at one day prior to spray treatment as (pre count) and three, seven and ten days after each spray. Four sprays were given at an interval of fifteen days starting from 41 days after transplanting.

For succession and population dynamics of major insect pests, Thrips count per plant, fruit borer - larvae per plant, red spider mite - both nymphs and adults per 3 leaves per plant, cutworm-counting the total number of leaves infested by cutworm per plant, above observations were taken from 5 randomly selected plants. The number of natural enemies particularly predators (spiders) were also recorded.

3.4 Statistical analysis

The data on average survival population of thrips were transformed into square root values ($\sqrt{x}$) and then data were subjected to statistical analysis was done by the method of “Analysis of variance" as suggested by Fisher and Yates, 1963. The standard error (S.E.) and Critical Difference (C.D.) at 5 percent level of probability was calculated to determine the efficacy of each insecticide, Further, mean percent reduction of thrips over untreated control was determined considering mean survival population of thrips.

3.5.1 Analysis of Correlation and regression studies:

Correlation and regression of the abiotic factors on major insects were worked out by using the formula as suggested by Snedecor and Cochran (1967).

$$\textbf{Correlation 'r'} = \frac{\sum xy - \frac{\sum x . \sum y}{n}}{\sqrt{\left\{\sum_x 2 - \frac{((\sum x)^2)}{n}\right\}\left\{\sum_y 2 - \frac{((\sum y)^2)}{N}\right\}}}$$

Regression $\hat{Y}$ = a + bx (R^2)

a = Intercept.

b = Regression coefficient.

R^2 = Coefficient of multiple determination.

Test of significance ‘r’

$$t = \frac{r}{\sqrt{1 - r^2}}\sqrt{n - 2}$$

Weather factors and the data collected on the succession & population dynamics of major insect pest of onion was statistically analyzed to study the correlation and regression between meteorological data and insect pest population on onion.

Table 2: Skeleton of Analysis of Variance (ANOVA)

Source of variance	Degree of freedom	Sum of square (SS)	Mean sum of square (MSS)	Calculated F value	Table value at 5%
Replication	(r-1)	SSR	MSR	MSR/MSE	
Treatments	(t-1)	SSTr	MSTr	MSTr/MSE	
Error	(r-1)(t-1)	SSE	MSE		
Total	(rt-1)	TSS			

The significant differences between different treatments were judged by using critical differences (CD) which was calculated as follows:

S.Ed = $\sqrt{\frac{MSE}{r}} X \sqrt{2}$

S.Ed = Standard error of differences between two treatment means.

MSE (Ve) = Error mean sum of square (Error variance).

CD = for treatment at 5% = S.Ed X + (e.df) at 5% x $\sqrt{2}$

CD = Critical difference

Where,

r = Number of replication

t = Value for fishers table for error degree of freedom at 5%

E.d.f. = Error degree of freedom.

The data were subjected to analysis after suitable transformation.

3.5.2 Statistical Analysis for split plot design

The experiment was laid in a split plot design with the (Main plot-different dates of planting, Sub plot-Insecticide effect). The data on average survival population of thrips were transformed into square root values ($\sqrt{x}$) and then data were subjected to statistical analysis was done by the method of “Analysis of variance" as suggested by Gomez and Gomez (1984). The results obtained through analysis of variance are given in appendix and the skeleton of analysis of variance table 4 is given below:

Table 3: Skeleton of analysis of variance for the split plot design

Source of variation	d.f.	S.S.	M.S.S.	F. Cal.	'F' Tab. 5% E.d.f
Replication	(r-1)	SSr	Vr		
Main treatment (Dates of planting)	(p-1)	SSp	Vp	Vp/VEa	
Error A	(r-1) (p-1)	SSEa	VEa		
Sub treatment (Insecticide effect)	(s-1)	SSs	Vs	Vs/VEb	
Error B	r (p-1) (s-1)	SSEb	VEb		
Total	rps -1				

Where,

r = number of replications

p = number of main treatment (Date of planting)

s = number of sub treatment (Insecticde spray)

Vr = replication mean sum of square

Vp = main treatment mean sum of square

Vs = sub treatment mean sum of square

VEa = error mean sum of square due to a

VEb = error mean sum of square due to b

The significance among different treatment means was judged by critical difference (C.D) at 5% level of significance for comparison among the treatments, the marginal means of each treatment was considered. The following formula was used for various estimations.

i. Standard error of mean = $S.Em \pm = \sqrt{\frac{E.\ ms}{r}}$

ii. Critical difference (C.D) = SEm x $\sqrt{2}$x t 0.05

Where,

Ems = error mean sum of square

t = 't' value at 5 % level at error d.f.

r = number of replications

RESULTS

The results on insect pest succession, population dynamics of major insect pests in relation to weather parameters and Management of onion thrips including effect of planting dates on thrips incidence and efficacy of insecticides and NSKE against onion thrips are described in this chapter.

4.1 Succession of insects and natural enemies in onion

Studies on insect pest succession and field incidence revealed that about four species of insects and one order of predator were observed to be associated with various stages of the onion crop (after transplanting) at Jabalpur, M.P during *rabi* 2015-16 (Table 4).

The major group of insects attacking in the vegetative stage was thrips, cut worm and fruit borer, among these, thrips was available till maturity of the crop and the attack of red spider mite was available at maturity stage of the crop.

4.1.1 Onion Thrips, *Thrips tabaci* Lindeman: (Thysanoptera:Thripidae)

In the present study thrips were first observed when the crop age was about 32 days old (DAT) *i.e.* 2nd December 2015 during the 48th SW *i.e.* 26th November to 2nd December (Table 4 and Figure 3). From the figure it is evident that the pest was present on the crop during the entire cropping season and remained available up to the crop till maturity stage.

4.1.2 Cut worm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera)

In the present study incidence of cut worm was first observed when the crop age was about 32 days old (DAT) *i.e.* 2nd December 2015 during the 48th SW *i.e.* 26th November to 2nd December (Table 4 and Figure 3). From the figure, it is evident that the pest was present on the crop till the reproductive stage (flowering/fruiting stage) of the crop *i.e.*14th January 2015.

4.1.3 Fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera)

In the present study fruit borer was first observed when the crop age was about 37 days old (DAT) *i.e* 7th December 2015 during the 48th SW *i.e*. 3rd December to 9th December (Table 4 and Figure 3) and it was present on the crop during the vegetative and upto reproductive stage (flowering/fruiting stage) *i.e.* 25th January 2015.

4.1.4 Red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes)

In the present study, incidence of red spider mite was first observed when the crop age was about 68 days old (DAT) *i.e.* 7th December 2015 during the 48th SW *i.e.*3rd December to 9th December (Table 4 and Figure 3). From the figure, it is evident that the pest was active on the crop upto the maturity.

4.1.6 Natural enemies

1) Spiders:

Spiders were first observed when the crop age was about 12 days old (DAT) (Table 4 and Figure 3). From the figure it is evident that the predator was present on the crop from the vegetative stage and remained available up to the crop maturity.

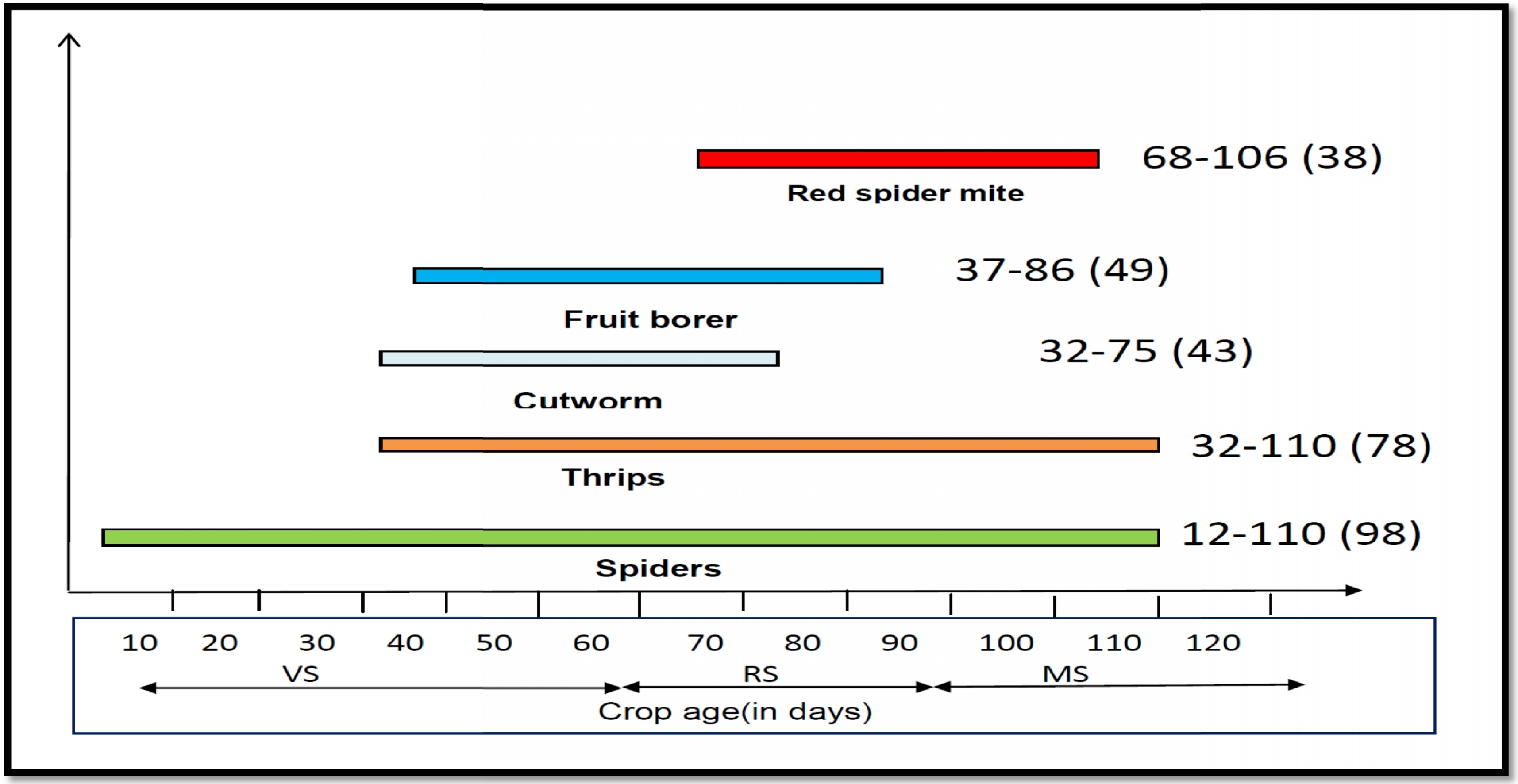
Table 4: Succession of insect pest complex on onion *Allium cepa* Linnaeus during *rabi* 2015-16

SW	Date of observation	Insects				Crop age (DAT)	Crop stage
		Name		Order	Family		
		Common	Scientific				
46	12th &16th Nov.2015	Spiders	Un identified	Arachnida	Un identified	Dec-16	VS
47	19th & 23rd Nov.2015	Spiders	Un identified	Arachnida	Un identified	19-23	VS
48	26th & 30th Nov.2015	Spiders	Un identified	Arachnida	Un identified	26-30	VS
49	2nd & 5th Dec. 2015	Spiders	Un identified	Arachnida	Un identified	32-35	VS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
50	7th &10th Dec.2015	Spiders	Un identified	Arachnida	Un identified	37-40	VS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
51	14th &17th Dec.2015	Spiders	Un identified	Arachnida	Un identified	44-47	VS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
52	21st & 24th Dec.2015	Spiders	Un identified	Arachnida	Un identified	51-54	VS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
52	28th & 31st Dec.2015	Spiders	Un identified	Arachnida	Un identified	58-61	VS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		

VS = Vegetative Stage RS = Reproductive Stage (Flowering / Fruiting Stage), MS = Maturity Stage, DAT (Days after transplanting)

SW	Date of observation	Insects				Crop age (DAT)	Crop stage
		Name		Order	Family		
		Common	Scientific				
1	4th &7th Jan.2016	Spiders	Un identified	Arachnida	Un identified	65-68	RS
		Onion Thrips	*Thrips tabaci*L indeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
2	11th &14th Jan.2016	Spiders	Un identified	Arachnida	Un identified	72-75	RS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae		
		Fruit Borer	*Helicoverpa armigera*Hubner	Lepidoptera	Noctuidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
3	18th& 21stJan.2016	Spiders	Un identified	Arachnida	Un identified	79-82	RS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
4	25th& 28th Jan.2016	Spiders	Un identified	Arachnida	Un identified	86-89	RS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
5	1st& 4th Feb.2016	Spiders	Un identified	Arachnida	Un identified	92-94	
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
6	8th&11th Feb.2016	Spiders	Un identified	Arachnida	Un identified	100-103	MS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		
7	15th& 18th Feb.2016	Spiders	Un identified	Arachnida	Un identified	107-110	MS
		Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae		
		Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae		

VS = Vegetative Stage RS = Reproductive Stage (Flowering / Fruiting Stage), MS = Maturity Stage, DAT (Days after transplanting)



Crop stage: VS = Vegetative stage, RS = Reproductive stage, MS = Maturity stage

( ) duration of stay on the crop (days)

Fig. 3. Succession of insect pest complex on onion *Allium cepa* Linnaeus during *rabi* 2015-16

Compilation of the information on insect succession on onion revealed that three species of insect pests, one non insect pest and one natural enemy spiders were appeared at different stages of crop growth which constituted 1 species of Thysanoptera, 2 species of Lepidoptera 1 species of Tetranychidae and unidentified species of spiders, Arachnida order respectively (Table 5).

Table 5: Succession of insects and natural enemy on onion at Jabalpur during *rabi* season 2015-16

Common name	Scientific name	Order	Family
Onion Thrips	*Thrips tabaci* Lindeman	Thysanoptera	Thripidae
Cut worm	*Agrotis ipsilon* Hufnagel	Lepidoptera	Noctuidae
Fruit Borer	*Helicoverpa armigera* Hubner	Lepidoptera	Noctuidae
Red spider mite	*Tetranychus telarius* Linnaeus	Trombidiformes	Tetranychidae
Spiders	-	Arachnida	-

Table 6: Incidence of insect pest on onion during *rabi* 2015-16

Months	Standard Weeks	Thrips/ plant	Fruit borer larvae/plant	Red spider mite / 3leaves	Leaves infested by cutworm (%)
November	48	31.60	0	0	22.40
December	49	41.50	0.22	0	27.05
	50	36.40	0.47	0	31.27
	51	31.67	0.53	0	31.67
	52	32.77	0.67	0	26.05
January	1	49.60	0.96	1.93	21.92
	2	42.30	1.43	1.74	17.98
	3	21.47	0.60	1.93	0
	4	15.77	0.43	2.24	0
February	5	44.57	0	2.80	0
	6	30.43	0	2.07	0
	7	33.80	0	1.18	0

Table 7: Correlation (r) and regression coefficient (byx) of abiotic factors on insect pest complex on onion crop during *rabi* 2015-16

Weather factors	Insect pest							
	Thrips		Fruit borer		Red spider mite		% Leaves infested by cutworm	
	r	byx	r	byx	r	byx	r	byx
Maximum temperature.(°C)	0.58*	2.26	0.19 NS	-	-0.19 NS	-	-0.45 NS	-
Minimum temperature.(°C)	0.11 NS	-	-0.002 NS	-	-0.40 NS	-	-0.21 NS	-
Morning relative humidity (RH) (%)	-0.33 NS	-	-0.58 NS	-	0.43 NS	-	0.11 NS	-
Evening RH (%)	-0.41 NS	-	-0.08 NS	-	-0.16 NS	-	0.29 NS	-
Wind velocity (km/hr)	-0.39 NS	-	-0.41 NS	-	-0.10 NS	-	0.73 NS	-
Sunshine(hrs)	0.19 NS	-	0.004 NS	-	0.60 NS	-	-0.30 NS	-
Rainfall (mm)	-0.43 NS	-	-0.07 NS	-	-0.05 NS	-	-0.19 NS	-
No. of rainy days	-0.43 NS	-	-0.07 NS	-	-0.05 NS	-	0 NS	-
Morning vapor pressure (mm)	0.001 NS	-	-0.20 NS	-	-0.37 NS	-	0 NS	-
Evening vapor pressure (mm)	-0.15 NS	-	-0.06 NS	-	-0.42 NS	-	-0.17 NS	
Evaporation (mm)	0.52 NS	-	0.59 NS	-	-0.02 NS	-	-0.67 NS	-

* Significant at 5% level NS=Non-significant

4.2.1 Onion Thrips, *Thrips tabaci* Lindeman: (Thysanoptera: Thripidae)

First appearance of the thrips was recorded on 2nd December 2015 during the 48th SW *i.e.* 26th November to 2nd December and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 6 and illustrated in Figure 4.

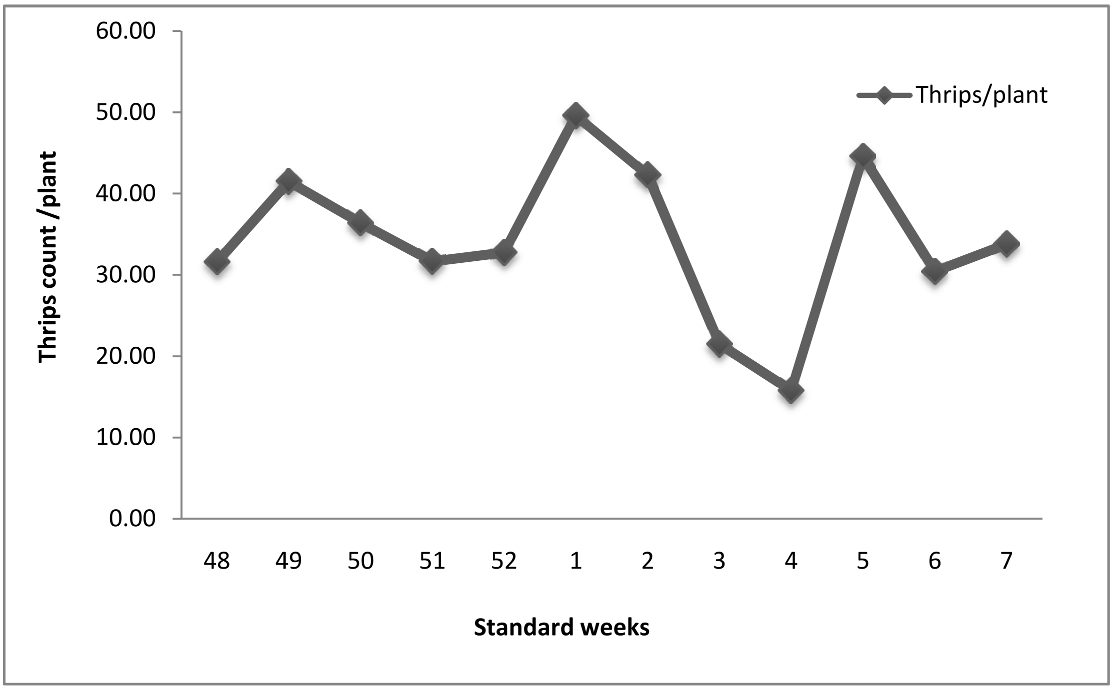


Fig. 4: Incidence of thrips on onion at Jabalpur during *rabi* 2015

From the figure 4 it is seen that the thrips population started increasing from 48th SW *i.e.* 26th November to 2nd December and reached at its peak (49.60 thrips/ plant) during 1st SW *i.e.* 1st to 7th January. During this period maximum and minimum temperature were 27.5°C and 7.9°C respectively, whereas, morning and evening relative humidity were 88 and 27 percent, respectively. Further, wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.8 km/hrs., 8.5 per hrs., 8 mm, 7.4 mm and 3.7 mm, respectively and 0 mm rainfall was recorded in 6 days during this period. After 2nd SW there was a decline in the thrips population and it was available up to harvest of the crop.

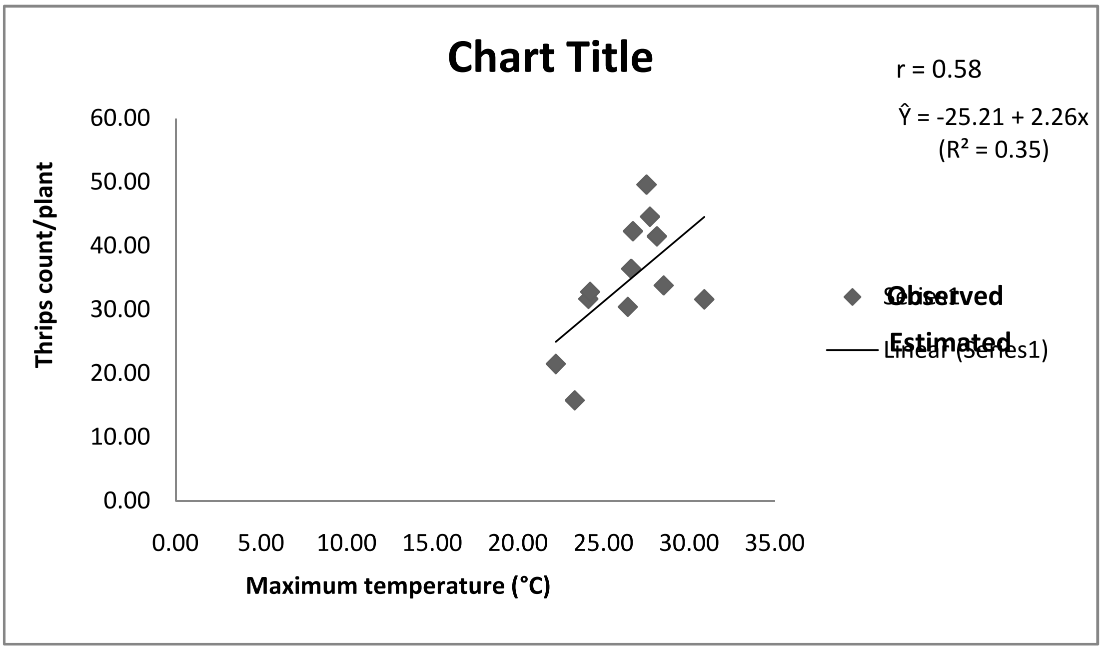


Fig. 5: Regression of maximum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that maximum temperature showed a significant positive correlation (r =0.58) with thrips population (Table 7).

The regression equations being:

$\hat{Y} = -25.21 + 2.26x$ ($R^2 = 0.35$)

From the above equation it may be expressed that with every unit increase in maximum temperature there was positively increase of 2.26 thrips population per plant (Fig.5).

Further, minimum temperature, sunshine, morning vapour pressure and evaporation exhibited positive correlation (r=0.11, 0.19, 0.001 and 0.52, respectively). While morning & evening relative humidity, wind velocity, rainfall, no. of rainy days and evening vapour pressure showed negative correlation (r= -0.33, -0.41, -0.39, -0.43, -0.43 and -0.15, respectively) with thrips population but statistically found to be non-significant.

4.2.2 Cut worm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera)

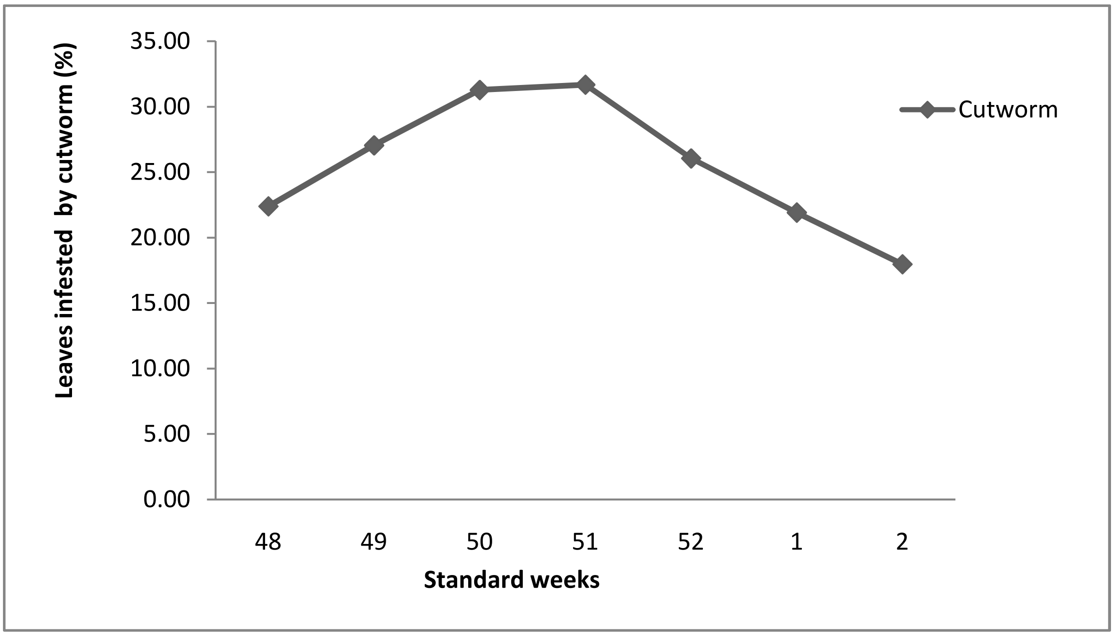


Fig. 6: Incidence of cut worm on onion at Jabalpur during *rabi* 2015-16

First appearance of the cutworm was recorded on 2nd December 2015 during the 48th SW *i.e.* 26 November to 2nd December and thereafter observations were recorded regularly twice in a standard week. The percentage of leaves infestation was worked out at weekly interval and data of percentage of leaves infested by cutworm is presented in Table 6 and illustrated in Figure 6.

From the figure 6 it is seen that the cutworm infestation started from 48th SW *i.e.* 26th November to 2nd December and reached at its peak (31.67%) during 51st SW *i.e.* 17th to 23rd December. During this period maximum and minimum temperature were 24.1°C and 7.0°C respectively, whereas, morning and evening relative humidity were 86 and 37 percent, respectively. Further, wind velocity, sunshine, morning & evening vapour pressure and evaporation were 2.8 km/hrs., 7.0 per hrs., 7.3 mm, 8.1 mm and 2 mm, respectively. However, no rainfall was recorded during this period. After 51st SW there was a decline in the cutworm infestation and it was disappeared after 2nd SW *i.e.* 8th January to 14th January, 2015.

Correlation between various abiotic factors and cut worm population showed that, morning relative humidity, evening relative humidity, wind velocity were found to have positive correlation (r = 0.11, 0.29, 0.73, respectively). While no. of rainy days and morning vapour pressure were found to have zero correlation. While maximum & minimum temperature, sunshine hour, rainfall, evening vapour pressure and evaporation showed negative correlation (r = -0.45, -0.21, -0.30, -0.19, -0.17, -0.67, respectively) with leaves infested by cutworm but statistically found to be non significant.

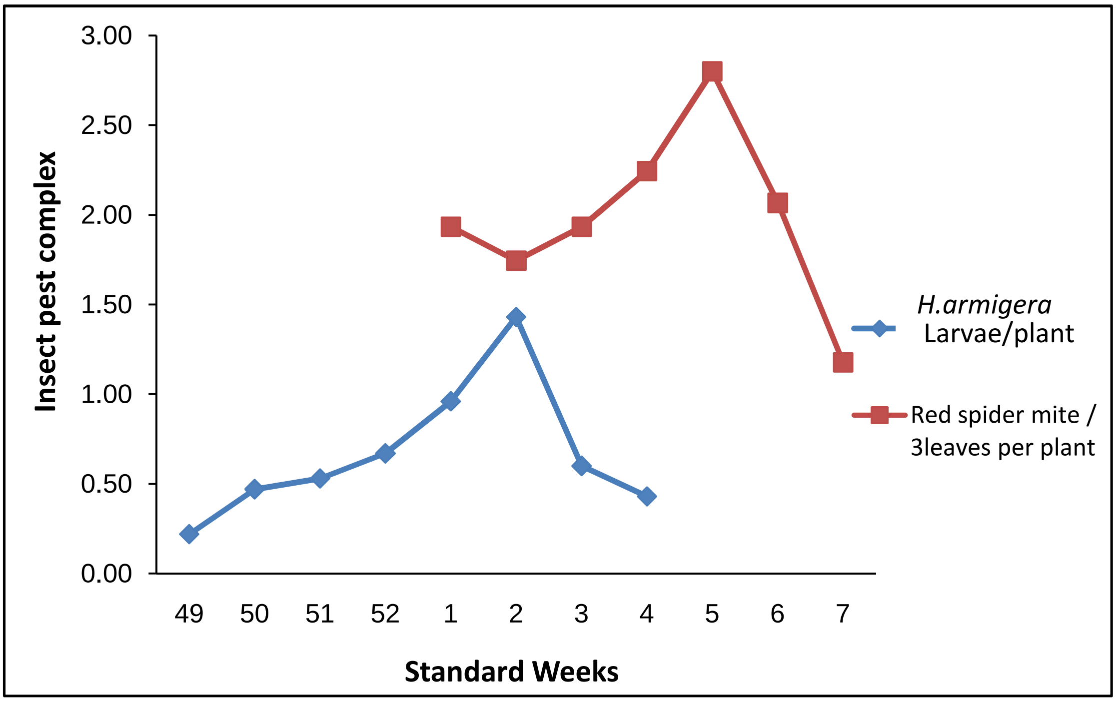


Fig. 7. Incidence of insect pest complex on onion at Jabalpur during *rabi* 2015-16

4.2.3 Fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera)

First appearance of the fruit borer was recorded on 7th December 2015 during the 49th SW *i.e.* 3rd December to 9th December and thereafter observations were recorded regularly twice in a standard week. The number of fruit borer larva was observed at weekly interval and data of average (larvae/plant) are presented in Table 6 and illustrated in Figure 7.

From the figure 7 it is seen that the fruit borer population started from 49th SW *i.e.* 3rd December to 9th December and reached at its peak (1.43/plant) during 2nd SW i.e. 8th to 14th January. During this period maximum and minimum temperature were 26.7°C and 8.0°C respectively, morning and evening relative humidity were 81 and 32 percent respectively. Further, wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.7 km/hrs., 7.7 per hrs., 7.6 mm, 8 mm and 3 mm respectively and 0 mm rainfall was recorded during this period. After 3rd SW there was a decline in the fruit borer population and it was available up to 4th SW *i.e.* 22nd to 28th January, 2015.

Correlation studies

Correlation studies revealed that maximum temperature, sunshine hours and evaporation showed positive correlation (r=0.19, 0.004 and 0.59, respectively). Further, minimum temperature, morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlation (r= -0.002, -0.58, -0.08, -0.41, -0.07, -0.07, -0.20 and -0.06, respectively) with fruit borer population but statistically found to be non-significant (Table 7).

4.2.4 Red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes)

First appearance of the pest was recorded on 7th January 2015 during the 1st SW *i.e.*1st January to 7th January and thereafter observations were recorded regularly twice in a standard week. The number of red spider mite (nymph & adult) was worked out at weekly interval and data of average (3 leaves per plant) are presented in Table 6 and illustrated in Figure 7.

From the figure 7 it is seen that the red spider mite population started from 1st SW *i.e.* 1st January to 7th January and reached at its peak (2.80) during 5th SW *i.e.* 29th Januaryto 4th February. During this period maximum and minimum temperature were 27.7°C and 9.1°C respectively, where as, morning and evening relative humidity were 92 and 35 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 2.8 km/hrs., 9.3 per hrs., 8.9 mm, 9.3 mm and 2.5 mm respectively and 0 mm rainfall was recorded during this period.

After 6th SW there was a decline in the red spider mite population and was available up to 7th SW *i.e.* 12th to 18th February 2015.

Correlation studies

Correlation studies revealed that, morning relative humidity, and sunshine showed positive correlation (r=0.43 and 0.60, respectively). While maximum temperature, minimum temperature, evening relative humidity, wind velocity, rain fall and no. of rainy days, morning & evening vapour pressure and evaporation showed negative correlation (r= -0.19, -0.40, -0.16, -0.10, -0.05, -0.05, -0.37, -0.42 and -0.02, respectively) with red spider mite population but statistically were found non-significant (Table 7).

4.3 To study the efficacy of insecticides and NSKE against onion thrips

4.3.1 First spray

4.3.1.1 Pre- treatment

The data recorded on thrips are presented in Table 8. Average thrips populations per plant among different treatments were not significant 24 hours before treatment, indicating more or less uniform distribution of the pest.

4.3.1.2 Three days after first spray

Data presented in the Table 8 showed that at 3rd day after first spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (42.60 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37ml a.i./ha was found to be the most effective and recorded lowest thrips population (15.20 thrips/plant) which was significantly better than all other treatments. Followed by Cypermethrin 10% EC @ 100 ml a.i./ha (16.60 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (29.13 thrips/plant) was found to be the least effective among different insecticides but significantly better than control.

4.3.1.3 Seven days after first spray

At 7th day after first spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (50.33 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all other treatments as it recorded lowest thrips population (12.47 thrips/plant). Followed by Cypermethrin 10% EC @ 100 ml a.i./ha (14.80 thrips/ plant) which showed significantly lower population than all other treatments except Triazophos 40% EC @ 400 ml a.i./ha (15.07thrips/ plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.40 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly superior to control.

Table 8: Efficacy of insecticides and NSKE against onion thrips (after first spray)

Treatment code	Treatments	Dose g a.i./ha.	Mean Thrips count / plant				Mean
			Pre-Treatment	Days after first spray			
				3.00	7.00	10.00	
T_1	Profenophos 50% EC	500 ml	35.00 (5.91)	19.00 (4.47)	15.60 (4.07)	11.27 (3.50)	15.29 (4.02)
T_2	Cypermethrin 10% EC	100 ml	33.13 (5.75)	16.60 (4.20)	14.80 (3.98)	11.93 (3.60)	14.44 (3.92)
T_3	Imidacloprid 17.8% SL	29.37 ml	34.00 (5.83)	15.20 (4.03) **L**	12.47 (3.67) **L**	9.60 (3.26) **L**	12.42 (3.65) **L**
T_4	Chlorpyrifos 20% EC	200 ml	36.13 (6.01)	20.27 (4.61)	16.53 (4.19)	12.47 (3.67)	16.42 (4.16)
T_5	Triazophos 40% EC	400 ml	34.53 (5.87)	21.53 (4.75)	15.07 (4.01)	9.87 (3.30)	15.49 (4.02)
T_6	Neem Seed Kernel Extract 5%	1250 g	34.73 (5.89)	29.13 (5.49)	24.40 (5.04)	19.67 (4.55)	24.40 (5.02)
T_7	Check		37.13 (6.09)	42.60 (6.60) **H**	50.33 (7.16) **H**	56.67 (7.59) **H**	49.87 (7.12) **H**
	SE(M) ±		0.07	0.05	0.06	0.07	0.23
	C.D. at 5%	-	NS	0.14	0.19	0.21	0.70

Figures in parentheses are √**x** square root transformed values, NS = Non-significant, **L**- Lowest, **H**- Highest

4.3.1.4 Ten days after first spray

At 10^{th} day after first spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (56.67 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha exhibited significantly lowest thrips population (9.60 thrips/plant) among the all treatments except Triazophos 40% EC @ 400 ml a.i./ha (9.87 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (19.67 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly superior to control.

4.3.1.5 Over all mean of first spray

On the basis of overall mean of first spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (49.87 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (12.42 thrips/plant) than all the treatments but it was at par with Cypermethrin 10% EC @ 100 ml a.i./ha (14.44 thrips/plant). Plots treated with Cypermethrin recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (15.29 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.40 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly superior to control.

4.3.2 Second spray

4.3.2.1 Third day after second spray

At 3^{rd} day after second spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (42.73 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all the treatments as it recorded the lowest thrips population (17.47 thrips/plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (19.80 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (27.27 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly superior to control.

Table 9: Efficacy of insecticides and NSKE against onion thrips (after second spray)

Treatment code	Treatments	Dose g a.i./ha.	Mean Thrips count / plant Days after second spray			Mean
			3	7	10	
T_1	Profenophos 50% EC	500 ml	21.67 (4.76)	16.33 (4.16)	10.93 (3.45)	16.31 (4.13)
T_2	Cypermethrin 10% EC	100 ml	21.53 (4.75)	14.87 (3.98)	12.93 (3.73)	16.44 (4.15)
T_3	Imidacloprid 17.8% SL	29.37 ml	17.47 (4.30) **L**	11.33 (3.51) **L**	8.13 (3.02) **L**	12.31 (3.61) **L**
T_4	Chlorpyrifos 20% EC	200 ml	21.87 (4.78)	17.47 (4.30)	11.87 (3.59)	17.07 (4.22)
T_5	Triazophos 40% EC	400 ml	19.80 (4.56)	13.27 (3.78)	9.27 (3.20)	14.11 (3.85)
T_6	Neem Seed Kernel Extract 5%	1250 g	27.27 (5.32)	23.60 (4.96)	20.40 (4.63)	23.76 (4.97)
T_7	Check		42.73 (6.61) **H**	50.33 (7.17) **H**	58.33 (7.70) **H**	50.47 (7.16) **H**
	SE(M) ±		0.03	0.04	0.05	0.26
	C.D. at 5%		0.11	0.12	0.14	0.80

Figures in parentheses are √**x** square root transformed values, NS = Non-significant, **L**- Lowest, **H**- Highest

4.3.2.2 Seven days after second spray

Data presented in the Table 9 showed that at 7th day after second spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (50.33 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all the treatments as it recorded the lowest thrips population (11.33 thrips/ plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (13.27 thrips/ plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (23.60 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly better than control.

4.3.2.3 Ten days after second spray

At 10th day after second spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (58.33 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all the treatments as it recorded the lowest thrips population (8.13 thrips/plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (9.27 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (20.40 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly better than control.

4.3.2.4 Overall mean of second spray

On the basis of overall mean of second spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (50.47 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (12.31 thrips/ plant) than all the treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (14.11 thrips/plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (16.31 thrips/plant). Treatment NSKE 5%@ 1250 g a.i./ha (23.76 thrips/plant) was found to be the least effective in comparison to other insecticides but at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (17.07 thrips/plant) and significantly better than control.

4.3.3 Third spray

4.3.3.1 Third day after third spray

Data presented in Table 10 showed that at 3rd day after third spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (58.33 thrips/plant). Among the all treatments Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all the treatments as it recorded lowest thrips population (18.73 thrips/ plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (21.13 thrips/ plant) which showed significantly lower thrips population than all other treatments except Profenophos 50% EC @ 500 ml a.i./ha (22.13 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (31.00 thrips/plant) was found to be the least effective in comparison to other insecticides but significantly better than control.

4.3.3.2 Seven days after third spray

At 7th day after third spray among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all other treatments as it recorded the lowest thrips population (12.13 thrips/ plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (14.73 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (22.93 thrips/plant) was found to be the least effective in comparison to other insecticides, but significantly better than control (60.47 thrips/ plant).

4.3.3.3 Ten days after third spray

At 10th day after third spray among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha exhibited significantly the lowest thrips population (9.60 thrips/plant) than all other treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (11.07 thrips/ plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (12.53 thrips/ plant). Treatment NSKE 5% @ 1250 g a.i./ha (20.73 thrips/ plant) was found to be the least effective in comparison to other insecticides, but significantly better than control (56.00 thrips/ plant).

Table 10: Efficacy of insecticides and NSKE against onion thrips (after third spray)

Treatment code	Treatment	Dose g a.i./ha.	Mean Thrips count / plant			Mean
			Days after third spray			
			3	7	10	
T_1	Profenophos 50% EC	500 ml	22.13 (4.81)	17.87 (4.34)	12.53 (3.68)	17.51 (4.28)
T_2	Cypermethrin 10% EC	100 ml	26.67 (5.26)	20.40 (4.63)	14.60 (3.95)	20.56 (4.61)
T_3	Imidacloprid 17.8% SL	29.37 ml	18.73 (4.44) **L**	12.13 (3.62) **L**	9.60 (3.26) **L**	13.49 (3.77) **L**
T_4	Chlorpyrifos 20% EC	200 ml	27.80 (5.37)	21.20 (4.71)	14.87 (3.98)	21.29 (4.69)
T_5	Triazophos 40% EC	400 ml	21.13 (4.70)	14.73 (3.97)	11.07 (3.47)	15.64 (4.05)
T_6	Neem Seed Kernel Extract 5%	1250 g	31.00 (5.66)	22.93 (4.89)	20.73 (4.66)	24.89 (5.07)
T_7	Check		58.33 (7.70) **H**	60.47 (7.84) **H**	56.00 (7.55) **H**	58.27 (7.70) **H**
	SE(M) ±		0.04	0.05	0.08	0.13
	C.D. at 5%		0.13	0.16	0.25	0.42

Figures in parentheses are √**x** square root transformed values, NS = Non-significant, **L**- Lowest, **H**- Highest

4.3.3.4 Overall mean of third spray

On the basis of overall mean of third spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (58.27 thrips/plant). Among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (13.49 thrips/ plant) than all the treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (15.64 thrips/ plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (17.51 thrips/ plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.89 thrips/plant) was found to be the least effective in comparison to other insecticides but remained at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (21.29 thrips/ plant) and significantly better than control.

4.3.4 Fourth spray

4.3.4.1 Third day after fourth spray

Data presented in Table 11 showed that at 3rd day after fourth spray all the insecticidal treatments have significantly reduced the thrips population as compared to control (54.60 thrips/plant). Among the all treatments Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (18.80 thrips/plant) than all the treatments but remained at par with Triazophos 40% EC @ 400 ml a.i./ha (18.93 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (30.13 thrips/plant) was found to be the least effective in comparison to other insecticides but at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (29.00 thrips/plant) and significantly better than control.

4.3.4.2 Seven days after fourth spray

At 7th day after fourth spray among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all the treatments as it recorded lowest thrips population (11.53 thrips/plant). Followed by Triazophos 40% EC @ 400 ml a.i./ha (12.93 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (22.00 thrips/plant) was found to be the least effective in comparison to other insecticides but at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (20.93 thrips/plant) and significantly better than control (58.47 thrips/ plant).

Table 11: Efficacy of insecticides and NSKE against onion thrips (after fourth spray)

Treatment code	Treatment	Dose ga.i./ha.	Mean Thrips count / plant			Mean
			Days after fourth spray			
			3	7	10	
T_1	Profenophos 50% EC	500 ml	21.80 (4.78)	16.47 (4.18)	11.73 (3.57)	16.67 (4.17)
T_2	Cypermethrin 10% EC	100 ml	25.13 (5.11)	20.07 (4.59)	14.00 (3.87)	19.73 (4.52)
T_3	Imidacloprid 17.8% SL	29.37 ml	18.80 (4.45) **L**	11.53 (3.54) **L**	8.80 (3.13) **L**	13.04 (3.71) **L**
T_4	Chlorpyrifos 20% EC	200 ml	29.00 (5.48)	20.93 (4.68)	15.73 (4.09)	21.89 (4.75)
T_5	Triazophos 40% EC	400 ml	18.93 (4.46)	12.93 (3.73)	9.80 (3.29)	13.89 (3.83)
T_6	Neem Seed Kernel Extract 5%	1250 g	30.13 (5.58)	22.00 (4.80)	21.87 (4.78)	24.67 (5.05)
T_7	Check		54.60 (7.46) **H**	58.47 (7.71) **H**	57.87 (7.67) **H**	56.98 (7.61) **H**
	SE(M) ±		0.05	0.05	0.06	0.17
	C.D. at 5%		0.15	0.15	0.20	0.54

Figures in parentheses are √**x** square root transformed values, NS = Non-significant, **L**- Lowest, **H**- Highest

4.3.4.3 Ten days after fourth spray

At 10th day after fourth spray among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (8.80 thrips/plant) than all the treatments but at par with Triazophos 40% EC @ 400 ml a.i./ha (9.80 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (21.87 thrips/plant) was found to be least effective in comparison to other insecticides, but significantly better than control (57.87 thrips/plant).

4.3.4.4 Overall mean of fourth spray

On the basis of overall mean of fourth spray all the insecticidal treatments significantly reduced the thrips population as compared to control (56.98 thrips/plant). Among the all treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha showed significantly lowest thrips population (13.04 thrips/plant) than all the treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (13.89 thrips/plant). Plots treated with Triazophos recorded significantly lower thrips population than all other treatments except Profenophos 50% EC @ 500 ml a.i./ha (16.67 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.67 thrips/plant) was found to be the least effective in comparison to other insecticides but remained at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (21.89 thrips/plant) and significantly better than control.

4.3.5.1 Overall mean of all sprays (3rd DAS)

Looking to the overall mean of all sprays at three days after spray, the insecticidal treatments have significantly reduced the thrips population as compared to control (49.57 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha showed significantly better than all other treatments as it recorded the lowest thrips population (17.55 thrips/plant), followed by Triazophos 40% EC @ 400 ml a.i./ha (20.35 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (29.38 thrips/plant) was found to be the least effective in comparison to other insecticides, but significantly better than control.

Table 12: Efficacy of insecticides and NSKE against onion thrips (over all mean of four sprays)

Treatment code	Treatment	Dose ga.i./ha.	Mean Thrips count / plant			Mean
			Days after spray			
			3	7	10	
T_1	Profenophos 50% EC	500 ml	21.15 (4.71)	16.57 (4.19)	11.62 (3.55)	16.44 (4.15)
T_2	Cypermethrin 10% EC	100 ml	22.48 (4.85)	17.53 (4.31)	13.37 (3.79)	17.79 (4.31)
T_3	Imidacloprid 17.8% SL	29.37 ml	17.55 (4.31) **L**	11.87 (3.59) **L**	9.03 (3.17) **L**	12.82 (3.69) **L**
T_4	Chlorpyrifos 20% EC	200 ml	24.73 (5.07)	19.03 (4.48)	13.73 (3.84)	19.17 (4.46)
T_5	Triazophos 40% EC	400 ml	20.35 (4.62)	14.00 (3.87)	10.00 (3.32)	14.78 (3.94)
T_6	Neem Seed Kernel Extract 5%	1250 g	29.38 (5.51)	23.23 (4.92)	20.67 (4.65)	24.43 (5.03)
T_7	Check		49.57 (7.11) **H**	54.90 (7.48) **H**	57.22 (7.63) **H**	53.89 (7.41) **H**
	SE(M) ±		0.02	0.03	0.03	0.19
	C.D. at 5%		0.06	0.08	0.10	0.58

Figures in parentheses are √**x** square root transformed values, NS = Non-significant, **L**- Lowest, **H**- Highest

4.3.5.2 Overall mean of all sprays (7^{th} DAS)

In overall mean of all sprays at seven days after spray the insecticidal treatments have significantly reduced the thrips population as compared to control (54.90 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all other treatments as it recorded lowest thrips population (11.87 thrips/plant), followed by Triazophos 40% EC @ 400 ml a.i./ha (14.00 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (23.23 thrips/plant) was found to be least effective in comparison to other insecticides, but significantly better than control.

4.3.5.3 Overall mean of all sprays (10^{th} DAS)

Considering overall mean of all sprays at ten days after spray, the insecticidal treatments significantly reduced the thrips population as compared to control (57.22 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly better than all other treatments as it recorded lowest thrips population (9.03 thrips/plant), followed by Triazophos 40% EC @ 400 ml a.i./ha (10.00 thrips/plant) which was also significantly superior to all other treatments. Treatment NSKE 5% @ 1250 g a.i./ha (20.67 thrips/plant) was found to be the least effective in comparison to other insecticides, but significantly better than control.

4.3.5.4 Overall mean of all four sprays

On the basis of overall mean of all sprays all the insecticidal treatments have significantly reduced the thrips population as compared to control (53.89 thrips/plant). Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha recorded significantly lowest thrips population (12.82 thrips/plant) than all other treatments but at par with Triazophos 40% EC @ 400 ml a.i./ha (14.78 thrips/plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (16.44 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.43 thrips/plant) was found to be the least effective in comparison to other insecticides but at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (19.17 thrips/plant) and significantly better than control.

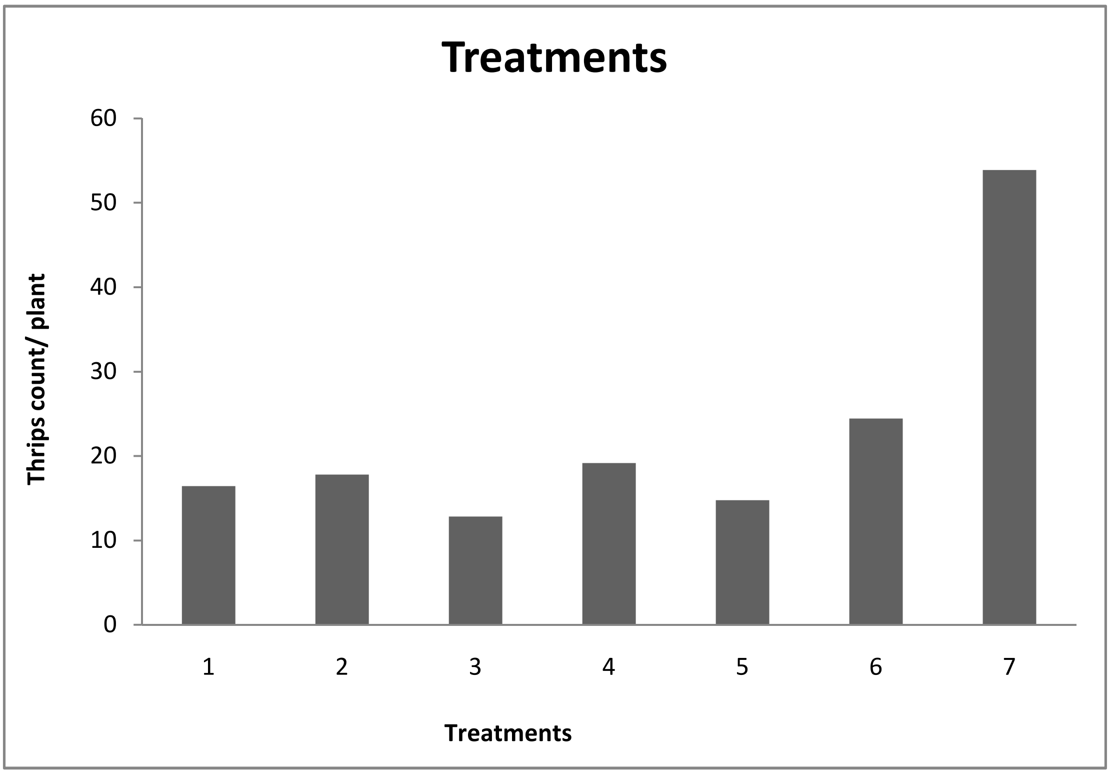


Fig. 8: Efficacy of insecticides and NSKE against onion thrips, *Thrips tabaci* Lindeman (over all mean of 4 sprays)

4.4 To study the effect of planting dates on thrips

The results of the effect of date of transplanting on the population of thrips are presented, eight dates of planting (Factor D) and Insecticide effect Factor B. the data presented in Tables.13

4.4.2 Factor D: planting dates:

Among the different date of transplanting evaluated, significantly highest population of thrips (15.78 thrips/plant) was recorded in December 15th date of transplanting, followed by December 1st (15.65 thrips/plant) and October 15th (15.61 thrips/plant), but they were at par with each other. The next dates of transplanting were November 1st (15.10 thrips/plant) and November 15th (15.08 thrips/plant), but they were at par with each other. The next date of transplanting was October 1st (14.87 thrips/plant) and September 1st (14.46 thrips/plant) they differ significantly from each other. The lowest Thrips population was recorded in September 15th (14.17 thrips/plant) date of transplanting.

4.4.4 Factor B: Insecticide effect:

Evaluation of Insecticide effect on population of thrips in the subplot (protected) revealed significantly lowest population of thrips (12.35 thrips/plant) and subplot (unprotected) recorded the highest population of thrips (17.83 thrips/plant).

4.4.5 Interactions:

Interaction of the two factors *i.e.* planting dates and unprotected plot have a significant impact on the population of thrips. Among the different date of transplanting and unprotected plot evaluated, significantly highest population of thrips (6.23 thrips/plant) was recorded in interaction (D_8xB_2) *i.e.* December 15th date of transplanting and unprotected plot, but it was at par with interaction (D_7xB_2) *i.e.* December 1st date of transplanting and unprotected plot (6.20 thrips/plant), followed by interaction (D_4xB_2) *i.e.* October 15th date of transplanting and unprotected plot which recorded significantly highest population of thrips (6.05 thrips/plant) but remained at par with interaction (D_5xB_2) *i.e.* November 1st date of transplanting and unprotected plot, (6.01 thrips/plant), followed by interaction (D_6 x B_2) *i.e.* November 15th date of transplanting and unprotected plot which has significantly highest population of thrips (5.92 thrips/plant). Interaction (D_3xB_2) *i.e.* October 1st date of transplanting and unprotected plot showed significantly highest population of thrips (5.76 thrips/plant). The lowest Thrips population (5.68 thrips/plant) was recorded in interaction (D_1xB_2) *i.e.* September 1st date of transplanting and unprotected plot, but it was at par with interaction (D_2xB_2) *i.e.* September 15th date of transplanting and unprotected plot in population of thrips (5.70 thrips/plant).

Further, interaction of the two factors *i.e.* planting dates and protected plot have a significant impact on the population of thrips. Among the different date of transplanting and protected plot evaluated, significantly highest population of thrips (4.36 thrips/plant) was recorded in interaction (D_4xB_1) *i.e.* October 15th date of transplanting and protected plot. Followed by interaction (D_8xB_1) *i.e.* December 15th date of transplanting and protected plot was found to recorded significantly highest population of thrips (4.30 thrips/plant), followed by interaction (D_7xB_1) *i.e.* December 1st date of transplanting and protected recorded significantly highest population of thrips (4.23 thrips/plant). The next interaction (D_3xB_1) *i.e.* October 1st date of transplanting and protected plot recorded significantly highest population of thrips (4.15 thrips/plant) but it was at par with interaction (D_6 xB_1) *i.e.* November 15th date of transplanting and protected plot in population of thrips (4.13 thrips/plant), followed by interaction (D_5xB_1) November 1st date of transplanting and protected plot which has significantly highest population of thrips (4.05 thrips/plant). Interaction (D_1xB_1) September 1st date of transplanting and protected plot recorded significantly highest population of thrips (3.96 thrips/plant). The lowest Thrips population (3.76 thrips/plant) was recorded in interaction (D_2 xB_1) *i.e.* September 15th date of transplanting and protected plot.

Table 13: Effect of planting dates and Insecticide effect on onion thrips

Main Treatment	Sub Treatment	
MT (Date of planting)	ST	
	ST_1 (protected)	ST_2 (un protected)
MT_1 (sep-1st)	15.68 (3.96)	32.23 (5.68)
MT_2(sep-15th)	14.12 (3.76)	32.38 (5.69)
MT_3 (Oct-1st)	17.21 (4.15)	33.23 (5.76)
MT_4 (Oct-15th)	18.98 (4.36)	36.58 (6.05)
MT_5 (Nov-1st)	16.41 (4.05)	36.17 (6.01)
MT_6 (Nov-15th)	17.07 (4.13)	35.04 (5.92)
MT_7 (Dec-1st)	17.88 (4.23)	38.48 (6.20)
MT_8 (Dec-15th)	18.50 (4.30)	38.70 (6.22)

( ) figures in parentheses are square root transformed values.

Table 14: Effect of planting dates and Insecticide effect on population of thrips

Planting dates (D)	
Treatments	Mean
D_1	14.455
D_2	14.171
D_3	14.868
D_4	15.606
D_5	15.096
D_6	15.077
D_7	15.648
D_8	15.784

Protected & Un protected(B)	
Treatments	mean
Sub 1	12.35
Sub 2	17.826

Interactions (C) D X B	
Interaction	Mean
D_1 x B_1	3.96
D_1 x B_2	5.68
D_2 x B_1	3.76
D_2 x B_2	5.69
D_3 x B_1	4.15
D_3 x B_2	5.76
D_4 x B_1	4.36
D_4 x B_2	6.05
D_5 x B_1	4.05
D_5 x B_2	6.01
D_6 x B_1	4.13
D_6 x B_2	5.92
D_7 x B_1	4.23
D_7 x B_2	6.20
D_8 x B_1	4.30
D_8 x B_2	6.22

	Main Treatments	Sub Treatments	Interactions (C) D X B
CD 5%	0.05	0.02	0.05
SE(M) ±	0.02	0.01	0.02

Table 15: Effect of dates of transplanting on incidence of onion thrips *Thrips tabaci* L. during *rabi* 2015-2016

Months	Standard Weeks	Mean thrips population (nymph & adult) per plant							
		Dates of Transplanting							
		D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8
Nov-15	47	16.07	15.57	0.00	0.00	0.00	0.00	0.00	0.00
	48	40.27	39.17	45.67	45.30	32.30	0.00	0.00	0.00
Dec-15	49	36.53	38.03	45.30	43.00	39.50	0.00	0.00	0.00
	50	28.47	27.09	43.00	49.80	35.92	28.60	0.00	0.00
	51	44.60	46.53	49.80	47.33	31.35	38.60	0.00	0.00
	52	0.00	46.07	47.33	47.83	32.44	39.45	32.44	0.00
Jan-16	1	0.00	43.93	47.83	52.40	48.52	40.23	44.37	44.50
	2	0.00	0.00	52.40	40.87	46.21	41.12	44.67	41.07
	3	0.00	0.00	40.87	39.23	20.31	21.30	44.43	44.73
	4	0.00	0.00	39.23	38.83	16.32	28.62	49.97	48.07
Feb-16	5	0.00	0.00	0.00	41.20	44.65	31.50	46.97	51.23
	6	0.00	0.00	0.00	47.83	30.43	32.54	51.30	52.47
	7	0.00	0.00	0.00	0.00	33.80	23.12	52.30	52.00
	8	0.00	0.00	0.00	0.00	0.00	49.37	41.73	45.90
Mar-16	9	0.00	0.00	0.00	0.00	0.00	51.23	47.17	48.70
	10	0.00	0.00	0.00	0.00	0.00	54.93	54.93	47.17
	11	0.00	0.00	0.00	0.00	0.00	0.00	55.63	54.93
	12	0.00	0.00	0.00	0.00	0.00	0.00	59.50	68.50
SE(M) ±		0.04	0.05	0.11	0.09	0.15	0.22	0.08	0.05
C.D.at 5%		0.13	0.16	0.32	0.27	0.43	0.65	0.24	0.16

D_1 = 1st Sept 2015 D_3 = 1st Oct 2015 D_5 = 1st Nov 2015 D_7 = 1st Dec 2015
D_2 = 15th Sept 2015 D_4 = 15th Oct 2015 D_6 = 15th Nov 2015 D_8 = 15th Dec 2015

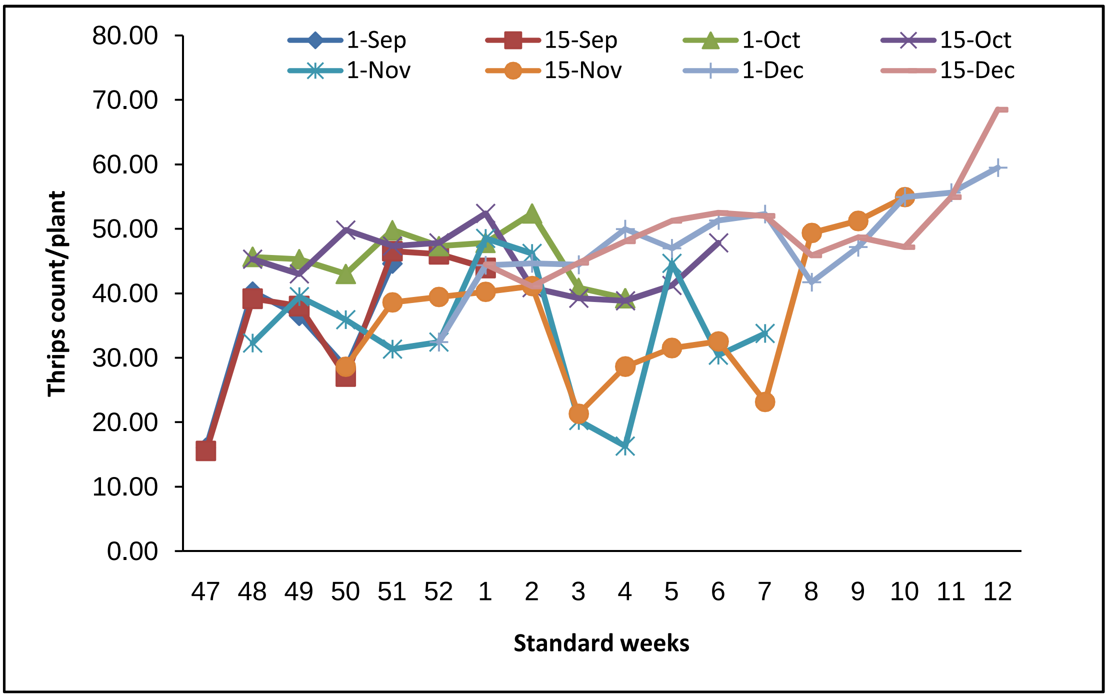


Fig.9: Effect of transplanting dates of onion on thrips at Jabalpur during 2015-16

Date of transplanting: Sep-1

First appearance of the thrips was recorded on 25th November 2015 during the 47th standard week (*i.e.* 19th November to 25th November) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average perplant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 47th SW (*i.e.* 19th November to 25th November) and reached at its peak (44.60 thrips/plant) during 51st SW (*i.e.* 17th Decemberto 23rd December). During this period maximum and minimum temperature were 24.1°C and 7.0°C, respectively, whereas, morning and evening relative humidity were 86 and 37 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 2.8 km/hrs., 7.0 per hrs., 7.3 mm, 8.1 mm and 2.0 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 51st SW there was a decline in the thrips population and it was available up to harvest of the crop.

Date of transplanting: Sep-15

First appearance of the thrips was recorded on 25th November 2015 during the 47th standard week (*i.e.* 19th November to 25th November) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 47th SW (*i.e.* 19th November to 25th November) and reached at its peak (46.53 thrips/plant) during 51st SW (*i.e.*17th December to 23rd December). During this period maximum and minimum temperature were 24.1°C and 7.0°C, respectively, whereas, morning and evening relative humidity were 86 and 37 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 2.8 km/hrs., 7.0 per hrs., 7.3 mm, 8.1 mm and 2.0 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 51st SW there was a decline in the thrips population and it was available up to harvest of the crop.

Date of transplanting: Oct-1

First appearance of the thrips was recorded on 2nd December 2015 during the 48th standard week (*i.e.* 26th November to 2nd December) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 48th SW (*i.e.* 26th November to 2nd December) and reached at its peak (52.40 thrips/plant) during 2nd SW (*i.e.* 8th January to 14th January). During this period maximum and minimum temperature were 26.7°C and 8.0°C respectively, whereas, morning and evening relative humidity were 81 and 32 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.7 km/hrs., 7.7 per hrs., 7.6 mm, 8.0 mm and 3.0 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 2nd SW there was a decline in the thrips population and it was available up to harvest of the crop.

Date of transplanting: Oct-15

First appearance of the thrips was recorded on 2nd December 2015 during the 48th standard week (*i.e.* 26th November to 2nd December) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 48th SW (*i.e.* 26th November to 2nd December) and reached at its peak (52.40 thrips/plant) during 1st SW (*i.e.* 1st January to 7th January). During this period maximum and minimum temperature were 27.5°C and 7.9°C respectively, whereas, morning and evening relative humidity were 88 and 27 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.8 km/hrs., 8.5 per hrs., 8.0 mm, 7.4 mm and 3.7 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 1st SW there was a decline in the thrips population and it was available up to harvest of the crop.

Date of transplanting: Nov-1

First appearance of the thrips was recorded on 2nd December 2015 during the 48th standard week (*i.e.* 26th November to 2nd December) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in (Table 15) and illustrated in (Figure 9).

From the figure 9 it is seen that the thrips population started increasing from 48th SW (*i.e.* 26th November to 2nd December) and reached at its peak (48.52 thrips/plant) during 1st SW (*i.e.* 1st January to 7th January). During this period maximum and minimum temperature were 27.5°C and 7.9°C respectively, whereas, morning and evening relative humidity were 88 and 27 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.8 km/hrs., 8.5 per hrs., 8.0 mm, 7.4 mm and 3.7 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 1st SW there was a decline in the thrips population and it was available up to harvest of the crop

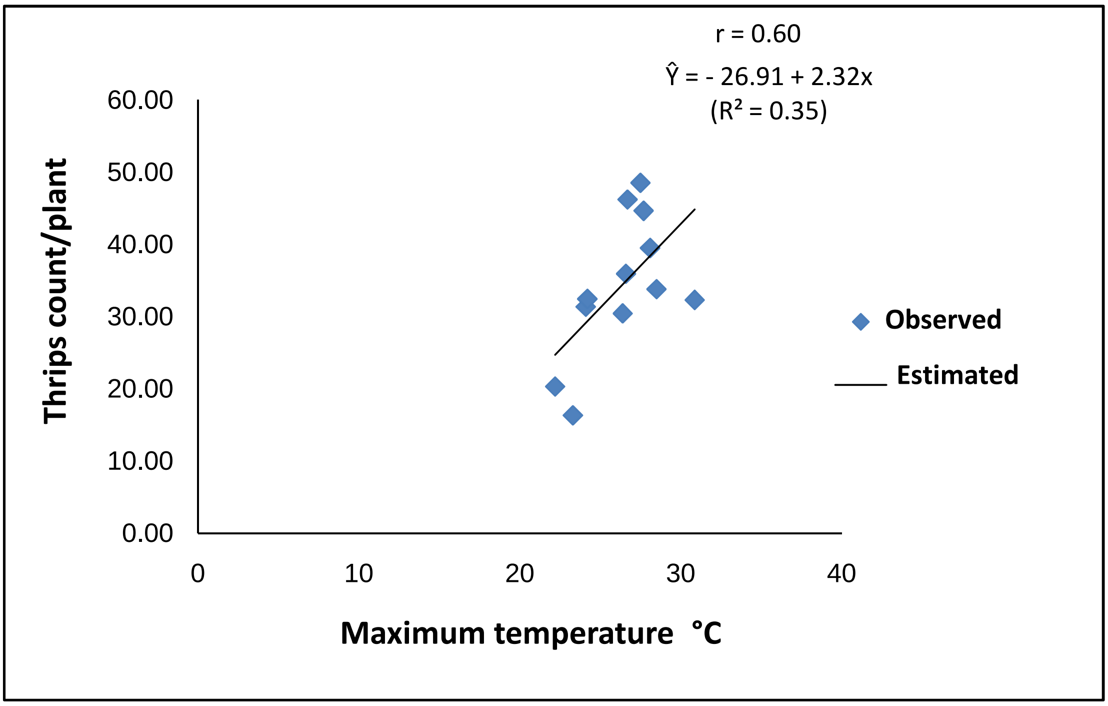


Fig.10: Regression of maximum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that maximum temperature showed a significant positive correlation (r = 0.60) with thrips population (Table 16).

The regression equations being:

$\hat{Y}$ = - 26.91 + 2.32x (R^2 = 0.35)

From the above equation it may be expressed that with every unit increase in maximum temperature there was positively increase of 2.32 thrips population per plant. (Fig.10)

The minimum temperature, sunshine and evaporation exhibited positive correlation (r = 0.10, 0.21 and 0.56). While morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlations (r = -0.40, -0.43, -0.42, -0.46, -0.46, -0.02 and -0.15, respectively) with thrips population but statistically found to be non-significant.

Table 16: Correlation (r) and regression coefficient (byx) of abiotic factors on onion thrips during *rabi* 2015-16

Weather factors	Date of transplanting															
	D_1		D_2		D_3		D_4		D_5		D_6		D_7		D_8	
	r	byx	r	byx	r	byx	r	byx	r	byx	r	byx	r	byx	r	byx
Max. temp.(°C)	-0.30 NS	-	-0.46 NS	-	0.33 NS	-	0.28 NS	-	0.60*	2.3	0.68*	2.5	0.61*	1.2	0.60*	1.19
Min. temp.(°C)	-0.35 NS	-	-0.58 NS	-	-0.05 NS	-	-0.03 NS	-	0.10 NS	-	0.44 NS	-	0.60*	1.1	0.36 NS	-
Morning Relative Humidity (RH) (%)	0.01 NS	-	0.22 NS	-	-0.61 NS	-	-0.45 NS	-	-0.40 NS	-	-0.21 NS	-	-0.54 NS	-	-.697*	-0.7
Evening RH (%)	-0.03 NS	-	-0.44 NS	-	-0.35 NS	-	-0.44 NS	-	-0.43 NS	-	-0.27 NS	-	0.02 NS	-	-0.44 NS	-
Wind velocity (km/hr)	0.48 NS	-	-0.02 NS	-	-0.53 NS	-	-0.15 NS	-	-0.42 NS	-	-0.11 NS	-	0.71**	6.3	0.50 NS	-
Sunshine(hrs)	0.32 NS	-	0.57 NS	-	-0.02 NS	-	0.07 NS	-	0.21 NS	-	0.27 NS	-	0.30 NS	-	0.57 NS	-
Rainfall (mm)	-0.36 NS	-	0	-	-0.43 NS	-	-0.41 NS	-	-0.46 NS	-	0.31 NS	-	0.28 NS	-	-0.16 NS	-
No. of rainy days	0	-	0	-	-0.43 NS	-	-0.41 NS	-	-0.46 NS	-	0.05 NS	-	0.29 NS	-	-0.09 NS	-
Morning Vapour Pressure (mm)	0	-	-0.57 NS	-	-0.17 NS	-	-0.10 NS	-	-0.02 NS	-	0.39 NS	-	0.54 NS	-	0.24 NS	-
Evening Vapour Pressure (mm)	-0.29 NS	-	-0.56 NS	-	-0.22 NS	-	-0.32 NS	-	-0.15 NS	-	0.29 NS	-	0.35 NS	-	-0.19 NS	-
Evaporation (mm)	-0.46 NS	-	0.11 NS	-	0.31 NS	-	0.27 NS	-	0.56 NS	-	0.03 NS	-	-0.19 NS	-	-0.47 NS	-
n	5		7		9		11		12		13		13		12	

* Significant at 5% level, **significant at 1% level, NS= Non-significant

D_1 = 1st Sept 2015 | D_3 = 1st Oct 2015 | D_5 = 1st Nov 2015 | D_7 = 1st Dec 2015

D_2 = 15th Sept 2015 | D_4 = 15th Oct 2015 | D_6 = 15th Nov 2015 | D_8 = 15th Dec 2015

Date of transplanting: Nov-15

First appearance of the thrips was recorded on 10th December 2015 during the 50th standard week (*i.e.*10th December to 16th December) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 50th SW (*i.e.* 10th December to 16th December) and reached at its peak (54.93 thrips / plant) during 10th SW (*i.e.* 5th March to 11th March). During this period maximum and minimum temperature were 31.9°C and 17°C respectively, whereas, morning and evening relative humidity were 88 and 47 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 3.5 km/hrs., 8 per hrs., 14.1 mm, 15.3 mm and 2 mm, respectively and 29.6 mm rainfall was recorded in 2 days during this period. After 10th SW there was a decline in the thrips population and it was available up to harvest of the crop

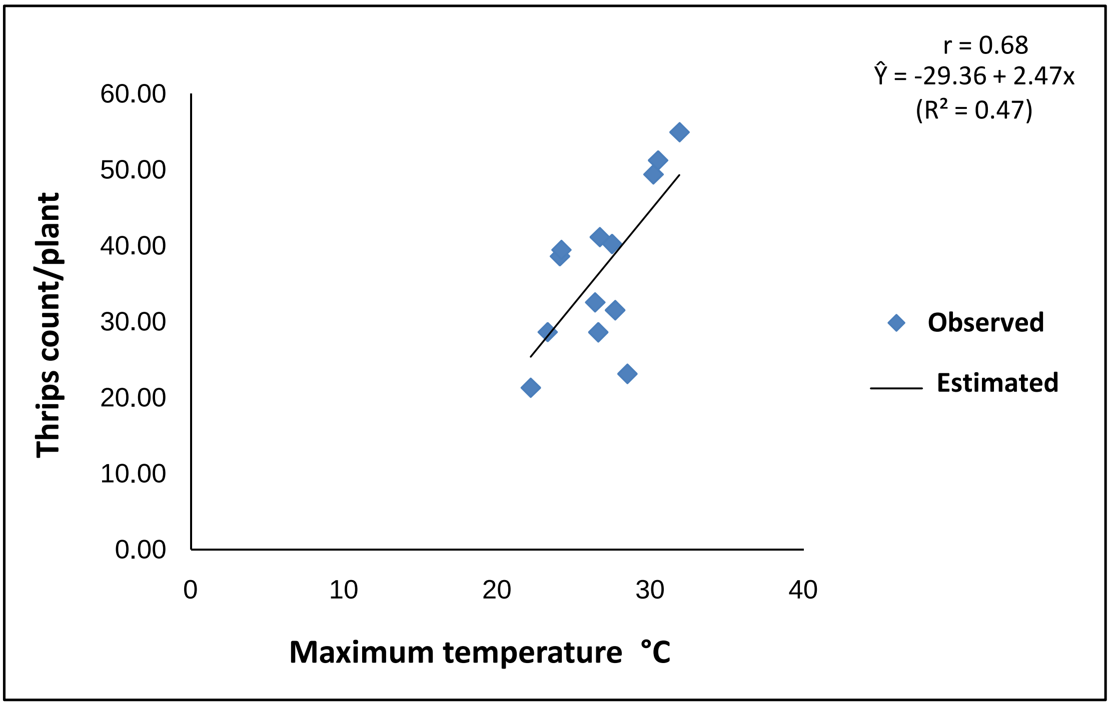


Fig.11: Regression of maximum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that maximum temperature showed a significant positive correlation (r = 0.68) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = -29.36 + 2.47x$ ($R^2 = 0.47$)

From the above equation it may be expressed that with every unit increase in maximum temperature there was positively increase of 2.47 thrips population per plant (Fig.11).

The minimum temperature, sunshine,rainfall, no. of rainy days, morning and evening vapour pressure and evaporation exhibited positive correlation (r = 0.44, 0.27, 0.31, 0.05, 0.39, 0.29 and 0.03). While morning and evening relative humidity and wind velocity showed negative correlation (r = -0.21, -0.27 and -0.11) with thrips population but statistically found to be non-significant.

Date of transplanting: Dec-1

First appearance of the thrips was recorded on 26th December 2015 during the 52th standard week (*i.e.* 24th December to 31st December) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 52th SW (*i.e.* 24th December to 31st December) and reached at its peak (59.50 thrips / plant) during 12th SW (*i.e.* 19th March to 25th March). During this period maximum and minimum temperature were 34.5°C and 14.1°C respectively, whereas, morning and evening relative humidity were 67 and 18 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 3.3 km/hrs., 10.2 per hrs., 10.5 mm, 7.3 mm and 1.8 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 12th SW there was a decline in the thrips population and it was available up to harvest of the crop

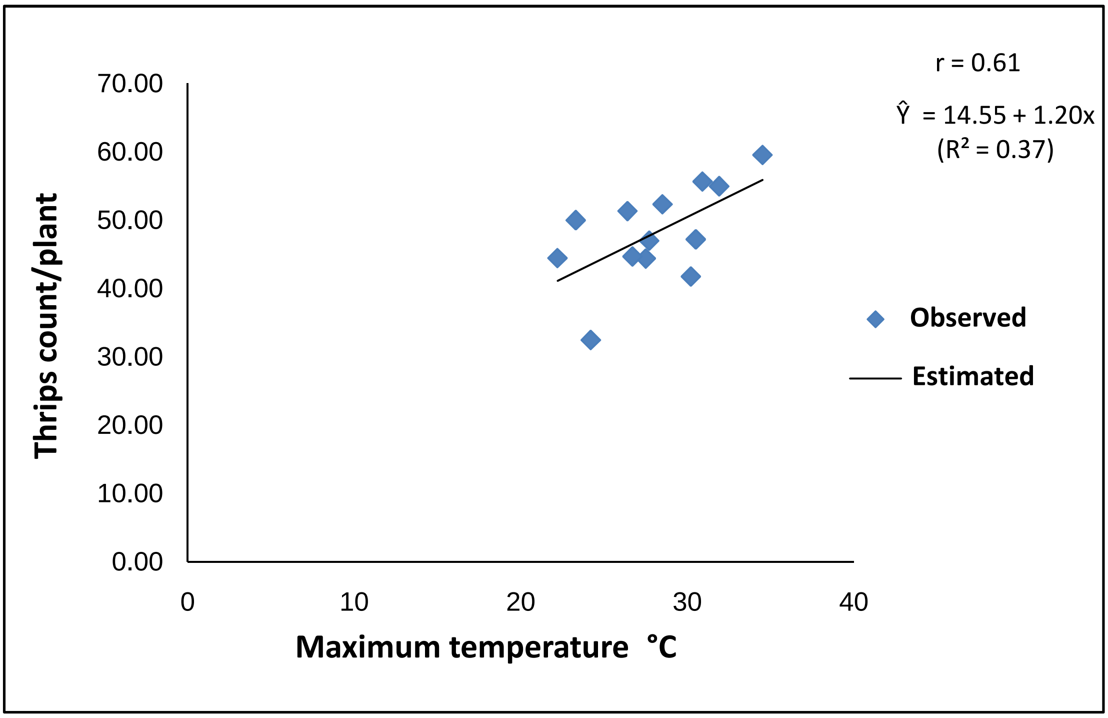


Fig.12: Regression of maximum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that maximum temperature showed a significant positive correlation (r = 0.61) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = 14.55 + 1.20x$ ($R^2 = 0.37$)

From the above equation it may be expressed that with every unit increase in maximum temperature there was positively increase of 1.20 thrips population per plant (Fig.12).

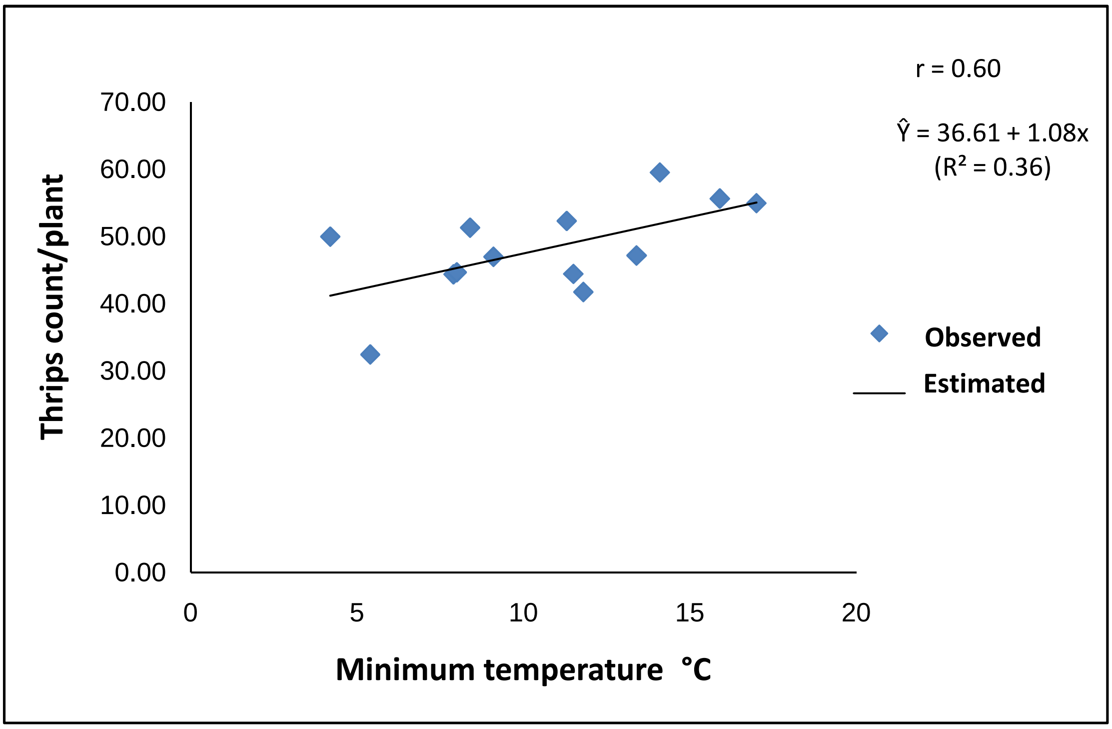


Fig.13: Regression of minimum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that minimum temperature showed a significant positive correlation (r = 0.60) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = 36.61 + 1.08x$ ($R^2 = 0.36$)

From the above equation it may be expressed that with every unit increase in minimum temperature there was positively increase of 1.08 thrips population per plant (Fig.13).

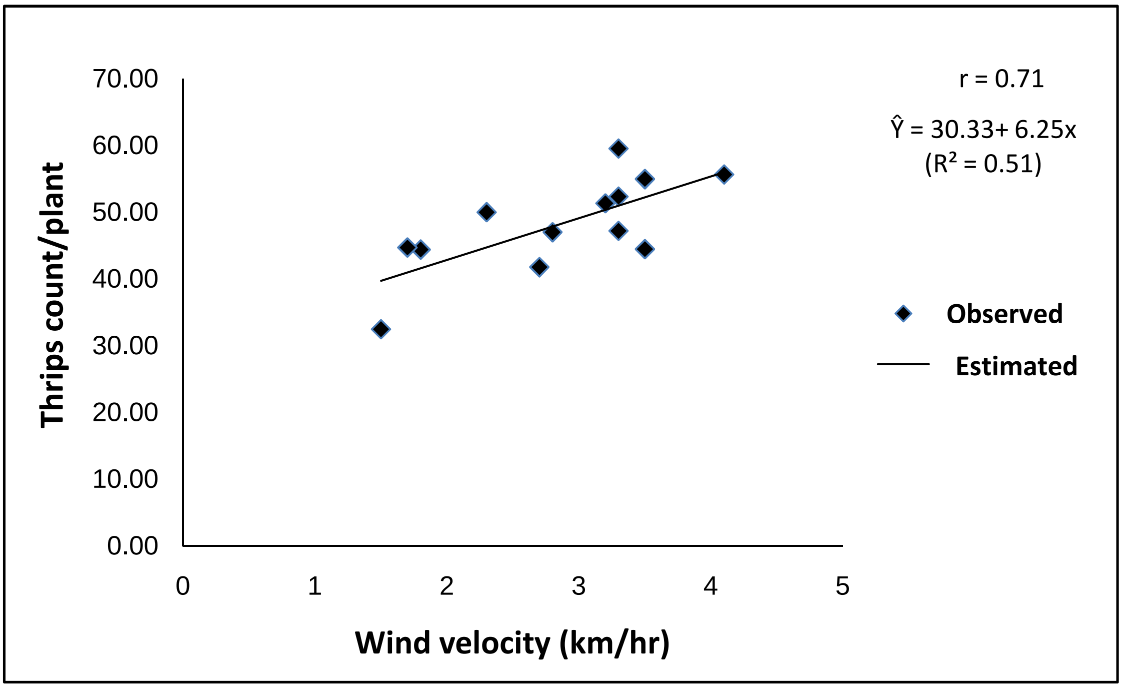


Fig.14: Regression of wind velocity on thrips infesting onion

Correlation studies

Correlation studies revealed that wind velocityshowed a significant positive correlation (r = 0.71) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = 30.33 + 6.25x$ ($R^2 = 0.51$)

From the above equation it may be expressed that with every unit increase in wind velocity here was positively increase of 6.25 thrips population per plant (Fig.14).

Evening relative humidity, sunshine, rainfall, no. of rainy days, morning and evening vapour pressure exhibited positive correlation (r = 0.02, 0.30, 0.28, 0.29, 0.54, and 0.35, respectively). While morning relative humidity and evaporation showed negative correlation (r = -0.54 and -0.19, respectively) with thrips population but statistically found to be non-significant.

Date of transplanting: Dec-15

First appearance of the thrips was recorded on 4th January 2016 during the 1st standard week (*i.e.*1st January to 7th January) and thereafter observations were recorded regularly twice in a standard week. The number of thrips (nymph & adult) was worked out as weekly average per plant and presented in Table 15 and illustrated in Figure 9.

From the figure 9 it is seen that the thrips population started increasing from 1st SW (*i.e.* 1st January to 7th January) and reached at its peak (68.50 thrips / plant) during 12th SW (*i.e.* 19th March to 25th March). During this period maximum and minimum temperature were 34.5°C and 14.1°C respectively, whereas, morning and evening relative humidity were 67 and 18 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 3.3 km/hrs., 10.2 per hrs., 10.5 mm, 7.3 mm and 1.8 mm, respectively and 0 mm rainfall was recorded in 7 days during this period. After 12th SW there was a decline in the thrips population and it was available up to harvest of the crop

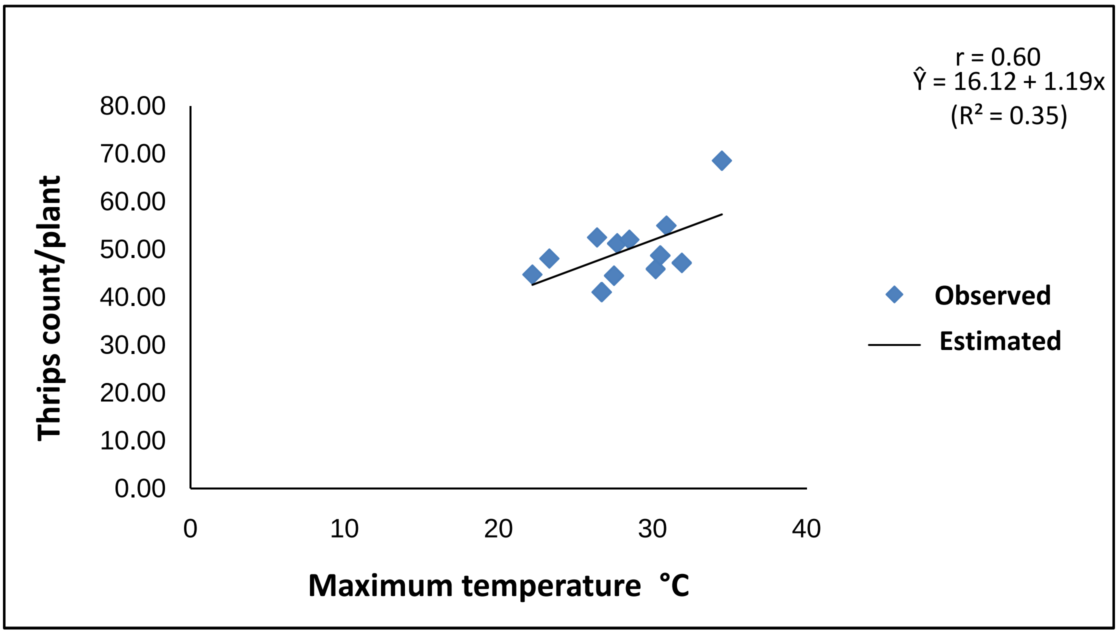


Fig.15: Regression of maximum temperature on thrips infesting onion

Correlation studies

Correlation studies revealed that maximum temperature showed a significant positive correlation (r = 0.60) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = 16.12 + 1.19x$ ($R^2 = 0.35$)

From the above equation it may be expressed that with every unit increase in maximum temperature there was positively increase of 1.19 thrips population per plant (Fig.15).

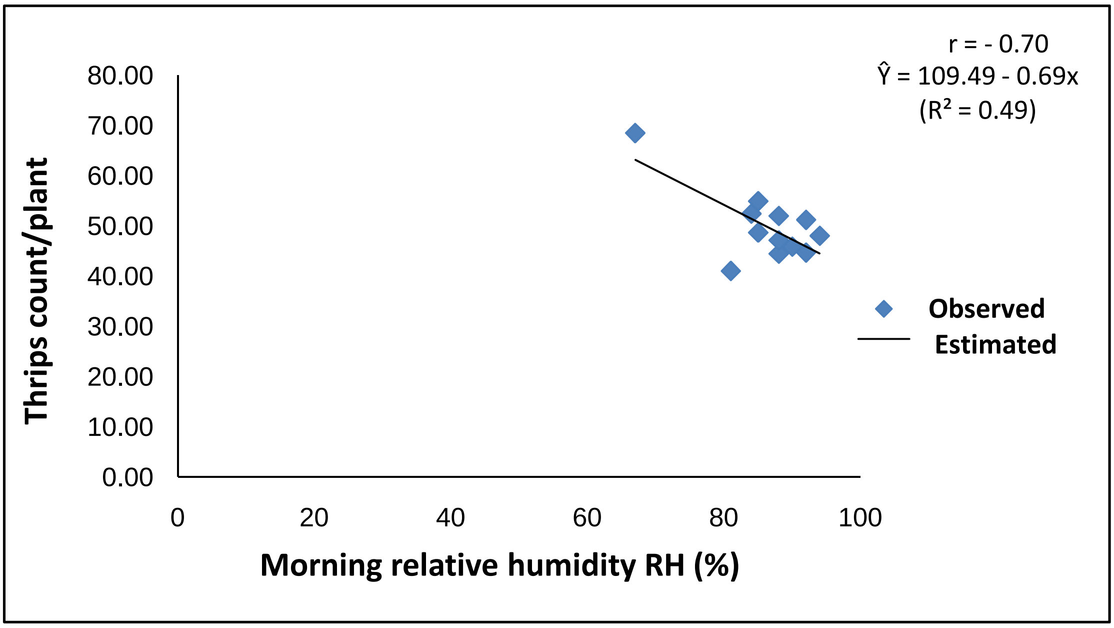


Fig.16: Regression of morning relative humidity on thrips infesting onion

Correlation studies

Correlation studies revealed that morning relative humidity showed a significant negative correlation (r = -0.70) with thrips population (Table 16).

The regression equations being:

$\hat{Y} = 109.49 - 0.69x$ ($R^2 = 0.49$)

From the above equation it may be expressed that with every unit increase in morning relative humidity there was negatively decrease of -0.69 thrips population per plant (Fig.16).

Minimum temperature, wind velocity, sunshine and morning vapour pressure exhibited positive correlation (r = 0.36, 0.50, 0.57 and 0.24 respectively). While evening relative humidity, rainfall, no. of rainy days, evening vapour pressure and evaporation showed negative correlation (r = -0.44, -0.16, -0.09, -0.19 and -0.47 respectively) with thrips population but statistically found to be non-significant.

DISCUSSION

The findings on insect pest succession, population dynamics and management of thrips infesting onion, the effect of planting dates on thrips incidence and efficacy of insecticides and NSKE against onion thrips have been discussed below:

5.1 To study the succession of insects and natural enemies in onion

During the course of study from November 2015 to February 2015**,** incidence of different insect pests on onion was recorded regularly at different stages of the crop *i.e.* vegetative stage, flowering stage, maturity stage and at harvest. In all, three insect pests, one non insect pest and one predator order listed below were recorded on different stages of the crop.

1. Onion Thrips, *Thrips tabaci* Lindeman
2. Cut worm, *Agrotis ipsilon* Hufnagel
3. Fruit borer, *Helicoverpa armigera* Hubner
4. Red spider mite (*Tetranychus telarius* Linnaeus)
5. Spiders

Total of three insects and one non insect pest appeared as pests in different stages of crop growth belonging to three orders viz. Thysanoptera (Family: Thripidae), Lepidoptera (Family: Noctuidae), Tetranychidae (Family: Trombidiformes) and a group of predators namely spiders (Order: Arachnida) were recorded.

One of the important limiting factor in the cultivation of onion is insect pests. Onion thrips, *Thrips tabaci* Lindeman, cutworm, *Agrotis ipsilon* Hufnagel, fruit borer, *Helicoverpa armigera* Hubner, causes significant damage to the crop.

5.1.1 Onion Thrips (*Thrips tabaci* Lindeman): (Thysanoptera: Thripidae)

The thrips appeared when the crop age was about 32 days old and their activity continued till the maturity of the crop. the pest was not only present throughout the growing stage of the crop but plant show curling, twisting, turn in to white blotches and silvery patches on leaves and resulted in yield loss up to 50 percent. If the attack is on seed crop, the flowers became discoloured, deformed and dry. Hence it considered as a major pest of onion.

Present findings are in accordance with those of Montano et al. (2011), Jenser et al. (2003), Kumar et al. (2001), Childres (1997), Fournier et al. (1995), Gupta et al. (1994), they also reported thrips as an important sucking pest of onion which was present throughout the growing period of the crop.

5.1.2 Cut worm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera)

Cutworm appeared after transplanting when the crop age was about 32 days old and their activity continued till the reproductive stage of the crop. Thus, the pest was not only present throughout the growing stage of crop, but it caused young larva feeds on tender foliage and grown up larva cut the stem at collar region. The infested fields sometimes looked as it has been grazed. In grown crops it usually damaged tender shoots and branches. After bulb development its damage was confined to the bulb, reducing the market value. It was considered to be one of the most important pest of onion.

5.1.3.1 Fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera)

Fruit borer also appeared when the crop age was about 37 days old and their activity continued till the reproductive stage of the crop. Thus, the pest was not only present throughout the growing stage of crop, but the larvae caused leaf damage, sometimes entire small plants consumed. Larvae bore into leaves, hide inside the leaves during the day time, severe infestations caused defoliation. It was also considered to be one of the important pests of onion.

5.1.4 Red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes)

The red spider mite appeared when the crop age was about 68 days old and their activity continued for a very short period (up to 106th day old crop). It direct damage in terms of loss of chlorophyll, stunting of growth, stippling, leaf yellowing, defoliation, leaf burning, reduction in size and quality of bulbs, appearance of various types of plant deformities, followed by death etc.

5.1.5 Natural enemies

The first predation of spiders was observed during the vegetative stage of the crop *i.e.* about 12 days old crop (after transplanting). It is evident that the spiders were available on the crop up to maturity stage *i.e.* 110 days old crop. In accordance with the present findings Mallinath et al. (2014) also reported spiders was a predatory order on onion.

5.2 To study the population dynamics of major insect pests of onion in relation to weather parameters

5.2.1 Onion Thrips (*Thrips tabaci* Lindeman): (Thysanoptera: Thripidae)

The thrips was first recorded in the first week of December (31.60 thrips/ plant) *i.e.* 2^{nd} December 2015 during the 48^{th} standard week. The activity of the pest continued from 2^{nd} December (*i.e.*26^{th} November to 2^{nd} December, 48^{th} SW) to third week of February (*i.e.* 12^{th} to 18^{th} February, 7^{th} SW). In conformity with the present findings Verma et al. 2012. also reported the activity of *T. tabaci* from December to March. Tripathy et al. (2012) also recorded almost similar findings. The peak activity of the pest was observed (49.60 thrips/plant) during 1^{st} SW (*i.e.* 1^{st} to 7^{th} January). During this period maximum and minimum temperature were 27.5°C and 7.9°C respectively, whereas, morning and evening relative humidity were 88 and 27 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.8 km/hrs., 8.5 per hrs., 8 mm, 7.4 mm and 3.7 mm, respectively and 0 mm rainfall was recorded in 6 days during this period. Tripathy et al. (2012) reported the peak of thrips population during first week of January on onion in Odisha.

Correlation between maximum temperature and thrips population was found significantly positive (r=0.58*), while rest of the weather parameters were statistically found to be non-significant. Observations are comparable to those of Domiciano et al. (1993) who observed that the typical condition with temperature of 20.29°C in absence of rainfall favoured rapid increase in the thrips population. Lorini and Dezordi (1990) reported that high temperature and lack of rainfall increased population density of *T. tabaci* on garlic in Brazil. Verma et al. (2012) also reported that in garlic the rate of development of *T. tabaci* was positively affected by increased temperature and decreased by increased relative humidity.

5.2.2 Cutworm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera)

The Cutworm, *A. ipsilon* Hufnagel was first recorded in the first week of December and 22.40 percent leaves were infested by cutworm *i.e.* 2nd December 2015 during the 48th standard week (SW). The activity of the pest continued from 2nd December (*i.e.* 26th November to 2nd December, 48th SW) to second week of January 2nd SW (*i.e.* 8th to 14th January).

The peak activity of the pest was 31.67 percent leaves infested by cutworm during 51th SW (*i.e.* 17th to 23rd December). During this period maximum and minimum temperature were 24.1°C and 7.0°C respectively, whereas, morning and evening relative humidity were 86 and 37 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation 2.8 km/hrs., 7.0 per hrs., 7.3 mm, 8.1 mm and 2 mm, respectively. However, no rainfall was recorded during this period. After 51th SW there was a decline in the cutworm population and it was available upto 2nd SW (*i.e.* 8th to 14th January).

correlation between various abiotic factors and cut worm population showed that morning relative humidity, evening relative humidity, wind velocity were found to have positive correlation (r=0.11, 0.29, 0.73, respectively). While no. of rainy days and morning vapour pressure were found to have no correlation. While maximum & minimum temperature, sunshine hour, rainfall, evening vapour pressure and evaporation showed negative correlation (r= -0.45, -0.21, -0.30, -0.19, -0.17, -0.67, respectively) with leaves infested by cutworm but statistically found to be non significant.

5.2.3 Fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera)

The Fruit borer, *H. armigera* Hubner was first recorded in the second week of December (0.22 larvae/plant) *i.e.* 7th December (49th SW). The activity of the pest continued from 7th December (*i.e.* 3rd to 9th December, 49th

SW) to fourth week of January (*i.e.* 22nd to 28th January, 4th SW). The peak activity of the pest was observed 1.43 larvae/ plant during 2nd SW (*i.e.* 8th to 14th January).

During this period maximum and minimum temperature were 26.7°C and 8.0°C respectively, whereas, morning and evening relative humidity were 81 and 32 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation 1.7 km/hrs., 7.7 per hrs., 7.6 mm, 8 mm and 3 mm, respectively and 0 mm rainfall was recorded in a 7 days during this period. After 3rd SW there was a decline in the fruit borer population and it was available up to 4th SW (*i.e.* 22nd to 28th January, 2015).

Correlation studies revealed that maximum temperature, sunshine hours and evaporation showed positive correlation (r=0.19, 0.004 and 0.59, respectively). The minimum temperature, morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlation (r= -0.002, -0.58, -0.08, -0.41, -0.07, -0.07, -0.20 and -0.06, respectively) with fruit borer population but statistically found to be non significant.

5.2.4 Red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes)

The Red spider mite, *T. telarius* Linnaeus was first recorded (1.93 red spider mites/ 3 leaves) in the first week of January (*i.e.* 7th January, (1st SW). The activity of the pest was continued from first week of January (*i.e.* 1st January to 7th January) to third week of February (*i.e.* 12th to 18th February, SW (7th). The peak activity of the pest was (2.80) during 5th SW (*i.e.* 29th January to 4th February).

In the present study, during this peak activity period, maximum and minimum temperature were 27.7°C and 9.1°C, respectively, whereas, morning and evening relative humidity were 92 and 35 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 2.8 km/hrs., 9.3 per hrs., 8.9 mm, 9.3 mm and 2.5 mm, respectively and 0 mm rainfall was recorded in 7 days during this period.

5.3 Management of onion thrips:

5.3.1 To study the efficacy of insecticides and NSKE against thrips on onion

The efficacy of five insecticides and NSKE namely Profenophos 50% EC @ 500 ml a.i./ha, Cypermethrin 10% EC @ 100 ml a.i./ha, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha, Chlorpyrifos 20% EC @ 200 ml a.i./ha, Triazophos 40% EC @ 400 ml a.i./ha, NSKE 5% @ 1250 g a.i./ha, were tested against thrips on onion. Results revealed that all the insecticides showed their effectivity against thrips.

Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to have significantly lowest thrips population (12.82 thrips/plant) than all other treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (14.78 thrips/plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (16.44 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.43 thrips/plant) was found to be the least effective in comparison to other insecticides but it was at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (19.17 thrips/plant) and significantly better than control. The findings are in agreement with Ali et al. 2015, They reported that Imidacloprid 20% SL and Endosulphan 35% EC were very effective in controlling thrips in onion crop. Similarly, Ullah et al. 2010 as reported that Imidacloprid 200 SL was significantly effective against onion thrips as compared with chemical insecticides.

Mallinath and Biradar 2013 Reported that among the different treatments, Imidacloprid 70 WG @ 0.33 g/l and Thiamethoxam 25 WG @ 0.2 g/l found significantly superior over rest of the treatments. Kadri and Goud (2006) studied the effectiveness of Imidacloprid, Emamectin benzoate and Acetamiprid against onion thrips and discovered that these insecticides have significantly reduced thrips populations Hazara et al. (1999) evaluated the efficacy of Lambda cyhalothrin, Endosulfan, Imidacloprid and Profenophos against thrips.

Neem has been found to be a very good alternative to synthetic insecticides and also found neem seed kernel extract (NSKE) to be effective against this pest Vijayalakshmi et al. 1995.

On the contrary Gupta and Sharma (1998) found botanical insecticides ineffective. However, Hazara et al. (1999), Patel et al. (2001) and Noor (2001) found Profenophos as effective against onion and chilli thrips.

5.4.1 To study the effect of planting dates on thrips

Transplanting were staggered in order to assess whether early planting had any advantage in reducing insect pests and increasing bulb yield of onion. Figures 9 indicate that population of thrips was low up to the third week of November even on the early transplant and it dosenot therefore require any insecticidal spray. The results regarding mean thrips population (table 13) showed that maximum mean thrips population of 15.78/plant was recorded in the plots on December 15th (D_8) and least mean thrips population was 14.17/plant in the plots on September 15th (D_2). The peak mean thrips population (68.50/plant) (table-14) was recorded in the 4th week of March and lowest mean thrips population (15.57 thrips/plant) in fourth week of September. The thrips population showed a rising trend from fourth week of September to 4th week of March and then increased upto last week of March.

The present finding is supported by Ibrahim and Adesiyun. 2009. They also reported that January planted crop had lower thrips population and March and April transplanted had significantly higher thrips population. Dharmatti et al. 2013. also supported the present finding and reported that November 1st and December 1st transplanted seedlings had a peak population of thrips in protected as well as in unprotected plots.

Ibrahim and Adesiyun. 2010. also found the same finding that November transplanted onion had a peak population of thrips. In late February while December and January transplanted onion had a peak population in March and February, respectively. Sathe and Pranoti, 2015. also indicated that in onion and garlic incidence of thrips was started from November and steadily increased during the hot months.

In conformity with the present findings Verma et al. (2012) also reported that the activity of *T. tabaci* was from December to March. While Tripathy et al. (2012) reported that the high thrips population in the month of March might be due to high temperature in this growth period which indicated by the positive correlation between mean thrips population per plant and weekly maximum temperature (SW) and the low thrips population in the month of September might be due to high relative humidity. They also suggested transplanting of onion on 1st week of November to obtain lower incidence of pests and diseases.

This agrees with the findings of Lorini and and Dezordi (1990) as they reported that high temperature and lack of rainfall increased population density of *T. tabaci* on garlic in Brazil. Verma et al. (2012) also reported that the rate of development of *T. tabaci* is positively affected by increased temperature and decreased by increased relative humidity.

This supported the findings of Lewis (1997) where he observed that time of sowing and harvesting crops can also reduce the severity of injury. Kisha (1977) stated that early transplanted onions were usually well established before attack began in mid- February of 1971.

5.4.2 Insecticide effect: (Factor B)

Evaluation of insecticide effect on population of thrips in the subplot (protected) revealed that significantly lowest population of thrips (12.35 thrips/plant) and subplot (unprotected) found to be highest population of thrips (17.83 thrips/plant) was recorded.

Dharmatti et al. 2013. also supported the present finding and reported that November 1st and December 1st transplanted seedlings had a peak population of thrips in protected as well as in unprotected plots.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

Present research work on "Succession and population dynamics of insect pest complex of onion and management of thrips" was carried out in the experimental field of Department of Horticulture, JNKVV, Jabalpur, (M.P.) during 2015-16.

The experiment was conducted with the following objectives

6.1.1 To study the succession of insect pest complex on onion

6.1.2 To study the population dynamics of major insect pests of onion

6.1.3 Management of onion thrips :

a) To study the effect of planting dates on thrips incidence

b) To study the efficacy of insecticides and NSKE against onion thrips

6.1.1 To study the succession of insect pest complex on onion

Studies on succession of insects and natural enemies revealed that insects which were observed in onion crop includes, onion thrips, *Thrips tabaci* Lindeman: (Thysanoptera: Thripidae), cutworm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera), fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera), red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes) and Spiders.

Among them, thrips appeared when the crop age was about 32 days old *i.e.* during vegetative stage and remained available upto maturity stage of the crop.

Cutworm was the next insect pest appeared on the crop, when the crop age was about 32 days old *i.e.* during the vegetative stage and remained available upto reproductive stage (flowering/ fruiting stage) of the crop *i.e.* 14th January.

Fruit borer was also appeared at vegetative stage when the crop was about 37 days old and remained available upto the reproductive stage (flowering/ fruiting stage) of the crop *i.e.* 25th January.

Red spider mite was appeared on the crop, when the crop age was about 68 days old and present for a very short duration (up to 107th day) *i.e.* during the maturity stage of the crop.

Spiders were appeared on the crop, when the crop age was about 12 days old *i.e.* during vegetative stage and remained available upto maturity stage of crop.

6.1.2 To study the population dynamics of major insect pests of onion.

6.1.2.1 Onion Thrips, *Thrips tabaci* Lindeman: (Thysanoptera: Thripidae)

The thrips *T. tabaci* was first recorded in the first week of December (31.60 thrips/plant) *i.e.* 2nd December 2015 during the 48th standard week (SW). The activity of the pest continued from 2nd December (*i.e.* 26th November to 2nd December, 48th SW) to third week of February (*i.e.* 12th to 18th February, 7th SW). The peak activity of the pest was observed (49.60 thrips / plant) during 1st SW (*i.e.* 1st to 7th January). During this period maximum and minimum temperature were 27.5°C and 7.9°C, respectively, whereas, morning and evening relative humidity were 88 and 27 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation were 1.8 km/hrs., 8.5 per hrs., 8 mm, 7.4 mm and 3.7 mm, respectively and 0 mm rainfall was recorded in 6 days during this period.

Correlation between maximum temperature and thrips population was found to be significant and positive (r=0.58). The minimum temperature, sunshine, morning vapour pressure and evaporation exhibited positive correlation (r=0.11, 0.19, 0.001 and 0.52, respectively). While, morning & evening relative humidity, wind velocity, rainfall, no. of rainy days and evening vapour pressure showed negative correlation (r= -0.33, -0.41, -0.39, -0.43, -0.43 and -0.15, respectively) with thrips population but statistically found to be non significant.

6.1.2.2 Cutworm, *Agrotis ipsilon* Hufnagel: (Noctuidae: Lepidoptera)

The cutworm, *A. ipsilon* Hufnagel was first recorded in the first week of December 22.40 percent leaves infested by cutworm *i.e.* 2nd December 2015 during the 48th standard week (SW). The activity of the pest continued from 2nd December (*i.e.* 26th November to 2nd December, 48th SW) to second week of January 2nd SW (*i.e.* 8th to 14th January).

. The peak activity of the pest (31.67 percent leaves infestation was observed) during 51th SW (*i.e.* 17th to 23rd December). During this period maximum and minimum temperature were 24.1°C and 7.0°C respectively, whereas, morning and evening relative humidity were 86 and 37 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation 2.8 km/hrs., 7.0 per hrs., 7.3 mm, 8.1 mm and 2 mm, respectively. However, no rainfall was recorded during this period. After 51th SW there was a decline in the cutworm population and it was available upto 2nd SW (*i.e.* 8th to 14th January).

Correlation between various abiotic factors and cutworm population showed that, morning relative humidity, evening relative humidity, wind velocity were found have positive correlation (r=0.11, 0.29, 0.73, respectively). While no. of rainy days and morning vapour pressure were found have zero correlation. Maximum & minimum temperature, sunshine hour, rainfall, evening vapour pressure and evaporation showed negative correlation (r= -0.45, -0.21, -0.30, -0.19, -0.17, -0.67, respectively) with leaves infested by cutworm but statistically found to be non significant.

6.1.2.3 Fruit borer, *Helicoverpa armigera* Hubner: (Noctuidae: Lepidoptera)

The Fruit borer, *H. armigera* Hubner was first recorded in the second week of December 0.22 larvae/plant *i.e.* 7th December (49th SW). The activity of the pest continued from 7th December (*i.e.* 3rd to 9th December, 49th SW) to fourth week of January (*i.e.* 22nd to 28th January, 4th SW). The peak activity of the pest was observed 1.43 larvae/ plant during 2nd SW (*i.e.* 8th to 14th January).

During this period maximum and minimum temperature were 26.7°C and 8.0°C respectively, whereas, morning and evening relative humidity were 81 and 32 percent respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation 1.7 km/hrs., 7.7 per hrs., 7.6 mm, 8 mm and 3 mm, respectively and 0 mm rainfall was recorded in a 7 days during this period. After 3rd SW there was a decline in the fruit borer population and it was available up to 4th SW (*i.e.* 22nd to 28th January, 2015).

Correlation studies revealed that maximum temperature, sunshine hours and evaporation showed positive correlation (r=0.19, 0.004 and 0.59, respectively). Minimum temperature, morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlation (r= -0.002, -0.58, -0.08, -0.41, -0.07, -0.07, -0.20 and -0.06, respectively) with fruit borer population but statistically found to be non significant.

6.1.2.4 Red spider mite (*Tetranychus telarius* Linnaeus): (Tetranychidae: Trombidiformes)

The Red spider mite, *T. telarius* Linnaeus was first recorded 1.93 red spider mites/3 leaves in the first week of January (*i.e.* 7th January, (1st SW). The activity of the pest was continued from first week of January (*i.e.* 1st January to 7th January) to third week of February (*i.e.* 12th to 18th February, 7th SW). The peak activity of the pest (2.80) during 5th SW (*i.e.* 29th January to 4th February).

In the present study, during its peak activity period, maximum and minimum temperature were 27.7°C and 9.1°C, respectively, whereas, morning and evening relative humidity were 92 and 35 percent, respectively. Wind velocity, sunshine, morning & evening vapour pressure and evaporation 2.8 km/hrs., 9.3 per hrs., 8.9 mm, 9.3 mm and 2.5 mm, respectively and 0 mm rainfall was recorded in 7 days during this period.

Correlation studies revealed that, morning relative humidity, and sunshine showed positive correlation (r=0.43 and 0.60). While maximum temperature, minimum temperature, evening relative humidity, wind velocity, rain fall and no. of rainy days, morning & evening vapour pressure and evaporation showed negative correlation (r= -0.19, -0.40, -0.16, -0.10, -0.05, -0.05, -0.37, -0.42 and -0.02, respectively) with red spider mite population but statistically were found non-significant.

6.1.3 Management

6.1.3.1 To study the efficacy of insecticides and NSKE against thrips on onion

The efficacy of five insecticides and NSKE, namely Profenophos 50% EC @ 500 ml a.i./ha, Cypermethrin 10% EC @ 100 ml a.i./ha, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha, Chlorpyrifos 20% EC @ 200 ml a.i./ha, Triazophos 40% EC @ 400 ml a.i./ha, NSKE 5% @ 1250 g a.i./ha were tested against thrips on onion. Results revealed that all the insecticides showed their effectivity against thrips. Among the treatments, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found have significantly lowest thrips population (12.82 thrips/plant) than all other treatments but it was at par with Triazophos 40% EC @ 400 ml a.i./ha (14.78 thrips/plant). Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha (16.44 thrips/plant). Treatment NSKE 5% @ 1250 g a.i./ha (24.43 thrips/plant) was found to be the least effective in comparison to other insecticides but at par with Chlorpyrifos 20% EC @ 200 ml a.i./ha (19.17 thrips/plant) and significantly better than control (53.89 thrips/plant).

6.1.3.2 To study the effect of planting dates on thrips: (Factor D)

The results regarding different date of transplanting evaluated, mean thrips population (table 15) showed that maximum mean thrips population of 15.78/ plant was recorded in the crop planted on December 15th (D_8) and least mean thrips population was 14.17/ plant in the crop planted on September 15th (D_2). The peak mean thrips population (68.50/plant) (table-14) was recorded in the 4th week of March and lowest mean thrips population (15.57 thrips/plant) in fourth week of September. The thrips population showed a rising trend from fourth week of September to 4th week of March and then increased upto last week of March. The high thrips population in the month of March might be due to high temperature in this growth period which indicated significant positive correlation between mean thrips population per plant and weekly maximum temperature (SW) and the low thrips population in the month of September might be due to high relative humidity.

6.1.3.3 Insecticide effect : (Factor B)

Evaluation of Insecticide effect on population of thrips in the subplot (protected, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha) revealed that significantly lowest population of thrips (12.35 thrips/plant) and subplot (unprotected) found to have highest population of thrips (17.83 thrips/plant).

6.2 Conclusion

Three different species of insect pests, one non insect pest and one natural enemy order were recorded on the onion crop at experimental field of Department of Horticulture, JNKVV, Jabalpur, (M.P) during *rabi* 2015-16. Which represented three pest orders viz. Thysanoptera (Family: Thripidae), Lepidoptera (Family: Noctuidae), Tetranychidae (Family: Trombidiformes) and a group of predators namely spiders, Order: Arachnida were also recorded.

The thrips appeared when the crop age was about 32 days old and their activity continued till the maturity of the crop. Cut worm appeared after transplanting when the crop age was about 32 days old and their activity continued till the reproductive stage of the crop. Fruit borer also appeared when the crop age was about 37 days old and their activity continued till the reproductive stage of the crop. Red spider mite appeared when the crop age was about 68 days old and their activity continued for a very short period (up to 106th day old crop).The first predation of spiders was observed during the vegetative stage of the crop *i.e.* about 12 days old crop (after transplanting) and remained available from vegetative stage to harvesting of crop.

The thrips *T. tabaci* was first recorded in the first week of December *i.e.* 2nd December 2015 during the 48th standard week and remained available upto maturity stage of the crop with. The peak activity during 1st SW (*i.e.* 1st to 7th January).

Correlation between various abiotic factors and thrips population showed that maximum temperature was found to have significant positive correlation. Further, minimum temperature, sunshine, morning vapour pressure and evaporation exhibited positive correlation. While morning & evening relative humidity, wind velocity, rainfall, no. of rainy days and evening vapour pressure showed negative correlation with thrips population but statistically found to be non-significant.

The activity of cutworm, *A. ipsilon* was first recorded in the first week of December *i.e.* 2nd December 2015 during the 48th standard week, with peak activity during 51th SW (*i.e.* 17th to 23rd December).

Correlation between various abiotic factors and cutworm population showed that, morning relative humidity, evening relative humidity, wind velocity were found to have positive correlation. While no. of rainy days and morning vapour pressure were found to have zero correlation. While maximum & minimum temperature, sunshine hour, rainfall, evening vapour pressure and evaporation showed negative correlation with leaves infested by cutworm but statistically found to be non significant.

The fruit borer, *H. armigera* was first recorded in the second week of December (*i.e.* 7th December 49th SW), with peak activity during 2nd SW (*i.e.* 8th to 14th January).

Correlation studies revealed that maximum temperature, sunshine hours and evaporation showed positive correlation. Further, minimum temperature, morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlation with fruit borer population but statistically found to be non-significant.

The Red spider mite, *T. telarius* was first recorded in the first week of January (*i.e.* 7th January, 1st SW), with peak activity during 5th SW (*i.e.* 29th January to 4th February).

Correlation studies revealed that, morning relative humidity, and sunshine showed positive correlation. While maximum temperature, minimum temperature, evening relative humidity, wind velocity, rain fall and no. of rainy days, morning & evening vapour pressure and evaporation showed negative correlation with red spider mite population but statistically were found non significant.

The various molecule evaluated in which Imidacloprid 17.8% SL @ 29.37 ml a.i./ha, followed by Triazophos 40% EC @ 400 ml a.i./ha and Profenophos 50% EC @ 500 ml a.i./ha against onion thrips, *Thrips tabaci* L. were found significantly more effective on onion, *Allium cepa* Linnaeus during *rabi* 2015.

Among the different date of transplanting evaluated, significantly highest population of thrips (table-15) was recorded in D_8 (December 15^{th}) date of transplanting. The lowest thrips population was recorded in D_2 (September 15^{th}) date of transplanting.

The peak mean thrips population (table-15) was recorded in the 4th week of March and lowest mean thrips population in fourth week of September. The high thrips population in the month of March might be due to high temperature in this growth period which indicated by the significantly positive correlation between mean thrips population per plant and weekly maximum temperature (SW) and the low thrips population in the month of September might be due to high relative humidity.

Evaluation of Insecticide effect on population of thrips in the subplot (protected, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha) revealed that significantly more effective against onion thrips, *Thrips tabaci* L., on onion, *Allium cepa* Linnaeus during 2015.

6.3 Suggestions for further work

In view of the changing climatic conditions, the studies on succession of insect pests and their natural enemies, population dynamics of major insect pests, effect of different dates of transplanting on incidence of onion thrips and testing of insecticides against the onion thrips, *Thrips tabaci* Lindeman on onion, *Allium cepa* Linnaeus should be carried out consecutively for 3 years in order to arrive at any concrete conclusion.

Studies should be carried out as sequential approach of insecticides for the management of thrips on onion.

Further identification of natural enemies, extent of predation or parasitization, abiotic factors favourable for their abundance is very essential, and is also the need of the day.

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Plate 1. Experimental field of objective: planting dates and insecticide protected

Plate 2. Infestation of onion thrips, *Thrips tabaci* Lindeman on onion

Plate 3. Leaf curling symptoms due to thrips infestation on onion leaves

Plate 4. Drying of leaves due to severe infestation of thrips on onion.

Plate 5. Healthy plants of onion at vegetative stage

Plate 6. Infestation of Fruit borer, *Helicoverpa armigera* Hubner on onion

Plate 7. Leaf damage by Fruit borer

Plate 8. Severe infestation of fruit borer on onion

Appendix I: Meteorological parameters during entire crop season of the year 2015-16 at Jabalpur

SW	Temp °C		RH (%)		Wind speed (km/hour)	Sun shine (hours)	Rain fall (mm)	Rainy days (No of days)	Vapour pressure		Evaporation (mm)
	MAX.	MIN.	MAX.	MIN.					MAX.	MIN.	
31	29.8	23.6	90	70	8.3	4.7	149.4	2	21.3	20.2	3.4
32	31.2	24.2	91	69	3.7	4.6	14.0	2	23.1	23.7	3.6
33	31.2	24.5	91	73	6.1	3.0	116.8	4	22.8	23.3	2.9
34	31.3	23.6	88	64	6.5	7.4	9.4	1	21.6	21.3	3.6
35	30.4	22.9	93	76	4.9	3.0	104.6	5	21.8	22.7	3.8
36	32.2	24.2	87	57	3.5	6.7	8.2	1	21.5	20.8	3.4
37	33.5	23.1	91	55	3.1	8.4	3.4	1	22.3	21.2	4.0
38	32.0	23.7	92	64	5.5	5.6	70.2	3	22.7	21.7	4.4
39	32.6	21.1	84	45	4.2	9.2	0.0	0	18.4	16.6	3.8
40	33.1	19.5	88	35	2.1	9.3	0.0	0	18.3	14.3	3.7
41	35.1	17.9	88	31	2.2	9.5	0.0	0	16.3	12.2	3.8
42	34.0	19.0	86	36	2.4	9.2	0.0	0	17.0	14.1	3.7
43	33.3	18.4	87	47	2.6	6.9	0.0	0	16.6	15.0	3.0
44	28.0	17.0	92	58	4.1	5.8	40.0	1	15.5	16.2	1.7
45	31.4	17.9	88	40	1.8	5.8	0.0	0	15.2	13.5	2.7
46	30.9	14.1	89	35	1.6	7.6	0.0	0	12.2	11.3	2.5
47	29.0	12.7	89	36	1.7	6.7	0.0	0	11.5	10.7	2.3
48	30.9	14.5	88	34	2.3	7.2	0.0	0	12.4	11.3	2.4
49	28.1	9.2	92	30	2.0	7.8	0.0	0	9.4	8.3	2.1
50	26.6	9.2	82	32	3.0	7.6	0.0	0	8.4	8.0	2.3
51	24.1	7.0	86	37	2.8	7.0	0.0	0	7.3	8.1	2.0
52	24.2	5.4	91	25	1.5	8.6	0.0	0	7.0	5.8	2.0
1	27.5	7.9	88	27	1.8	8.5	0.0	0	8.0	7.4	3.7
2	26.7	8.0	81	32	1.7	7.7	0.0	0	7.6	8.0	3.0
3	22.2	11.5	92	65	3.5	5.4	12.2	2	10.6	11.8	1.7
4	23.3	4.2	94	29	2.3	9.6	0.0	0	6.4	6.7	2.7
5	27.7	9.1	92	35	2.8	9.3	0.0	0	8.9	9.3	2.5
6	26.4	8.4	84	34	3.2	8.3	0.0	0	8.8	8.9	2.3
7	28.5	11.3	88	40	3.3	6.9	0.0	0	10.5	11.9	2.4
8	30.2	11.8	90	32	2.7	7.4	0.0	0	11.0	11.5	2.1
9	30.5	13.4	85	34	3.3	8.5	0.0	0	10.7	11.0	2.3
10	31.9	17.0	88	47	3.5	8.0	29.6	2	14.1	15.3	2.0
11	30.9	15.9	85	37	4.1	8.7	6.5	2	13.0	11.2	2.0
12	34.5	14.1	67	18	3.3	10.2	0.0	0	10.5	7.3	1.8
13	35.8	16.4	78	17	2.3	10.0	8.0	1	12.9	7.1	2.1
14	39.1	20.1	62	18	3.0	9.1	0.0	0	13.6	9.1	1.3
15	38.9	19.6	56	12	3.8	10.2	0.0	0	12.2	6.5	1.9
16	41.1	21.9	48	12	5.0	10.5	0.0	0	11.7	7.1	2.5
17	40.2	20.9	46	11	5.1	10.4	0.0	0	11.6	6.2	2.8

APPENDIX II

Efficacy of insecticides and NSKE against thrips infesting onion

ANOVA 1: Pre-treatment- before first spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.006	0.003	0.230769	3.88
Treatment	6	0.224	0.037	2.823	3
Error	12	0.159	0.013		
Total	20	0.39			

SEm ± 0.066 CD at 5% NS

ANOVA 2: Three days after first spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.011	0.0055	0.916666	3.88
Treatment	6	14.371	2.395	386.985	3
Error	12	0.074	0.006		
Total	20	14.456			

SEm ± 0.05 CD at 5% 0.14

ANOVA 3: Seven day after first spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.018	0.009	0.81818	3.88
Treatment	6	26.463	4.411	392.406	3
Error	12	0.135	0.011		
Total	20	26.617			

SEm ± 0.06 CD at 5% 0.19

ANOVA 4: Ten day after first spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.011	0.0055	0.3928	3.88
Treatment	6	43.394	7.232	522.099	3
Error	12	0.166	0.014		
Total	20	43.571			

SEm ± 0.07 CD at 5% 0.21

ANOVA 5: Over all mean of first spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	1.58	0.79	5.26666	3.88
Treatment	6	26.28	4.38	28.96	3
Error	12	1.82	0.15		
Total	20	29.67			

SEm ± 0.23 CD at 5% 0.70

ANOVA 6: Three days after second spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.006	0.003	0.75	3.88
Treatment	6	10.673	1.779	499.188	3
Error	12	0.043	0.004		
Total	20	10.722			

SEm ± 0.03 CD at 5% 0.11

ANOVA 7: Seven day after second spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.001	0.0005	0.125	3.88
Treatment	6	27.647	4.608	1,118.69	3
Error	12	0.049	0.004		
Total	20	27.698			

SEm ± 0.04 CD at 5% 0.12

ANOVA 8: Ten day after second spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.005	0.0025	0.4166	3.88
Treatment	6	47.944	7.991	1,288.31	3
Error	12	0.074	0.006		
Total	20	48.024			

SEm ± 0.05 CD at 5% 0.14

ANOVA 9: Over all mean of second spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	2.37	1.185	5.925	3.88
Treatment	6	26.40	4.40	22.44	3
Error	12	2.35	0.20		
Total	20	31.12			

SEm± 0.26 CD at 5% 0.80

ANOVA 10: Three days after third spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.03	0.015	3	3.88
Treatment	6	21.417	3.57	686.151	3
Error	12	0.062	0.005		
Total	20	21.509			

SEm± 0.04 CD at 5% 0.13

ANOVA 11: Seven days after third spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.003	0.0015	0.2142	3.88
Treatment	6	34.674	5.779	773.179	3
Error	12	0.09	0.007		
Total	20	34.766			

SEm± 0.05 CD at 5% 0.16

ANOVA 12: Ten days after third spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.022	0.011	0.57894	3.88
Treatment	6	39.169	6.528	352.075	3
Error	12	0.223	0.019		
Total	20	39.414			

SEm± 0.08 CD at 5% 0.25

ANOVA 13: Over all mean of third spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	3.91	1.955	39.1	3.88
Treatment	6	31.09	5.18	96.20	3
Error	12	0.65	0.05		
Total	20	35.64			

SEm± 0.13 CD at 5% 0.42

ANOVA 14: Three days after fourth spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.009	0.0045	0.6428	3.88
Treatment	6	19.459	3.243	489.839	3
Error	12	0.079	0.007		
Total	20	19.548			

SEm± 0.05 CD at 5% 0.15

ANOVA 15: Seven days after fourth spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.012	0.006	0.8571	3.88
Treatment	6	34.894	5.816	806.191	3
Error	12	0.087	0.007		
Total	20	34.993			

SEm± 0.05 CD at 5% 0.15

ANOVA 16: Ten days after fourth spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.029	0.0145	1.2083	3.88
Treatment	6	44.257	7.376	608.619	3
Error	12	0.145	0.012		
Total	20	44.431			

SEm± 0.06 CD at 5% 0.20

ANOVA 17: Over all mean fourth spraying

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	2.77	1.385	12.5909	3.88
Treatment	6	28.64	4.77	45.41	3
Error	12	1.26	0.11		
Total	20	32.68			

SEm± 0.17 CD at 5% 0.54

ANOVA 18: Over all mean foursprays (3DAS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.006	0.003	3	3.88
Treatment	6	15.782	2.63	2,814.97	3
Error	12	0.011	0.001		
Total	20	15.799			

SEm± 0.02 CD at 5% 0.06

ANOVA 19: Over all mean foursprays (7DAS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.002	0.001	0.5	3.88
Treatment	6	30.441	5.074	2,392.99	3
Error	12	0.025	0.002		
Total	20	30.468			

SEm± 0.03 CD at 5% 0.08

ANOVA 20: Over all mean foursprays (10DAS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	0.01	0.005	1.6666	3.88
Treatment	6	43.481	7.247	2,267.16	3
Error	12	0.038	0.003		
Total	20	43.53			

SEm± 0.03 CD at 5% 0.10

ANOVA 21: Over all mean four sprays (Over all mean)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F.tab 5%
Replication	2	2.77	1.385	12.5909	3.88
Treatment	6	28.64	4.77	45.41	3
Error	12	1.26	0.11		
Total	20	32.68			

SEm± 0.19 CD at 5% 0.58

ANOVA 22: Effect of planting dates and Insecticide effect on population of thrips

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F.tab 5%
Replications	2	0.01	0.003	2.5	3.74
Main	7	1.57	0.22	142.17	2.76
Error (a)	14	0.02	0.002	-	-
Sub	1	39.99	39.99	57876.05	4.49
Main x Sub	7	0.21	0.03	42.38	2.66
Error (b)	16	0.01	0.001	-	-
Total	47	-	-	-	-

-	CD 5%	SEm ±
Main Treatments	0.05	0.02
Sub Treatments	0.02	0.01
Main x Sub	0.05	0.02

ANOVA 23: Effect of planting dates and Insecticide effect on population of thrips SEP-1st (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.062	0.031	6.2	4.46
Treatment	4	12.977	3.244	690.36	3.89
Error	8	0.038	0.005		
Total	14	13.077			

SEm± 0.04 CD at 5% 0.13

ANOVA 24: Effect of planting dates and Insecticide effect on population of thrips SEP-15th (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.007	0.0035	0.4375	3.88
Treatment	6	19.201	3.2	419.58	3.0
Error	12	0.092	0.008		
Total	20	19.299			

SEm± 0.05 CD at 5% 0.16

ANOVA 25: Effect of planting dates and Insecticide effect on population of thrips OCT-1st (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.096	0.048	1.41176	3.63
Treatment	8	2.284	0.285	8.51	2.59
Error	16	0.537	0.034		
Total	26	2.917			

SEm± 0.11 CD at 5% 0.32

ANOVA 26: Effect of planting dates and Insecticide effect on population of thrips OCT-15th (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.115	0.0575	2.3	3.49
Treatment	10	3.315	0.332	13.145	2.34
Error	20	0.504	0.025		
Total	32	3.934			

SEm± 0.09 CD at 5% 0.27

ANOVA 27: Effect of planting dates and Insecticide effect on population of thrips Nov-1st (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.091	0.0455	0.7	3.44
Treatment	11	24.135	2.194	33.866	2.26
Error	22	1.425	0.065		
Total	35	25.651			

SEm± 0.15 CD at 5% 0.43

ANOVA 28: Effect of planting dates and Insecticide effect on population of thrips NOV-15th (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.106	0.053	0.3655	3.40
Treatment	12	26.746	2.229	15.383	2.18
Error	24	3.477	0.145		
Total	38	30.329			

SEm± 0.22 CD at 5% 0.65

ANOVA 29: Effect of planting dates and Insecticide effect on population of thrips DEC-1st (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.12	0.06	3.1578	3.40
Treatment	12	9.502	0.792	41.289	2.18
Error	24	0.46	0.019		
Total	38	10.083			

SEm± 0.08 CD at 5% 0.24

ANOVA 30: Effect of planting dates and Insecticide effect on population of thrips DEC-15th (DAT)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F. tab 5%
Replication	2	0.03	0.015	1.875	3.44
Treatment	11	7.428	0.675	80.659	2.25
Error	22	0.184	0.008		
Total	35	7.642			

SEm± 0.05 CD at 5% 0.16

Part I of Abstract

Title of the thesis	:	**"Succession and population dynamics of insect pest complex of onion and management of thrips"**
Student's Name	:	**Kommireddy Naresh**
Permanent address	:	Sitannagari Street Village- Achanta (Post) Distt.- West Godavari (A.P.) Pin – 534123
Name and address of Major advisor	:	**Dr. A. K. Saxena, Associate Professor** **Department of Entomology, JNKVV, Jabalpur (M.P.)**
Degree to be awarded	:	Master of Science in Agriculture
Year of award of degree	:	2016
Major subject	:	Entomology
Total no. of pages in the thesis	:	98
Number of words in the abstract	:	1005

Signature of Advisor	Signature of Head of Department	Signature of Student
(Dr. A. K. Saxena)	**(Dr. A.K. Bhowmick)**	**(Kommireddy Naresh)**

Part II of Abstract

Present research work on "succession and population dynamics of insect pest complex of onion and management of thrips" was carried out in the experimental field of Department of Horticulture, JNKVV, Jabalpur, (M.P) during 2015-16.

The experiment was conducted with the following objectives

1) To study the succession of insect pest complex on onion
2) To study the population dynamics of major insect pests of onion
3) Management of onion thrips :

   a) To study the effect of planting dates on thrips incidence

   b) To study the efficacy of insecticides and NSKE against onion thrips

Three different species of insect pests, one non insect pest and one natural enemy order were recorded on the onion crop at experimental field of Department of Horticulture, JNKVV, Jabalpur, (M.P) during *rabi* 2015-16. Which represented three pest orders viz. Thysanoptera (Family: Thripidae), Lepidoptera (Family: Noctuidae), Tetranychidae (Family: Trombidiformes) and a group of predators namely spiders, Order: Arachnida were also recorded.

The thrips appeared when the crop age was about 32 days old and their activity continued till the maturity of the crop. Cutworm appeared after transplanting when the crop age was about 32 days old and their activity continued till the reproductive stage of the crop. Fruit borer also appeared when the crop age was about 37 days old and their activity continued till the reproductive stage of the crop. Red spider mite appeared when the crop age was about 68 days old and their activity continued for a very short period (up to 106th day old crop). The first predation of spiders was observed during the vegetative stage of the crop *i.e.* about 12 days old crop (after transplanting) and remained available from vegetative stage to harvesting of crop.

The thrips *T. tabaci* Lindeman was first recorded in the first week of December *i.e.* 2nd December 2015 during the 48th standard week (SW) and remained available up to maturity stage of the crop with The peak activity

during 1st SW (*i.e.* 1st to 7th January).

Correlation between various abiotic factors and thrips population showed that maximum temperature was found to be significant positive correlation. Further, minimum temperature, sunshine, morning vapour pressure and evaporation exhibited positive correlation. While morning & evening relative humidity, wind velocity, rainfall, no. of rainy days and evening vapour pressure showed negative correlation with thrips population but statistically found to be non-significant.

The activity of cutworm, *A. ipsilon* Hufnagel was first recorded in the first week of December *i.e.* 2nd December 2015 during the 48th standard week, with peak activity during 51th SW (*i.e.* 17th to 23rd December).

Correlation between various abiotic factors and cutworm population showed that, morning relative humidity, evening relative humidity, wind velocity was found to be positive correlation. While no. of rainy days and morning vapour pressure were found to be zero correlation. While maximum & minimum temperature, sunshine hour, rainfall, evening vapour pressure and evaporation showed negative correlation with leaves infested by cutworm but statistically found to be non significant.

The Fruit borer, *H. armigera* Hubner was first recorded in the second week of December (*i.e.* 7th December 49th SW), with peak activity during 2nd SW (*i.e.* 8th to 14th January).

Correlation studies revealed that maximum temperature, sunshine hours and evaporation showed positive correlation. Further, minimum temperature, morning and evening relative humidity, wind velocity, rainfall, no. of rainy days, morning and evening vapour pressure showed negative correlation with fruit borer population but statistically found to be non-significant.

The Red spider mite, *T. telarius* Linnaeus was first recorded in the first week of January (*i.e.* 7th January, 1st SW), with peak activity during 5th SW (*i.e.* 29th January to 4th February).

Correlation studies revealed that, morning relative humidity, and sunshine showed positive correlation. While maximum temperature, minimum temperature, evening relative humidity, wind velocity, rain fall and no. of rainy days, morning & evening vapour pressure and evaporation showed negative correlation with red spider mite population but statistically were found non significant.

The various molecule evaluated in which Imidacloprid 17.8% SL @ 29.37 ml a.i./ha was found to be significantly lowest thrips population than all other treatments but at par with Triazophos 40% EC @ 400 ml a.i./ha. Plots treated with Triazophos recorded significantly lower thrips population than other treatments except Profenophos 50% EC @ 500 ml a.i./ha. Against onion thrips, *Thrips tabaci* L. were found significantly more effective on onion , *Allium cepa* Linnaeus during *rabi* 2015.

Among the different date of transplanting evaluated, significantly highest population of thrips was recorded in D_8 (December $15^{th)}$ date of transplanting. The lowest thrips population was recorded in D_2 (September 15^{th}) date of transplanting.

The peak mean thrips population was recorded in the 4th week of March and lowest mean thrips population in fourth week of September.

Evaluation of Insecticide effect on population of thrips in the subplot (protected, Imidacloprid 17.8% SL @ 29.37 ml a.i./ha) revealed that significantly more effective against onion thrips, *Thrips tabaci* L., on onion, *Allium cepa* Linnaeus during 2015.

Interaction of the two factors *i.e.* planting dates and protected plot have a significant impact on the population of thrips. Among the different date of transplanting and protected plot evaluated, significantly highest population of thrips was recorded interaction (D_4 x B_1) *i.e* October 15^{th} date of transplanting and protected plot. The lowest Thrips population was recorded in interaction (D_2 x B_1) *i.e* September 15^{th} date of transplanting and protected plot was found significantly.

Interaction of the two factors *i.e.* planting dates and unprotected plot have a significant impact on the population of thrips. Among the different date of transplanting and unprotected plot evaluated, significantly highest population of thrips was recorded interaction (D_8 x B_2) *i.e* December 15th date of transplanting and unprotected plot, but at par with interaction (D_7 x B_2) *i.e* December 1st date of transplanting and unprotected plot. The lowest Thrips population (5.68 thrips/plant) was recorded in interaction (D_1 x B_2) *i.e* September 1st date of transplanting and un protected plot, but at par with interaction (D_2 x B_2) *i.e* September 15th date of transplanting and un protected plot.

CURRICULUM VITAE

The author of this thesis, Mr. Kommireddy Naresh S/o Shri. K. China Nageswarao and Smt. K. Anantha Lakshmi was born on 22 April. 1992 at, Achanta, Distt. West Godavari (A.P.).

After graduation, for further study, he got admission in M.Sc. (Ag.) for specialization in Entomology at the college of Agriculture, JNKVV, Jabalpur (M.P) where successfully completed all the course requirement for master's degree with OGP 7.85 out of 10 point scale in the year 2016.

For the partial fulfillment of the master's degree "Succession and population dynamics of insect pest complex of onion and management of thrips" under Jabalpur condition, which was successfully conducted by him and being submitted in the form of this thesis.

He took admission for B.Sc. (Ag.) in the College of Agriculture, ANGRAU (Hyderabad) in the year 2009. He has successfully completed his graduation with 7.78 OGPA in the year 2013.

He passed his High School (10^{th}) with (76. 50%) in the year 2007 from Govt High School, Achanta, Distt. West Godavari (A.P.) and Diploma in agriculture (12^{th}) with (80.80%) in the year 2009 from Agricultural Polytechnic, Maruteru, Distt. West Godavari, (A.P.).