BIO-ECOLOGY, TAXONOMIC CHARACTERIZATION AND MANAGEMENT OF THRIPS INFESTING MUNGBEAN

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This is to certify that Dissertation entitled **"BIO-ECOLOGY, TAXONOMIC CHARACTERIZATION AND MANAGEMENT OF THRIPS INFESTING MUNGBEAN"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **SABERA YASMIN, Registration no. 26136/00435** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED

TO

MY BELOVED

PARENTS

BIBLIOGRAPHIC SKETCH

The author, Sabera Yasmin was born on October 21, 1981 in the district of Narail, Bangladesh. She is the elder daughter of Syed Mokaddes Ali and Kamrun Nahar.

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ABBREVIATIONS AND ACRONYMS

%	:	Percent
μL	:	microliter
a.i.	:	Active Ingredient
AGA	:	Alcohol- glycerin-acetic acid
BARC	:	Bangladesh Agricultural Research Council
BBS	:	Bangladesh Bureau of Statistics
BARI	:	Bangladesh Agricultural Research Institute
BINA	:	Bangladesh Institute of Nuclear Agriculture
BSMRAU	:	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CABI	:	Center for Agriculture and Bioscience International
CV	:	Coefficient of variation
DAS	:	Days After Sowing
DMRT	:	Duncans' Multiple Range Test
DNA	:	Deoxyribonucleic acid
DPPH	:	2,2-diphenyl-1-picrylhydrazyl.
EC	:	Emulsifiable Concentrate
et al.	:	And others
etc.	:	Etcetra
ETL	:	Economic threshold level
FAO	:	Food and Agriculture Organization
FS	:	Flowable concentration for seed treatment
FYT	:	Final yield trial
IPPC	:	International Plant Protection Convention
IPM	:	Integrated Pest Management
J.	:	Journal
L:D	:	Light : Dark
MS	:	Microsoft
Na_2CO_3	:	Sodium carbonate
nm	:	Nanometer
OD	:	Optical density
P	:	Phosphorous
p^H	:	Hydrogen ion concentration

ABBREVIATIONS AND ACRONYMS

PBNV	:	Peanut Bud Necrosis Virus
RCBD	:	Randomized Completely Block Design
RH	:	Relative Humidity
SAU	:	Sher-e-Bangla Agricultural University
SC	:	Soluble Concentration
SE	:	Standard Error
SL	:	Soluble liquid
SMW	:	Standard Materological Week
S$\bar{x}$	:	Standard error of the mean
T	:	Temperature
TS	:	Top Shoot
TTL	:	Top Trifoliate Leaf
UV	:	Ultra Violet
V	:	Volume
w	:	Weight
WAS	:	Weeks After Sowing
WG	:	Wettable Granule
WP	:	Wettable Powder

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BIO-ECOLOGY, TAXONOMIC CHARACTERIZATION AND MANAGEMENT OF THRIPS INFESTING MUNGBEAN

ABSTRACT

Sabera Yasmin

Six experiments were conducted during the study period of which two experiments in the laboratory of Entomology department and four experiments in the experimental field of Sher-e-Bangla Agricultural University to study the taxonomic identification, bio-ecology, varietal screening and management of thrips infesting mungbean from February 2016 to June 2018. Two thrips species *Megalurothrips usitatus* and *Thrips palmi* were identified on different plant parts of mungbean, causing damage to plants and responsible for shedding flower bud and flower. The adult female of *M. usitatus* was dark brown with 8-segmented antennae and the segment III was yellow. The male of *M. usitatus* was smaller and paler with almost yellow legs and pronotum. Adult female of *T. palmi* was yellow with 7-segmented antennae. A pair of ocellar setae was located outside the triangular red pigmented ocelli. Average body length of adult female and male *M. usitatus* was 1.97 ± 0.13 mm and 1.42 ± 0.12 mm, respectively, and female *T. palmi* was 1.20 ± 0.02 mm. The incubation period, first instar larva, second instar larva, prepupa, pupal period, and total developmental time (egg to adult) of *M. usitatus* were 3.13 ± 0.06 days, 1.48 ± 0.05 days, 2.30 ± 0.08 days, 1.30 ± 0.07 days, 2.26 ± 0.13 days and 10.54 ± 0.15 days, respectively. Mortality of the first instar larvae 14.41%, second instar larvae 22.77%, pre-pupa 14.10%, pupa 65.67% and total pre-adult mortality of *M. usitatus* 80.51% were observed. The longevity of adult males was (6.42 ± 0.44 days) of *M. usitatus* but shorter than adult females (12.07 ± 1.56 days). Among the different dates of sowing, the lowest number of *M. usitatus* and *T. palmi* (2.21 and 1.02, respectively per 10 top trifoliate leaves, 2.67 and 1.43, respectively per 10 terminal shoots at pre-flowering stage, 4.22 and 2.18, respectively per 5 flower buds, 5.28 and 1.42, respectively per 5 flowers at flowering stage) was recorded on 21 March sown mungbean followed by 11 March and 31 March sown mungbean. *M. usitatus* and *T. palmi* population showed significantly positive relationship with temperature and bright sunshine hour but negatively related with rainfall and relative humidity. Comparatively, lower incidence of *M. usitatus* and *T. palmi* in four plant parts was observed in BARI Mung-7 (T_8), which was followed by BARI mung-8 (T_9), BU mug 2 (T_2) and Binamoog-6 (T_5), respectively. There was no significant variations in phosphorous (P) content in leaf of 11 mungbean varieties, but significantly maximum leaf trichome density (32.67 per 0.5 cm midrib) from lower surface, leaf moisture (84.19%), chlorophyll$_{(a+b)}$ (1.11 mg per 100 g), potassium (K) (2.34%), phenol (8.39 mg g^{-1}) and minimum total soluble sugar (2.12 mg g^{-1}) content were measured in BARI Mung-7. Among six colored sticky board traps, the blue colored sticky board trap captured the maximum number of *M. usitatus* and *T. palmi* (9.23 and 3.88, respectively), resulting lower incidence of thrips in the trapped plots compared to control plots. Among the bio-pesticides and chemical insecticides, nicotinoid clothianidin (Stargate 48SC) gave the best result. The highest percent reductions over control of *M. usitatus* and *T. palmi* were 100.00% and 100.00%, respectively on top trifoliate leaves, 85.23% and 99.28%, respectively on terminal shoots, 81.23% and 100.00%, respectively on flower buds, 79.64% and 97.75%, respectively on flowers, and highest yield (1026.91 kg ha^{-1}) was recorded in Stargate 48SC (T_2) treated plot which was followed by Confidor 70WG (T_3) and Actara 25WG (T_4) treated plots. Among bio-pesticides, Ecomec 1.8EC showed better result.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

APPENDIX

Appendix I

Weekly average Temperature, Relative Humidity, Rainfall and bright sunshine hour at Sher-e-Bangla Agricultural University, Bangladesh during March - June in 2016

Name of the month	Duration	Average Temperature (ºC)	Rainfall (mm)	Relative Humidity (%)	Bright Sunshine hour (hr.)
March	14.3.16-20.3.16	27.04	3.00	55.86	6.51
	21.3.16-27.3.16	28.77	0.00	54.14	8.51
	28.3.16-3.4.16	25.09	6.71	78.29	3.01
April	4.4.16-10.4.16	29.97	3.57	77.00	6.73
	11.4.16-17.4.16	31.09	0.00	71.14	8.56
	18.4.16-24.4.16	31.29	0.00	68.43	7.63
	25.4.16-1.5.16	31.49	0.00	68.29	9.07
May	2.5.16-8.5.16	27.96	3.00	68.71	4.66
	9.5.16-15.5.16	29.14	7.14	72.43	7.11
	16.5.16-22.5.16	28.29	13.71	79.43	4.61
	23.5.16-29.5.16	28.26	6/43	78.57	5.60
June	30.5.16-5.6.16	30.37	0.43	71.00	7.97
	6.6.16-13.6.16	28.49	24.00	81.00	3.70
	14.6.16-19.6.16	29.4	4.71	78.29	4.60
	20.6.16-26.6.16	30.59	0.86	74.00	5.96

Appendix II

Weekly average Temperature, Relative Humidity, Rainfall and bright sunshine hour at Sher-e-Bangla Agricultural University, Bangladesh during April - June in 2017

Name of the month	Duration	Average Temperature (ºC)	Rainfall (mm)	Relative Humidity (%)	Bright Sunshine hour (hr.)
April	23.4.17-29.4.17	27.6	16.29	79.71	5.73
May	30.4.17-6.5.17	29.09	10.86	72.14	8.8
	7.5.17-13.5.17	29.84	0.14	70.86	6.64
	14.5.17-20.5.17	29.33	15.86	75	6.16
	21.5.17-27.5.17	31.59	0.29	71.43	7.81
June	28.5.17-3.6.17	28.84	8.00	80.86	3.67
	4.6.17-10.6.17	30.13	0.86	75.57	5.03
	11.6.17-17.6.17	28.19	34.57	87.14	2.56
	18.6.17-24.6.17	28.99	15.71	80.29	3.96

CHAPTER I
INTRODUCTION

Mungbean [*Vigna radiata* (L.) Wilczek], often known as green gram is one of the most important food grain legume crops in tropical and sub-tropical countries of the world under the family of Fabaceae. It is widely cultivated throughout the South and Southeast Asia, including Bangladesh, India, Pakistan, Srilanka, Myanmar, Thailand, Philippines, China, Indonesia and in parts of East and Central Africa, West Indies, USA and Australia (Banglapedia 2015)). Mungbean is considered as a poor man's meat because it is a good source of protein. Mungbean contains about 51% carbohydrate, 26% protein, 4% mineral, 3% vitamins (Yadav *et al.* 1994). It is consumed as soup in South Asia, and food products such as fried snacks, desserts, and bean sprouts. Sprouts, which are good source of vitamin C (8 mg per 100 g) can be produced year-round at home or commercially (Calloway *et al.* 1994).

Among the pulse crops in Bangladesh, mungbean ranks fourth in area and production. The production of mungbean in Bangladesh is about 32 thousand metric tons in the area of 39 thousand hectares and the average yield is 842 kg ha^{-1} (BBS 2015). With the availability of newly-released high-yielding and disease-tolerant BARI varieties, the area under mungbean is increasing. Now-a-days, it is being cultivated after harvesting of rabi crops (wheat, mustard, lentil, etc.). As mungbean is a short duration crop and suitable to crop rotation and crop mixtures, it can fit in as a cash crop between major cropping season. Mungbean is suitable for summer season but it can be grown throughout the year in all cropping seasons i.e., Kharif-I, Kharif-II and Late Rabi seasons in Bangladesh (BARI 2017).

There are several biotic and abiotic stresses which limit pulse cultivation. One of the major limiting factors of mungbean production is the attack of insect pests. Several insect pests have been reported to infest the crop in seedlings, leaves, stems, buds, flowers and pods causing considerable losses (Karim and Rahman 1991). Mungbean insect pests caused 42% and 58% losses at pre-flowering and post-flowering stages, respectively (Malik 1992). In mungbean, flower shedding to the extent of 40-89% has been reported (Sinha 1977). Insect attack is one of the major causes of flower shedding and low yield levels in grain legumes. More than twelve species of insect pests were found to infest mungbean in the field in Bangladesh

1

(Rahman *et al.* 2000). Among them, thrips is one of the major insect pests causing considerable losses (Hossain *et al.* 2004; Rahman *et al.* 2000). The feeding apparatus of thrips is unique amongst insects. Thrips have only one mandible which is used to punch a hole in to the plant surface through which paired maxillary stylets are then inserted. These stylets suck the contents of the damaged plant part inducing a range of symptoms on the plant tissue due to their feeding. Silvering is the most common symptom occurring as a result of the cell contents being removed, and is readily seen on leaf tissue (Duff 2012).

Thrips have a very short life cycle from egg to adult stage in two to three weeks. The duration varies with the host and with abiotic factors such as temperature and humidity. Eggs being laid inside plant tissue, leaves or flowers, hatching within as little as 3 days and as long as 10 days depending on the temperature. Both larvae and adults are found within the bean flower, which is generally only open for a few days. It is likely that the adults lay their eggs on the developing flower buds and adjacent soft stems (Caon and Burfield 2006) allowing the larvae quick access to the flower once the eggs hatch. It is not clear when the adult gains entry into the flower. They may only be able to gain access as it is opening. Green bean flowers are only open for a very short period of time, a matter of days, until the flowers are pollinated, yet this is long enough for damage to take place and pods to be scarred. Not all thrips attack developing pods; some feed on the pollen and nectar produced by the flower. In flowers, both larvae and adults of thrips nourish on pollen and scratch other flower parts and suck the plant sap oozing out from the injured plant parts, the flower sheds before opening and there is elongation of terminal shoot. Thrips cause 40-60% yield losses of french bean at farm level, mainly through abscission of buds, flower shedding early with the result that pods are not formed and also malformation of pod making them unfit for the export market (Seif *et al.* 2001). Their punching and sucking feeding behaviour also blemishes and causes silvery lesions on pods, resulting in a further 20% loss at harvest sites (Kibata and Anyango 1996; Lohr 1996). It has been investigated that thrips can cause damages to crop up to 37.6% (Khan *et al.* 2011).

Megalurothrips is an old world genus associated with the flowers of Fabaceae, with one species from Africa and 12 from Southeast Asia. The African species, *M. sjostedti* (Trybom) and two of the Asian species, *M. usitatus* (Bagnall) and *M. distalis*, are known as pests of legume crops that sometimes require insecticidal control (Kooner *et*

2

al. 2007). Most species in this *Megalurothrips* genus can be distinguished satisfactorily only in the male sex, because females all look very similar to each other (Palmer 1987). Moritz (1997) reported that most Thysanoptera are arrhenotokous, with females developing from fertilized eggs and males developing from unfertilized eggs.

Duraimurugan and Tyagi (2014) reported that the flower thrips species collected on mungbean and urdbean was identified as *M. usitatus* which was contrast to the report of Kooner *et al.* (2006) who reported that the thrips infesting flowers of mungbean and urdbean in Punjab as *M. distalis. M. usitatus* is the most common thrips in the flowers of cultivated legume plants across most of tropical Asia (Palmar 1987). On adzuki beans *M. usitatus* lays its eggs on foliage, petals and sepals with larval aggregation within the flowers resulting from the concentration of eggs laid within the individual flowers (Chang 1992). It is therefore likely that this also happens in green beans when this particular thrips is present. During vegetative stage *M. usitatus* feed inside vegetative buds, rasping the top, unopened trifoliate leaves and sucking plant juice oozing out of the plant part. Thrips colonize in the crop at pre-flowering, forming a pool that infests flowers once they form pool (Gitonga 1999). During reproductive stage when plants start bearing flowers, more thrips are found in flowers on the 7th and 8th node on main stem of soybean plant. Within the flowers, male and female thrips were randomly distributed in the initial blooming stage (Chang 1992). In flowers, both larvae and adults feed on pollen and rasp other flower parts and suck the plant juice oozing out from the injured plant parts. As a result of this type of damage, flowers drop of and affects on pod formation. There are many reasons why thrips colonize different plant parts. These include preferred microhabitats in the plant, nutritional niches, or hide/seek behaviour with their natural enemies (Reitz 2002; Brodbeck *et al.* 2001 and Toapanta *et al.* 2001).

Thrips palmi is a polyphagous pest, with a wide host range causing damage both directly by feeding and indirectly by transmitting viral diseases (Honda *et al.* 1989; Kameya-Iwaki *et al.* 1988). Capinera (2008) reported that *T. palmi* is the best known as a pest of cucurbitaceae and solanaceae. *T. palmi* attacks various legumes, fruiting and leafy vegetables in many countries in tropical and subtropical regions. In India, Watermelon Bud Necrosis Virus (WBNV) and Peanut Yellow Spot Virus (PYSV) are transmitted by *T. palmi* and *S. dorsalis,* respectively (Gopal *et al.* 2010). The peculiar

feature of thrips transmission of virus is that only the nymphs can acquire the virus, while the adults can transmit (Whitefield *et al.* 2005). The pattern of population growth and development of *T. palmi* on different host crops vary and contribute to the survival of the pest throughout the year.

Correct identification of thrips is important for a number of reasons i.e., to know the host range of crops adequate for crop rotation, correct selection of insecticides, possible virus transmission concerns, history of when the thrips is most prevalent and whether the thrips is known to cause damage to the crop. It is important to learn the biological attributes of a new insect pest in order to understand its potential spread (Morse and Hoddle 2006). Thrips populations fluctuate with temperatures, rainfall and relative humidity (Chyzik and Ucko 2002) making it difficult to accurately predict when one species will become dominant over another during the growing season. Pest appearance, population fluctuation, infestation rate and crop yield are very much dependent on seasonal variation following sowing dates. Rainfall adversely affects the survival of thrips. The water drops accumulated in the flowers and vegetative buds drown and kill the thrips. This pest therefore, is not important during rainy season but can be devastating during dry season. Flower thrips populations are higher during the dry season, which favors rapid reproduction of thrips. Most of the farmers usually sow mungbean just after harvesting the rabi crops without considering optimum sowing dates. As a result, crops growth is affected by unfavorable prevailing climatic condition and also crop encountered higher insect pest's infestation and accordingly to crop yields is reduced remarkably. Information regarding insect pest's appearance, infestation and its severity of damage in relation to seasonal variation depending on sowing dates are not available in Bangladesh especially for mungbean crops in kharif-I season. Farmers of different countries adopted different ways to control this pest. Monitoring the crop regularly and early detection of thrips is important to determine an appropriate control strategy. Thrips can be easily detected by shaking leaves and flowers on a white piece of paper. Adult thrips can be monitored by mass trapping with coloured (blue, yellow or white) sticky traps or water traps in the nursery or field. A study in Taiwan in adzuki bean field, in winter season, efficiency of blue PVC plate traps coated with sticky substance attract significantly more *M. usitatus* than yellow or green traps (Chang 1990b). In spring, blue trap also attracted more thrips than white, yellow or green. However, when the population increased, there was no difference in the number of thrips being attracted

to the blue or white traps. Potentiality exists to use these traps for reducing *M. usitatus* damage to legumes grown at least on small scale farms.

Ploughing, harrowing, and solarisation can kill pupae in the soil from previously infested crops. The use of resistant varieties is one important technique in integrated pest management (Dilawari and Dhaliwal 1993). However, sole dependence on resistant varieties cannot be sufficient due to differences in environment. It should be integrated with chemical control to keep the pest population below the economic threshold level (Chhabra and Kooner 1985). The number of thrips found within the flowers or on the plant can help in developing thresholds that can then be used when deciding whether to spray a crop. Such thresholds may increase or decreases during the season, as different thrips become more dominant. This will allow the grower to better tailor insecticide sprays. Neem based pesticides are reported to control young nymphs, inhibit growth and development of older nymphs and reduce egg-laying by adult thrips. Adding 0.1 to 0.5% of soft soap enhances efficacy of neem-based pesticides. Other botanical pesticides that have been recommended for management of thrips include garlic, rotenone, ryania, pyrethrum and sabadilla. Using chemical insecticides is one of the import management tools in IPM but to overcome the misuse of insecticides and environmental hazard, there is a necessity to develop an effective and economic insecticide application schedule for the protection of mungbean against thrips.

Sucking pests have developed resistance to almost all conventional synthetic insecticides and also developing resistance to multiple classes of insecticides (Palumbo *et al.* 2001). Moreover, conventional insecticides provide poor control of insect pests and generally lead to pest resurgence. Therefore, to overcome these problems the use of new generation chemical neonicotinoids is the ultimate alternative for effective pest management. Considering the importance of the insect pests of mungbean, many experiments have been planned to find out the field efficacy of different pesticides namely biopesticides (neem), microbial pesticide (spinosad) and chemical pesticides (quinalphos, profenfos, lambda-cyhalothrin, thiamethoxan and imidacloprid) against major field thrips of mungbean. The focus has also been made on the development of newer chemistries-newer classes of products with novel mode of action that are active at very low dosages and manage thrips population. Khattak *et al.* (2004) reported on the efficacy of Mospilan 20SP, Actara 25WG, Polo 500EC, Tamaron 60SI and Confidor 200SL against thrips on mungbean. Seed

treatment with imidacloprid (Confidor 20% SL), acetamiprid (Acelan 20% SL), thiomethoxam (Actara 25 WG) and acephate also helped to reduce the thrips population Iqbal *et al.* (2013).

The success in management of thrips requires a thorough understanding of its biology, ecology, population dynamics in relation to climatic factors. However, many researches regarding biology, ecology, seasonal abundance of thrips have been done in elsewhere but reports on thrips attacking mungbean in respect of Bangladesh are very much scanty. To develop research on eco-friendly and sustainable management practices of thrips in relation to climate change and to reduce yield loss of the crop more studies should be done. Considering the above points, a comprehensive study has been undertaken to achieve the following objectives:-

Research objectives

1. To identify thrips species attacking mungbean and to determine the morphometric measurements of adult thrips species;
2. To study the biology of thrips on mungbean and to determine the pre-adult mortality percentage and adult longevity of thrips;
3. To investigate the effect of sowing dates on thrips infestion attacking mungbean;
4. To screen some mungbean varieties against thrips and to identify the resistant sources;
5. To find out the efficacy of mass trapping with colored sticky board traps against thrips on mungbean; and
6. To evaluate some selected bio-pesticides and chemical insecticides against thrips on mungbean.

CHAPTER II
REVIEW OF LITERATURE

The review of literature on the relevant field of bio-ecology of thrips, its responses on mungbean, damages in field condition, varietal screening, mass trapping and management in Bangladesh and elsewhere of the world were searched and discussed under the following sub-headings:-

2.1. Thrips species on mungbean

The thrips species found on mungbean are enlisted in Table 1.

Table 1. List of thrips found on mungbean with their common name and scientific name along with plant parts affected and references

Common name	Scientific name	Plant part affected	References
Western flower thrips	*Frankliniella occidentalis* Pergande	Leaves/ Flowers	Brier 2007
Tomato thrips	*Frankliniella schultzei* (Trybom)	Leaves/ Flowers	Brier 2007
Southern Plague thrips	*Thrips imaginis* Bagnall	Leaves/ Flowers	Brier 2007
Flower thrips	*Megalurothrips distalis* Karny	Flowers	Chabbra and Kooner 1985
Bean blossom thrips	*Megalurothrips usitatus* (Bagnall)	Flowers, leaves	Duraimurugan and Tyagi 2014; Chang 1992
African bean flower thrips	*Megalurothrips sjostedti*	flowers	Mogotsi 2006
Ground nut or pea nut thrips	*Caliothrips indicus* Bagnall	Leaves	Singh and Singh 2014
Chilli thrips	*Scirtothrips dorsalis* Hood	Leaves	Kansagara 2018
Melon thrips	*Thrips palmi* Karny	Leaves, flower	Kumar and Williams 2012
Onion thrips	*Thrips tabaci* Lindeman	Leaves/ Flowers	Charleston 2014; Brier 2007

Chang (1992) found *M. usitatus* in leaves and flowers of green gram in Taiwan. Among three major species of Thysanoptera damaging mungbean and other legumes in Asia, *M. distalis* (Karny) and *Caliothrips indicus* (Bagnall) are prevalent in South Asia and *M. usitatus* (Bagnall) mostly in Southeast Asia (http://203.64.245.61/fulltext_pdf/EAM/1991-2000/eam0121.pdf). *Thrips palmi*

recently has found in mung bean (*Vigna radiata*) in Bangladesh (European Commission 2010).

2.2. Taxonomic Information, Origin and Distribution of *Megalurothrips usitatus* (Bagnall)

Common Name: Bean flower thrips, Oriental bean thrips, Asian bean thrips

Current valid name: *Megalurothrips usitatus* (Bagnall 1913)

Taxonomic position:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Sud-order: Terebrantia

Family: Thripidae

Genus: *Megalurothrips*

Species: *Megalurothrips usitatus*

Area of origin: Southeast Asia

Distribution: *M. usitatus* is widespread in Asia, Oceania. It is recorded from Australia, Fiji, French Polynesia, Kiribati, Papua New Guinea, Tonga, and Tuvalu. (Jackson 2017).

2.3. Taxonomic Information, Origin and Distribution of *Thrips palmi* Karny

Common name: Melon thrips

Current valid name: *Thrips palmi* Karny 1925

Taxonomic position:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Sud-order: Terebrantia

Family: Thripidae

Genus: *Thrips*

Species: *Thrips palmi*

Origin and distribution: *T. palmi* appears to have originated in Southern Asia. The species was first described by Karny (1925) from specimens collected on tobacco in

Indonesia. It was named after Dr B. T. Palm and not palmson which it has not been found. Over the past 15 years, *T. palmi* has spread throughout Asia, to Japan, several Indian and Pacific Ocean islands, into India, Northern Africa and most recently to Australia, the Caribbean and the USA.

Asia: Bangladesh, Brunei, China (numerous provinces, including Hong Kong), India (numerous states), Indonesia (Jave, Sumatra), Korea (North and South), Malaysia, Myanmar, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand

Africa: Mauritius, Nigeria, Reunion, Sudan

Caribbean: Throughout

North America: United States (Florida and Hawaii).

Oceania: American Samoa, Australia (Queensland, Northern Territory, Western Australia), Federated States of Micronesia, French Polynesia, Guam, New Caledonia, Palau, Papua New Guinea, Samoa, and others

South America: Brazil, Columbia, French Guiana, Venezuela (CABI 1998).

2.4. Detection of thrips

*M. usitatus***:** Look for the wilting of flowers and leaves, and adult thrips and nymphs, in the leaves and flowers. After feeding, the immatures drop from the plant and pupate in the soil (Jackson 2017).

Thrips palmi may be found in different locations depending on the life stages present.

- Eggs in the leaf, flower and fruit tissue
- Larva I on the leaves, flowers and fruits
- Larva II on the leaves, flowers and fruits
- Pupa I in the soil, packing cases and growing medium
- Pupa II in the soil, packing cases and growing medium
- Adult on the leaves, flowers and fruits

On plant material, *T. palmi* may potentially be found on most above-ground parts of the plant. During visual examination of plant material for the presence of *T. palmi*, attention must be paid to silvery feeding scars on the leaf surfaces of host plants, especially alongside the midrib and the veins. Heavily infested plants are often characterized by a silvered or bronzed appearance of the leaves, stunted leaves and terminals, or scarred and deformed fruits (IPPC 2016).

2.5. Collection of thrips

Specimens for morphological examination are best collected in a fluid called AGA, which is a mixture of 10 parts of 60% ethanol with 1 part of glycerine and 1 part of acetic acid. If the specimens are to be stored, they should be transferred to 60% ethanol and kept in the dark, preferably in a freezer to prevent loss of colour. However, several laboratories have reported that AGA may act to denature the DNA of the thrips thereby hindering any subsequent molecular work. An alternative is to use 80–95% ethanol as the collecting fluid as any unmounted specimens may then be used for molecular studies. However, in this case specimens must be stored in the freezer until use, or they may prove difficult to slide mount.

Several methods can be used to collect thrips specimens (Mantel and Vierbergen 1996). Some modified methods are discussed below:

- Thrips may be individually removed from the plant (leaves, flowers or fruit), and transferred into microtubes containing AGA, using a moist, fine brush.

- Thrips may be beaten from plant parts onto a small plastic tray (e.g., a white tray for dark-coloured specimens or a black tray for light-coloured specimens). In cooler conditions, the thrips usually start walking across the tray rather than flying off, allowing time for the thrips to be picked off with a moist fine brush, whereas in warmer conditions collection has to be done more rapidly as the thrips are likely to fly off much more quickly. The thrips are easily seen on the tray using just a hand lens, but an experienced observer can also see them easily with the naked eye.

- Plant parts may be sealed in a plastic bag for 24 hours, with a piece of filter paper enclosed to absorb condensation. Most thrips will leave the plant parts and can then be collected from the inside of the bag.

- A Berlese funnel can be used to process plant material such as bulbs, flowers, turf, leaf litter, moss and even dead branches of trees. The funnel contains a sieve on which the plant material is deposited. Beneath the sieve, the bottom of the funnel leads into a receptacle containing 70–96% ethanol. An alternative is to use 10% ethanol plus wetting agent as some workers find that this makes the preparation of good quality microscope slide mounts easier. The funnel is placed under an electric lamp (60 W), and the heat and light will drive most of the thrips present in the plants down towards the receptacle. After an appropriate period (e.g. 8 hours for cut flowers), the content of the receptacle can then be checked under a stereomicroscope.

- Thrips may be monitored (winged adults only) using coloured sticky traps or other appropriate methods. The ability of a colour to attract thrips varies for different thrips species, but blue or white traps are good for *T. palmi*, though yellow traps will also work. For microscope slide preparation and identification, the thrips will have to be removed from the traps using glue removing fluids such as those based on citrus oils, dichloromethane or a turpentine substitute (Mantel and Vierbergen 1996).

2.6. Identification of thrips

Identification of thrips species by morphological examination is restricted to adult specimens because there are no adequate keys for the identification of eggs, larvae or pupae. However, the presence of larvae in samples can give important additional information such as confirming their development on the host plants. The primary method of identification of adult material is from morphological characters. In order to achieve species identification, these must be examined using a high-power microscope (e.g. 400X). Using this protocol with good-quality slide preparations should allow adult Thrips to be identified with certainty by morphological examination alone. Those thrips with only 2 pair of setae on the back of the pronotum, are typically *Thrips* species, but if they are large dark brown with a distinct white band towards the apex of the forewing they are *M. usitatus*. To differentiate the *Thrips* into species, individuals should be mounted onto a microscope slide in order to look at more detailed characteristics such as microtrichia, the number of marginal setae on parts of the abdomen and the rows of setae on the forewings. Thrips can be mounted on microscope slides with their wings spread eitherside of their body and examined under a dissecting microscope and higher powered light microscope. This allowed for those very small characters that can not be seen with a small 10X or 20X hand lens to be readily identified. Identification of thrips cannot be readily carried out using colour alone. Microscope examination is usually necessary to determine species.

Molecular assays can be applied to all life stages including the immature stages for which morphological identification to species is not possible. Additionally, in cases where adult specimens are typical or damaged, molecular assays may provide further relevant information about their identity. However, specificity of molecular assays is limited as they have been developed for specific purposes and evaluated against a restricted number of species, using samples from different geographic regions; therefore, such information needs to be carefully interpreted.

2.7. Description and Life Cycle of thrips

2.7.1. Description and Life Cycle of *M. usitatus*

The following description of *M. usitatus* is based on publications of Chang (1992 1990 a, b).

M. usitatus has six distinct developmental stages: egg, larval I, larva II, prepupa, pupa, and adult. Eggs are laid in petals and sepals. This is the reason for occurrence of large number of larvae in coups in adzuki bean flowers. In laboratory, at constant temperatures between 14 and 30°C, the egg, larval, pupal periods and adult longevity were 2-19, 5-10, 2-7, and 6-30 days, respectively. Female longevity is greater than that of the male at all temperatures. All *M. usitatus* died after hatching at upper (30°C) and lower (14°C) temperatures (Chang 1992; 1990 a, b).

The length of the life cycle depends on the temperature and the quality of the food source; as little as 10-12 days at 30 ℃ or as great as 19 days at 20℃ (Persley *et al.* 2007). Eggs are laid in slots flowers and leaves cut with the ovipositor; nymphs are yellow at first, but later deep yellow or orange-red. The mature larvae crawl downward and pupate 1-6 cm below the soil surface. Adults emerged in about 5 days. Adults and nymphs are readily seen when opening the flowers. The adults are greyish-brown, with deepest colours on the head and striped abdominal segments. Spread is by active flight, but also winged adults and nymphs can be picked up by winds and carried long distances.

2.7.2. Description and Life Cycle of *T. palmi* (Plate 1)

T. palmi is almost entirely yellow in coloration and its identification is hampered by both its small size (1.0–1.3 mm) and its great similarity to certain other yellow or predominantly yellow species of *Thrips*.

A complete generation may be completed in about 20 days at 30℃, but it is lengthened to 80 days when the insects are cultured at 15℃. Melon thrips are able to multiply during any season that crops are cultivated but are favored by warm weather. When crops mature, their suitability for thrips declines, so this thrips growth rate diminishes even in the presence of warm weather. The biology of *T. palmi* is described below (Capinera 2015):

Eggs: Eggs are deposited in leaf tissue, in a slit cut by the female. One end of the egg protrudes slightly. The egg is colorless to pale white in color, and bean-shaped in

form. Duration of the egg stage is about 16 days at 15ºC, 7.5 days at 26ºC, and 4.3 days at 32ºC.

Larvae: The larvae resemble the adults in general body form though they lack wings and are smaller. There are two instars during the larval period. Larvae feed in groups, particularly along the leaf midrib and veins, and usually on older leaves. Larval development time is determined principally by the suitability of temperature, but host plant quality also has an influence. Larvae require about 14, 5, and 4 days to complete their development at 15, 26, and 32ºC, respectively. At the completion of the larval instars, the insect usually descends to the soil or leaf litter where it constructs a small earthen chamber for a pupation site.

Pupa: There are two instars during the "pupal" period. The prepupal instar is nearly inactive, and the pupal instar is inactive. Both instars are nonfeeding stages. The prepupae and pupae resemble the adults and larvae in form, except that they possess wing pads. The wing pads of the pupae are longer than that of the prepupae. The combined prepupal and pupal development time is about 12, 4, and 3 days at 15, 26, and 32ºC, respectively.

Adult: Adults are pale yellow or whitish in color, but with numerous dark setae on the body. A black line, resulting from the juncture of the wings, runs along the back of the body. The slender fringed wings are pale. The hairs or fringe on the anterior edge of the wing are considerably shorter that those on the posterior edge. They measure 0.8 to 1.0 mm in body length, with females averaging slightly larger than males. Unlike the larval stage, the adults tend to feed on young growth, and so are found on new leaves. Adult longevity is 10 to 30 days for females and 7 to 20 days for males. Development time varies with temperature, with mean values of about 20, 17, and 12 days at 15, 26, and 32ºC. Females produce up to about 200 eggs, but average about 50 per female. Both mated and virgin females deposit eggs.

Careful examination is required to distinguish melon thrips from other common species. The *Frankliniella* species are easily separated because their antennae consist of eight segments, whereas in *Thrips* species there are seven antennal segments. To distinguish melon thrips from onion thrips, *Thrips tabaci* Lindeman, it is helpful to examine the ocelli. There are three ocelli on the top of the head, in a triangular

formation. A pair of setae is located near this triangular formation, but unlike the arrangement found in onion thrips, the setae do not originate within the triangle. Also, the ocelli bear red pigment in melon thrips whereas they are grayish in onion thrips. In general, the basic body color of adult melon thrips is yellow, but in onion thrips it is yellowish gray to brown (Capinera 2015).
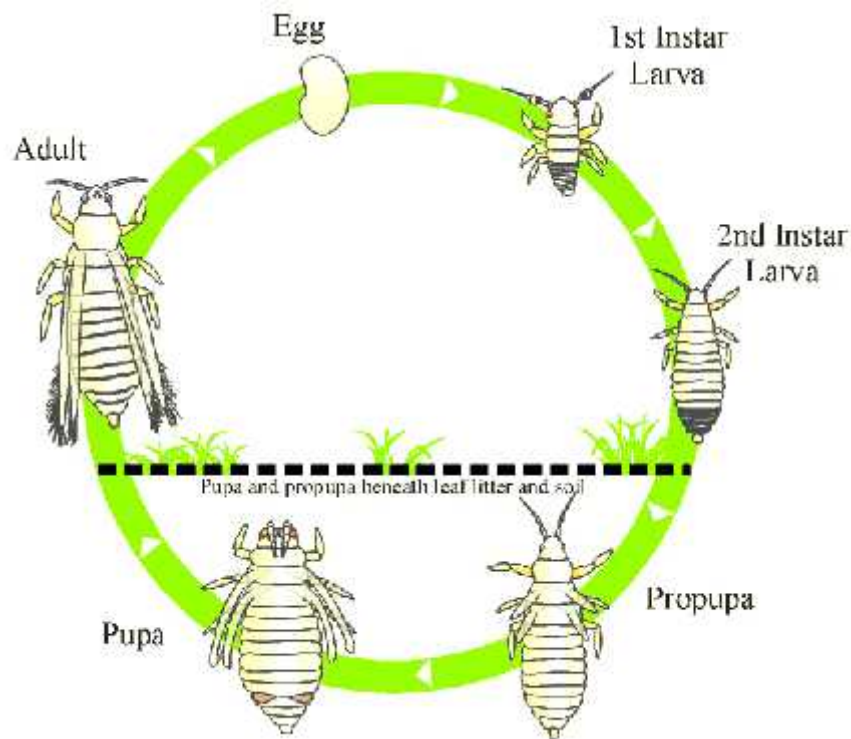
Plate 1. Generalized thrips Life cycle (Hoddle and Morse 1997)

Most thrips complete their life cycle from eggs to adult in 2-3 weeks depending on temperature and humidity (Kirk 1997). Thrips reproduce faster at an average temperature of 25ºC and a relative humidity of 70%. Soil-dwelling stages survive better in soils with moisture content between 10 and 13% (Lewis 1997). Adult thrips are weak to good flyers but their small size makes their dispersal susceptible to influences of wind and weather. Their activity peaks during hot weather when up drifts may carry them for greater distances.

2.8. Host plant of thrips

Members of *Megalurothrips* are commonly associated with damage to bean crops (Fabaceae) (Jackson 2017). Common hosts are cowpea, French bean, pea, peanut,

pigeonpea, mung bean, and soybean. (http://www.ozthrips.org/terebrantia/thripidae/thripinae/megalurothrips-usitatus/)

Melon thrips *(Thrips palmi* Karny) is a polyphagous species and has been recorded from more than 36 plant families, but is best known as a pest of Cucurbitaceae and Solanaceae. Among vegetables injured are bean, cabbage, cantaloupe, chili, Chinese cabbage, cowpea, cucumber, bean, eggplant, lettuce, melon, okra, onion, pea, pepper, potato, pumpkin, squash, and watermelon. Other crops infested include avocado, carnation, chrysanthemum, citrus, cotton, hibiscus, mango, peach, plum, soybean, tobacco, and others. Also, weeds can serve as important hosts, including species of nightshades (Solanaceae), legumes (Fabaceae or Leguminosae), and asters (Asteraceae or Compositae) (Capinera 2015).

2.9. Pest status

Hossain *et al.* (2018) reported that flower thrips (viz., *M. distalis* Karny, *M. usitatus* Bagnall and *Caliothrips indicus* Bagnall are associated mostly with the damage of tender buds and flowers of mungbean. *T. palmi* was also found in mungbean in Bangladesh. Rahman *et al*. (2000) reported that thrips is a major pest of mungbean in Bangladesh which cause flower drop.

Reddy *et al.* (1998) observed that among 37 species of insects recorded at various stages of crop growth on Pegionpea, only 7 species of insects attained major pest status where *M. usitatus* acquired major pest status at the flowering stage of the crop. Among different pests, thrips (*M. siostedti*) alone contributed 35-41% yield variation of the cowpea (Karungi *et al.* 2000). EIL of *M. siostedti* on cowpea was seven thrips per inflorescences. The pest status of *T. palmi* in South East Asia has been reviewed by Talekar (1991). Thrips are major pests of French beans accounting for 63 - 68% yield loss of fresh marketable pods (Nyasani *et al.* 2012).

2.10. Spatial distribution of thrips

Plant architecture can also influence thrips population levels. Gupta and Singh (1990) reported that *M. distalis* on green gram (*V. radiata*) preferred the middle leaf to lower and upper trifoliate leaves and the population was higher on the lower surface of the leaf than on the upper surface.

Sepswasdi *et al.* (1991) observed that the infestations of *M. usitatus* on Mung bean (*Vigna radiata*) during the end of the vegetative stage to the pod filling stage were

negatively correlated with grain yield and thereby resulted in reduction of yield. The flowering stage of the crops is particularly vulnerable to this pest.

2.11. Nature of damage

M. usitatus damage is caused by direct feeding on the contents of individual plant cells and the consequent reduction of photosynthetic capacity (Shipp *et al.* 2000). Losses caused by petal and fruit malformation and scarring are of even greater economic importance (Zhang *et al.* 2007). Thrips occur every growing season and cause yield losses through premature dropping of flowers. Thrips can cause various levels of damage to the bean pod, from light scaring to severly twisted and scared pods. This damage occurs within the flower when the pods are being fertilized and where the thrips are protected. Those thrips found within the flower can live on the pollen and nectar produced by the flower but can also feed on the developing pods which are soft green and easily damaged (Duff, 2012). Dozens to hundreds of adults and nymphs per flower may be found at peak pest occurrence on cowpea (Fan *et al.* 2013) and on snap bean (Tang *et al.* 2015). This species of thrips is not known to spread viruses. The larvae of thrips cause more damage than adults due to their large numbers, low mobility, gregariousness and commitment to feeding (Childers 1997). All the scars made by thrips on the leaves, petals, pods and young stem lead to dehydration of French bean plant leading to leaf and flower fall.

Thrips palmi breed on leaves and in flowers. Both the adult and the nymphal stages feed gregariously on their host. Silvering, yellowing or browning of the plant will be occur, leaves may crinkle and die; growing tips become stunted, discolored and deformed; fruits may abort or produce deformed or scarred fruit. The overall effect of a heavy infestation is a loss of plant vigour and a possible reduction in marketability of fruit (Layland *et al.* 1994). Melon thrips prefer foliage, but on pepper, a less suitable host, flowers are preferred to foliage. *T. palmi* causes economic damage to plant crops both as a direct result of its feeding activity and from its ability to vector tospoviruses such as Groundnut bud necrosis virus, Melon yellow spot virus and Watermelon silver mottle virus. Leaf curl disease caused by Peanut Bud Necrosis Virus (PBNV), which is transmitted by *T. palmi* (Karny) is considered to be a major threat, causing 40 percent yield loss (Nene 1972). Lipa (1999) and Vijayalaksmi (1994) documented that *T. palmi* was the vector of PBNV on groundnut.

2.12. Seasonal abundance and Population dynamics of thrips on mungbean in relation to weather parameters

The effects of weather factors that influence the population changes is essential in predicting thrips population. Weather variables including rainfall, temperature, relative humidity and wind have been reported as important factors that significantly affect thrips numbers (Ananthakrishnan 1993). In addition to their effect on thrips activity, temperature and relative humidity further influence the intrinsic rate of natural increase of the thrips. A basic understanding of the relationship of these factors with thrips population is important in developing an integrated control strategy for thrips and in determining the potential pest control needs for a given climatic trend.

Vijayalakshmi *et al.* (2017) observed correlation between the incidence of thrips (*Scirtothrips dorsalis* Hood.) on groundnut and rainfall, temperature, relative humidity and sunshine hours. In kharif (August-September), thrips population showed negative correlation with morning and evening relative humidity -0.025, -0.223 and positive correlation with maximum and minimum temperature (0.266 and 0.146), rainfall (0.335) and sunshine hours (0.277) respectively.

Yadav and Singh (2013) studied the seasonal abundance of insect pests on mungbean and it's relation to abiotic factors and found that the thrips population was started after flowering with intensity (0.4 per ten flowers) in 33 standard week and gradually increased and reached its peak in 36 standard week (2.4 per ten flowers). The correlation coefficient analysis of thrips population with prevailing weather condition indicated positive correlation with the sunshine and evaporation and non-significant with temperature, relative humidity, rainfall and windspeed.

Hossain *et al.* (2012) reported that during kharif-I in 2009 thrips population on mungbean flower was higher at early (February l4 to March 07) and late sown (April 11 to May 02) crops than mid sown (March 14 to April 04) crops. Thrips population exhibited significantly negative correlation with temperature but positive correlation with bright sun shine hours.

Khan *et al.* (2011) found that temperature had a negative and significant correlation with thrips ($r = -0.860$) infesting green gram, the relative humidity displayed a positive and significant correlation with thrips ($r = 0.313$).

Seal (2011) reported that *T. palmi* population abundance was recorded on snap bean all round the year during the study. Sampling for *T. palmi* was initiated 3 weeks after each planting. Sampling was conducted by collecting four subsamples of five full-grown young leaves, one leaf/plant, from each block. Mean numbers of thrips were significantly low in October and start increasing thereafter. Thrips population peaked during March to May, and starts decreasing in June. This pattern of *T. palmi* population abundance was observed in each year of the study.

Nagaraju (2008) observed that in kharif 2007, the *T. palmi* population on urdbean crop was 1.26 per plant during 29th standard week (July 16-22) i.e., at 15 DAS. The thrips population per plant increased gradually from 30th to 33rd standard week i.e. with advance in the age of the crop from vegetative stage to flowering stage. However, the thrips population started decreasing from 34th standard week (Aug 20-26) i.e., from 50 DAS starting from pod formation to maturity stage of the crop. The highest incidence was observed during 33th standard week i.e., at 43 days after sowing with 16.9 thrips per plant. The population reached a level of 0.9 thrips per plant by 35th standard week i.e., 57 DAS, a few days prior to harvest. The morning relative humidity, evening relative humidity and rainfall showed negative association with the incidence of *T. palmi* during Kharif 2007, maximum temperature showed positive association with the incidence of *T. palmi* while, the minimum temperature, morning relative humidity, evening relative humidity and rainfall showed negative association.

Bhede *et al*. (2008) reported that thrips population showed positive correlation with bright sunshine hour but did not show any significant correlation with temperature.

Chakraborti (2006) recorded the incidence of thrips (*M. distalis)* on mungbean during post-kharif season in 2004. The population of thrips was first recorded on 3rd week of September (38th standard week) i.e., 29 days after sowing. The maximum population (3.12/plant) of thrips was found in 1st week of October (40th standard week) when the temperature (Max.) of 29.5°C, temperature (Min.) 21.3°C, RH (max.) 95%, RH (min.) 85% and 306.0 mm rainfall were recorded. Then the population decreased gradually and observed on the crop till the 2nd week of November (45th standard week) i.e., 78 days after sowing. In general weather has pronounced effect on the population dynamics of thrips. However, correlation between thrips population with the weather parameters showed that the correlations in most of the cases were non-

significant indicating little influence of weather on seasonal fluctuation of thrips population. Only RH (minimum) exhibited positive and significant correlation with the thrips population reflecting that thrips population increased with the increase of minimum relative humidity. It is noteworthy to mention here that thrips can feed only from soft succulent plant parts. High humidity makes the leaves more succulent favourable for thrips.

Yadav and Singh (2006) studied about the forecast model of major insect pests of mungbean. Thrips population at Kanpur location during summer had a significant positive correlation (0.574) with maximum temperature, whereas, a non-significant negative effect of maximum humidity and rainfall was noticed along with a slight positive influence of minimum temperature and humidity when the cumulative effect of weather on the population build up was studied.

Upendhar *et al.* (2006) reported that the thrips population on sunflower varied from 4.8 to 16.4 thrips/head with not much variation among seasons except on rainydays /week. There was a positive correlation of thrips population with maximum temperature and negative correlation with minimum temperature, RH (morning and evening) and rainfall.

Vijayalakshmi *et al.* (1999) indicated that the mean temperatures (25-28.9ºC) were optimum or slightly above optimum temperature of 25ºC to *T. palmi* and were favourable for fecundity, development, productivity and longevity.

Pal (2004) reported that the seasonal incidence of *T. palmi* on groundnut was higher in summer and *Kharif* season.

Tsai *et al.* (1995) reported that *T. palmi* populations were low in summer months and high in winter and spring seasons, as *T. palmi* could tolerate low temperatures better than high temperatures.

2.13. Varietal performance of mungben for resistance against thrips

The development of insect pest resistant cultivars offers a better alternative in management of insect-pests to the pulse crops. This method is stable, incurring less expenditure and safer to health and environment, which can be easily well blended in integrated pest management programme of mung bean. Role of plant resistance to insects in pest management programme varies with crop to crop and insect to insect, depending on the prevailing agro-ecosystem in a particular growing zone. Its importance in the management strategy depends on the availability and utility of other

control measures. Thus resistance is a contributing feature and used as an adjunct to other components of pest control. In the initial phases, a plant resistance should generally be focused on the key pests of the area (Upadhyay *et al.* 1998).

Tamang *et al.* (2017) tested five varieties of moong (Sonali (B-1)), Bireswar (WBM-4-34-1-1), Samrat (PDM 24-139), Sukumar (WBM-29) and Panna (B-105) which were sown on two different seasons (December 2012 to April 2013) and (February to May 2013) for evaluations against different pests of moong. All the testing varieties carried a lowest to a very few thrips population per flower. However, varieties showed significant difference to each other, which reflected their resistance and low or non- resistant ability against thrips. Samrat (PDM 24-139), Panna (B-105) and Sonali (B-1) with 2.21, 1.93 and 1.58 thrips per flower, respectively, were the most susceptible varieties. Bireswar (WBM-34-1-1) variety with 0.27 thrips per flower was found the most resistant variety followed by Sukumar (WBM-29) which had fewer (0.48 thrips per flower) during first season. Similar trend of thrips incidence was found in the second season. The high yield of Bireswar (WBM-34-1-1) and Sukumar (WBM-29) was mainly attributed to the low attack of sucking insect pests because of their resistant abilities.

Nadeem *et al.* (2014) reported that population of thrips (numbers per leaf) showed significant variations among the tested mungbean cultivars. It was observed that the population trend of thrips (4.0 per leaf) was lowest on the MH 3153 whereas, the highest (12.3 per leaf) on MH34143. Population of thrips on other lines were observed as 8.7, 5.3, 9.3, 7.7, 7.3, 9, 5.7 and 7.3 per leaf in MH 5251, MH 5254, MH 5255, MH 34144, MH34164, MH 34241, NM 2006 (Check 1) and AZRI2006 (Check 2), respectively. Complete resistance against thrips was not observed in any of the tested cultivar, except MH 3153 which showed comparatively better resistance among the tested genotypes.

Iqbal *et al.* (2007) reported that among nine cultivars of mung bean, cultivars NM-54 and chakwal-96 attracted significantly least number of thrips (4.33 thrips per leaf) and were therefore, relatively more resistant. Local variety and NM-92 attracted significantly large number of thrips (5.3 thrips per leaf) showing least resistance. The remaining cultivars were intermediate.

Chakraborti (2006) revealed that among 24 mung bean genotypes, the genotypes Sbl-17(a)-1/4, A-228, NBM-100 and Sbl-17(a)-6/2 harboured lower population meant for

less susceptible while A-267, Pusa-Baishakhi and PDM-84-143 harboured higher population indicating more susceptible to the thrips. Although thrips population on all genotypes over two years (2003-2004 planting season) were at lower level. None of the genotypes of mung bean was completely free from the thrips (*M. distalis*) infestation *i.e.* resistant to thrips. Higher population of thrips on Sbl-17(a)-1/4and Sbl-17(a)-6/2 at initial infestation *i.e.* on 29 and 36 DAS might be due to early flower inhabit (flowering occurred in 27-28 DAS) of these genotypes because thrips usually appeared with the initiation of flowering.

A number of plant characteristics are known to render the cultivars less suitable or unsuitable for feeding, oviposition and development of insect pests. Broadly these characters can be classified into two categories i.e. biophysical and biochemical. Plant resistance/susceptibility is controlled by these characters. Some bio-physical and bio-chemical characteristics responsible for resistance are discussed below-

2.13.1. Bio-physical characteristics responsible for resistance

Tamang *et al.* (2017) measured trichome density (0.5 cm^2) in five mungbean varieties in which Bireswar (WBM34-1-1) followed by Sukumar (WBM-29) showed comparatively better resistant cultivars regarding low mean population of sucking pests i.e. aphids, thrips and whitefly as compared to other tested varieties. Dense trichomes (30.0 and 33.50 /cm^2) were observed on the leaves of Sukumar (WBM-29) during first and second seasons, respectively. In contrary, the trichome density was lowest (13.5 and 18.0 /cm^2) in Samrat (PDM 24-139) had relatively higher thrips incidence during first and second seasons, respectively.

Surujana (2014) reported that the genotype of blackgram with high trichome density i.e., VBG-10-008 recorded less number of whiteflies (2.12 nymphs/trifoliate/plant). The trichome density was lowest in susceptible check, LBG-623 (11.53 trichomes /cm^2) which recorded highest number of whiteflies (6.98 nymphs/ trifoliate/plant).

Setiawati *et al.* (2009) reported that the tomato variety which has a high density of glandular trichomes will decrease the egg laying and feeding of *B.tabaci* nymphs.

Lakshminarayan *et al.* (2008) studied the morphological basis of resistance in 15 green gram genotypes against *Bemisia tabaci* (whitefly). Among the morphological characters, the thickness of leaf lamina, palisade layer, trichome density and length on the lower surface of the green gram genotypes seemed to be responsible for imparting

resistance or susceptibility to the whitefly. The genotypes resistant to the whitefly showed thinner leaf lamina and palisade layer with shorter trichomes which were in lower number on the lower surface of the leaf. These characters were quite the reverse in the susceptible green gram genotypes.

Chakraborti (2006) reported trichome as an important base of bio-physical resistant also played important role in determining resistant /susceptible to insect-pests.

Ali (2008) reported that presence of leaf trichomes and their types in the relatively resistant mungbean variety could be attributed to the host non-preference for whitefly.

Oriani *et al.* (2005) reported that the type of trichome hair influences the incidence of whitefly rather than trichome density, where number of eggs significantly correlated with long straight trichomes and short hooked trichomes.

Indiati (2004) reported that the mungbean genotype MLG716 was resistant to thrips due to presence of higher fibre, thinner leaves, longer and glabrous trichomes and lower total N.

Zeier and Wright (1995) investigated thrips resistance in *Gladiolus spp* and reported that the density of epidermal leaf protrusions on leaves was negatively correlated with damage.

2.13.2 Bio-chemical analysis of varieties responsible for resistance or susceptibility

Ali (2008) reported that the moisture contents in mungbean leaves had a significant positive correlation (r = 0.8156) with the number of adult whitefly but Chlorophyl-A and Chlorophyl-B content of leaf was negatively correlated with the number of adult whitefly.

Phenol is an important biochemical content in the plant system which plays an important role in plant resistance. Sinha (2013) estimated the highest amount of phenol content in leaves of mungbean variety HUM-1 (14.77 mg g^{-1}) that had the minimum incidence of whiteflies (2.00 per 10 cm twig) and YMV disease (7.49 % leaf infestation). It revealed that the variety was tolerant one. The lowest phenol content was estimated in leaves of variety TM-37 (6.29 mg g^{-1}) that recorded highest incidence of whiteflies (3.30 per 10 cm twig) and YMV incidence (32.54 % leaf infestation). Significantly highest thrips population per 6 leaves was recorded on variety TM-37 (1.93) where phenol content was lower.

Vijayalakshmi (2013) observed a highly significant and negative correlation between leaf water content and onion thrips population (-0.866). Significant negative correlation between phenol content and onion thrips population was also found in the study.

Chakraborti (2006) reported that phenol was found to be negatively correlated with the thrips (*M. distalis*) population in mungbean genotypes and the OD-Phenol also showed negative correlation indicating higher level of phenol was responsible for low thrips population.

Jat and Pareek (2003) reported that there was negative correlation between total phenolic content and fruit damage by brinjal shoot and fruit borer. They observed higher phenolic content (0.54 to 0.55 %) in less susceptible varieties such as Arka kusumakar and SM-10. The phenolic content (0.47-0.49 %) was low in highly susceptible varieties such as Unnati, Black round and Pusa purple round.

Kennedy (2003) reported that phenols are often associated with feeding deterrence or growth inhibition.

Rao (2002) also found the pest incidence (*Empoasca kerri* and *Aphis craccivora*) on groundnut was positively correlated with nitrogen content and negatively correlated with phenols and tannin levels.

Ahuja *et al.* (2001) observed that the morphotypes of cotton with high phenol content showed less bollworm and leafhopper incidence.

Veeranna (1998) reported that in cowpea higher levels of phenol were found in tolerant genotypes than in susceptible and was responsible for reduced damage due to pod borer. Phenols are the extremely abundant plant allelochemicals, often associated with feeding deterrence or growth inhibition. Phenolics in a fairly large concentration could ward off insect pests because of direct toxicity.

Sugar is an important biochemical content in the plant system which plays a pivotalrole in governing lot of physiological activities. Sinha (2013) estimated the highest amount of total sugar, reducing sugar and non-reducing sugar in mungbean variety TM-37 (3.57 mg g^{-1}, 2.27 mg g^{-1} and 1.30 mg g^{-1}, respectively) and this variety registered highest thrips population. In contrary, the lowest amount of total sugar, reducing sugar and non-reducing sugar was estimated in variety K- 851 (2.55 mg g^{-1}, 1.19 mg g^{-1} and 1.36 mg g^{-1} respectively) and this variety registered minimum thrips population (1.25) per six leaves.

Jaydeep *et al.* (2006) studied relation between total sugar, non reducing sugar and reducing sugar in pods and expression of varietal reaction towards spotted pod borer *Maruca vitrata* (Geyer) in ten varieties of mung bean. The highly susceptible cultivar LGG- 450 had highest amount of total sugar (1.38 mg g^{-1}), reducing sugar (0.59 mg g^{-1}), non-reducing sugar (0.79 mg g^{-1}) as compared to highly tolerant cultivar LGG- 497 which had 1.13 mg g^{-1}, 0.48 mg g^{-1} and 0.65 mg g^{-1}, respectively. A significant and positive correlation exists between total sugars, reducing sugar, non reducing sugar, with pod damage.

Sanehdeep *et al.* (1999) observed less amount of reducing sugars in wild species of chickpea (1.57 -1.95 %) as compared to the cultivated genotypes.

Nawalgatti *et al.* (1993) observed that the resistant chilli genotypes had lower sugar content. The resistant accessions G-5 and Pant C-1 contained low levels of reducing sugars (5.11 and 5.33 mg g^{-1}, non-reducing sugars (9.56 and 9.62 mg g^{-1}) and total sugars (14.70 and 14.90 mg g^{-1}), respectively. Hence, low sugar content was considered as one of the important factors in resistant varieties (Varadharajan and Veeravel 1996).

Das *et al.* (2001) evaluated the infestation of *Aphis craccivora* in 11 green gram cultivars in field and laboratory conditions to determine their relationship with phosphorus and potassium content of the cultivars and observed that the K content in the leaves of two least preferred cultivars (Kopergaon, PMB-14) were substantially high compared to those of other cultivars and the K content in leaves exhibited significant negative correlation with the population density of *A. craccivora* but leaf P content was not significantly correlated with infestation.

Negm *et al.* (1978) conducted a multiple regression analysis in Egypt to evaluatethe simultaneous effect on the multiplication and mortality of *Aphis craccivora* Koch on 10 varieties of beans [*Phaseolus*] and 3 of cowpea with 9 variables (total nitrogen, % amino acid, total carbohydrates, soluble sugars, phosphorus, potassium, calcium, sodium and the pubescence of the food plants) and observed that total carbohydrate and soluble sugars were the key factors limiting aphid multiplication (68.99% of population change was affected by them) whereas, amino acids and hair density played a minor role (9.78% and 5.8%, respectively) of the change.

2.14. Evaluation of different colored sticky traps for thrips preference

Monitoring to identify when thrips arrive and to determine population levels is helpful in designing an appropriate control strategy. Color sticky trap can be used as a tool for monitoring or early detection and sometimes controlling thrips.

A variety of trap colors have been evaluated for monitoring thrips populations. However, different species of thrips attracted to different colors, with blue, white, and yellow being the most attractive ones (Table 2).

Table 2. Thrips species and their respose to trap colors with references

Thrips	Preferred trap color	References
Ceratothripoides claratris (Shumsher)	Blue	Ranamukhaarachchi and Wickramarachchi (2007)
Frankliniella occidentalis (Pergande)	Blue and white	Muvea *et al.* (2014); Allsopp (2010)
Megalurothrips usitatus (Bagnall)	Blue	Tang *et al.* (2016); Chang (1990)
Megalurothrips sjostedti Trybom	Blue	Muvea *et al.* (2014)
Scirtothrips perseae Nakahara	Yellow	Hoddle *et al.* (2002)
Thrips imagines Bagnall	Blue, yellow and white	Kirk (1984)
Thrips tabaci L.	Blue	Natwick *et al.* (2007)

Muthuram *et al.* (2017) reported that green colour sticky boards were found effective in attracting *Thrips tabaci* in onion field than yellow boards. Violet, orange and white sticky boards were found on par with each other. Regarding crop damage, the green sticky board placed plot recorded only 4.26% and in control it was 13.72%. There was 11.48% increase in yield by using green sticky boards. Green sticky boards were recommended in the study to manage thrips in onion @ 1 board per 4m^2. Dark green was used in the study because onion thrips have a broad host range that includes grasses and broad leaves.

Tang *et al.* (2016) investigated the response of thrips and beneficial insects to different-colored sticky traps on cowpea, *Vigna unguiculata*. They found that more thrips were caught on blue, light blue, white, and purple traps than on yellow, green, pink, gray, red, or black traps. There was a weak correlation on the number of thrips

caught on yellow traps and survey from flowers (r = 0.139), whereas, a strong correlation was found for blue traps and thrips survey on flowers (r = 0.929). On commercially available sticky traps (Jiaduo®), two and five times more thrips were caught on blue traps than on white and yellow traps, respectively. The economic threshold for *M. sjostedti* on cowpea was reported at seven thrips per flower (Nabirye *et al.* 2003). Based on this information, they suggested that 200 thrips/blue trap/week could be the economic threshold for *M. usitatus* on cowpea.

Sridhar and Naik (2015) revealed that thrips attraction has differential attraction to various colours in the sequence of blue>yellow>pink>white under both field and polyhouse conditions.

Hossain *et al.* (2014) reported that installation of sticky white trap @ 40 traps per ha reduce 28.56% thrips population in onion.

Demirel *et al*. (2008) observed that yellow sticky color traps were significantly attractive for thrips species in 2006, but in 2007 blue color traps were significantly attracted thrips species. The yellow, blue, white sticky color traps for thrips species and the yellow and orange sticky color traps for leafhopper species were strongly suggested for monitoring their population densities in cotton crops.

Nagaraju (2008) reported that the pink trap caught significantly maximum number of *Thrips palmi* (104.0), followed by white trap (54.3), blue trap (51.4) and yellow trap (38.5) and were significantly superior to orange trap (14.3) in an urdbean field. Green trap had minimum number of thrips (11.6) and was found to be significantly inferior to the pink, white, blue, yellow and orange traps.

Ranamukhaarachchi and Wickramarachchi (2007) tested color cards i.e., yellow, blue, white, light green, dark green, orange, purple, red and black cards against thrips and a clear polypropylene sheet covered with the insect adhesive was used as a control. Blue and white cards attracted more thrips (*Ceratothripoides claratris*) compared with other colors. A correlation existed between cumulative thrips counts and the leaf infestation level of tomato. The tomato plots without sticky traps showed higher leaf infestation by thrips.

Chu *et al.* (2000) found that among the white, rumred, yellow, lime green, spring green, wood land green (dark green), true blue and black color traps, the true blue and

the white were the most attractive trap base colours for *F. occidentalis* (Pergande) adults.

Huaping *et al.* (1997) conducted experiment on the preference of *Thrips palmi* to eight color sticky cards was carried out in an eggplant field at China. The thrips had the strongest preference to blue sticky card (P<0.01) and its preference order to the other 7 color cards was as follows: blue, turguoise, yellow, deep blue, green, orange, red and black. Results on the trapping effect of blue sticky card from east, south, west and north directions show that most thrips were trapped from the north, which existed a significant difference with those from the other three directions (P<0.05). Five blue sticky cards were set up at the heights of 73.9, 101.7, 129.5, 157.3 and 185.1 cm above the ground to trap thrips, when the average height of eggplant was approximately 70 cm. More thrips were trapped of 73.9 and 101.7 cm height, which existed significant difference with those at the other three heights.

Vernon and Gillespie (1995) studied on *F. occidentalis* (Pergande) captured on yellow or violet traps of four different shapes when placed in front of plywood frames painted violet, blue, green, or yellow as background colors in a cucumber greenhouse. Among traps with cubic, spherical, rectangular prism, or cylindrical shapes of approximately the same surface areas, only yellow cylindrical traps in front of a violet background were significantly more attractive than the other shapes. Yellow traps placed in front of violet or blue backgrounds caught significantly more thrips than traps with yellow backgrounds, which in turn captured significantly more thrips than traps with green backgrounds. Violet traps with a yellow background caught significantly more thrips compared with violet traps with blue, green, or violet backgrounds. Catch of thrips on flat traps increase linearly with increase in trap area between 74 and 300 cm^2.

Matteson and Terry (1992) reported that number of thrips was higher on blue, violet, white traps, while lower numbers were found on green, red, yellow and highly UV reflective white traps. Highly significant correlations of preference with the brightness in the blue-violet range ($R = 0.69$ for females; $R = 0.86$ for males, $P < 0.0021$), but no significant correlation with brightness in the visible, green yellow, or UV range was found.

Gillespie and Vernon (1990) assessed the catch of western flower thrips, *Frankliniella occidentalis* (Pergande), on sticky traps by height, color, and sex in commercial greenhouse cucumber crops. At 2.4 m. catches on blue, violet, yellow, and white traps were not significantly different, but were significantly greater than catches on green, UV + white, and black traps. At this height, blue captured more females than other colors, and yellow captured more males.

Lu (1990) reported that pale blue traps were most attractive to *Thrips tabaci* on shallot crop, with an average of 19.78 caught per 20×25 cm trap, compared with 12.50, 7.61, 7.14, 7.11 and 1.17 caught by white, green, yellow, grey and red traps, respectively. No thrips were caught in black traps.

2.15. Evaluation of bio-pesticides and chemical insecticides against thrips
2.15.1. Use of neem and other bio-pesticides for control of thrips

Neem pesticides are plant extracts derived from the Indian Neem Tree, *Azadirachta indica* (Meliaceae). Azadirachtin is the active ingredient found in neem and its mode of action on insects includes phagorepellency, growth inhibition, oviposition deterrence, mating disruption and chemo sterilization (Morgue *et al.* 1998; Prakash and Rao 1997). The most important mode of action of azadirachtin is its effect on metamorphosis through the inhibition of the release of prothroracicotropic hormones, allatotrophines and allatoinhibins (Rembold 1989). It also affects vitellogenesis, which leads to vitallarium and the oviducts being reabsorbed. This culminates in a drastic reduction in egg laying activity of the adult thrips (Mogue *et al.* 1998; Prakash and Rao 1997). Neem compounds affect 400-500 species of insect pests (Schmutterer 1995). Neem seeds contain more than a dozen azadirachtin analogs, but the major forms are azadirachtin and considerable quantities of other triterpenoids, notably 3–15 tigloylazadirachtol, salannin and nimbin (Kraus 2002). However, the success in the commercial utilization of neem products has fallen well short of expectation due to the relatively high cost of its refined product (Isman *et al.* 2005; 2004) slow action on pest insects and relatively short persistence due to its sensitivity to temperature and ultraviolet light. This necessitates frequent applications to achieve an effective control of thrips which rapidly build up again from non-treated plant parts or recolonize from refuges such as soil (Barrek *et al.* 2004).

Khattak *et al*. (2006) reported that neem oil at 2% and neem seed water extract at 3% significantly reduced the population of whitefly, jassids and thrips on cotton up to 168 hours after spray.

Theoming *et al.* (2003) reported that neem had systemic effects and killed 51% of *F. occidentalis* on French beans.

Shahnawaz (2005) evaluated some newer molecules of insecticides and neem products under field condition with nine treatments during kharif and Rabi 2002. The results revealed that acetamiprid 20 SP @ 0.2 g L^{-1} of water was highly effective in reducing the onion thrips.

Spinosad (e.g., Conserve®) may also be useful in controlling thrips in the field. Spinosad is a recently discovered insecticide, derived from the fermentation of *Actinomyces* bacteria commonly found in the soil. The National Organic Standards Board has recommended that spinosad be allowed in organic production. Organic growers should consult their certifier before using (Kuepper 2004).

Seal *et al. (*2013) reported that abamectin (glycoside) was a commonly used insecticide for managing vegetable leafminers, and when tested against *T. palmi,* it provided a 55-65% reduction of the thrips population. Spinosad provided high levels of control (80-95%) and was commonly used by the vegetable growers for the management of *T. palmi* in vegetable crops.

Duff (2012) reported that Spinosad did have a positive effect against the larval population could be due to this product having some translaminar effect: if this were to happen on the flower petals, where thrips eggs are most likely laid, then this product could be responsible for affecting the newly hatched larvae before they move into the flowers. The spinosad and dimethoate treatment were the best performer of all treatments at controlling the adult thrips.

Prasad and Khalid (2009) found Spinosad 45 SC @ 125 ml ha^{-1} effective against thrips.

2.15.2. Use of chemical insecticides

Although, the insect pests are controlled by diversified measures but chemical control of insect pests is yet considered as more effective than rest of the methods. However, chemical insecticides are applied only if the insect population crosses the economic threshold level (ETL). Crop protection with chemicals is desirable and unavoidable

part of integrated pest management because of their quick knockdown action (Mohyuddin *et al.* 1997). Always follow label instructions when using any pesticide, and keep in mind that the decision to use a pesticide should be made only when other approaches to pest management fail to provide adequate crop protection. Since the development of insect resistance against insecticides was reported from various parts of the world, it is desirable to screen the new products and evaluate the efficacy of existing insecticides and record the development of resistance.

Most broadspectrum synthetic insecticides, including pyrethroids, organophosphates, and carbamates kill the native species of thrips that outcompete western flower thrips (Hansen *et al.* 2003 and Reitz *et al.* 2003), leading to dramatic large scale shifts in thrips demographics (Frantz and Mellinger 2009).

Reddy (2016) reported that among the synthetic insecticides and plant products under test, significantly better control of mungbean thrips was achieved with two round spraying of imidacloprid 17.8 SL @ 0.005% applied at fortnightly interval starting from bud formation stage, which was statistically on par to dimethoate 30 EC, thiomethoxam 25WG, profenophos 50 EC and triazophos 35 EC, at their test doses. Among the plant products, neem oil (3%) and yam been seed extract (5%) showed poor performance as compared to the synthetic insecticides but significantly superior over untreated control in respect of minimizing thrips population varied from 2.6 to 4.2 and 2.4 to 3.8 thrips per plant, respectively. These treatments were found most effective in decreasing thrips population to the tune of 66.03 percent to 33.96 percent with maximum and minimum being recorded in imidacloprid 17.8 SL @ 0.005% and neem oil (3%), respectively.

Hossain *et al.* (2015) found that after 24 hrs of spray, Success 2.5SC caused 94.05% mortality of thrips followed by Intrepid 10SC (90.89%), Confidor 70WG (64.68%), Movento 150SC (62.83%) and Actara 25WG (42.75%). They recommended spraying with Success 2.5SC (1.2 ml L^{-1} of water) or Intrepid 10SC (2ml L^{-1} of water) two times at an interval of 10 days from the first appearance of thrips infestation in onion.

Nadeem *et al.* (2015) observed the comparative efficacy of synthetic insecticides and neem oil. Mospilan 20 SP treated plot comparatively showed least population of thrips (5.08) per inflorescence throughout the study period followed but not significantly different to Actara 25 WG (5.75 thrips per inflorescence). Per

inflorescence population of thrips found in Actara 25 WG (5.75) and Confidar 200 SL (6.75) treated plots was found statistically similar with each other. In case of percent population reduction of thrips over control, it was evident that all the treatments reduced the population of thrips per inflorescence to significant level over untreated plot. Maximum population reduction of thrips (65.06%) was found in plots treated with Mospilan 20 SP followed but not significantly different to Actara 25 WG treated plot (60.57% population reduction of thrips) followed by Confidar 200 SL treated plot (53.59%). Spraying with neem oil 3% remained comparatively better and significantly different than other neem oil concentrations tested as it showed less (8.00) population of thrips per inflorescence. Neem oil 3% showed comparatively more thrips population reduction (25.51%) than neem oil 2% (10.22%) and neem oil 1% (9.13%). Although neem oil performed less than other chemicals tested but remained intermediate and effective against thrips as compared to control plot.

Sahito (2013) reported that the insecticides Radiant (a.i., Spinetorm 120% SC), Crown (a.i., Imidacloprid 200 SL) and Finvil (a.i., Fipronil) were applied thrice at the interval of 15 and 21 days of second and third spray respectively. The results showed that all three insecticides performed well in reducing pest population. However, Radiant gave best results against pea thrips, *Calothrip indicus.* The overall mean population per leaf 7.33, 8.78 and 10.23 of *Caliothrips indicus* was recorded in the plots treated with Radiant, Crown and Finvil, respectively as compared to control plot (12.13 thrips per leaf) during the first spray. During second spray the overall mean population per leaf 7.04, 8.02 and 8.97 of thrip was recorded in the plots treated with Radiant, Crown and Finvil, respectively as compared to control plot (14.30 thrips per leaf). Whereas, during third spray the overall mean population per leaf 3.92, 5.06 and 6.13 of thrip was recorded in the plots treated with Radiant, Crown and Finvil, respectively as compared to control plot (14.62 thrips per leaf). All insecticides performed well up to 72 hours interval.

Seal *et al*. (2013) found that insecticides of various chemical groups caused mortality of *T. palmi* adults and larvae. Imidacloprid (neonicotinoid) and organophosphates provided moderate levels (30-55% and 35-52%, respectively) of *T. palmi* control, while pyrethroids could only suppress 20-45% of the population. Among the carbamates, formetanate hydrochloride was the most effective in providing highest level (85-98%) of *T. palmi* mortality, followed by methomyl and oxamyl.

Ullah *et al.* (2010) found that Confidor was found to be most effective against thrips and the least efficacy was recorded in case of Actara.

Bhudev *et al.* (2005) reported that dimethoate 0.03% was more effective for the control of thrips whereas, azadirachtin 5 ml L^{-1} was found least effective.

Khattak *et al.* (2004) indicated that Mospilan 20SP, Actara 25WG, Polo 500EC, Tamaron 60SI and Confidor 200SL were effective against thrips on mungbean.

CHAPTER III
MATERIALS AND METHODS

Six experiments were conducted, of which two in the Laboratory of Department of Entomology and four in the experimental field of Sher-Bangla Agricultural University (SAU), during February 2016 to May, 2018. Other details of the methodology are furnished below:-

EXPERIMENT 1

3.1.1 Name of the experiment: Identification of Thrips Species Infesting Mungbean

3.1.2   Experiment Location and Duration

The study was conducted in the laboratory of Department of Entomology of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during March to April 2016 to identify the existed thrips species attacking mungbean with their important characters and to determine the morphometric measurements of adult thrips species. The detail methodology of the study has been presented under the following sub-headings:-

3.1.2.1 Materials used

The mungbean variety BARI Mung-6 was sown in 10 February 2016 in the research field of Sher-e-Bangla Agricultural University to collect thrips species.

3.1.2.2 Collection of thrips

Initially thrips were collected from the mungbean field by shaking flowers, leaves or twigs over a white plate (beating method) and transferred to 10 mL vial containing 70% Ethyl alcohol using a small soft brush before being placed onto microscope slides for identification (Plate 2 and 3). To confirm identification of thrips species a proportion of the thrips was collected in a vial containing 70% ethanol and sent to an expert on thrips Dr. Laurence A. Mound, Australian National Insect Collection CSIRO, Canberra, ACT 2601, Australia. This helped to refine identifications with only a very few needing further scrutiny.

Plate 2. Thrips on top trifoliate leaves of mungbean

Plate 3. Adult thrips in 70% Ethyl alcohol

3.1.2.3 Preparation of specimen

A rapid method of removing thrips from plant material for immediate examination was followed. To study the shape, color and morphometric measurement, adult thrips were observed under a dissecting steriomicroscope (model no. NZ 1903-P, Euromax microscope bv, The Netherlands) in SAU Entomological Laboratory, at a high magnification (40X–90X) for the setae on the wing veins to be clearly visible. Specimens were rejected when the first vein had a continuous row of setae for its full length. Care was taken to ensure that the first vein was examined and not the hind vein or costal setae (Plate 38). All thrips without the continuous row of setae on the first vein were regarded as suspect (Plate 38). Slides were then prepared for each suspect thrips by labelling each with the appropriate data. For routine slide preparation one popular method (Mound and Kibby 1998) using water soluble mountant such as Hoyer's mountant (50 ml water, 30 g pulverized gum Arabic, 20 ml glycerin, 125 g chloral hydrate, 2 g iodine crystal, 1g potassium iodide) was followed. A drop of Hoyer's medium was placed on slide. The specimens were transferred on slides from the collecting fluid into clean 70% ethanol. Thrips were mounted on microscope slides with their wings spread eitherside of their body using entomological micropins. A clean coverslip was then gently lowered onto the mountant to ensure no air bubbles were trapped beneath it. After removing excess mountant around cover slips, slides were ringed and sealed with clear fingernail polish. Labeling was done incuding locality, date of collection, host plant. The specimen was then ready for identification. Thrips were mounted on slides showing the variability in appearance and colour.

3.1.2.4 Identification

Slides were examined with a dissecting and high-powered light stereomicroscope (model no. NZ 1903-P, Euromax microscope bv, The Netherlands). Different body parts of thrips species i.e., antennae, wings, head, thoracic segments, legs, abdominal segments were examined. Photographs were taken by using a computer based software Image Focus Alpha (Windows and Linux).

3.1.2.5 Morphometric measurements

Different body parts of adult thrips species were measured in mm at 40X to 90X with a dissecting streomicroscope using Image Focus Alpha (Windows and Linux)

software. The length of antennae, length from head to abdomen, length and width of head, length of thorax, width of prothorax and mesothorax, length and width of abdomen of male and female *M. usitatus* and female *T. palmi* were meseared.

3.1.2.6 Data analysis: Data were analyzed using MS office excel 2007.

EXPERIMENT 2

3.2.1 Name of the experiment: Biology of Thrips Reared on Mungbean in Laboratory

3.2.2 Experiment Location and Duration

The study was conducted in the laboratory of Department of Entomology of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during May to July 2016 to observe the duration of different instars (life cycle), pre-adult mortality percentage and adult longevity (male and female) of *Megalurothrips usitatus*. The detail methodology of the study has been presented under the following sub-headings:-

3.2.2.1 Thrips (*M. usitatus*) rearing and preparation

The population of the *M. usitatus* was collected from a field at Sher-e-Bangla Agricultural University, Dhaka where BARI Mung-6 variety was sown on 21 March 2016. This population was subsequently reared by the bean pod method (Mollema *et al.* 1993). The colony was kept at 26 ± 1°C, 75 ± 3% RH and 16:8 h L:D in a climate control chamber.

3.2.2.2 Development time and mortality

Initially, 7 fresh pods of the mungbean were transferred into a single glass jar used for rearing, containing near about 100 of adult thrips of different ages. Adult females were allowed to oviposit on the pods for 12 h (Plate 4). Thereafter, the adults were removed and each egg-bearing pods was placed in seperate Petridishes (9 cm diam) with the bottom covered by a water-soaked filter paper to prevent desiccation of the eggs and the pod (Plate 5). The lid of the Petridishes was secured using parafilm to prevent escapes. The Petridishes were then kept in a climate control chamber at 26 ± 1°C, 75 ± 3% RH, and 16:8 h L:D until larvae hatched from the eggs (Plate 6). Because thrips eggs are laid into the pod tissue, the egg development period was determined by recording the passage of time until the appearance of larvae, but egg mortality could not be determined (Park *et al.* 2010; Zhang *et al.* 2007 and van Rijn *et al.* 1995). One hundred eighteen (118) newly hatched larvae were transferred using a fine hair brush into each 5 ml vial containing a 2 cm length of pod (Plate 7). Each vial

was sealed with a cotton plug to prevent thrips from escaping. Each such vial constituted a replicate. Pods of mungbean were replaced with fresh ones every 3 days. Immature stage development was assessed at 12 h intervals until the larvae either died or matured. Dead individuals of any developmental stage were not included when calculating the average developmental time at a specific stage. The various immature instars were identified by the method elaborated by Zhang *et al.* (2007). Six developmental stages of the insect were assessed. The transition from the first to second instar stage was determined from the occurrence of a moulted skin on the vial, as there are no obvious morphological differences between the two stages (van Rijn *et al.* 1995). Prepupae are recognized by their short wing sheaths and erect antennae. Pupae have long wing sheaths, which almost reach the end of the abdomen, and the antennae are bent backwards along the head. Both the prepupal and the pupal stages do not suck or move unless being disturbed. Adults are determined by their wings. As soon as eggs hatched, each first instar larva was put individually on a fresh pod, which was again replaced during the second larval stage. Each pod sample was considered as a replication. The pods were not replaced for the duration of the pre-pupal and pupal stages. The development of immature stages was monitored with a dissecting microscope until adult emergence. The length of immature stages and mortality were recorded daily.

The percent mortality of each immature stage was calculated as-

$$= \frac{\text{Number of dead insects in each immature stage}}{\text{Initial number of insects in each immature stage}} \times 100$$

3.2.2.3 Duration of adult longevity

To determine adult longevity about 13 of newly emerged adults were collected and transferred (using a soft small brush) each in a glass tube (2.5 cm diameter, 15 cm length) containing a fresh pod as described above. Each tube constituted a replication. All glass tubes were incubated at the mentioned conditions. The pods were changed daily and the lids were sealed with a cotton plug. The number of live adults of each sex was recorded until all adults had died. The adult longevity of both male and female was recorded.

3.2.2.4 Data analysis

Data were analyzed using MS office excel 2007.

Plate 4. Adult females of *M. usitatus* on mungbean pod in a glass jar

Plate 5. Single pod in separate petridishes

Plate 6. Petridishes placed in a climate control chamber.

Plate 7. 2-cm pod in vial for rearing thrips.

EXPERIMENT 3

3.3.1 Name of the experiment: Effect of Sowing Dates on the Incidence of Mungbean Thrips in Kharif-1

3.3.2 Experiment Location and Duration

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh. Seeds of BARI Mung-6 were sown in kharif-I season during 2016. Nine sowing dates at 10 days interval starting from 10 February 2016 to 30 April 2016 were considered as different treatments to find out the thrips incidence on mungbean and its peak infestation in relation to climatic factors. The detail methodology of the study has been presented under the following sub-headings:-

3.3.2.1 Land preparation, manuring and fertilization

The plots selected for each season was well prepared with good tilth and recommended fertilizers were applied for mungbean production during final land preparation in each sowing (BARC 2012).

3.3.2.2 Layout and design of the experiment

The experiments were laid out in Randomized Completely Block Design (RCBD) with three replications. The treatments were randomly allotted in each block.

3.3.2.3 Seed sowing and intercultural operation

The seeds of BARI Mung-6 were directly sown in $6m^2$ (3m x 2m) experimental unit plot with a distance of 50 cm between the plots and 100 cm between the blocks. The seeds were sown in rows with the spacing of 30 cm. The population of the plant was maintained constant by keeping plant to plant distance of 10 cm. After sowing seeds, irrigation and other intercultural operations were done.

3.3.2.4 Treatments

The following nine sowing dates were considered as treatments:-

T_1 = 10 February	T_2 = 20 February
T_3 = 1 March	T_4 = 11 March
T_5 = 21 March	T_6 = 31 March
T_7 = 10 April	T_8 = 20 April
T_9 = 30 April	

3.3.2.5 Data collection

3.3.2.5.1 Number of thrips and percent incidence of thrips population

The adult number of *M. usitatus* and *T. palmi* was counted from five top trifoliate leaves (Plate 8) and terminal shoots at pre-flowering stage and from five flower buds and flowers at flowering stage at weekly interval from five randomly selected plants of each plot avoiding border plants by beating method on the white paper.

The following formula was used to determine the percent incidence of thrips population:-

$$\text{Percent incidence of thrips} = \frac{\text{Number of thrips (in each species)}}{\text{Total number of thrips}} \times 100$$

3.3.2.5.2 Number of infested top trifoliate leaves (Plate 8), terminal shoots (Plate 9, 10) and their percent infestation by thrips

Number of infested top trifoliate leaf and terminal shoot were recorded at pre-flowering stage at an interval of 7 days commencing from first incidence of thrips. Five randomly selected plants and five top trifoliate leaves and terminal shoots of those plants were considered for the collection of data. Top trifoliate leaf and terminal shoot infestation percentage was recorded by using following formulae:-

$$\% \text{ top trifoliate leaf infestation} = \frac{\text{No. of infested top trifoliate leaf}}{\text{No. of observed top trifoliate leaf}} \times 100$$

$$\% \text{ terminal shoot infestation} = \frac{\text{No. of infested terminal shoot}}{\text{No. of observed terminal shoot}} \times 100$$

3.3.2.5.3 Flower bud and flower infestation (Plate 11, 12) and shedding per plant by thrips

Number of total flower bud and flower, number of infested flower bud and flower by thrips and number of shedding flower bud and flower (per plant) were recorded at flowering stage from five randomly selected plants in a plot. Data were recorded at an interval of 7 days commencing from first incidence of thrips in flower bud and flower and continued up to the adult thrips present in the flower bud and flower in the

mungbean field. Percent flower bud or flower infestation and shedding was calculated by using the following formulae:-

$$\% \text{ flower bud or flower infestation} = \frac{\text{No. of infested flower bud or flower}}{\text{Total No. of flower bud or flower}} \times 100$$

$$\% \text{ flower bud or flower shedding} = \frac{\text{No. of shedding flower bud or flower}}{\text{No. of total flower bud or flower}} \times 100$$

3.3.2.5.4 Number of total pod plant[-1] (Plate 13, 14)

Total pod number per plant was recorded from five sample plants at harvest.

3.3.2.5.5 Pod length (Plate 14)

The average pod length (cm) was recorded from ten randomly selected pods collected from five sample plants after harvesting of the crop.

3.3.2.5.6 Number of seeds pod[-1] (Plate 15, 16)

Number of seeds per pod was recorded after harvesting of the crop from the ten randomly selected pods from five pre-selected plants.

3.3.2.5.7 1000 seed weight

Thousand (1000) seed weight was recorded after harvesting of the crop from five sample plants.

3.3.2.5.8 Yield (kg ha^{-1})

The pods harvested from each plot were sun-dried and threshed by pedal thresher. Seeds were properly sundried and their weights were recorded. Seed yield was then converted to kg ha^{-1}.

3.3.2.6 Effect of weather parameters on incidence of thrips population

The weekly observations recorded on thrips population of both the species of *M. usitatus* and *T. palmi* in flower were correlated with various weather parameters. The weather data on weekly average temperature, relatively humidity, rainfall and sunshine hour were obtained from the weather office, Bangladesh Meterological Department, Sher-e-Bangla Nagar, Dhaka.

3.3.2.7 Statistical analysis

The data obtained for different parameters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package program. The significant differences among the treatment means were compared by DMRT at 5% level of probability (Duncan 1955).

(a)

(b)

(c)

Plate 8. **(a), (b) and (c) Thrips on trifoliate leaves of mungbean at pre-flowering stage.**

(a)	**(b)**

Plate 9. (a) and (b) Second instar larval thrips on mungbean shoot.

(a)	(b)

Plate 10. (a) Infested shoot and (b) Scarred shoot by thrips.

43

Plate 11. An experimental mungbean plot.

Plate 12. Infested mungbean flower by thrips.

Plate 13. Infested pod of mungbean.

Plate 14. Healthy pod of mungbean.

Plate 15. Infested seed.

Plate 16. Healthy seed.

44

3.4.1 Name of the experiment: Screening of some Mungbean Varieties against Thrips to Explore the Resistant Source(s)

3.4.2 Experiment Location and Duration

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh during 20 February to 3 May 2018 to find out the resistant/tolerant mungbean varieties against thrips. The detail methodology of the study has been presented under the following sub-headings:-

3.4.2.1 Land preparation, manuring and fertilization

The plots selected for the experiment was well prepared with good tilth and recommended fertilizers were applied for mungbean production during final land preparation (BARC 2012).

3.4.2.2 Layout and design of the experiment

The experiments were laid out in Randomized Completely Block Design (RCBD) with three replications. The treatments were randomly allotted in each block.

3.4.2.3 Seed sowing and intercultural operation

The seeds of eleven mungbean varieties were directly sown in 3m x 2m experimental unit plot with a distance of 50 cm between the plots and 100 cm between the replications on 20 February 2018. The seeds were sown in rows with the spacing of 30 cm. The population of the plant was maintained constant by keeping plant to plant distance of 10 cm. After sowing seeds, irrigation and other intercultural operations were done.

3.4.2.4 Treatments

Eleven mungbean varieties were considered as different treatments which are as follows:

T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local.

3.4.2.5 Data collection

3.4.2.5.1 Number of thrips and percent incidence of thrips population

The adult number of *M. usitatus* and *T. palmi* was counted from ten top trifoliate leaves and terminal shoots at pre-flowering stage starting from the first incidence of thrips and from ten flower buds and flowers at flowering stage at weekly interval from

ten randomly selected plants of each plot avoiding border plants by beating method on the white paper. The percent incidence of thrips population in each species was calculated using the formula as mentioned in previous experiment.

3.4.2.5.2 Number of infested top trifoliate leaves and terminal shoots and their percent infestation by thrips

Number of infested top trifoliate leaf and terminal shoot was recorded at pre-flowering stage at an interval of 7 days commencing from first incidence of thrips. Ten randomly selected plants and ten top trifoliate leaves and terminal shoots of those plants were considered for the collection of data. Top trifoliate leaf and terminal shoot infestation percentage was recorded by using the formula as mentioned in previous experiment.

3.4.2.5.3 Flower bud and flower infestation and shedding per plant by thrips

Number of total flower bud and flower, number of infested flower bud and flower by thrips and number of shedding flower bud and flower (per plant) were recorded at flowering stage from ten randomly selected plants in a plot. Data were recorded at an interval of 7 days commencing from first incidence of thrips in flower bud and flower and continued up to the adult thrips present in the flower bud and flower in the mungbean field. Percent flower bud and flower infestation and shedding were calculated by using the formula as mentioned in previous experiment.

3.4.2.5.4 Mechanism of resistance

Several morphological and bio-chemical characteristics play a major role in plant resistance. To study the mechanism involved in imparting resistance against thrips some morphological measurements and biochemical tests were done with the following methodologies:

3.4.2.5.4.1 Studies on morphological characters

Observations were made on some morphological characters of 11 mungbean varieties. The technique (s) followed for each character were as follows:

3.4.2.5.4.1.1 Leaf trichome hair

The leaves were collected from all the eleven mungbean varieties at 25 DAS. From each variety 3 plants were selected at random and from each plant, one leaf was selected randomly. The type of leaf trichome hair was observed from fully opened top trifoliate leaves of eleven mungbean varieties under a stereomicroscope (model no. Motic SMZ-168 Series) using a computer based motic software at 20X in the

laboratory of department of Entomology. The density of leaf trichome hair per 0.5 cm midrib from undersurface from a single leaflet of fully opened top trifoliate leaf from each plant were counted and expressed as numbers and the length of leaf trichome hair was measured in cm under a steriomicroscope at 20X. The length of three trichome hairs from a single leaflet of a top fully opened trifoliate leaf from the three selected plants of eleven mungbean varieties was measured.

3.4.2.5.4.2 Biochemical Studies (Plate 17, 18, 19, 20, 21, 22, 23, 24)

An attempt was made to study the relationship between biochemical constituent and resistance to thrips attack. A total of eleven varieties of mungbean were taken for analyzing biochemical constituent and to establish relationship with pest incidence. Leaf samples were collected from mungbean field during March-April, 2018. Biochemical constituents like leaf moisture, chlorophyll$_{(a+b)}$, total soluble sugar, phenol, phosphorus and potassium content in leaves were estimated.

3.4.2.5.4.2.1 Leaf moisture content

Samples of leaves from different mungbean varieties were collected at 25 DAS and weighted immediately after collection and then placed in an oven at 70ºC for 72 hours in the central laboratory of SAU. Leaf moisture content was estimated as follows:

$$\text{Leaf moisture content (\%)} = \frac{\text{Fresh weight of leaves - Dry weight of leaves}}{\text{Fresh weight of leaves}} \times 100$$

3.4.2.5.4.2.2 Estimation of total chlorophyll

The leaf samples of eleven mungbean varieties were collected at 25 DAS. After collection, around 20 mg fresh leaf sample was weighted and pored into glass vial containing 20 ml of 80% acetone solution. The glass vials were kept into dark condition for 48 hours. After 48 hours, chlorophyll was determined by using double beam spectrophotometer at 663 nm and 645 nm wave lengths in the laboratory of Agricultural Chemistry, SAU and chlorophyll was determined by using the following formula (according to Witham *et al.* 1971)

$$\text{mg chlorophyll (a + b) g}^{-1} \text{ leaf tissue} = \frac{[20.2 \, (D_{645}) + 8.02 \, (D_{663})] \times v}{1000 \times w}$$

47

Where,

        D = Optical density regarding of the chlorophyll extract at wave length of 663 and 645 nm.

        V = Final volume (ml) of the 80 % acetone with chlorophyll extract.

        W = Weight of fresh sample in g.

3.4.2.5.4.2.3 Estimation of total phenol (Plate 17, 18, 19, 20)

Total phenol content was determined according to Singleton and Rossi (1965) Folin phenol reduction method with few modifications in the laboratory of plant physiology division, BARI, Gazipur. 0.2 g frozen samples were ground with 2 ml 80% methanol and less sand in the ice bath followed by ultra sonication for 30 min. The homogenates were centrifuged at 4°C, 2000 × g 20 min and the resulting supernatant was used for total phenolic content and DPPH free radical scavenging activity assay. The reaction system was as follows: 150 µL Folin-Ciocalteu's reagent (Sigma), 200 µL supernatant, 2 ml 2% Na_2CO_3. The reaction mixture was incubated in dark at 25°C for 20 min. After that the absorbance was measured immediately at OD_{765} and gallic acid was used to prepare standard curve for total phenol content.

3.4.2.5.4.2.4 Estimation of total soluble sugar (Plate 21, 22, 23, 24)

Total soluble sugars were estimated by anthrone reagent (Yemm and Willis 1954) in the laboratory of plant physiology division, BARI, Gazipur. Aliquot (0.05 ml) was taken in test tubes and the volume was made upto 1 ml. To this solution 4 ml of anthrone reagent was added and mixture was heated in boiling water bath for 10 min followed by cooling. Optical density of green to dark green color was read at 625 nm. A blank was prepared by using all the reagents to adjust the absorbance to zero. The total soluble sugar in the samples was determined by using a standard curve prepared withglucose.

3.4.2.5.4.2.5 Estimation of total phosphorus

Total phosphorus (P) content in mungbean leaf samples was determined by modified Olsen method (Ascorbic acid blue color method) (Olsen *et al.* 1954) in the laboratory of Department of Soil Science, SAU. Oven dried leaf samples were grounded with a ml nitric acid and 5 ml perchloric acid and heated for 30 minutes at 180-200°C. After digestion of sample, filtration was done with Whatman filter paper and distilled water was added to make volume 50 ml from which 1 ml solution was taken in a 100 ml volumetric flask. 20 ml of color developing reagent (Sulphuric acid, Ammonium

molibdate, Antimony potassium tartrate) was added and then required volume of distilled water was added to make the volume 100 ml. Phosphorous in the extract was determined by the intensity of blue color and the color intensity was measured colorimetrically in a spectrophotometer at 660 nm wavelength. Blank samples were also considered to compare the reading of true (leaf) samples.

3.4.2.5.4.2.6 Estimation of total potassium

Leaf sample was digested similarly as mentioned above in measuring total phosphorous. After digestion, 1 ml sample was taken in a 100 ml volumetric flask and added distilled water to make volume 100 ml. After calibration with standard solutions, sample reading was taken in a flame photometer at 420 nm in the laboratory of Department of Soil Science, SAU.

3.4.2.5.5 Yield contributing characters

3.4.2.5.5.1 Number of total pods plant^{-1}

Total pod number per plant was recorded from ten sample plants at harvest.

3.4.2.5.5.2. Pod length

The average pod length (cm) was recorded from ten randomly selected pods collected from ten sample plants at harvest of the crop.

3.4.2.5.5.3. Number of seeds pod^{-1}

Number of seeds per pod was recorded after harvesting of the crop from the ten randomly selected pods from ten pre-selected plants.

3.4.2.5.5.4. 1000 seed weight

1000 seed weight was recorded after harvesting of the crop from ten sample plants.

3.4.2.5.5.5. Yield (kg ha^{-1})

The pods harvested from each plot were sun-dried and threshed by pedal thresher. Seeds were properly sundried and their weights were recorded. Seed yield was then converted to kg per ha.

3.5.2.6. Statistical analysis

The data obtained for different parameters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package program. The significant differences among the treatment means were compared by DMRT at 5% level of probability (Duncan 1955).

Plate 17. Chemicals used in the laboratory of Plant Physiology Division, BARI, Gazipur.

Plate 18. Chemicals measured with a balance.

Plate 19. Leaves meshed with morter and pastle.

Plate 20. Chemicals stirred on an electric shaker.

Plate 21. Leaf extractions in ependorf tubes.   **Plate 22. Filtered extractions.**

Plate 23. Ependorf tubes filled with   **Plate 24. Absorbance reading taken**
extractions kept in an ice-box.   **in a spectrophotometer.**

3.5.1 Name of the experiment: Performance of different Colored Sticky Board Traps against Mungbean Thrips

3.5.2 Experiment Location and Duration

The use of color sticky traps for monitoring and mass trapping of thrips and many other insects has been well documented as an eco-friendly approach. The study was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh. The present study was taken up to study the colour preference of *M. usitatus and T. palmi* to sticky traps in mungbean during April 2017 to June 2017. The detail methodology of the study has been presented under the following sub-headings:-

3.5.2.1 Treatments

Seven treatments including six colored sticky board traps and one untreated control treatment were considered for this experiment and these were T_1 = Blue color sticky board trap, T_2 = White color sticky board trap, T_3 = Yellow color sticky board trap, T_4 = Violet color sticky board trap, T_5 = Pink color sticky board trap, T_6 = Orange color sticky board trap and T_7 = Untreated control.

3.5.2.1.1 Materials required

- Ply wood board or hard board (1ft X 0.5 ft size)
- Colored oil paint
- Grease
- Bamboo poles
- Wire

3.5.2.1.2. Procedures followed for making colored sticky traps (Plate 25, 26)

Painting were done on the plywood board or hardboard on both side with blue, white, yellow, violet, pink and orange color oil paint and allowed these for drying. Colorless and transparent insect trapping adhesive (grease) was uniformly applied as a thin layer on both surfaces of each painted board at weekly interval. These traps were erected above crop canopy in windward direction with the help of bamboo poles for proper visibiity and convenient handling. Color boards were installed to trap thrips during third week after seed sowing and kept in the field till thrips occurrence was found in flowers. Thrips stuck on glue of different colour boards were counted using hand magnifying lens. Weekly observations for nine successive weeks were made for *M.*

usitatus and T palmi attraction. The adult thrips stuck on different color sticky boards were cleared by scrapping every week and painted again before applying grease.

3.5.2.2 Land preparation, manuring and fertilization

The plots were well prepared with good tilth and recommended fertilizers were applied for mungbean production during final land preparation (BARC 2012).

3.5.2.3 Layout and design of the experiment

The experiments were laid out in Randomized Completely Block Design (RCBD) with three replications. The treatments were randomly allotted in each block.

3.5.2.4 Seed sowing and intercultural operation

The seeds of BARI Mung-6 were directly sown in 3m x 2m experimental unit plot with a distance of 50 cm between the plots and 100 cm between the replications on 4 April 2017. The seeds were sown in rows with the spacing of 30 cm. The population of the plant was maintained constant by keeping plant to plant distance of 10 cm. After sowing seeds, irrigation and other intercultural operations were done.

3.5.2.5 Data collection

3.5.2.5.1 Number of thrips captured by colored sticky board traps

The adult number of *M. usitatus* and *T. palmi* was counted captured by color sticky board traps at weekly interval, started from 25 days after sowing and continued up to the adult thrips present in the flower bud and flower in the mungbean field. Percent incidence was calculated by using the formula as mentioned in the previous study. Based on the counting of thrips caught on the color sticky board, the preference of color was assessed.

3.5.2.5.2 Number of thrips, percent incidence of thrips (each species) population and percent reduction of thrips

The adult number of *M. usitatus* and *T. palmi* was counted from five top trifoliate leaves and terminal shoots at pre-flowering stage and from five flower buds and flowers at flowering stage at weekly interval from five randomly selected plants of each plot avoiding border plants by beating method on the white paper.Reduction percentage was also recorded on the basis of control treated plant. The following formula was used for taking the reduction percentage over control:

$$\text{\% reduction of thrips over control} = \frac{\text{Number of thrips in control} - \text{Number of thrips in treatments}}{\text{Number of thrips in control}} \times 100$$

3.5.2.5.3 Number of infested top trifoliate leaves and terminal shoots, their percent infestation by thrips and reduction percent infestation

Number of infested top trifoliate leaf and terminal shoot was recorded at vegetative stage at an interval of 7 days commencing from first incidence of thrips. Five randomly selected plants and five top trifoliate leaves and terminal shoots of those plants were considered for the collection of data. Percent top trifoliate leaf and terminal shoot infestation was recorded by using the formula as mentioned in the previous experiment. The following formula was used for taking the reduction percentage:-

$$\text{(\%) Reduction of top trifoliate leaf (TTL) infestation over control} = \frac{\text{\% infestation of TTL in control - \% infestation of TTL in treatment}}{\text{\% infestation of TTL in control}} \times 100$$

Similarly, (%) reduction of terminal shoot infestation was also calculated.

3.5.2.5.4 Flower bud and flower infestation per plant by thrips and percent reduction of infestation over control (Plate 27)

Number of total flower bud and flower, number of infested flower bud and flower by thrips and number of shedding flower bud and flower per plant were recorded at flowering stage from five randomly selected plants in a plot. Data were recorded at an interval of 7 days commencing from first incidence of thrips in flower bud/ flower and continued up to the adult thrips present in the flower bud and flower in the mungbean field. Percent flower bud or flower infestation was calculated by using the formula as mentioned in the previous experiment. Percent flower bud and flower infestation reduction over control was calculated by using the following formula:-

$$\text{\% reduction of flower infestation over control} = \frac{\text{\% infestation of flower in control - \% infestation of flower in treatment}}{\text{\% infestation of flower in control}} \times 100$$

Similarly, Percent reduction of flower bud infestation over control was also calculated.

3.5.2.5.5. Flower bud and flower shedding per plant by thrips and percent reduction of shedding over control

Number of total flower bud and flower shedding per plant was recorded at flowering stage. Five randomly selected plants and total flowers and shedding flowers of those plants were considered for the collection of data. Data was recorded at an interval of 7

54

days. The formula was used for taking the flower bud or flower shedding percentage as mentioned in the previous experiment. Reduction percentage of shedding flower bud and flower was measured by using the following formula:-

$$\text{\% Reduction of flower shedding over control} = \frac{\text{\% shedding of flower in control - \% shedding of flower in treatment}}{\text{\% shedding of flower in control}} \times 100$$

Similarly, percent reduction of flower bud shedding was also calculated.

3.5.2.5.6. Number of total pod per plant and percent increase of pod over control

All pods were separated from five sample plants and the total number of pods were counted and recorded. Average number of pods per plant was calculated. Increase percentage was also recorded on the basis of treatments of treated plant where the maximum number of pod was found than untreated control plant.

The following formula was used for taking the increase percentage:-

$$\text{\% increase of pod over control} = \frac{\text{No. of total pod in treatments - No. of total pod in control}}{\text{No. of total pod in control}} \times 100$$

3.5.2.5.7. Pod length and percent increase of pod length over control

The average pod length (cm) was recorded from ten randomly selected pods collected from five sample plants after harvesting of the crop. The following formula was used for taking the increase percentage:-

$$\text{\% increase of pod length over control} = \frac{\text{Pod length observed in treatments - Pod length observed in control}}{\text{Pod length observed in control}} \times 100$$

3.5.2.5.8. Number of seeds pod^{-1} and percent increase of seeds pod^{-1} over control

Number of seeds per pod was recorded after harvesting of the crop from the ten randomly selected pods from five pre-selected plants.

$$\text{\% increase of seed pod}^{-1}\text{ over control} = \frac{\text{No.of seed pod}^{-1}\text{ in treatments - No. of seed pod}^{-1}\text{ in control}}{\text{No.of seed pod}^{-1}\text{ in control}} \times 100$$

3.5.2.5.9. 1000 seed weight and percent increase of 1000 seed weight over control

1000 seed weight was recorded after harvesting of the crop from five sample plants.

$$\text{\% increase of 1000 seed weight over control} = \frac{\text{1000 seed wt. in treatments - 1000 seed wt. in control}}{\text{1000 seed wt. in control}} \times 100$$

3.5.2.5.10. Yield (kg ha^{-1}) and percent increase of yield over control

The pods harvested from each plot were sundried and threshed by pedal thresher. Seeds were properly sundried and their weights were recorded. Seed yield was then converted to kg ha^{-1}.

$$\text{\% increase of yield over control} = \frac{\text{Yield in treatments – Yield in control}}{\text{Yield in control}} \times 100$$

3.5.2.6. Statistical analysis

The data obtained for different parameters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package program. The significant differences among the treatment means were compared by DMRT at 5% level of probability (Duncan 1955).
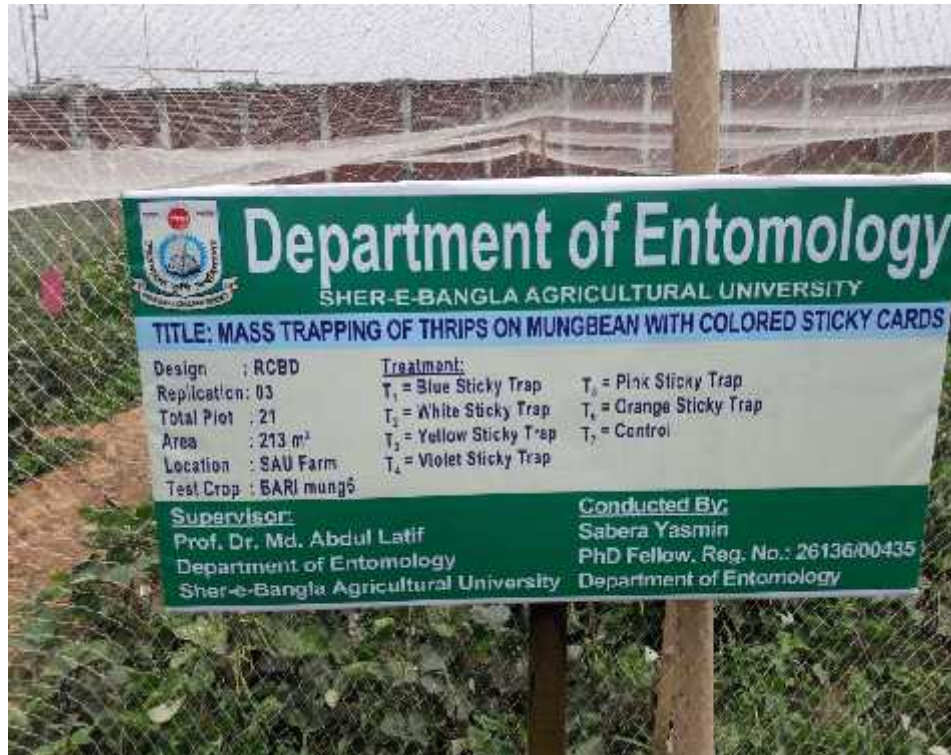
(a)

(b)

Plate 25 (a) and (b) Experimental plots using colored sticky board traps

Plate 26. An experimental field using different colored sticky board traps

| (a) | (b) |

Plate 27. (a) and (b) Different colored leaves, flowers and pods of mungbean in the experimental field.

3.6.1 Name of the experiment: Evaluation of some Chemical Insecticides and Bio-pesticides against Thrips on Mungbean

3.6.2 Experiment Location and Duration

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh to compare the efficacy of bio-pesticides and chemical insecticides against thrips on mungbean during November 2017 to February 2018. The detail methodology of the study has been presented under the following sub-headings:-

3.6.2.1 Land preparation, manuring and fertilization

The plots selected for the experiment was well prepared with good tilth and recommended fertilizers were applied for mungbean production during final land preparation (BARC 2012).

3.6.2.2 Layout and design of the experiment

The experiments were laid out in Randomized Completely Block Design (RCBD) with three replications. The treatments were randomly allotted in each block.

3.6.2.3 Seed sowing and intercultural operation

The seeds of BARI Mung-6 were directly sown in 2.5m x 2m experimental unit plot with a distance of 50 cm between the plots and 100 cm between the replications on 2 November 2017. The seeds were sown in rows with the spacing of 30 cm. The population of the plant was maintained constant by keeping plant to plant distance of 10 cm. After sowing seeds, irrigation and other intercultural operations were done.

3.6.2.4 Germination of seeds

Seed germination occurred from fourth day of sowing. On the fifth day the percentage of germination was more than 85% and on the sixth day nearly all the seedlings came out from the soil.

3.6.2.5 Treatments

The experiment comprised of eight treatments including an untreated control. The details of the pesticides are given in Table 3.

T_1 = Novastar 56EC $\quad\quad$ T_2 = Stargate 48SC

T_3 = Confidor 70WG $\quad\quad$ T_4 = Actara 25WG

T_5 = Tracer 45SC $\quad\quad$ T_6 = Ecomec 1.8EC

T_7 = Bioneem plus $\quad\quad$ T_8 = Untreated control

Table 3. Name of pesticides, their group name and doses

Trade name	Common name	Group name	Dose
Novastar 56EC	Bifenthrin+ Abamectin	Mixed of synthetic pyrethroid & biopesticide	1.0 ml L^{-1} of water
Stargate 48SC	Clothianidin	Neonicotinoid	0.4 ml L^{-1} of water
Confidor 70WG	Imidacloprid	Neonicotinoid	0.2 g L^{-1} of water
Actara 25WG	Thiamethoxam	Neonicotinoid	0.2 g L^{-1} of water
Tracer 45SC	Spinosad	Bio-pesticide	0.4 ml L^{-1} of water
Ecomec 1.8EC	Abamectin	Bio-pesticide	1.0 ml L^{-1} of water
Bioneem plus 1EC	Azadirachtin	Bio-pesticide	1.0 ml L^{-1} of water

3.6.2.6 Procedure of spray application

The actual amount of each bio-pesticide and chemical insecticide was taken in knapsack sprayer having pressure of 4-5 kg cm^{-2} and thoroughly mixed with water and sprayed in the respective plot. The required amount of liquid insecticides was taken by measuring cylinder in the sprayer. Chemical insecticides and bio-pesticides were applied to the foliage prior to flowering at seven days interval against thrips in the mungbean field (Plate 28).

3.6.2.7 Data collection

3.6.2.7.1 Number of thrips and percent incidence of thrips (each species) population and reduction percentage of thrips over control

The adult number of *M. usitatus* and *T. palmi* was counted from ten top trifoliate leaves and ten terminal shoots at pre-flowering stage and from ten flower buds and ten flowers at flowering stage at weekly interval from ten randomly selected plants of each plot avoiding border plants by beating method on the white paper and again released on the plants. The formula was used to determine the percent incidence and percent reduction of thrips population over control as mentioned in the previous experiment.

3.6.2.7.2 Number of infested top trifoliate leaves and terminal shoots by thrips, their percent infestation and reduction percentage of infestation over control

Number of infested top trifoliate leaves and terminal shoots were recorded in vegetative stage at an interval of 7 days commencing from first incidence of thrips. Ten randomly selected plants and ten top trifoliate leaves and terminal shoots of those plants were considered for the collection of data. Percent top trifoliate leaf and terminal shoot infestation and reduction percentage of infestation on the basis of control treated plants were recorded by using the formula as mentioned in the previous experiment.

3.6.2.7.3. Flower bud and flower infestation per plant by thrips and percent reduction of infestation over control

Number of total flower bud and flower, number of infested flower bud and flower by thrips and number of shedding flower bud and flower per plant were recorded at flowering stage from ten randomly selected plants in a plot. Data were recorded at an interval of 7 days commencing from first incidence of thrips in flower bud/ flower and continued up to the adult thrips present in the flower bud and flower in the mungbean field. Percent flower bud or flower infestation and reduction percentage of infestation were calculated by using the formula as mentioned in the previous experiment.

3.6.2.7.4. Flower bud and flower shedding per plant by thrips and percent reduction of shedding over control

Number of total flower bud and flower shedding per plant was recorded at flowering stage. Ten randomly selected plants and total flowers and shedding flowers of those plants were considered for the collection of data. Data was recorded at an interval of 7 days. The formula was used for taking the flower bud or flower shedding percentage and reduction of shedding percentage over control as mentioned in the previous experiment.

3.6.2.7.5. Number of total pod per plant and percent increase of pod over control

All pods were separated from ten sample plants and the total number of pods were counted and recorded. Average number of pod per plant was calculated. Percent increase of pod per plant over control was also recorded on the basis of treatments of treated plant where the maximum number of pod was found than untreated control plant.

3.6.2.7.6. Pod length and percent increase of pod length over control

The average pod length (cm) was recorded from ten randomly selected pods collected from ten sample plants after harvesting of the crop. Percent increase of pod length was calculated.

3.6.2.7.7. Number of seeds pod $^{-1}$ and percent increase of seeds pod $^{-1}$ over control

Number of seeds pod^{-1} was recorded after harvesting of the crop from the ten randomly selected pods from ten pre-selected plants and percent increase of seed pod^{-1} was calculated.

3.6.2.7.8. 1000 seed weight and percent increase of 1000 seed weight over control

1000 seed weight was recorded after harvesting of the crop from ten sample plants and percent increase of 1000 seed weight was calculated.

3.6.2.7.9. Yield (kg ha^{-1}) and percent increase of yield over control

The pods harvested from each plot were sundried and threshed by pedal thresher. Seeds were properly sundried and their weights were recorded. Seed yield was then converted to kg ha^{-1}. Percent increase of yield over control was also calculated.

3.6.2.8 Statistical analysis

Data were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package program. The significant differences among the treatment means were compared by DMRT at 5% level of probability (Duncan 1955).

Plate 28. The experimental mungbean field treated with different bio-pesticides and chemical insecticides.

CHAPTER IV

RESULTS AND DISCUSSION

Results on different experiments have been presented and probable interpretations are made here in.

4.1 Experiment 1: Identification of Thrips Species infesting Mungbean

4.1.1 Morphological characteristics of thrips infesting mungbean

Two species of thrips was found to attack mungbean in the field. The detail characteristics of thrips species are described in the following subheadings:

4.1.1.1 Morphological characteristics of the adult female *M. usitatus*

The adult females were mainly dark brown in color with striped abdominal segments and macroptera (fully winged) (Plate 29 and 30). Antennae were eight segmented and the segment III was yellow, IV was yellow at basal portion. The antennal segment I was found with pair of dorso-apical setae. The shape of segments II and III were more or less symmetrical. The antennal segments III–IV were with constricted apical neck and forked sensorium and VIII was almost twice as long as VII (Plate 31). Almost similar observations were reported by Sartiami and Mound (2013) who also described that this species can be distinguished by the the third antennal segment which was more extensively yellow than in the other members of the genus. Hoddle *et al.* 2012; Mound 2005 also supports the present findings about antennae of *M. usitatus.*

Head shape between compound eyes was not prolonged. Head was conspicuously transversely striated /reticulated at posterior portion. Three ocelli were present in triangle and the ocellar setae pair III was long, placed near the front ocelli, arising just inside triangle, postocular setae were not long (Plate 32, 33 and 34). The prothrox was wider than head. Median area of pronotum was weakly transversely reticulated. 2 pairs of long posteroangular setae were present and one pair of anteroangular setae was moderately prominent on pronotum (Plate 35). The lateral setae on mesothorax were not long. Mesosternal endofurca was with median spinula (Plate 36). Metathoracic endofurca was transverse, without spinula (Plate 37).

Fringed wings were present and more than half as long as abdomen. Forewings were with veins, setae and microtrichia. First vein of forewing was distinct from costal vein. Forewing anterior margin was with setae and cilia but cilia were longer than setae. Forewings were with alternating bands of dark and light color, brown with basal quarter pale and an extensive pale area sub-apically. Forewing's costal fringe of

cilia were arising at anterior margin of wing. Forewing's costal setae at middle of wings were shorter than median width of wing. The first vein setal row was incomplete, with long row of setae before distinct sub-apical gap followed by 2 setae. Forewing's posterior margin cilia were undulated near apex. Second vein setal row was complete, with setae closely and uniformly spaced (Plate 38). Tarsi, apices of mid and hind tibiae, also most of fore tibiae of legs were yellow. Hind tibiae were with 2 stout dark apical setae. Tarsi all were 2-segmented (Plate 39). Mound, 2005 and Palmer, 1987 also provided almost similar descriptions about wings and legs of *M. usitatus*.

Abdominal tergites II–VIII were with no sculpture medially but lateral thirds were with sub-parallel lines, median setae were small (Plate 40). Abdominal sternites III, IV, V, VI were with marginal setae but no discal setae was found (Plate 41). Abdominal segment VIII had posteromarginal comb of slender microtrichia (Plate 42). Abdominal sternite VII beared median marginal setae, arising infront of margin (Plate 43). Abdominal segment X was never tubular and was longitudinally incomplete (Plate 43). A well developed ovipositor was observed (Plate 43). Long slender setae on abdominal tergite X were present (Plate 44). http://www.ozthrips.org/terebrantia/thripidae/thripinae/megalurothrips-usitatus/.

Hoddle *et al.* (2012) provided almost similar descriptions of *M. usitatus.* Sartiami and Mound (2013) reported that this species can be distinguished by the presence of all three pairs of setae arising at the posterior margin of the seventh sternite in females, instead of the median pair arising sub-marginally.

Plate 29. Adult male (upper) and females (middle and lower) of *M. usitatus.*

Plate 30. *M. usitatus* **(Female).**
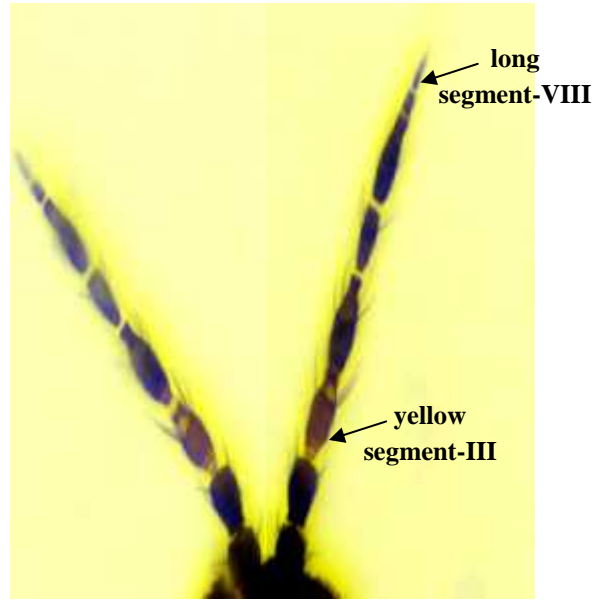
Plate 31. Antenna.

Plate 32. Head.
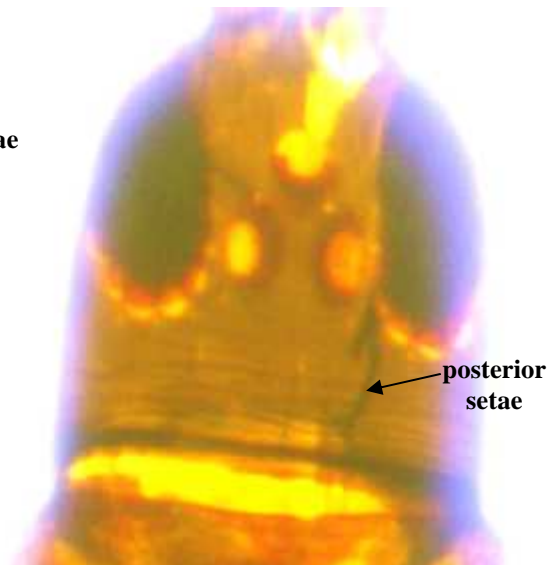
Plate 33. Triangle ocelli.
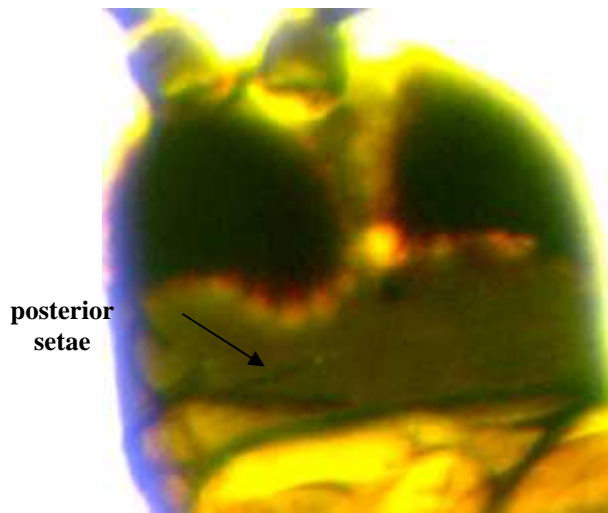
Plate 34. Head with setae posteriorly.
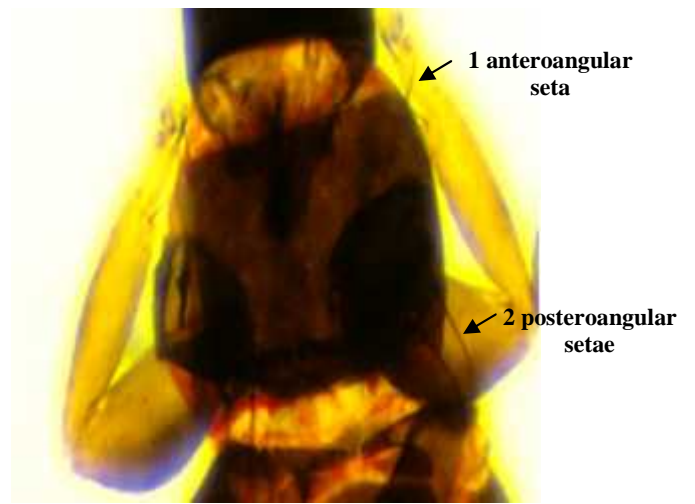
Plate 35. Prothorax.
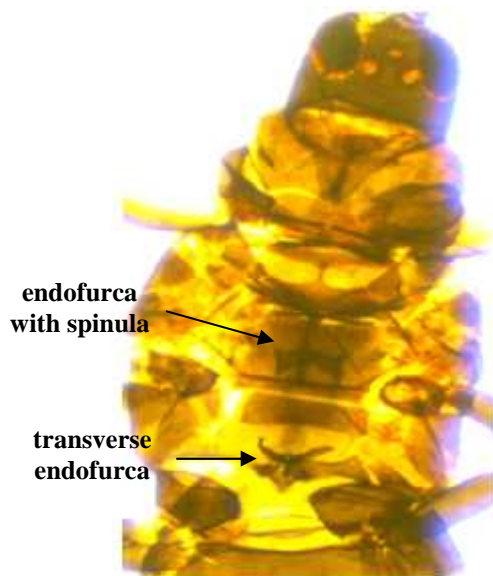
Plate 36. Head and thorax (ventral side).

Plate 37. Meso and Meta thorax (ventral side).
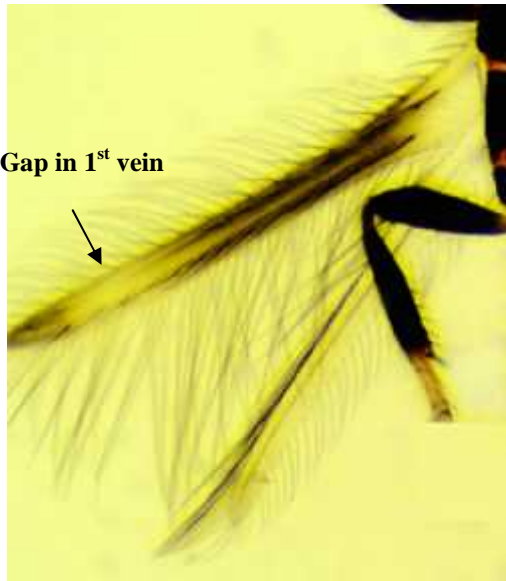
Plate 38. Fore and hind wings.
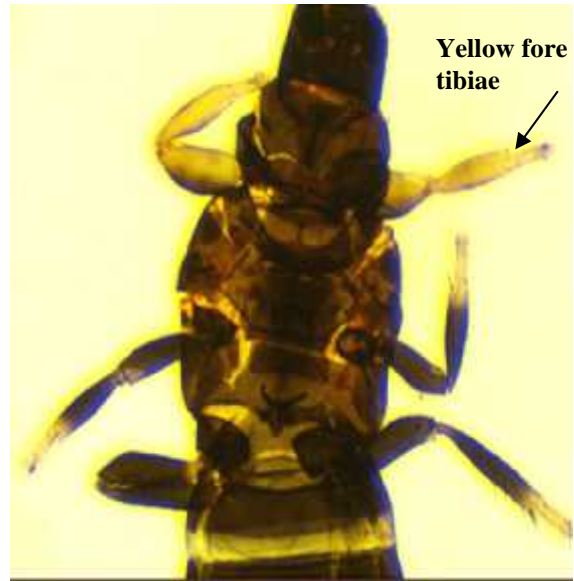
Plate 39. Three pairs of leg.

Plate 40. Abdominal tergite II-X.
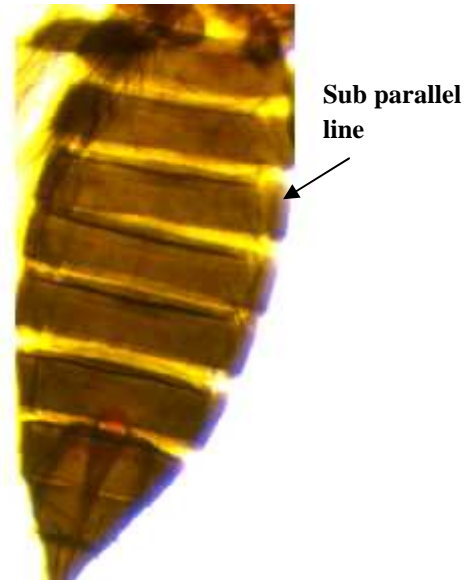
Plate 41. Abdominal sternites.

67

comb of microtrichia

Plate 42. Abdominal segment VIII.

ovipositor
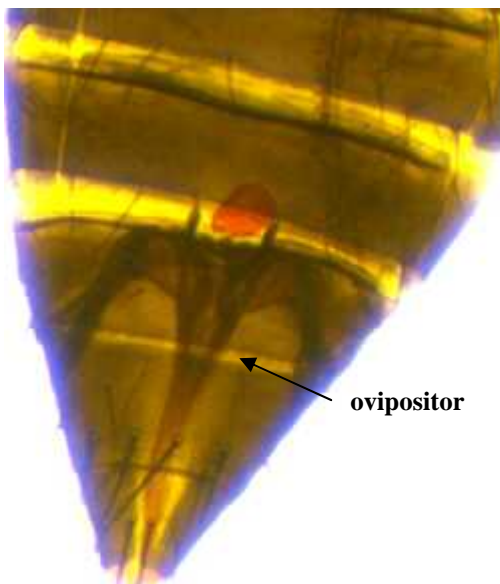
Plate 43. Abdominal sternite VII-X.   **Plate 44. Abdominal segment VI-X.**

4.1.1.2 Morphological characteristics of the adult male *M. usitatus*

The male of *M. usitatus* was similar to female but was smaller and paler (Plate 45). Legs were sometimes almost yellow (Plate 45). Pronotum was usually yellow than head which was deepest in colour (Plate 46). Well developed genital organ (Aedeagus) was present (Plate 47). Hoddle *et al.* (2012), Palmer (1987) supports the findings about *M. usitatus male* which helped to identify the species.

Plate 45. *M. usitatus* (Male).
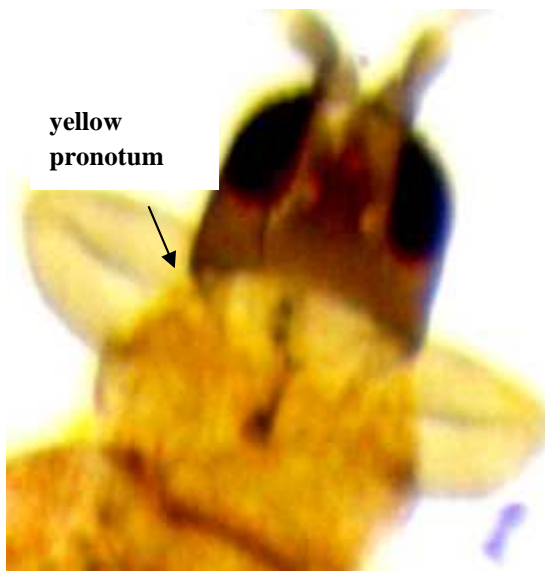
Plate 46. Head and pronotum (Male).
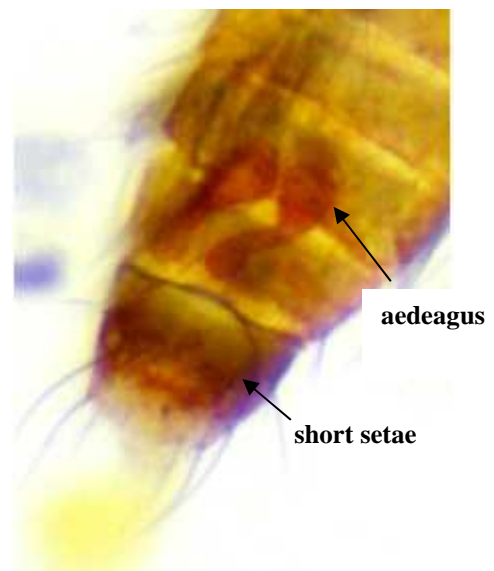
Plate 47. Abdominal segment VII- X (Male)

4.1.2 Morphological characteristics of the adult *T. palmi* Karny

Adult female: Adult females were yellow in color, but with numerous dark setae on the head, thorax and abdomen.The wings beared some dark pigments, and when they were folded over the back, the species appeared to possess a dark longitudinal stripe. Female macroptera (fully winged) with a downward projecting, saw-like ovipositor (Plate 48). Almost similar descriptions were reported by IPPC (2016), Funderburk *et al.* (2007), Layland *et al.* (1994). Antennae were 7 segmented and transluscent forked sense cones were present on segments III and IV. Antennal segments I and II were pale, III yellow with apex shaded, IV–V were dark brown distally, VI–VII were dark brown (Plate 49). The fringed wings were slender and pale. The hairs or fringe on the anterior edge of the wing were considerably shorter that those on the posterior edge. Fore wings were pale, prominent dark setae were present. First vein of forewing was found with a gap in the setal row followed by 3 well spaced distal setae, second vein with row of near about 15 setae (Plate 50 and 51). Capinera (2015) supported the findings of the present study. Head was found wider than long. There were three ocelli on the top of the head, in a triangular formation. A pair of ocellar setae was located outside this triangular formation. The ocelli beared red pigments (Plate 52).

Pronotum beared only two pairs of large setae at posterolateral angle and all secondary setae were small (Plate 53, 54, 55 and 56). Layland *et al.* (1994) reported similar observations about pronotum of *T. palmi.* Metanotum with median setae arising behind anterior margin was observed (Plate 57). There were four lateral marginal setae on abdominal tergite II (Plate 58). Abdominal Sternite III–VII with 3 pairs of marginal setae was found (Plate 59 and 60). A well developed ovipositor was present (Plate 60 and Plate 61). Abdominal tergite IX-X beared long seta (Plate 62). Hoddle *et al.* (2012), Nickle (2008), Mound and Masumoto (2005), Layland *et al.* (1994), Nakahara (1994) all provided detailed descriptions of *T. palmi* which supports the findings of the present study.

Plate 48. *Thrips palmi* **(female).**
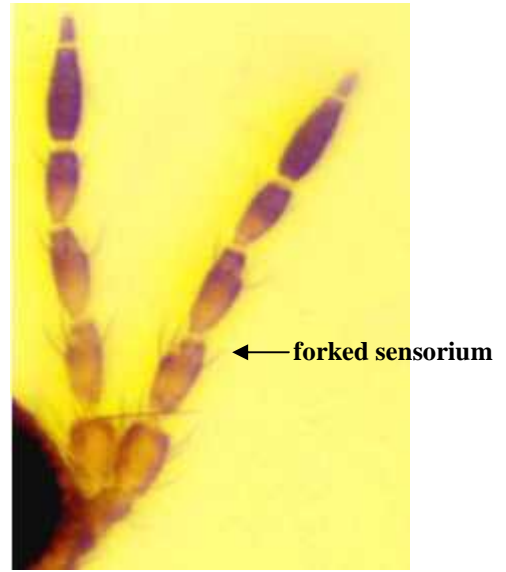
Plate 49. Antennae.
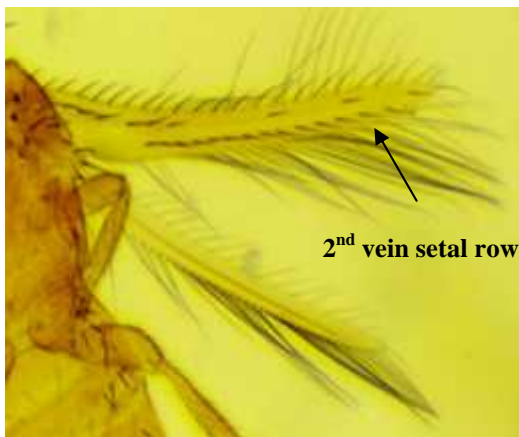
Plate 50. Fore wing and hindwings.

Plate 51. Fore wing.

long setae

Plate 52. Head.

2 posteroangular setae
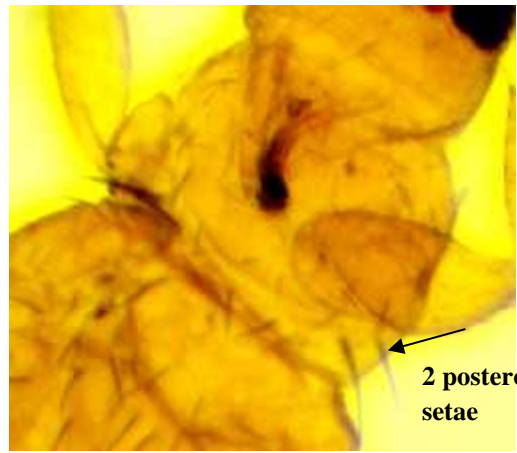
Plate 53. Head and pronotum.

Plate 54. Pronotum.

Plate 55. Head and thorax.
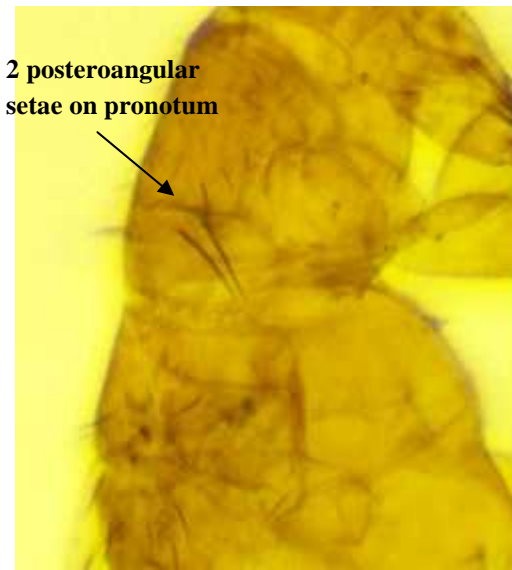
Plate 56. Thorax (lateral view).
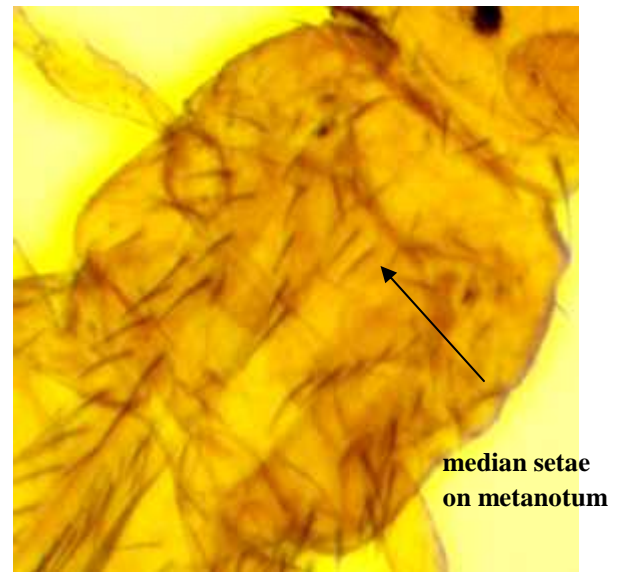
Plate 57. Meso and metanotum.
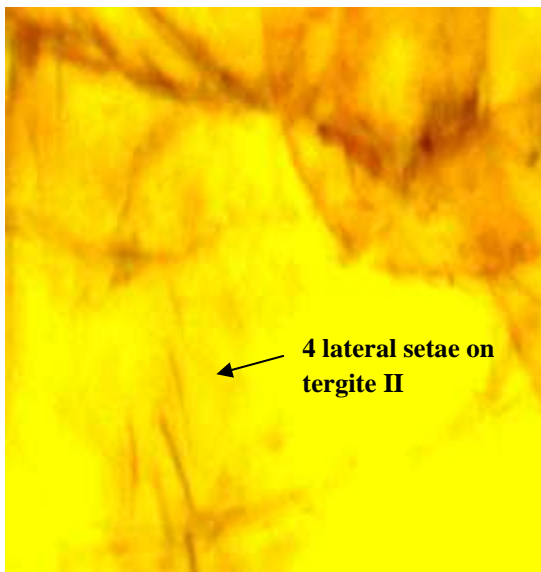
Plate 58. Abdominal tergite II.
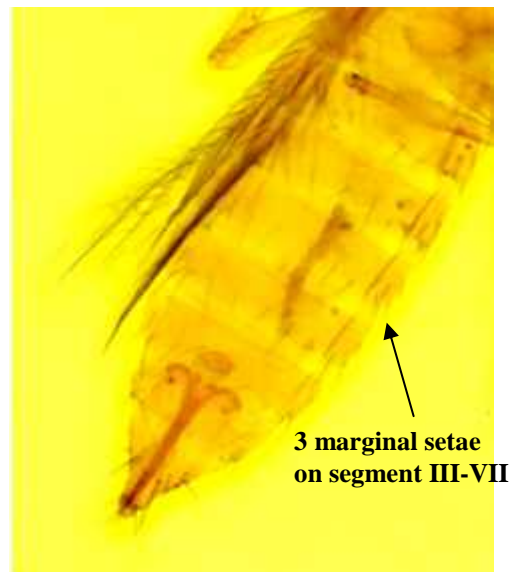
Plate 59. Abdominal sternites.

ovipositor
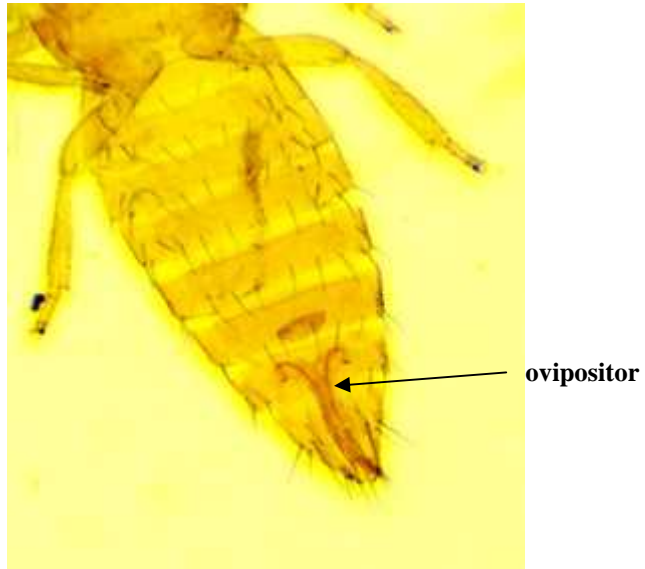
Plate 60. Abdominal sternite I-X.

Plate 61. Abdominal pleurotergite.   **Plate 62. Abdominal tergiteVIII-X.**
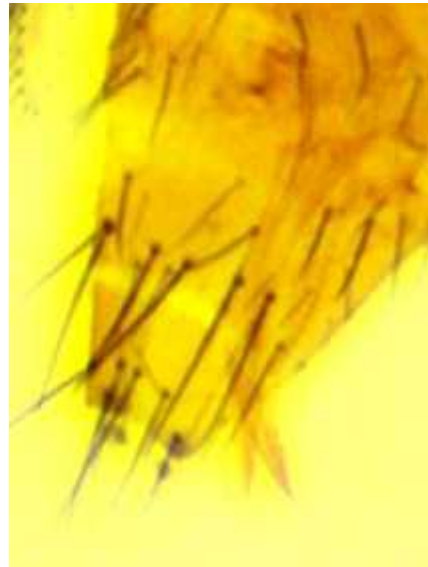
4.1.3 Morphometric measurements of adult thrips

4.1.3.1 Morphometric measurements of adult female *M. usitatus*:

Adult females were larger and darker than males having slender body with variable sizes ranged from 1.29-2.68 mm and average body length was 1.97 ± 0.13 mm (Table 4). The range of antenna length was 0.27 – 0.52 mm with average length 0.36 ± 0.03 mm. Head was almost as wide as length. The range of head leangth was 0.13-0.31 mm with average length 0.18 ± 0.02 mm and the range of head width was 0.12-0.26 mm with average width 0.18 ± 0.01 mm, respectively. The average thoracic length was 0.60 ± 0.04 mm with range 0.39-0.88 mm. The width of prothorax and mesothorax was 0.24 ± 0.01 mm and 0.43 ± 0.03 mm with ranges from 0.21-0.27 mm and 0.26-0.60 mm, respectively. The abdominal length and width were 1.18 ± 0.08 mm and 0.45 ± 0.03 mm with ranges 0.77-1.43 mm and 0.3-0.64 mm, respectively (Table 4). Other authors also supports the present findings Srinivashan (2014) observed that the adults of *Megalurothrips* were about 1.5-1.65 mm long. Kumari and Lyla (2001) reported similarly about body length size of another species of same genus i.e. *Megalurothrips distalis* which was deep black coloured thrips measuring about 1.65 mm in length. Koppert (2018) reported that the average width of thorax of westerns flower thrips (*Frankliniella occidentalis*) was 0.251 mm. Minimum and maximum width of abdomen were 0.242 mm and 0.315 mm, respectively with average width 0.282 mm.

Table 4. Morphometric measurements of *M. usitatus* (female)

Body parts	Range (mm)	Mean (mm)	Standard Error (± SE)	No. of observation
Head to abdomen length	1.29-2.68	1.97	0.13	10
Antenna length	0.27-0.52	0.36	0.03	10
Head length	0.13-0.31	0.18	0.02	10
Head width	0.12-0.26	0.18	0.01	10
Thorax length	0.39-0.88	0.60	0.04	10
Prothorax width	0.21-0.27	0.24	0.01	10
Mesothorax width	0.26-0.60	0.43	0.03	10
Abdomen length	0.77-1.43	1.18	0.08	10
Abdomen width	0.30 -0.64	0.45	0.03	10

4.1.3.2 Morphometric measurements of adult male *M. usitatus*

The adult males were paler and smaller than females with variable sizes ranged from 0.99-2.17 mm and average body length was 1.42 ± 0.12 mm. The range of antenna length was 0.26 -0.41 mm with average length 0.32 ± 0.02 mm. The range of head leangth was 0.10-0.18 mm with average length 0.13 ± 0.01 mm and the range of head width was 0.11 - 0.25 mm with average width 0.16 ± 0.01 mm, respectively. The average thoracic length was 0.48 ± 0.03 mm with range 0.33 – 0.70 mm. The width of prothorax and mesothorax was 0.22 ± 0.01 mm and 0.32 ± 0.03 mm, respectively with ranges from 0.19 -0.25 mm and 0.21-0.47 mm, respectively. The abdominal length and width were 0.79 ± 0.07 mm and 0.28 ± 0.02 mm, respectively with ranges 0.56 - 1.26 mm and 0.22 - 0.39 mm, respectively (Table 5). Hoddle *et al.* (2012) also reported that male was smaller than female.

Table 5. Morphometric measurements of *M. usitatus* (male)

Body parts	Range (mm)	Mean (mm)	Standard Error (±SE)	No. of observation
Head to abdomen length	0.99-2.17	1.42	0.12	10
Antenna length	0.26-0.41	0.32	0.02	10
Head length	0.10-0.18	0.13	0.01	10
Head width	0.11-0.25	0.16	0.01	10
Thorax length	0.33-0.70	0.48	0.03	10
Prothorax width	0.19-0.25	0.22	0.01	10
Mesothorax width	0.21-0.47	0.32	0.03	10
Abdomen length	0.56-1.26	0.79	0.07	10
Abdomen width	0.22-0.39	0.28	0.02	10

4.1.3.3 Morphometric measurements of Adult female *T. palmi*

T. palmi was yellow in color and very small in size. The average body length of female *T. palmi* was 1.20 ± 0.02 mm measuring ranges from 1.06 – 1.32 mm. The antenna length was 0.23 ± 0.01 mm with ranged 0.18 - 0.26 mm. The head was wider than length and the average length and width were 0.12 ± 0.01 mm and 0.14 ± 0.01 mm, respectively. The ranges of head length and width were 0.1-0.15 mm and 0.12-0.16 mm, respectively. The thoracic length was 0.39 ± 0.01 mm with range 0.35 - 0.41 mm. The mesothorax was wider than prothorax. The prothorasic and mesothorasic width were 0.19 ± 0.01 mm and 0.26 ± 0.01 mm, respectively with ranges from 0.15-0.24 mm and 0.2 - 0.31 mm, respectively. The abdominal length and width were 0.69 ± 0.02 and 0.28 ± 0.01 mm, respectively with ranges 0.6-0.81 mm and 0.22-0.32 mm, respectively (Table 6). Similarly, IPPC (2016) reported *T. palmi* as very small sized insect (1.0–1.3 mm). Capinera (2015) found that the body length of *T. palmi* was 0.8 to 1.0 mm. Nickle (2008) observed that the body length of *T. palmi* was 1.0-1.2 mm.

Table 6. Morphometric measurements of *T. palmi* (female)

Body parts	Range (mm)	Mean (mm)	Standard Error (±SE)	No. of observation
Head to abdomen length	1.06-1.32	1.20	0.02	10
Antenna length	0.18 -0.26	0.23	0.01	10
Head length	0.1-0.15	0.12	0.01	10
Head width	0.12-0.16	0.14	0.01	10
Thorax length	0.35-0.41	0.39	0.01	10
Prothorax width	0.15-0.24	0.19	0.01	10
Mesothorax width	0.2-0.31	0.26	0.01	10
Abdomen length	0.6-0.81	0.69	0.02	10
Abdomen width	0.22-0.32	0.28	0.01	10

4.2 Experiment 2: Biology of thrips reared on mungben in laboratory

Results on biology of *M. usitatus* have been presented with probable interpretation in the following sub headings:

4.2.1 Development time

Developmental time of different instars of *M. usitatus* have been furnished below:-

4.2.1.1 Incubation period

Adult female *M. usitatus* oviposited eggs in mungbean pods and needed 3.13 ± 0.06 days to hatch. The range of incubation period was 1.5- 4 days (Table 7). Almost similar findings were reported by other authors. Tang, *et al*. (2015) found that the egg hatching period was 3.02 ± 0.04, 3.29 ± 0.03 and 3.35 ± 0.04 days on cowpea, pea and lima bean, respectively. Srinivashan (2014) reported that the females of *M. usitatus* lay eggs within the leaf tissues, especially in the terminal leaflets. The egg may not be visible to the naked eye. The egg period was about 2 to 3 days.

4.2.1.2. Larval period

The larvae of *M. usitatus* resembled the adults in general body form though they lacked wings and were smaller and different in color. There were two instars during the larval period. The first instar was pale yellow in color and developed in 1.48 ± 0.05 days ranged 1-3 days (Table7, Plate 63 and 64). The first instar moulted to second instar (Plate 65). The second instar was deep yellow to orange in color and larger (Plate 66, 67 and 68). The developmental time of second instar was 2.30 ± 0.08 days (Table 7). Results recorded from the present study support the findings of Tang, *et al*. (2015) who found that the first instar larvae of *M. usitatus* developed in 1.68 ± 0.03, 1.73 ± 0.03 and 2.02 ± 0.04 days on cowpea, pea and lima bean, respectively at 26 ± 1° C. Srinivashan (2014) reported that the larva of *M. usitatus* was pale yellow in color, and turns to yellowish to orange-red. The larval period varies from 1 to 2 weeks depending on the temperature. Capinera (2015) also found that larvae of *thrips palmi* required 5 and 4 days to complete their development at 26° and 32° C, respectively.

4.2.1.3. Pupal period

The second instar larvae moulted to prepupa (Plate 69). There were two instars during the pupal period where the prepupal instar was nearly inactive, and the pupal instar was inactive. Both instars were nonfeeding stages. The prepupae and pupae resembled the adults and larvae in form, except that they possess wing pads. The wing pads of the prepupae were shorter (Plate 70 and 71) than that of the pupae (Plate 72). The

antennae of prepupa was erect (Plate 71) but was found bent in pupa (Plate 72). The prepupal period was 1.30 ± 0.07 days which ranges 0.5-2.5 days. The pupal stage on mungbean pod was 2.26 ± 0.13 days from ranges 1.5-3.5 (Table 4.2.1). Almost similar findings was reported by Tang *et al*. (2015), who found that the prepupal period was 1.05 ± 0.02, 1.06 ± 0.04 and 1.06 ± 0.04 days on cowpea, pea and lima bean, respectively. They also found that the pupal period was 2.13 ± 0.06, 2.19 ± 0.09 and 2.27 ± 0.09 on three crops i.e., cowpea, pea and limabean, respectively. Srinivashan (2014) reported that the pupal stage lasts for five days to one week. Capinera (2015) stated that the combined prepupal and pupal development time of *thrips palmi* was about 4 and 3 days at 26, and 32ºC, respectively.

4.2.1.4. Total development period (egg to adult)

The pupa moulted to adult which was dark brown in color. The male was paler (Plate 73) than female (Plate 74). Taken together, the developmental time from egg to adult was 10.54 ± 0.15 days on mungbean pods (Table 7). Tang *et al.* (2015) also reported similar results that the development times of *M. usitatus* egg to adult varied from 9.4 to 11.6 d on 4 leguminous host plant species i.e., snap bean, cowpea, pea and lima bean. The reduced development time of *M. usitatus* on suitable food was mainly due to the rapid development of the larval stages, but the non-feeding prepupal and pupal stages also experienced reduced developmental times. The development times of immature stages of *M. usitatus* on soybean foliage and flowers at various temperatures were reported to be in the range of 9.0–21.7 d (Chang 1987). Similar results were reported for *Frankliniella occidentalis* (Zhang *et al.* 2007; Hulshof *et al.* 2003). Maisnam *et al.* (2012) reported that the egg, larva I, larva II, prepupa, pupa and total duration of *M. peculiaris* on leaves of *Dolichos lablab* was 4.0 ± 0.4, 3.4 ± 0.3, 4.4 ± 0.3, 1.8 ± 0.2, 3.0 ± 0.2, 18.4 ± 1.9 days, respectively.

Table 7. The length of developmental periods of *M. usitatus* on mungbean pod

Developmental time in days			
Life stages	Mean ± SE	Range	No of observation
Egg	3.13 ± 0.06	1.5 – 4.0	118
First instar larva	1.48 ± 0.05	1.0 – 3.0	101
Second instar larva	2.30 ± 0.08	1.5 - 4.5	78
Prepupa	1.30 ± 0.07	0.5 – 2.5	67
Pupa	2.26 ± 0.13	1.5 – 3.5	23
Egg to adult	10.54 ± 0.15	9.5-12	23
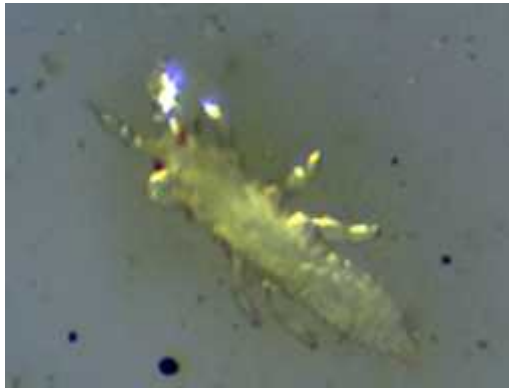
(a)	**(b)**

Plate 63. (a) and (b) Pale yellow first instar larva (at 90X).

(a)	**(b)**

Plate 64. (a) and (b) First instar larva (pale yellow, at 10X).

Plate 65. First instar larva moulted to second instar (with exuviae, at 10 X).

Plate 66. Newly emerged second instar larva (deep yellow, at 10X).

(a)

(b)

Plate 67. (a) and (b) Second instar larva (orange, at 10 X).

(a)   (b)   (c)

Plate 68. (a), (b) and (c) Second instar larva (Deep yellow to orange) at 80X.

(a)   (b)

Plate 69. (a) and (b) Second instar larva moulted to be prepupa (60 X).

| (a) | (b) |

Plate 70. (a) and (b) Prepupa with exuviae (orange-red, at 10 X).

| (a) | (b) |

Plate 71. (a) and (b) Prepupa (orange-red, at 10 X).

83

bent antennae

Long wing pad

(a)   (b)

Plate 72. (a) and (b) Pupa (orange-red, at 10 X).

Plate 73. Newly emerged adult   male
***M. usitatus* (at 10X).**

Plate 74. Newly emerged adult
female *M. usitatus* (at 10X).

4.2.2 Pre-adult mortality of *M. usitatus*

Data illustrated in Table 8 showed the pre-adult mortality percentage of *M. usitatus* on mungbean pods. Mortality of the first larval instar was 14.41%, second larval instar was 22.77%, pre-pupal stage was 14.10%, pupal stage was 65.67% and the total pre-adult mortality was 80.51%. Fekrat *et al*. (2009) reported 58.33% mortality for *Thrips tabaci* reared on mazandran tobacco. They stated that the mortality was occured mainly in larval period.

Table 8. The pre-adult mortality percentage (%) of different instars of *M. usitatus* on mungbean pod

Different instars	Mortality percentage (%)	No. of live insects at that developmental stage
First instar larva	14.41	101
Second instar larva	22.77	78
Prepupa	14.10	67
Pupa	65.67	23
Total	80.51	118

4.2.3 Adult longevity of *M. usitatus*

In the present study, the longevity of adult males and females reared on mungbean pod was 6.42 ± 0.44 days and 12.07 ± 1.56 days, respectively (Table 9). The longevity of adult males was shorter than adult females. Minimum and maximum longevity of adult males were 5 and 8 days, respectively whereas, minimum and maximum longevity of adult females were 8 and 18.5 days, respectively (Table 9). Tang *et al*. (2015) reported that adult longevity of *M. usitatus* was strongly dependent on the quality of food. The shortest female longevities when reproducing either sexually or parthenogenetically were 13.83 or 15.63 d, respectively, on lima bean, whereas, the longest female longevities were 15.63 or 20.61 d, respectively, on snap bean. Similar results were also obtained on the male longevities i.e., 6.42 d on lima bean and 14.67 d on snap bean, although females lived longer than males. Srinivashan (2014) found that adults of *M. usitatus* live from 1 to 3 weeks. Capinera (2015) reportd that adult longevity of *Thrips palmi* was 10 to 30 days for females and 7 to 20 days for males. Development time varies with temperature, with mean values of about

20, 17, and 12 days at 15, 26, and 32ºC. Comparable longevity data for *F. occidentalis* on bean plants (pods) were 27.88 d (Zhi *et al.* 2005), 24.45 d (Gerin *et al.* 1994) and 10.8 d (Brødsgaard 1994).

Table 9. The adult longevity of *M. usitatus* on mungbean pod

Sex type	Mean± SE (days)	Range (days)	No. of observation
Male	6.42 ±0.44	5-8	6
Female	12.07±1.56	8-18.5	7

4.3   Experiment 3: Effect of Sowing Dates on the incidence of Mungbean Thrips in Kharif-1 season

The results of the present study that was carried out in Kharif-1 season of 2016 regarding the effect of dates of sowing on the incidence of thrips and their bio-ecological effect on mungbean production along with the related factors have been discussed with interpretations and furnished under the following sub headings:-

4.3.1 Thrips population per five top trifoliate leaves of mungbean as influenced by sowing dates

The data presented in Table 10 clearly revealed that the population of thrips per 5 top trifoliate leaves varied significantly depending on seasonal variation in different dates of sowing. During kharif-I in 2016, the number of thrips ranged from 2.21 to 5.04 *M. usitatus* and 1.02 to 2.51 *T. palmi* per 5 top trifoliate leaves at pre-flowering stage in different sowing dates. Thrips population gradually declined with the advancing of sowing dates up to 21 March, then population increased again up to April 20. Afterthat, Thrips population again decreased. Among the different dates of sowing the lowest population of *M. usitatus* and *T. palmi* (2.21 and 1.02, respectively per 5 top trifoliate leaves) was recorded on 21 March sown crop with cumulative mean population (3.23 per 5 top trifoliate leaves) of both the thrips species which was followed by 11 March sown crop, in which population of *M. usitatus* and *T. palmi* was 2.61 and 1.13, respectively per 5 top trifoliate leaves with cumulative mean number of both the thrips species was 3.75 per 5 top trifoliate leaves. This was followed by 31 March sown crop, in which population of *M. usitatus* and *T. palmi* (2.91 and 1.40 per 5 top trifoliate leaves) with cumulative mean number (4.31 per 5 top trifoliate leaves) of both the thrips species. The highest population of *M. usitatus* and *T. palmi* (5.04 and 2.51, respectively per 5 top trifoliate leaves) with cumulative mean population (7.55 per 5 top trifoliate leaves) of both the thrips species was recorded when crop was sown on 10 February, 2016 which was followed by 20 February sown crop in respect of population of *M. usitatus* (4.55) and *T. palmi* (2.00) with cumulative mean population (6.55 per 5 top trifoliate leaves) of both the thrips species and 1 March sown crop, in which population of *M. usitatus* and *T. palmi* was 3.99 and 1.92, respectively, with cumulative mean population of both the thrips species was 5.92 per 5 top trifoliate leaves. In this season, thrips population was higher at early (10 February to 01 March) and late (10 April and onwards) sown crops

than mid (11 March to 31 March) sown crops. Between the two species, comparatively the percent incidence of *M. usitatus* was higher on mungbean top trifoliate leaves than *T. palmi* in all the sowing dates. In 21 March sown crop, the incidence of *M. usitatus* and *T. palmi* was 68.58% and 31.42%, respectively. On the other hand, in 10 February sown crop the incidence of *M. usitatus* and *T. palmi* was 66.80% and 33.20%, respectively (Table 10).

Table 10. Mean number of *M. usitatus* and *T. palmi* on top trifoliate leaves at pre-flowering stage of mungbean

Treatments (sowing dates)	Mean no. of thrips per 5 top trifoliate leaves		Cumulative mean no. of two thrips species per 5 top trifoliate leaves	Comparative incidence of *M. usitatus* and *T. palmi* on 5 top trifoliate leaves	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T_1 (10 Feb)	5.04 a	2.51 a	7.55 a	66.80 c	33.20 a
T_2 (20 Feb)	4.55 b	2.00 b	6.55 b	69.44 ab	30.56 bc
T_3 (1 March)	3.99 c	1.92 bc	5.92 c	67.50 bc	32.50 ab
T_4 (11 March)	2.61 g	1.13 e	3.75 g	69.80 a	30.20 c
T_5 (21 March)	2.21 h	1.02 e	3.23 h	68.58 abc	31.42 abc
T_6 (31 March)	2.91 f	1.40 d	4.31 f	67.56 bc	32.44 ab
T_7 (10 April)	3.50 d	1.55 d	5.06 d	69.28 ab	30.72 bc
T_8 (20 April)	3.84 c	1.82 c	5.66 c	67.86 abc	32.14 abc
T_9 (30 April)	3.14 e	1.50 d	4.64 e	67.63 abc	32.37 abc
S$\bar{x}$	0.06	0.05	0.10	0.66	0.66
CV (%)	3.11	5.81	3.44	1.69	3.63

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

On the basis of above findings it was revealed that the mungbean crop suffered most due to thrips attack in early and late sown crop from 10 February to 1 March, and 10 April to 30 April, respectively. The most favourable time for sowing of mungbean was observed from 11 March to 31 March having lower number of thrips per 5 top trifoliate leaves. Among March sowing crops, the lowest thrips population (3.23 per 5 top trifoliate leaves) of both the species was observed in 21 March sown crop. In April sowing crop, thrips population increased up to 20 April than those on crop

sowing after 31 March. After 20 April, thrips population again decreased when mungbean was sown on 30 April but it was higher than March sown crop. The percent incidence of *M. usitatus* was higher than *T. palmi* per 5 top trifoliate leaves in all the sowing dates. Several workers reported more or less similar results that thrips population found in vegetative stage of mungbean crop. Ahirwar *et al.* (2016) recorded the pooled data of two years (2010 and 2011) on the mean population of thrips per 6 trifoliate mungbean leaves and found the mean thrips population 2.34 and 4.64 at 23 and 30 days old mungbean plant, respectively. Seed sowing was done in the first week of March, 2010 and 2011. Vijayalakshmi *et al.* (2017) reported that during kharif season (August-September) thrips (*Scirtothrips dorsalis* Hood.) became severe during last week of September with the average number varying from 3.40 to 6.40 thrips per top bud leaves. The highest thrips population was recorded at 30 DAS and continued till 60 DAS while the minimum number was observed before 10 DAS.

4.3.2 Thrips population per five terminal shoots of mungbean as influenced by sowing dates

Thrips population on mungbean terminal shoot at pre-flowering stage differed significantly depending on sowing dates, ranging from 2.67 to 5.53 *M. usitatus* and 1.43 to 3.48 *T. palmi* per 5 terminal shoots (Table 11). The lowest *M. usitatus* and *T. palmi* population (2.67 and 1.43, respectively per 5 terminal shoots) with cumulative mean population (4.10 per 5 terminal shoots) of both the thrips species was observed in 21 March sowing crop which was followed by 11 March and 31 March sown crop. The population of *M. usitatus* (2.85 and 3.08, respectively per 5 terminal shoots), and *T. palmi* (1.77 and 1.85, respectively per 5 terminal shoots) with cumulative mean population of both the species (4.62 and 4.92, respectively per 5 terminal shoot) was observed in 11 March and 31 March sown crop, respectively. The highest *M. usitatus* and *T. palmi* population (5.53 and 3.48, respectively per 5 terminal shoots) with cumulative mean population (9.02 per 5 terminal shoot) of both the thrips species at pre-flowering stage of mungbean was observed in 10 February sown crop followed by 20 February and 1 March sowings where *M. usitatus* population was (5.11 and 4.51, respectively) and *T. palmi* population was (3.33 and 3.01, respectively) with cumulative mean population (8.44 and 7.52, respectively) of both the thrips species. In April sowings crop, thrips population per 5 terminal shoots increased than those of sowings crop from 11 March to end of March. Among April sowings, thrips

population per 5 terminal shoots increased till 20 April, then it declined. It was found that thrips population was higher in early (10 February to 01 March) and late (10 April to 30 April) sowings crop than mid sowings (11 March to 31 March). Between the two species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 terminal shoot in all the sowing dates. In 21 March sown crop, the incidence of *M. usitatus* and *T. palmi* was 65.04% and 34.96%, respectively. On the other hand, in 10 February sown crop the incidence of *M. usitatus* and *T. palmi* was 61.36% and 38.64%, respectively (Table 11).

Table 11. Mean number of *M. usitatus* and *T. palmi* on terminal shoots at pre-flowering stage of mungbean

Treatments (sowing dates)	Mean no. of thrips per 5 terminal shoots		Cumulative mean no. of two thrips species per 5 terminal shoots	Comparative incidence of *M. usitatus* and *T. palmi* on 5 terminal shoots	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T$_1$ (10 Feb)	5.53 a	3.48 a	9.02 a	61.36 bc	38.64 bc
T$_2$ (20 Feb)	5.11 b	3.33 b	8.44 b	60.59 bcd	39.41 abc
T$_3$ (1 March)	4.51 c	3.01 c	7.52 c	60.01 bcd	39.99 abc
T$_4$ (11 March)	2.85 h	1.77 g	4.62 h	61.76 b	38.24 c
T$_5$ (21 March)	2.67 h	1.43 h	4.10 i	65.04 a	34.96 d
T$_6$ (31 March)	3.08 g	1.85 g	4.92 g	62.50 b	37.50 c
T$_7$ (10 April)	3.61 e	2.53 e	6.13 e	58.81 cd	41.19 ab
T$_8$ (20 April)	4.04 d	2.86 d	6.90 d	58.51 d	41.49 a
T$_9$ (30 April)	3.35 f	2.20 f	5.55 f	60.35 bcd	39.65 abc
S$\bar{x}$	0.07	0.05	0.07	0.82	0.82
CV (%)	3.04	3.41	1.96	2.32	3.63

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the thrips population was higher in early (10 February to 01 March) and late (10 April and onward) sowing crops than mid sowings (11 March to 31 March) at pre-flowering stage on terminal shoot of the crop. It was generalized that the sowing of mungbean crop on 21 March suffered least and recorded lower number of *M. usitatus* and *T. palmi* followed by 11 March and 31 March sowing crop. The percent incidence of *M. usitatus* was higher than *T. palmi*

per 5 terminal shoot in all the sowing dates. The present findings also got good support from the reports of Reddy (2016) who recorded that mungbean crop sown from 24th March up to first week of April was found to suffer least due to lower level of thrips population ranging from 2.8 to 2.4 thrips per plant. Delaying in its sowing afterwards carry higher population of thrips (3.4- 6.2 thrips per plant). It has also been observed that the crop sown on 20th April, 2015 harbour maximum number of thrips per plant (6.2 thrips per plant) which might be due to increase in temperature and dry weather prevailing during the vegetative stage of the crop.

4.3.3 Thrips population per five flower buds of mungbean as influenced by sowing dates

The data presented in Table 12 clearly revealed that the population of thrips per 5 flower bud of mungbean varied significantly depending on seasonal variation in different dates of sowing. During kharif-I in 2016, the number of *M. usitatus* ranged from 4.22 to 8.41 per 5 flower buds and *T. palmi* ranged from 2.18 to 4.40 per 5 flower buds in different sowing dates. Thrips population gradually decreased with the advancing of sowing dates up to 21 March, then population gradually increased again till 20 April. Afterthat, in 30 April sown crop, thrips population decreased but it was higher than March sowings. Among the different dates of sowing the lowest population of *M. usitatus* and *T. palmi* (4.22 and 2.18, respectively per 5 flower buds) was observed when mungbean seeds sown on 21 March with cumulative mean population (6.41 thrips per 5 flower buds) of both the thrips species which was followed by 11 March sown crop, in which population of *M. usitatus* and *T. palmi* (4.53 and 2.42, respectively per 5 flower buds) with cumulative mean population (6.95 per 5 flower buds) of both the thrips species was found. This was followed by 31 March sown crop, in which population of *M. usitatus* and *T. palmi* (4.97 and 2.81, respectively per 5 flower buds) with cumulative mean population (7.78 per 5 flower buds) of both the thrips species was observed. The highest population of *M. usitatus* and *T. palmi* per 5 flower buds was recorded to be 8.41 and 4.40 per 5 flower buds with cumulative mean population (12.81 per 5 flower buds), when crop was sown on 10 February, 2016 which was followed by 20 February sowing crop in respect of population of *M. usitatus* (7.80) and *T. palmi* (4.12) per 5 flower buds with cumulative mean population (11.92 per 5 flower buds) of both the thrips species and 1 March sowing crop, in which population of *M. usitatus* and *T. palmi* were 7.29 and

3.81, respectively with cumulative mean population (11.10 per 5 flower buds) of both the thrips species. Between the two species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flower buds in all the sowing dates. In 21 March sown crop, the incidence of *M. usitatus* and *T. palmi* was 65.93% and 34.07%, respectively per 5 flower buds. On the other hand, in 10 February sown crop the incidence of *M. usitatus* and *T. palmi* was 65.62% and 34.38%, respectively (Table 12).

Table 12. Mean number of *M. usitatus* and *T. palmi* on flower buds at flowering stage of mungbean

Treatments (sowing dates)	Mean number of thrips per 5 flower buds		Cumulative Mean No. of two thrips species per 5 flower buds	Comparative incidence of *M. usitatus* and *T. palmi* on 5 flower buds	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T$_1$ (10 Feb)	8.41 a	4.40 a	12.81 a	65.62 ab	34.38 bc
T$_2$ (20 Feb)	7.80 b	4.12 b	11.92 b	65.46 ab	34.54 bc
T$_3$ (1 March)	7.29 c	3.81 c	11.10 c	65.65 ab	34.35 bc
T$_4$ (11 March)	4.53 h	2.42 f	6.95 h	65.19 ab	34.81 bc
T$_5$ (21 March)	4.22 i	2.18 g	6.41 i	65.93 a	34.07 c
T$_6$ (31 March)	4.97 g	2.81 e	7.78 g	63.86 bc	36.14 ab
T$_7$ (10 April)	5.92 e	3.32 d	9.24 e	64.06 abc	35.94 abc
T$_8$ (20 April)	6.63 d	3.71 c	10.35 d	64.11 abc	35.89 abc
T$_9$ (30 April)	5.31 f	3.14 d	8.46 f	62.84 c	37.16 a
S$\bar{x}$	**0.09**	**0.07**	**0.12**	**0.57**	**0.57**
CV (%)	**2.44**	**3.58**	**2.13**	**1.52**	**2.79**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the thrips population was higher on flower bud in early (10 February to 01 March) and late (10 April and 30 April) sowings than mid sowings (11 March to 31 March) at flowering stage of the crop. It was found that the lowest number of *M. usitatus* and *T. palmi* was found on flower buds in 21 March sowing mungbean which was followed by 11 March and 31 March sowings crop. Comparatively, the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flower buds of mungbean in all the sowing dates. Kasina *et al.* (2009) also reported that the number of adult *F. occidentalis* was higher in mature than in early

buds of French bean (> 66%). Comparably, *M. sjostedti* populations in all buds were negligible (< 1%).

4.3.4 Thrips population per five flowers of mungbean as influenced by sowing dates

The population of thrips per 5 flowers varied significantly depending on seasonal variation in different dates of sowing. During kharif-I in 2016, the number of *M. usitatus* ranged 5.28 to 9.34 per 5 flowers and *T. palmi* ranged 1.42 to 5.34 per 5 flowers in different sowing dates (Table 13). Among the different dates of sowing the lowest population of *M. usitatus* and *T. palmi* (5.28 and 1.42, respectively per 5 flowers) with cumulative mean population of both the thrips species (6.70 per 5 flowers) was recorded when crop was sown on 21 March, 2016 which was followed by 11 March sown crop, in which the population of *M. usitatus* and *T. palmi* was (5.64 and 1.85, respectively per 5 flowers) with cumulative mean population of both the thrips species (7.50 per 5 flowers). This was followed by 31 March, 2016 with population of *M. usitatus* and *T. palmi* (5.83 and 1.92, respectively per 5 flowers) and cumulative mean population of both the thrips species (7.75 per 5 flowers). The highest population of *M. usitatus* and *T. palmi* was found 9.34 and 5.34, respectively with cumulative mean population of both the thrips species 14.68 per 5 flower, when crop was sown on 10 February, 2016 which was followed by 20 February, 2016 sowing crop in respect of population of *M. usitatus* (7.56) and *T. palmi* (4.74) per 5 flowers with cumulative mean population of both the thrips species 12.30 per 5 flowers and 1 March sowing crop, when population of *M. usitatus* and *T. palmi* was 7.78 and 4.18, respectively with cumulative mean population of both the thrips species 11.96 per 5 flowers. Between the two species, comparatively the incidence of *M. usitatus* was 78.86% and *T. palmi* was 21.14% in flower on 21 March sown mungbean. On the other hand, the incidence of *M. usitatus* was 63.61% and *T. palmi* was 36.39% in flower on 10 February sown mungbean. It was observed that the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flowers in all the sowing dates (Table 13).

Table 13. Mean number of *M. usitatus* and *T. palmi* in flowers at flowering stage of mungbean

Treatments (sowing dates)	No. of thrips per 5 flowers		Cumulative no. of two thrips species per 5 flowers	Comparative incidence of *M. usitatus* and *T. palmi* on 5 flowers	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T$_1$ (10 Feb)	9.34 a	5.34 a	14.68 a	63.61 d	36.39 a
T$_2$ (20 Feb)	7.56 b	4.74 b	12.30 b	61.00 d	39.00 a
T$_3$ (1 March)	7.78 b	4.18 c	11.96 b	65.03 d	34.97 a
T$_4$ (11 March)	5.64 de	1.85 g	7.50 fg	75.29 ab	24.71 cd
T$_5$ (21 March)	5.28 e	1.42 h	6.70 g	78.86 a	21.14 d
T$_6$ (31 March)	5.83 de	1.92 g	7.75 ef	75.29 ab	24.71 cd
T$_7$ (10 April)	6.54 cd	2.79 e	9.33 d	70.10 c	29.90 b
T$_8$ (20 April)	6.91 bc	3.82 d	10.72 c	64.41 d	35.59 a
T$_9$ (30 April)	6.21 cde	2.43 f	8.63 de	71.93 bc	28.07 bc
S$\bar{x}$	0.32	0.07	0.33	1.29	1.29
CV (%)	8.17	4.05	5.71	3.21	7.32

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the thrips population was higher in flower in early (10 February to 01 March) and late (10 April to 30 April) sowing crops than mid sowings (11 March to 31 March) of the crop. Thrips population gradually decreased with the advancing of sowing dates up to 21 March, then population gradually increased again till 20 April. Afterthat, in 30 April sown crop, thrips population decreased but it was higher than March sowings. It was found that lower number of *M. usitatus* and *T. palmi* was recorded in flower on 21 March sown mungbean which was followed by 11 March and 31 March sowings crop. The percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flower of mungbean in all the sowing dates. The lowest thrips population might be due to synchrony with thrips population with most vulnerable stage of the plant, climatic factors etc. Some other authors also supported the present findings of the study. Hossain *et al.* (2009) reported that thrips population was higher in early (14 February to 06 March) and late (13 April and onward) sowing crops than mid sowings (13 March to 10 April).

Ascensión-Betanzos *et al.* (1999) mentioned that the highest thrips populations occurred during flowering periods and in the warmer periods. However, high thrips populations were also registered during the coldest period (Dec.–Jan), as in the case of tomatillo crops in Tlayacapan. Duraimurugan and Tyagi1 (2014) observed *M. usitatus* incidence in mungbean ranged between 2.2 (43-49 DAS) to 28.0 (64-70 DAS) per 100 flowers and its incidence in urdbean ranged between 0.4 (43-49 DAS) to 21.0 (64-70 DAS) per 100 flowers. The flower thrips (*M. usitatus*), a major pest of spring /summer mungbean assumed status of pests even in kharif season.

4.3.5 Effect of different sowing dates on top trifoliate leaves and terminal shoots infestation by thrips on mungbean

Data presented in Table 14 showed that among the different dates of sowing, the lowest number (2.00 per 5 top trifoliate leaves) of infested top trifoliate leaf with 40.00% infestation was observed in 21 March sowing crop which was followed by 11 March sowing crop where number of infested top trifoliate leaves was 2.33 per 5 top trifoliate leaves with 46.60% infestation. This was statistically identical with 31 March sowing crop in which number of infested top trifoliate leaves was 2.50 per 5 top trifoliate leaves with 50.00% infestation. On the other hand, the highest number (3.83 per 5 top trifoliate leaves) of infested top trifoliate leaves with 76.53% infestation was observed in 10 February sowing crop which was statistically similar with 20 February sowing crop, in which the number of infested top trifoliate leaves was 3.67 per 5 top trifoliate leaves with 73.33% infestation. In April sowings crop, percent top trifoliate leaves infestation was increased than those of sowings crop from 11 March to end of March. Similarly, the lowest number (2.83 per 5 terminal shoots) of infested terminal shoot with 56.67% infestation was observed in 21 March sowing crop which was statistically similar with 11 March and 31 March sowings crop, in which the number of infested terminal shoot was 3.00 and 3.17, respectively per 5 terminal shoots with 60.00% and 63.40% infestation, respectively. On the other hand, the highest number of infested terminal shoot (4.17 per 5 terminal shoots) with 83.33% infestation was observed in 10 February sowing crop which was statistically similar with 20 February sowing crop, in which the number of infested terminal shoot was 3.83 per 5 terminal shoots with 76.53% infestation. In April sowings crop, percent terminal shoot infestation increased than those of sowings crop on 11 March

to end of March. The number of infested terminal shoot was statistically identical in all the sowing dates of April (Table 14).

Table 14. Top trifoliate leaves and terminal shoot infestation by thrips at pre-flowering stage of mungbean

Treatments (sowing dates)	Mean no. of infested top trifoliate leaves per 5 top trifoliate leaves	% infestation of top trifoliate leaves	Mean no. of infested terminal shoot per 5 top shoots	% infestation of terminal shoot
T$_1$ (10 Feb)	3.83 a	76.53 a	4.17 a	83.33 a
T$_2$ (20 Feb)	3.67 a	73.33 a	3.83 ab	76.53 ab
T$_3$ (1 March)	3.33 b	66.60 b	3.67 bc	73.33 bc
T$_4$ (11 March)	2.33 e	46.60 e	3.00 ef	60.00 ef
T$_5$ (21 March)	2.00 f	40.00 f	2.83 f	56.67 f
T$_6$ (31 March)	2.50 e	50.00 e	3.17 def	63.40 def
T$_7$ (10 April)	2.83 d	56.60 d	3.50 bcd	70.00 bcd
T$_8$ (20 April)	3.17 bc	63.40 bc	3.67 bc	73.40 bc
T$_9$ (30 April)	3.00 cd	60.07 cd	3.33 cde	66.67 cde
S$\bar{x}$	0.09	1.93	0.13	2.68
CV (%)	5.65	5.65	6.70	6.70

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

This study revealed that thrips infestation of mungbean started from vegetative stage of the crop. The percent terminal shoot infestation was higher than percent top trifoliate leaves infestation by thrips. Percent top trifoliate leaves and percent terminal shoot infestation was higher in early (10 February to 01 March) and late (10 April to 30 April) sowing crops than mid sowings (11 March to 31 March) at vegetative stage. It was observed that the sowing of mungbean crop on 21 March suffered least percent top trifoliate leaves and terminal shoot infestation followed by 11 March and 31 March sowing crops. As thrips likes to habitate in hinder or closer parts of the plant, the number of thrips population was higher in terminal shoot than top trifoliate leaves. This may be the reason of higher percent terminal shoot infestation than top trifoliate leaves infestation. Several researchers reported more or less similar results that thrips population found in vegetative stage of mungbean crop. Reddy (2016) reported that the sowing of mungbean crop from 24th March up to first April suffered least by thrips

population at vegetative stage, but delaying in the sowing of crop up to 29th April, the problem of thrips population was more at vegetative stage of the crop.

Vijayalakshmi *et al.* (2017) reported that thrips (*Scirtothrips dorsalis* Hood.) feed on young unopened bud leaves of groundnut and caused dull yellowish-green patches on upper surface and dark-brown necrotic patches on lower leaf surface as well as curling of leaves. Kasina *et al.* (2009) found that that thrips infestation of French beans starts before flowering. At this time in crop development the thrips can only forage on vegetative plant parts as the crop has not flowered. This could be the reason why a large number of adult thrips were found at pre-flowering stage of the crop.

4.3.6 Effect of different sowing dates on flower bud infestation by thrips and shedding of flower bud of mungbean

Flower bud infestation by thrips as well as shedding of flower bud was significantly affected by dates of sowing (Table 15). Among the different dates of sowing, the highest number (49.77 plant^{-1}) of total flower bud and the lowest number of infested and shedded flower bud (11.17 and 5.16 plant^{-1}, respectively) was observed in 21 March sown crop with 22.44% infestation and 10.36% shedding flower bud by thrips which was followed by 11 March sown crop, in which total number of flower bud was 46.73 plant^{-1}, number of infested and shedded flower bud were (13.23 and 5.52 plant^{-1}, respectively) with 28.24% infestation and 11.84% shedding of flower bud. This was followed by 31 March sown crop, in which total number of flower bud was 40.83 plant^{-1}, number of infested and shedded flower bud were (12.34 and 6.40 plant^{-1}, respectively) with 30.23% infestation and 15.67% shedding of flower bud. On the other hand, the lowest number of total flower bud was 29.23 plant^{-1} and the highest number of infested and shedded flower bud were 17.56 and 7.63 plant^{-1}, respectively with 60.08% infestation and 26.06% shedding were observed in 10 February sown crop which was followed by 20 February sown crop, in which total number of flower bud was 32.54 plant^{-1} and number of infested and shedded flower bud were 17.34 and 7.29 plant^{-1}, respectively with 53.23% infestation and 22.38% shedding. This was followed by 01 March sown crop, in which total number of flower bud was 34.21 plant^{-1} and number of infested and shedded flower bud were 16.22 and 6.86 plant^{-1}, respectively with 47.41% infestation and 20.08% shedding of flowerbud. In April sowings crop, percent flower bud infestation and shedding increased than those of sowings crop on 11 March to end of March. Infestation levels on French beans by

thrips peaks during the hot period and especially during the flowering stage (Moritz *et al.* 1997). During this period of high infestation, thrips cause abortion of flower buds hence reducing pod set and yield significantly (Kibata and Ong῭aro 1997). Tamò *et al.* (1993) showed that the feeding activity of six larvae of a closely related *Megalurothrips* species *M. sjostedti* during five days induced the shedding of all flower buds of a cowpea inflorescence.

Table 15. Flower bud infestation and shedding by thrips at flowering stage of mungbean

Treatments (sowing dates)	No. of total flower bud plant^{-1}	No. of infested flower bud plant^{-1}	% infestation of flower bud	No. of shedding flower bud plant^{-1}	% shedding of flower bud
T$_1$ (10 Feb)	29.23 g	17.56 a	60.08 a	7.63 a	26.06 a
T$_2$ (20 Feb)	32.54 f	17.34 a	53.23 b	7.29 ab	22.38 b
T$_3$ (1 March)	34.21 ef	16.22 a	47.41 c	6.86 abc	20.08 bc
T$_4$ (11 March)	46.73 b	13.23 bc	28.24 f	5.52 e	11.84 e
T$_5$ (21 March)	49.77 a	11.17 d	22.44 g	5.16 e	10.36 e
T$_6$ (31 March)	40.83 c	12.34 cd	30.23 ef	6.40 cd	15.67 d
T$_7$ (10 April)	36.31 e	12.39 cd	34.13 de	6.45 bcd	17.77 cd
T$_8$ (20 April)	38.43 d	14.24 b	37.14 d	6.56 bcd	17.16 d
T$_9$ (30 April)	35.12 e	12.45 cd	35.52 de	5.81 de	16.49 d
S$\bar{\text{x}}$	0.71	0.56	1.75	0.28	0.81
CV (%)	3.23	6.83	7.85	7.43	8.04

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Figure 1 showed a proportional relationship between number of thrips and rate of flower bud shedding. There was a positive relationship between number of thrips and rate of flower bud shedding. The result showed that the flower bud shedding percentage increase with the increase of thrips population.
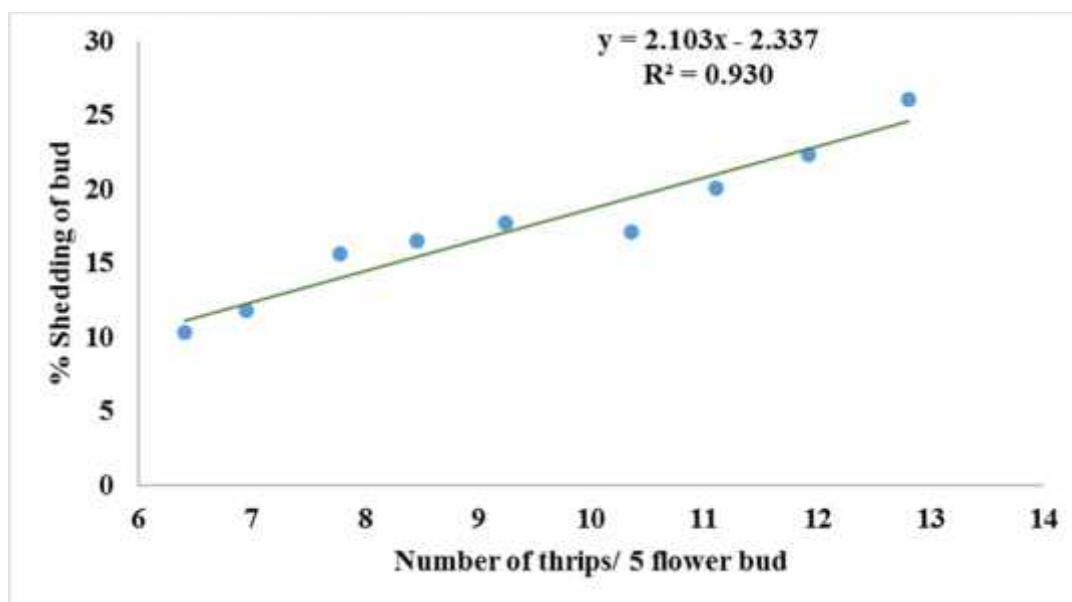
Figure 1. Relationship between incidence of thrips population and flower bud shedding of mungbean.

4.3.7. Effect of different sowing dates on flower infestation and shedding by thrips on mungbean

Flower infestation as well as shedding of flower by thrips was significantly affected by dates of sowing (Table 16). Among the different dates of sowing, the highest number (17.85 plant^{-1}) of total flower and the lowest number of infested and shedded flower (6.85 and 3.73 plant^{-1}, respectively) were observed in 21 March sown crop with 38.23% infestation and 20.92% shedding flower by thrips which was followed by 11 March sown crop, in which total number of flower was 17.27 plant^{-1}, number of infested and shedded flower was 7.19 and 3.90 plant^{-1}, respectively with 41.86% infestation and 22.58% shedding of flower by thrips. This was followed by 31 March sown crop, in which total number of flower plant^{-1} was 16.57, number of infested and shedded flower was 7.74 and 4.24 plant^{-1}, respectively with 45.34% infestation and 25.62% shedding of flower. On the other hand, the lowest number of total flower was 11.70 plant^{-1} and the highest number of infested and shedded flower was (8.81 and

5.32 plant^{-1}, respectively) with 75.81% infestation 45.61% shedding of flower by thrips were observed in 10 February sown crop which was followed by 20 February sown crop, in which total number of flower was 12.67 plant^{-1} and number of infested and shedded flower was 8.80 and 5.08 plant^{-1} with 68.82% infestation and 40.15% shedding of flower by thrips. This was followed by 01 March sown crop, in which total number of flower was 13.43 plant^{-1} and number of infested and shedded flower by thrips was 8.59 and 4.85 plant^{-1}, respectively with 64.18% infestation and 36.15% shedding. In April sowings crop, percent flower infestation and shedding were increased than those of sowings crop on 11 March to end of March. Fan *et al.* (2013) reported that the thrips *M. usitatus* occurs every growing season and causes necrosis and premature dropping of buds and flowers as a result of its feeding and ovipositing.

Table 16. Flower infestation and shedding by thrips at flowering stage of mungbean

Treatments (sowing dates)	No. of total flower plant^{-1}	No. of infested flower plant^{-1}	% flower infestation	No. of shedding flower plant^{-1}	% shedding flower
T$_1$ (10 Feb)	11.70 g	8.87 a	75.81 a	5.32 a	45.61 a
T$_2$ (20 Feb)	12.67 f	8.72 ab	68.82 b	5.08 b	40.15 b
T$_3$ (1 March)	13.43 e	8.62 b	64.18 c	4.85 c	36.15 c
T$_4$ (11 March)	17.27 a	7.19 e	41.86 h	3.90 f	22.58 g
T$_5$ (21 March)	17.85 a	6.85 f	38.23 i	3.73 g	20.92 g
T$_6$ (31 March)	16.57 b	7.74 d	45.34 g	4.24 e	25.62 f
T$_7$ (10 April)	15.40 c	8.17 c	53.32 e	4.49 d	29.17 e
T$_8$ (20 April)	15.60 c	7.88 d	51.34 f	4.54 d	29.09 e
T$_9$ (30 April)	14.68 d	8.23 c	56.44 d	4.82 c	32.85 d
S$\bar{x}$	0.20	0.05	0.04	0.32	0.76
CV (%)	2.36	1.17	0.13	1.24	4.18

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Figure 2 showed a proportional relationship between number of thrips and rate of flower shedding. There was a positive relationship between number of thrips and rate of flower shedding. The result showed that the flower shedding percentage increase with the increase of thrips population.

$y = 2.914x + 2.341$
$R^2 = 0.891$
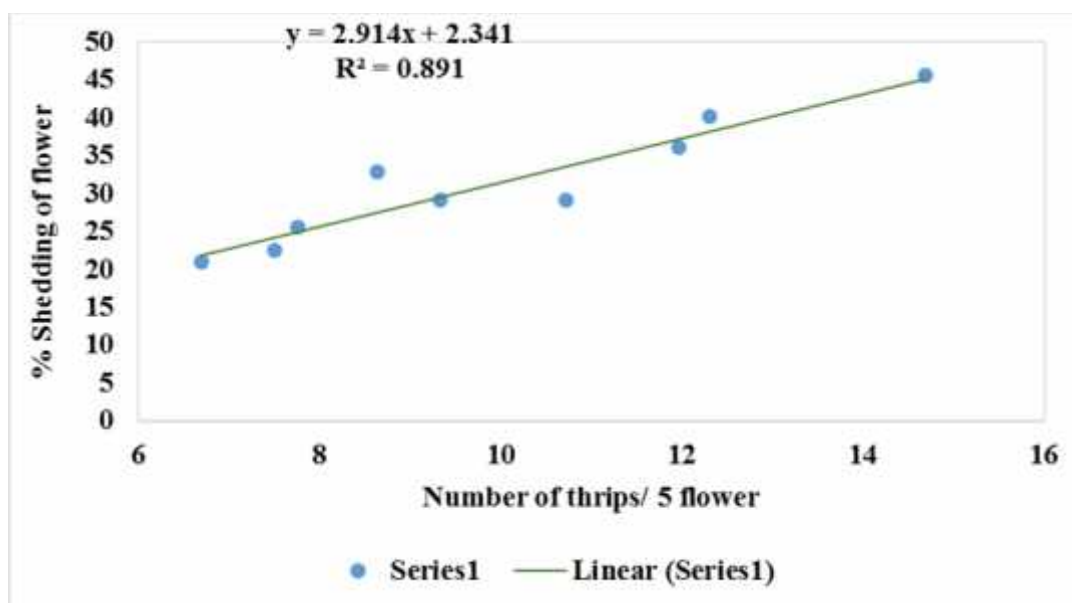
Figure 2. Relationship between incidence of thrips population and flower shedding of mungbean.

4.3.8 Percent incidence of *M. usitatus* and *T. palmi* in different plant parts of mungbean

The lowest number of thrips and percent infestation of different plant parts was observed on 21 March (T_5) sown mungbean, in which the bean flower thrips, *M. usitatus* comprised (68.58%, 65.04%, 65.93% and 78.86%) of the species collected from top trifoliate leaves, terminal shoots, flower buds and flowers, respectively and *T. palmi* comprised (31.42%, 34.96%, 34.07% and 21.14%) on top trifoliate leaves, terminal shoots, flower buds and flowers, respectively (Figure 3). On the other hand, the highest number of thrips and percent infestation of different plant parts was observed on 10 February (T_1) sown mungbean where *M. usitatus* comprised (66.80%, 61.36%, 65.62% and 63.61%) of the species collected from top trifoliate leaves, terminal shoots, flower buds and flowers, respectively and *T. palmi* comprised (33.20%, 38.64%, 34.38% and 36.39%) on top trifoliate leaves, terminal shoots, flower buds and flowers, respectively (Figure. 4). *M. usitatus* comprised more than

60% of the species collectecd whereas, melon thrips (*T. palmi*) comprised 20-40 % of the species observed from top trifoliate leaves, terminal shoots, flower buds and flowers of mungbean on 10 February and 21 March sowings. *M. usitatus* was the most abundant species colonizing different plant parts of mungbean. At pre-flowering stage, *T. palmi* found more in terminal shoot than top trifoliate leaves. The incidence of thrips in different plant parts may vary crop to crop for many reasons, i.e., thrips species, crop type, crops phenology, crops availability and suitability, weather factors etc.

Other studies have also found evidence that thrips generally occur in aggregated form both within and among plants (Joost and Riley 2004; Cho *et al.* 1995). *M. usitatus* is an important pest of mungbean at its vegetative growth phase (Farajallah 2013). However, the principal point of plant attack of thrips is on the flower buds and later, on the flowers themselves (Singh and Taylor 1978). Kumar and Williams (2012) collected *T. palmi* from terminal leaves of mungbean from three weeks after sowing during kharif when seeds were sown on 21 June 2006. Kasina *et al.* (2009) reported that thrips infestation of flowers was significantly different from that of leaves and buds. Ugine *et al*. (2006) observed high presence of adult *F. occidentalis* on young flowers of garden impatiens [*Impatiens wallerana* (Hook. F.)] to feed pollen compared with vegetative parts and older flowers that already have shed their pollen. This probably explains its preference for young flowers, leaving *M. sjostedti* in relatively older flowers, which have fewer resources.
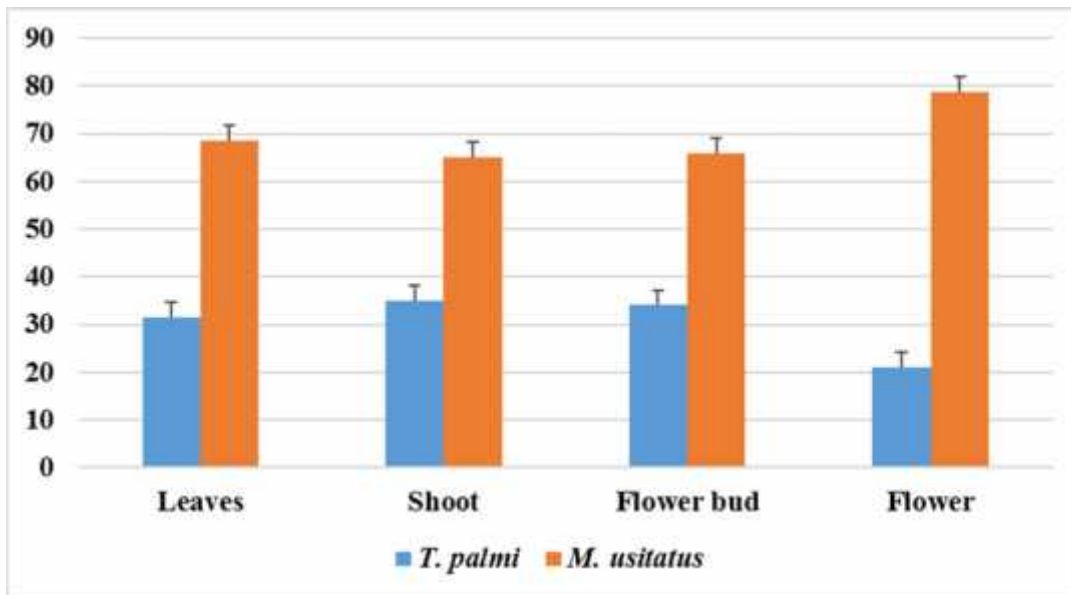
Figure 3. Percent incidence of *T. palmi* and *M. usitatus* on different plant parts on 21 March (T$_5$) sown mungbean.
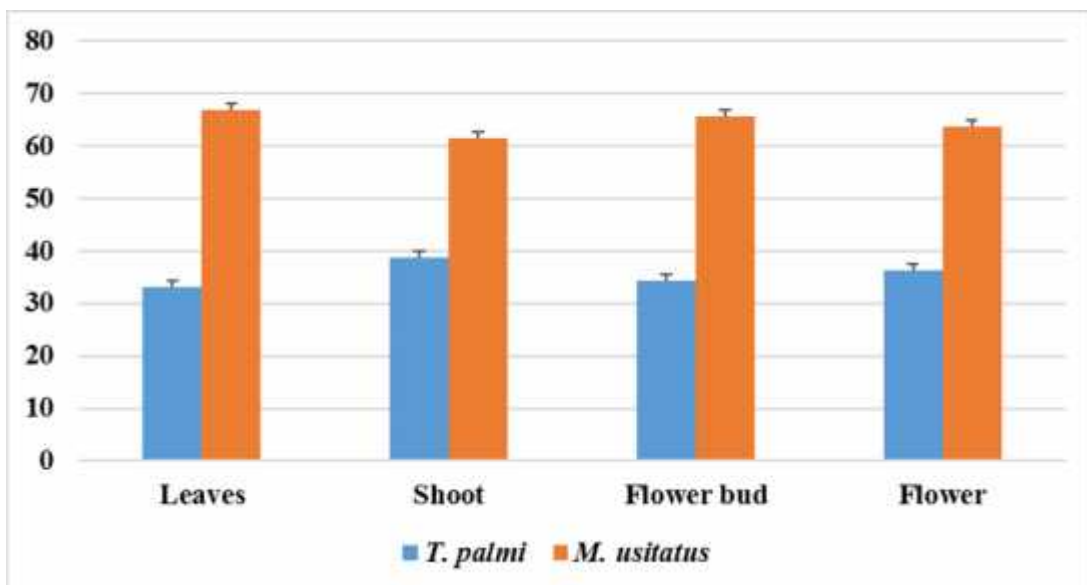
Figure 4. Percent incidence of *T. palmi* and *M. usitatus* on different plant parts on 10 February (T$_1$) sown mungbean.

4.3.9 Effect of different sowing dates on population dynamics of thrips in flowers of mungbean

The population of *M. usitatus* and *T. palmi* was recorded at weekly interval on five flowers from five randomly selected and tagged plants per plot. The populations of *M. usitatus* and *T. palmi* in flowers (5.73 and 3.19 per 5 flowers, respectively) were first observed at 39 DAS (days after sowing) i.e., 20 March, 2016 in 10 February (T_1) sown mungbean crop. The incidence of the two species increased in 46 DAS (12.67 *M. usitatus* and 6.78 *T. palmi* per 5 flowers) but drastically decreased in 53 DAS (2.11 *M. usitatus* and 1.47 *T. palmi* per 5 flowers). After that, the populations of *M. usitatus* and *T. palmi* increased and it reached to a peak level (15.83 *M. usitatus* and 8.97 *T. palmi* per 5 flowers) in 67 DAS i.e., 17 April 2016. Thereafter, both the thrips population decreased gradually but was active till 88 DAS (Figure 5). The incidence of both the thrips population decreased in 53 DAS may be due to rainfall during that week (Appendix 1). The abundance of thrips population may be influenced not only by the weather condition but also the crop phenology. The peak populations were observed during vulnerable stage of crop growth i.e., during flowering stage of the crop. Other authors also supported the findings of the present study. Tamang *et al.* (2017) conducted an experiment in 2013 to observe the population dynamics of major insect pests of mungbean and sowing was done in the second week of February. The incidence of thrips population was recorded in 9 WAS with intensity of 2.45 per flower and reached its peak of 6.89 per flower (11 WAS). Thereafter, thrips population decreased in 12 WAS during the season. Meena *et al.* (2013), Khan *et al.* (2011) also supported the above findings.
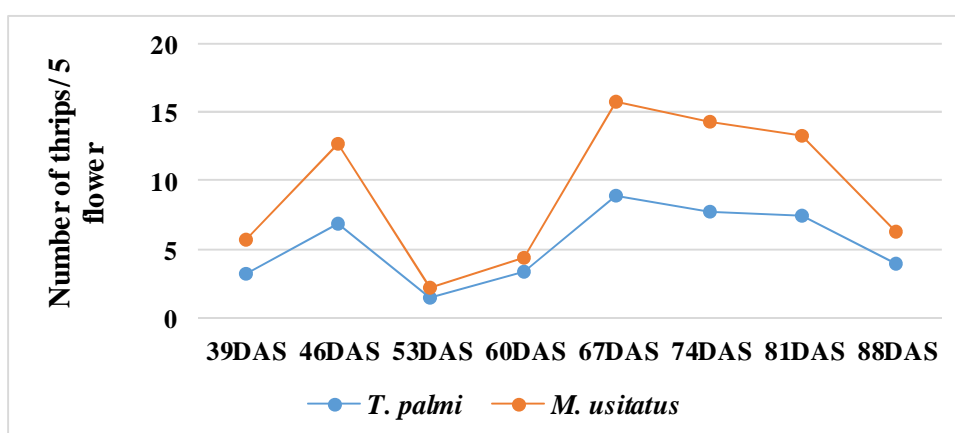
Figure 5. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 10 February (T_1) sown mungbean.

104

The data illustrated in Figure 6 clearly revealed that the number of *M. usitatus* and *T. palmi* per 5 flowers varied significantly in 20 February (T$_2$) sown mungbean. The population of *M. usitatus* and *T. palmi* on flowers (4.11 and 3.13 per 5 flowers, respectively) was first observed at 36 DAS i.e., 27 March 2016. The population of both the species decreased in 43 DAS. Then the population of both the species increased in 50 DAS and the maximum population of *M. usitatus* and *T. palmi* (13.59 and 8.65 per 5 flowers, respectively) was observed in 57 DAS i.e., 17 April 2016. Afterthat, the population of both the thrips species decreased gradually and maintained up to 85 DAS i.e., 15 May. Both the thrips population decreased in 43 DAS may be due to rainfall during that period (Appendix 1). Incidence of thrips under present investigation was in accordance with the observations by Kasina *et al.* (2009) on French bean. They found that the population of *F. occidentalis* and *M. sjostedti* decreased from the third to the sixth week in the cropping season, coinciding with rain at that period on. The number of *F. occidentalis* on leaves decreased from pre-flowering period as more flowers continued to form. Their number in flowers was significantly higher than the number of *M. sjostedti*.
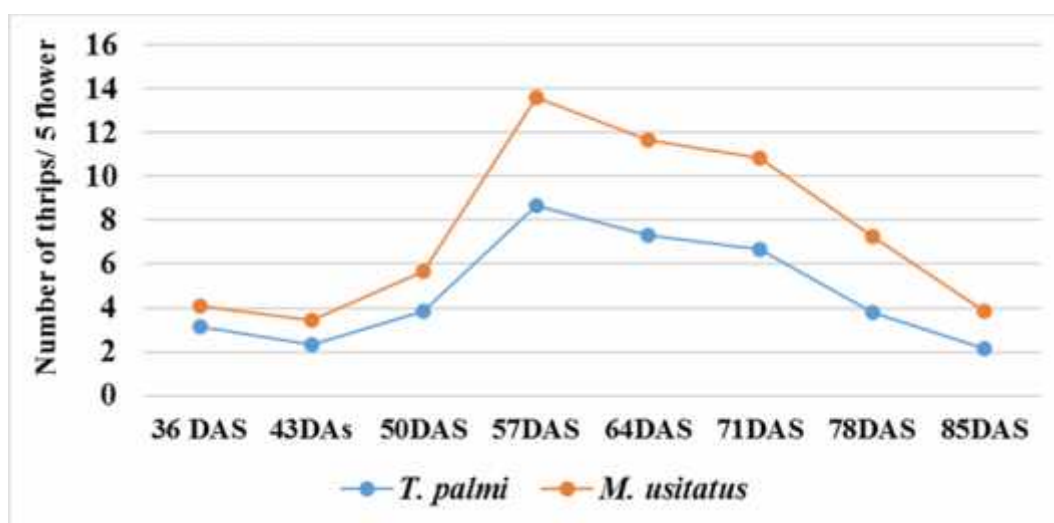
Figure 6. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 20 February (T$_2$) sown mungbean crop.

In 1 March 2016 (T₃) sown mungbean, the population of *M. usitatus* and *T. palmi* (2.33 and 1.07 per 5 flowers) was noticed first on flower in the 3 Apri 2016 i.e., 34 DAS. Then the population increased and attained at peak (16.67 *M. usitatus* and 9.67 *T. palmi* per 5 flowers) in the third week of April (17 April, 48 DAS). Thereafter, the population of both the thrips species was started to decline and observed up to last week of May (29 May, 90 DAS) with a of population *M. usitatus* and *T. palmi* (2.67 and 1.67 per 5 flowers, respectlvely) (Figure 7). The peak population of both the thrips population observed in 48 DAS may be due to no rainfall during that period (Appendix I) and flowers were also available for inhabiting thrips. Babu *et al*. (2004) reported that the peak build up of *T. palmi* coincided with six weeks age of the crop which in turn coincided with beginning of the flowering period.
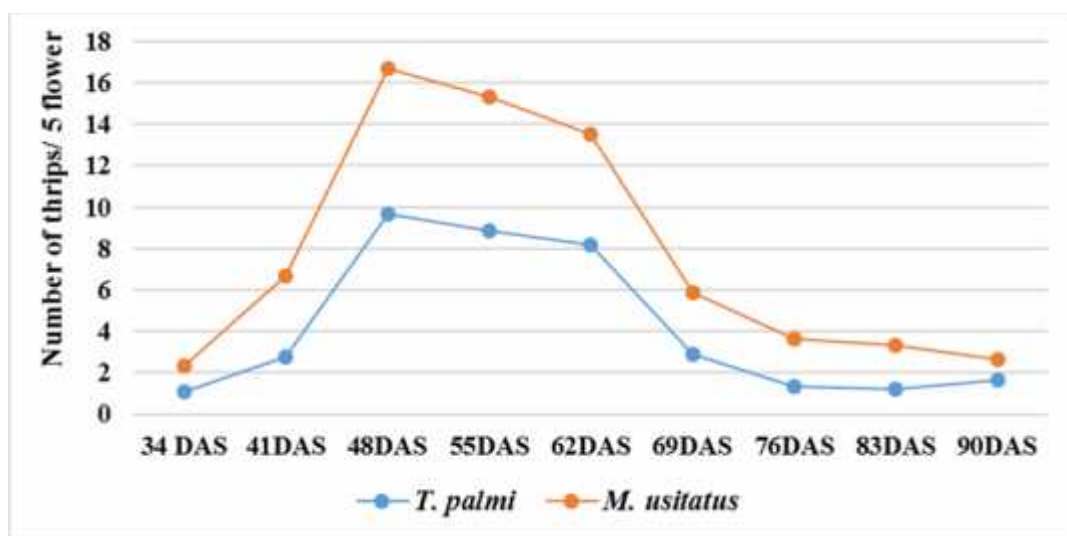
Figure 7. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 1 March (T₃) sown mungbean crop.

In 11 March (T$_4$) sowing mungbean, the populations of *M. usitatus* and *T. palmi* (3.87 and 1.33 per 5 flowers) were first recorded on flower in second week of April (10 April) i.e. 30 days after sowing. The population of both the species gradually increased and attained maximum population of *M. usitatus* and *T. palmi* (9.57 and 3.12 per 5 flowers) in 1 May (51 DAS) in flowers when the average temperature, sunshine hr. and relative humidity were 31.49$^\bullet$C, 9.07, 68.29, respectively but without any rainfall (Appendix I). Then the population decreased gradually up to 22 May (72 DAS) when average temperature, sunshine hr., relative humidity and rainfall were 28.29^{o}C, 4.61, 79.43% and 13.71 mm, respectively. Then the population of both the species slightly increased and thereafter decreased again and observed on the crop till the first week of May (6 May) i.e., 86 days after sowing (Figure 8). Chakraborty (2006) also reported that the incidence of thrips (*M. distalis*) was initiated in the 11th standard week i.e. 3rd week of March in Pre-kharif season of 2003 in mungbean. The initial population was 0.4 per plant, which was increased sharply (2.07 per plant) in the 12th standard week i.e. 36 DAS. The maximum population (4.8 per plant) was observed in 14th standard week i.e. 2nd week of April when the temperature (Max.), temperature (min.), RH (max.), RH (min.) and rainfall were 31.4^{o}C, 17.0^{o}C, 92%, 71% and 19 mm, respectively. Then the population of thrips decreased gradually and maintained up to 2nd week of May i.e., 18th standard week.
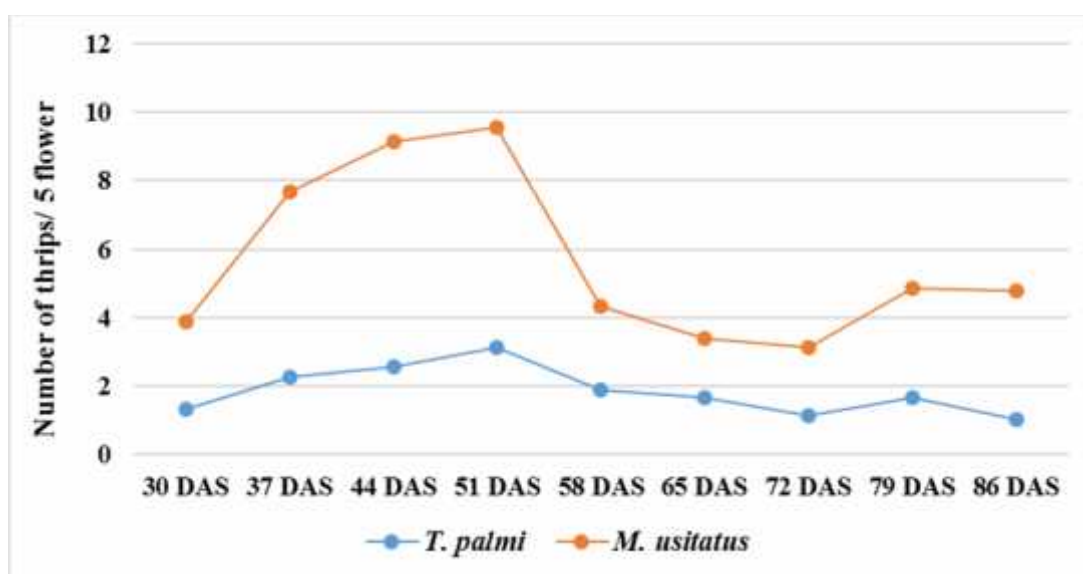
Figure 8. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 11 March (T$_4$) sown mungbean crop.

The population of both the thrips species i.e., *M. usitatus* and *T. palmi* was first recorded in flowers on 4th week of April (24 April) i.e., 34 DAS and observed upto 2nd week of June (13 June) i.e., 83 DAS in 21 March (T$_5$) sown mungbean (Figure 9). The maximum population of *M. usitatus* and *T. palmi* (9.98 and 2.61 per 5 flowers) was found in 1 May (41 DAS) when average temperature 31.49 ^{o}C, sunshine hr 9.07, relative humidity 68.29% and rainfall 0.00 mm were recorded (Appendix 1). Then the population decreased gradually till 22 May (62 DAS) when rainfall was 13.71 mm. Thereafter, The population of both the thrips species i.e., *M. usitatus* and *T. palmi* increased upto 1st week of June 5 (June) i.e., 76 days after sowing when rainfall was 0.43 mm and then declined again in 2nd week of June (13 June, 83 DAS) when rainfall was 24 mm (Appendix 1). Higher population of thrips in flowers at initial infestation i.e., in 34 to 48 DAS was observed on 21 March 2016 (T$_5$) sown crops might be due to early flower inhabit (flowering occurred in 30-33 DAS) of the crop because thrips usually appeared in high with the initiation of flowering. Hamdy and Salem (1994) reported that relatively high temperatures and lack of rainfall have been associated with increase in thrips population, while high relative humidity and rainfall reduce thrips population. Temperatures above 35°C and drought have been found to be unfavorable to the survival of thrips (Waiganjo *et al.* 2008).
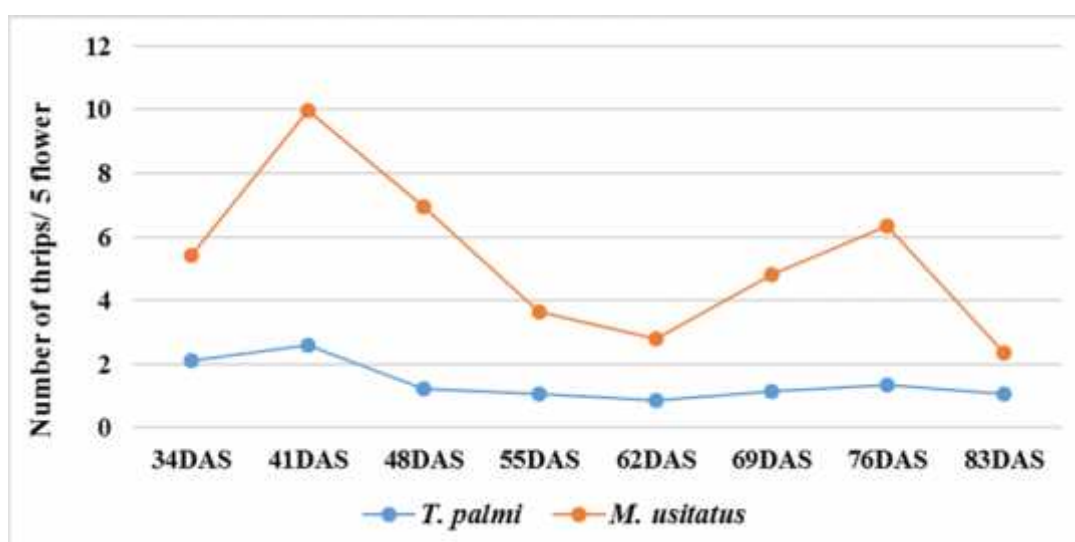
Figure 9. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 21 March (T$_5$) sown mungbean crop.

Figure 10 showed that in 31 March, 2016 (T_6) sown mungbean, the population of both *M. usitatus* and *T. palmi* was appeared first in flowers on 1 May i.e., 31 DAS. Then the population of both the thrips species increased till 38 DAS. Afterthat, the population of *M. usitatus* decreased gradually up to 22 May (52 DAS) when rainfall was 13.71 mm and then again increased sharply till 66 DAS. The population of *T. palmi* gradually increased after 45 DAS till 66 DAS. Both the species attained peak population in 66 DAS (5 June) when rainfall was only 0.43 mm but the pest population decreased drastically on 13 June (73 DAS) may be due to heavy rainfall (24 mm) during that week (Appendix I). *M. usitatus* and *T. palmi* increased again in 80 DAS and then *M. usitatus* decreased but *T. palmi* increased slightly. Both the thrips species observed in flower till 87 DAS (26 June).
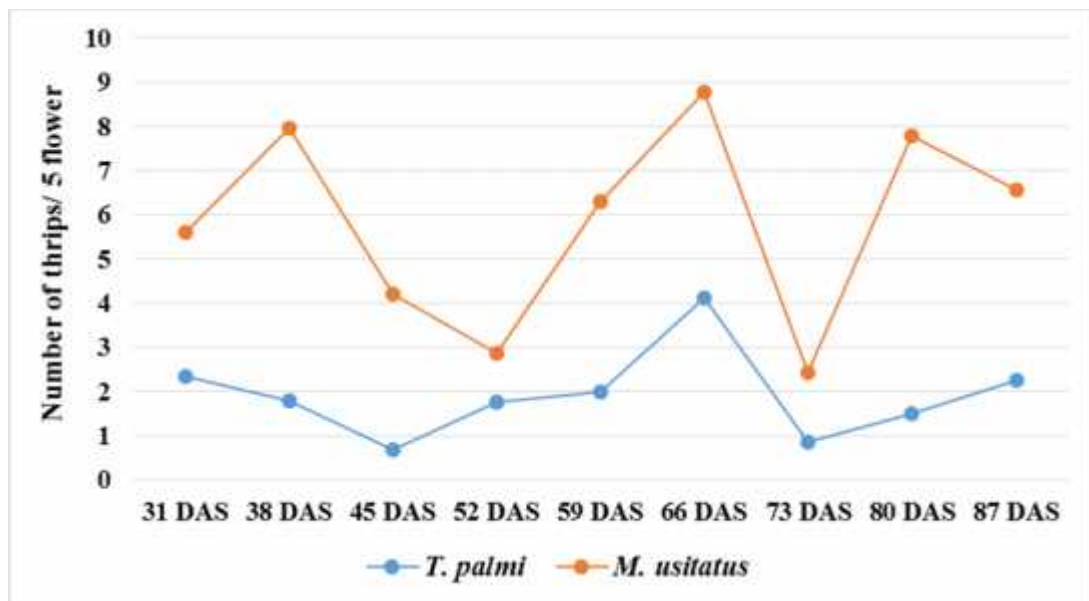
Figure 10. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 31 March (T_6) sown mungbean crop.

From the Figure 11 it was revealed that in 10 April (T_7) sown mungbean, the incidence of *M. usitatus* and *T. palmi* in flowers was initiated from the 15 May i.e., 35 DAS. Then the population of *M. usitatus* decreased on 42 DAS when rainfall was recorded 13.71 mm during that period (Appendix 1). The population of *T. palmi* gradually increased but the population of *M. usitatus* increased rapidly to attain its peak (*M. usitatus* 9.87 and *T. palmi* 5.87 per 5 flowers, respectively) in the first week of June (5 June) i.e., 56 days after sowing. At the time of peak population, the average temperature, sunshine hr., relative humidity and rainfall were 30.37^{o}C, 7.97 h, 71.00% and 0.43 mm, respectively (Appendix I). Thereafter, the population of both the thrips species lowered down may be due to heavy rainfall (24 mm) and increased again and maintained till fourth week of May (26 June) i.e., 77 DAS.
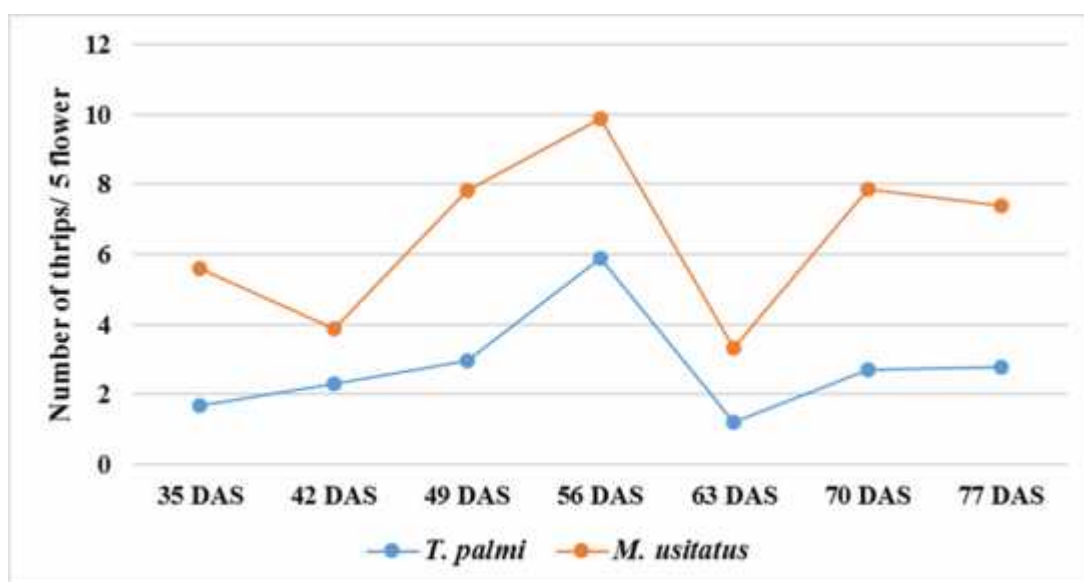
Figure 11. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 10 April (T_7) sown mungbean crop.

The population of *M. usitatus* and *T. palmi* in flowers was recorded from 22 May, i.e., (32 DAS) to last week of June (26 June, i.e., 67 DAS) in 20 April (T8) sown mungbean. The population of *M. usitatus* and *T. palmi* in flowers first recorded in 32 DAS and gradually increased and attained it's peak on first week of June (5 June) i.e 46 DAS, when the average temperature, sunshine hr., relative humidity and rainfall were 30.37^{o}C, 7.97 h, 71% and 0.43 mm, respectively (Appendix I). Then the population of *M. usitatus* and *T. palmi* drastically decreased on 53 DAS (13 June) may be due to heavy rainfall (24 mm). Afterthen, the population of *M. usitatus* and *T. palmi* increased gradually and was noticed in the field upto 67 DAS (26 June) when rainfall was lower (0.86 mm) but average temperature was 30.59^{o}C (Figure 12).
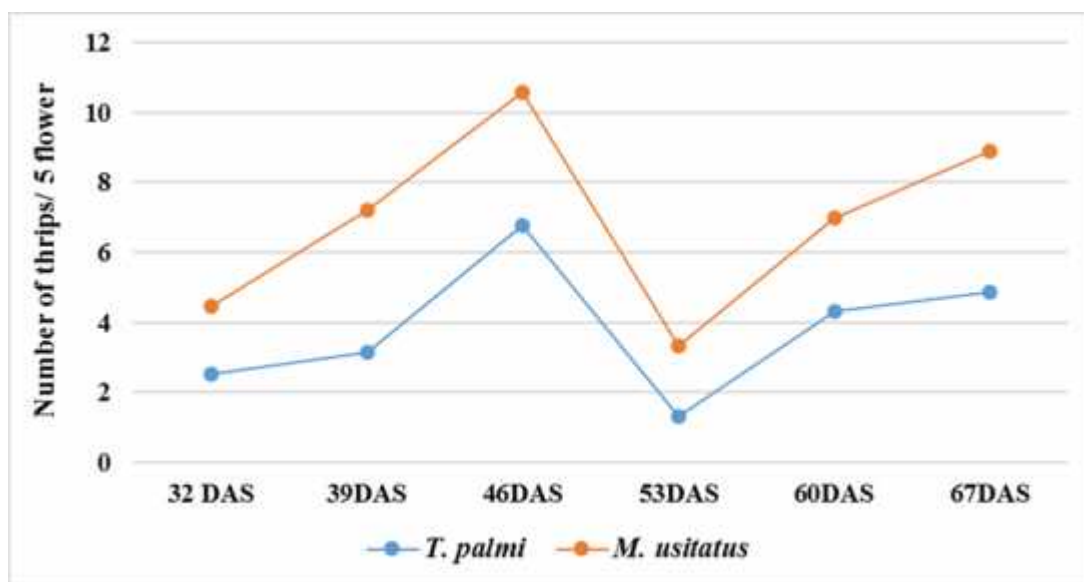
Figure 12. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 20 April (T$_8$) sown mungbean crop.

From the Figure 13 it was revealed that the data on the population of *M. usitatus* and *T. palmi* in flowers was recorded five times at weekly interval from the experimental plot in 30 April (T_9) sown mungbean because of heavy rainfall in July 2016, crop in the field was more or less damaged. The populations of *M. usitatus* and *T. palmi* were started to appear in flowers from the last week of May (29 May i.e., 29 DAS) and attained its peak (*M. usitatus* and *T. palmi* were 9.63 and 4.67, respectively per 5 flowers,) in 36 DAS (5 June). In the next week, the population of both the species declined drastically may be due to heavy rainfall (24.00 mm). But the population of both the thrips species increased again and attained very much close to maximum population on 26 June (57 DAS) when rainfall 0.86 mm, average temperature 30.59^{o} C, relative humidity 74.00% and bright sunshine 5.96 hrs. were recorded (Appendix I). Duraimurugan and Tyagi (2014) reported that during kharif season, bean flower thrips incidence in mungbean ranged between 2.2 (43-49 DAS, 36th SMW) to 28.0 (64-70 DAS, 39th SMW) per 100 flowers and during summer season, the population ranged from 17.0 (43-49 DAS, 20th SMW) to 57.2 (57-63 DAS), 22th SMW) per 100 flowers. The population of thrips reached its peak at 57-63 DAS in mungbean.
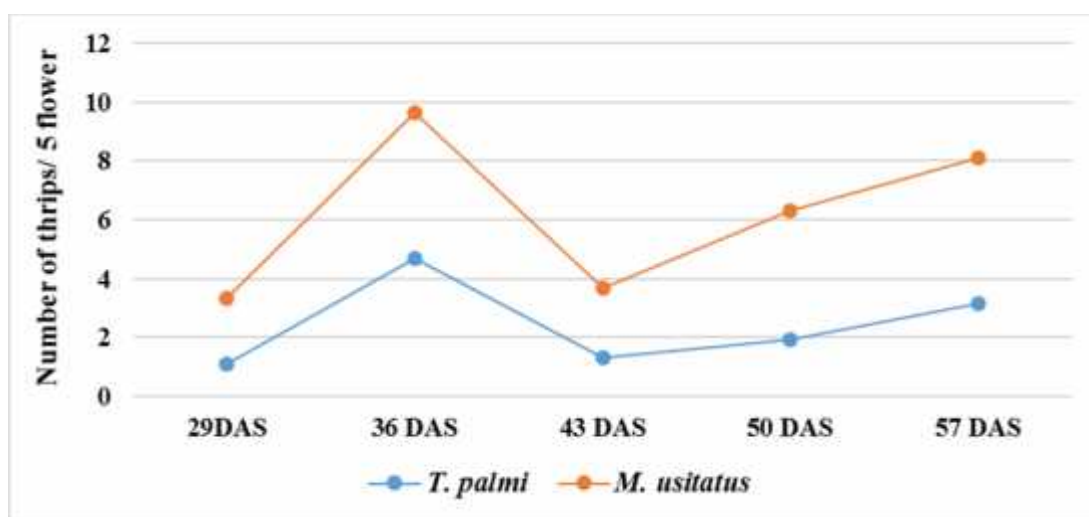
Figure 13. Population dynamics of *T. palmi* and *M. usitatus* in flowers on 30 April (T_9) sown mungbean crop.

From the above findings it was revealed that the number of *M. usitatus* and *T. palmi* per five flowers, had a mark variation among different dates of sowing. The thrips population of both the species was higher in flower in early (10 February to 01

March) and late (10 April to 30 April) sowing crops than mid sowings (11 March to 31 March) at flowering stage of the crop which was illustrated in Table 13. It was found that lower number of *M. usitatus* and *T. palmi* was found in flowers on 21 March sowing mungbean which was followed by 11 March and 31 March sowings crop. After February sowings, thrips population comparatively found early on flowers because of early coming of flower in mungbean or fast growing of plants in March sowings. After 20 April sowing, number of observation dates on thrips population on flowers at weekly interval decreased due to heavy rainfall during last week of June to July and crop were more or less damaged. Among the different dates of sowing, in 21 March sowing crop, the population of *M. usitatus* (5.43, 9.98, 6.97, 3.63, 2.78, 4.81, 6.33, 2.34 per five flower) and *T. palmi* (2.11, 2.61, 1.21, 1.07, 0.85, 1.13, 1.33, 1.07 per five flowers) at 34 DAS, 41 DAS, 48 DAS, 55 DAS, 62 DAS, 69 DAS, 76 DAS, 83 DAS, respectively was recorded with significantly lowest mean population of *M. usitatus* (5.28) and *T. palmi* (1.42), while the population of *M. usitatus* (5.73, 12.67, 2.11, 4.33, 15.83, 14.35, 13.33, 6.33, 9.34 per five flowers) and *T. palmi* (3.19, 6.78, 1.47, 3.33, 8.97, 7.67, 7.41, 3.87 per five flowers) at 39 DAS, 46 DAS, 53 DAS, 60 DAS, 67 DAS, 74 DAS, 81 DAS, 88 DAS, respectively with significantly highest mean population of *M. usitatus* (9.34) and *T. palmi* (5.34) was observed in 10 February sowing crop. The crop sown on 21 March (T_5) was considered to be the best date of sowing in terms of recording lower level of thrips population varied from 2.34 to 9.98 *M. usitatus* and 0.85 to 2.61 *T. palmi* per 5 flowers among different dates after sowing and it is also suitable for proper growth of mungbean crop to avoid heavy rainfall during month of July.

4.3.10. Relationship of *M. usitatus* and *T. palmi* population in mungbean flowers with weather parameters

The population of *T. palmi* and *M. usitatus* in mungbean flowers showed significantly positive relationship with temperature (Figure 14 and Figure 15, respectively) and bright sunshine hours (Figure 16 and Figure 17, respectively) i.e., when temperature and bright sunshine hour increased, thrips population of both the species also increased but the population of *T. palmi* and *M. usitatus* on mungbean flowers was negatively related with rainfall (Figure 18 and Figure 19, respectively) and relative humidity (Figure 20 and Figure 21, respectively) i.e., when rainfall and relative humidity increased, thrips population of both the species significantly decreased. Similar findings also reported by Tamang *et al.* (2017), who described that during kharif season (February to April, 2013) thrips population showed significant positive correlation with maximum temperature ($r = 0.94$), average temperature ($r = 0.71$) and morning relative humidity ($r = 0.51$), significant negative correlation with evening relative humidity ($r = -0.68$) and rainfall ($r = -0.70$). Duraimurugan and Tyagil (2014) reported that in both mungbean and urdbean, incidence of bean flower thrips found positive correlation ($r = 0.39$ in mungbean and $r = 0.38$ in urdbean) with maximum temperature, ($r = 0.83$ in mungbean and $r = 0.67$ in urdbean) with minimum temperature, ($r = 0.44$ in mungbean and $r = 0.74$ in urdbean) with sunshine hours and negative correlation with mean relative humidity ($r = - 0.37$ in mungbean and urdbean) and rainfall ($r = - 0.25$ in mungbean and $r = -0.15$ in urdbean), though it was non-significant.
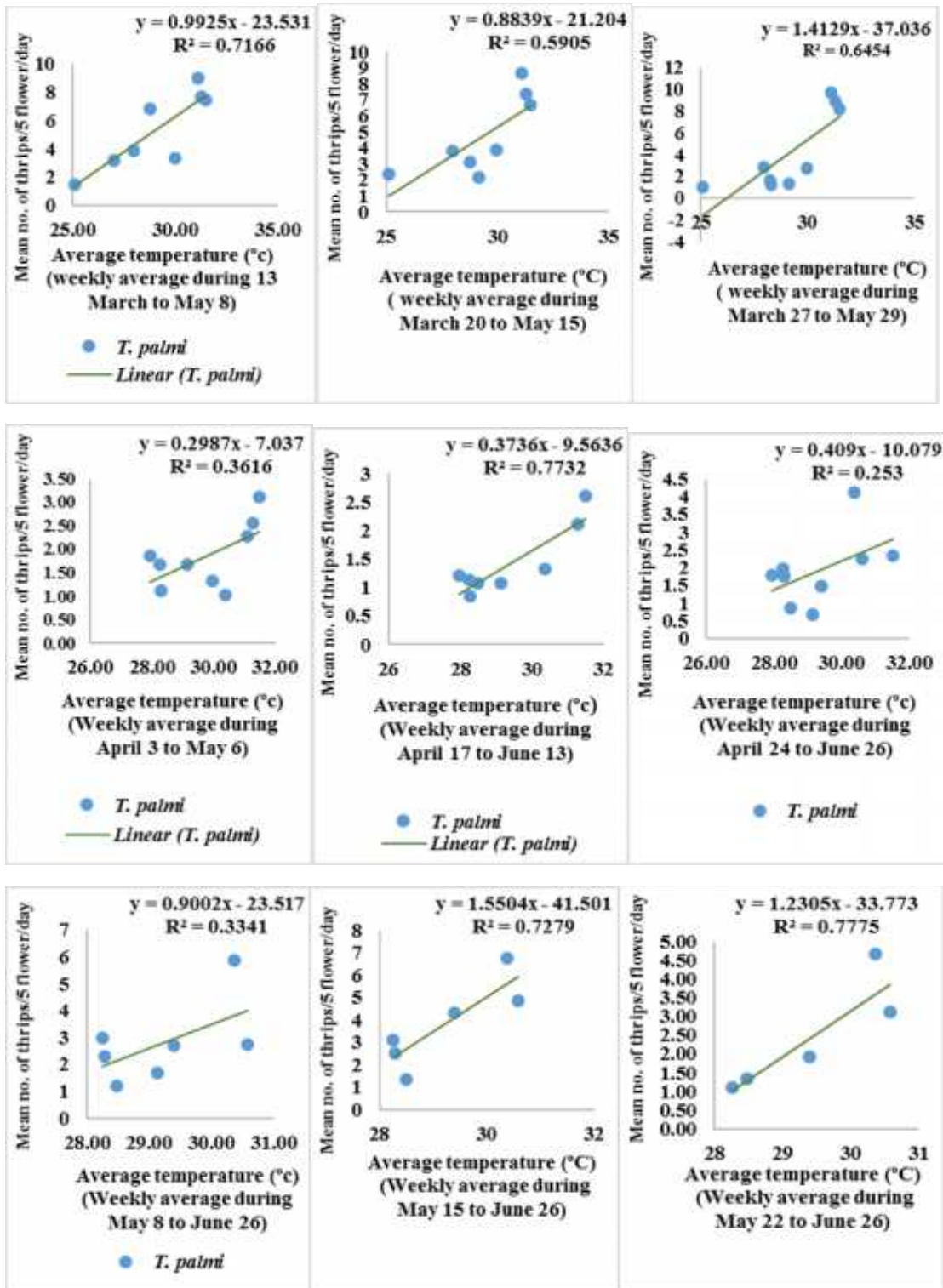
Figure 14. Relationship between average temperature and *T. palmi* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T₁ = 10 February, T₂ = 20 February, T₃ = 1 March, T₄ = 11 March, T₅ = 21 March, T₆ = 31 March, T₇ = 10 April, T₈ = 20 April, T₉ = 30 April].

115
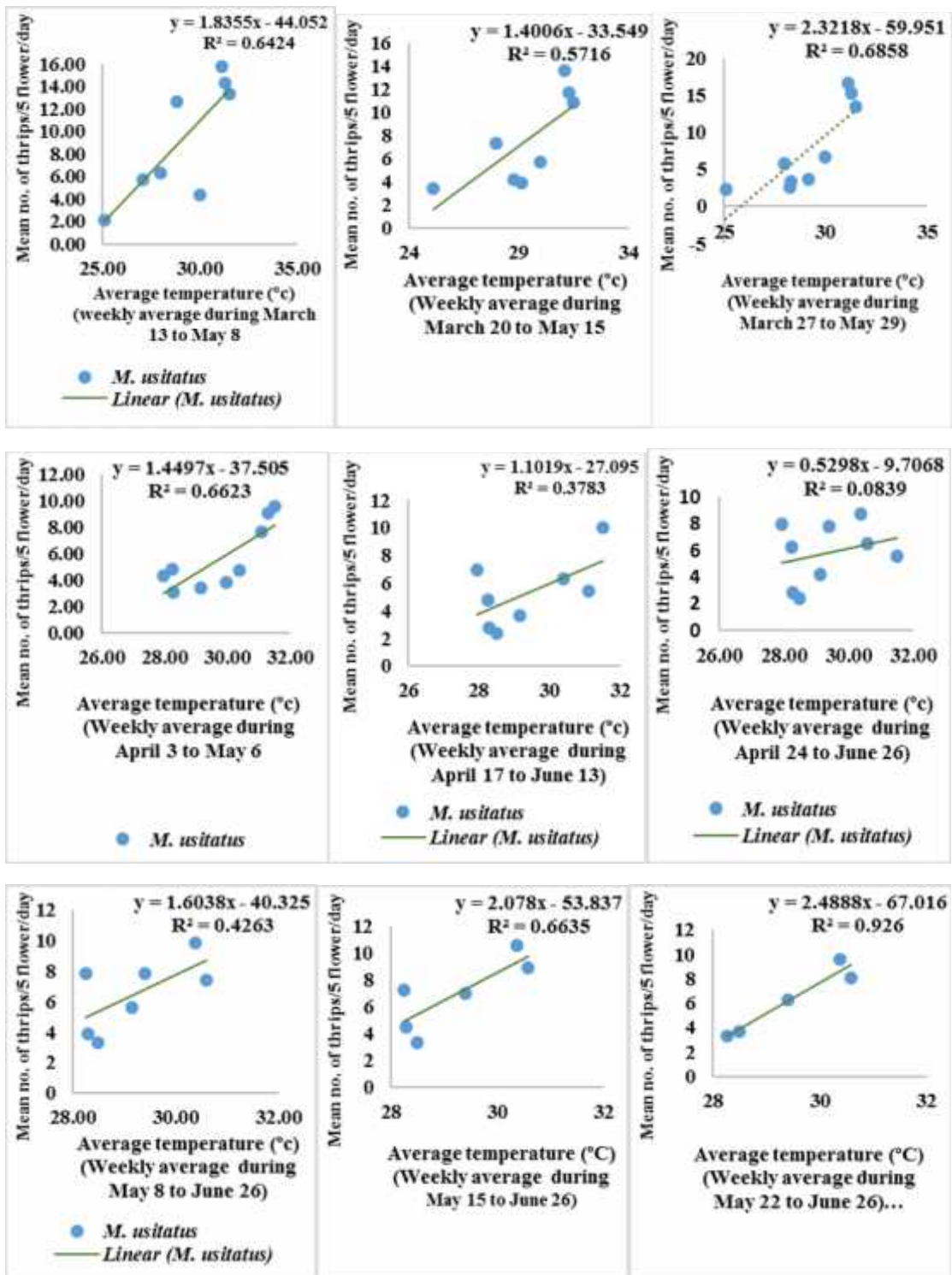
Figure 15. Relationship between average temperature and *M. usitatus* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T$_1$ = 10 February, T$_2$ = 20 February, T$_3$ = 1 March, T$_4$ = 11 March, T$_5$ = 21 March, T$_6$ = 31 March, T$_7$ = 10 April, T$_8$ = 20 April, T$_9$ = 30 April].
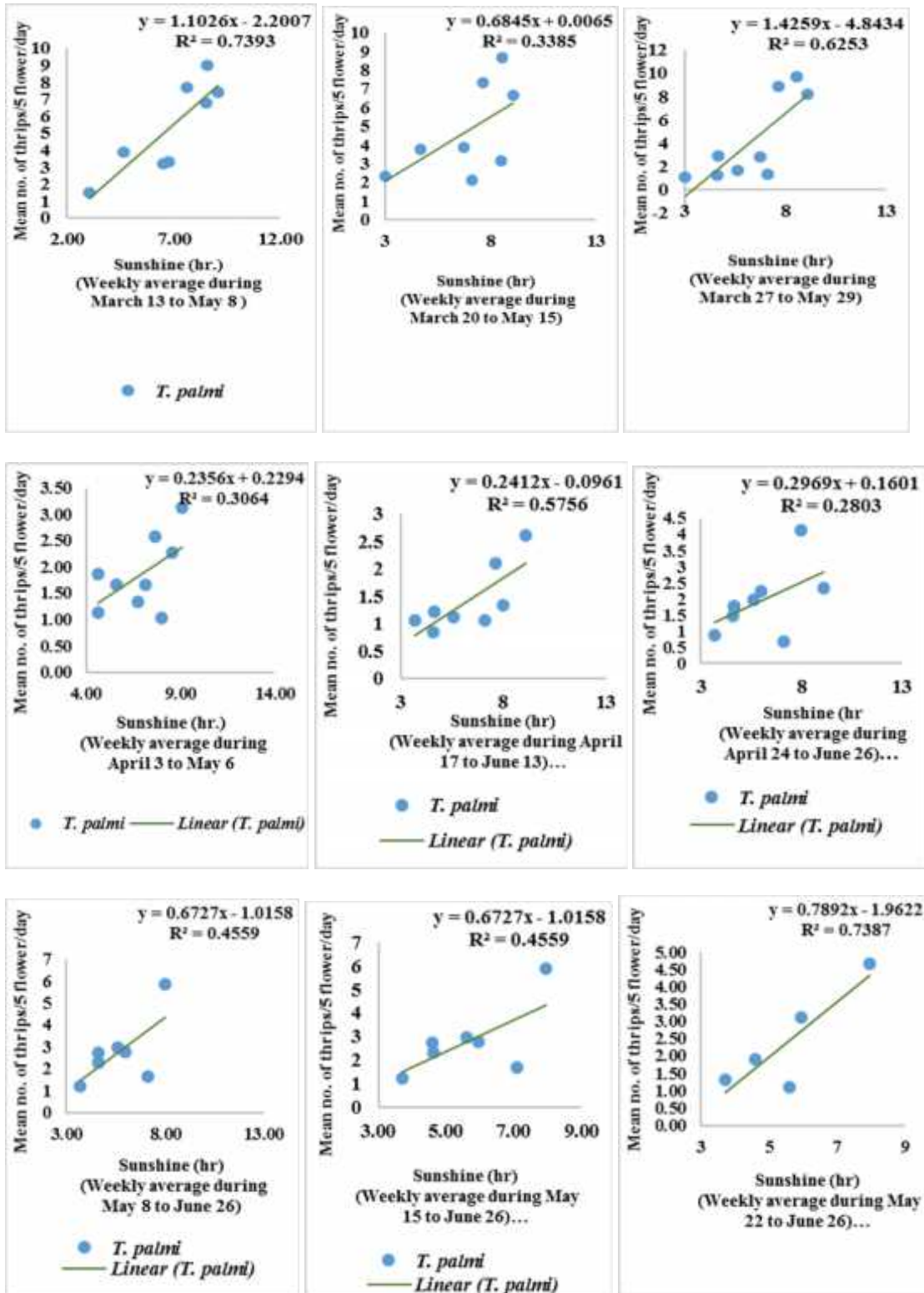
Figure 16. Relationship between sunshine hr. and *T. palmi* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T₁ = 10 February, T₂ = 20 February, T₃ = 1 March, T₄ = 11 March, T₅ = 21 March, T₆ = 31 March, T₇ = 10 April, T₈ = 20 April, T₉ = 30 April].

117
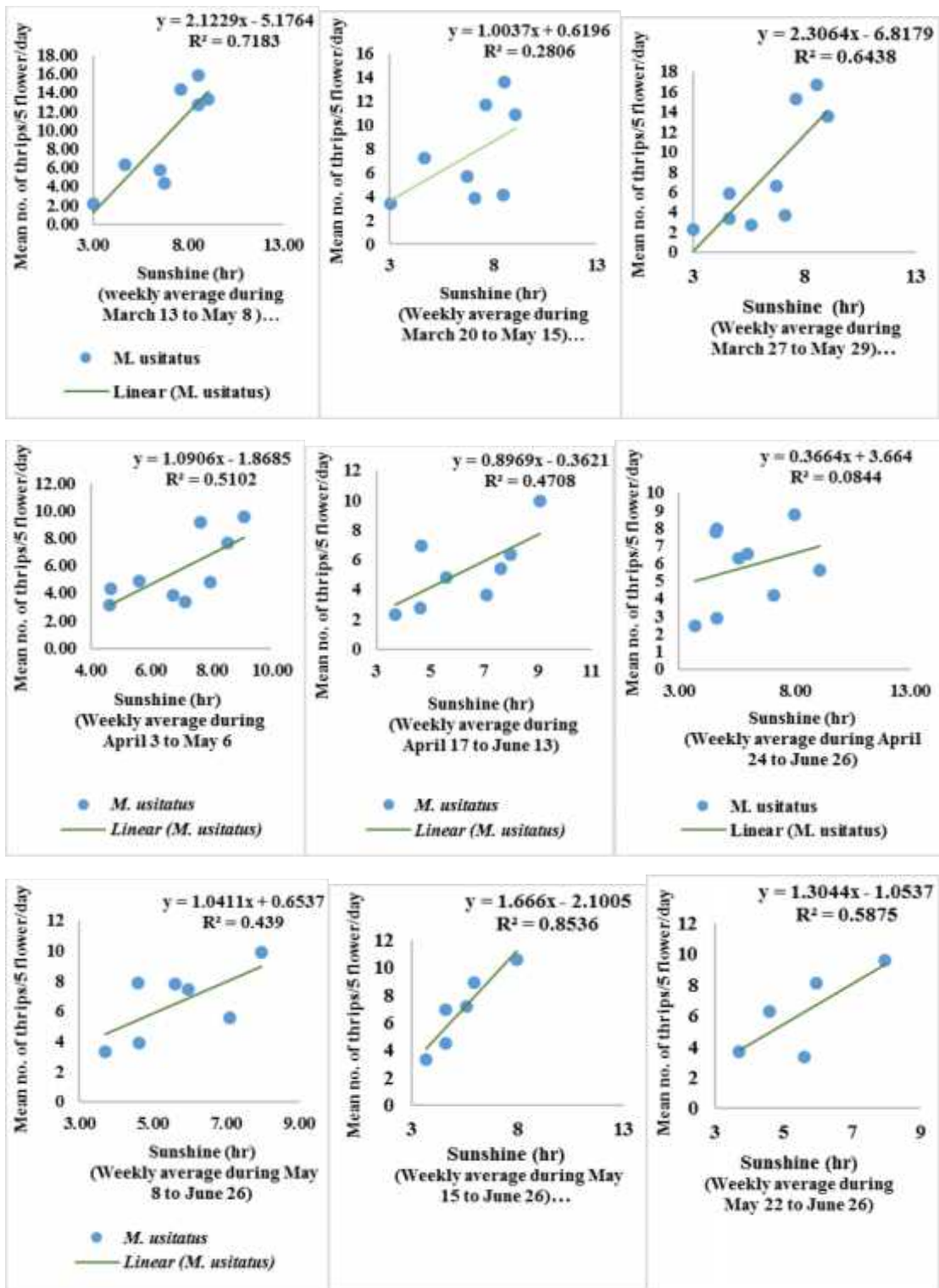
Figure 17. Relationship between sunshine hr. and *M. usitatus* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T$_1$ = 10 February, T$_2$ = 20 February, T$_3$ = 1 March, T$_4$ = 11 March, T$_5$ = 21 March, T$_6$ = 31 March, T$_7$ = 10 April, T$_8$ = 20 April, T$_9$ = 30 April].

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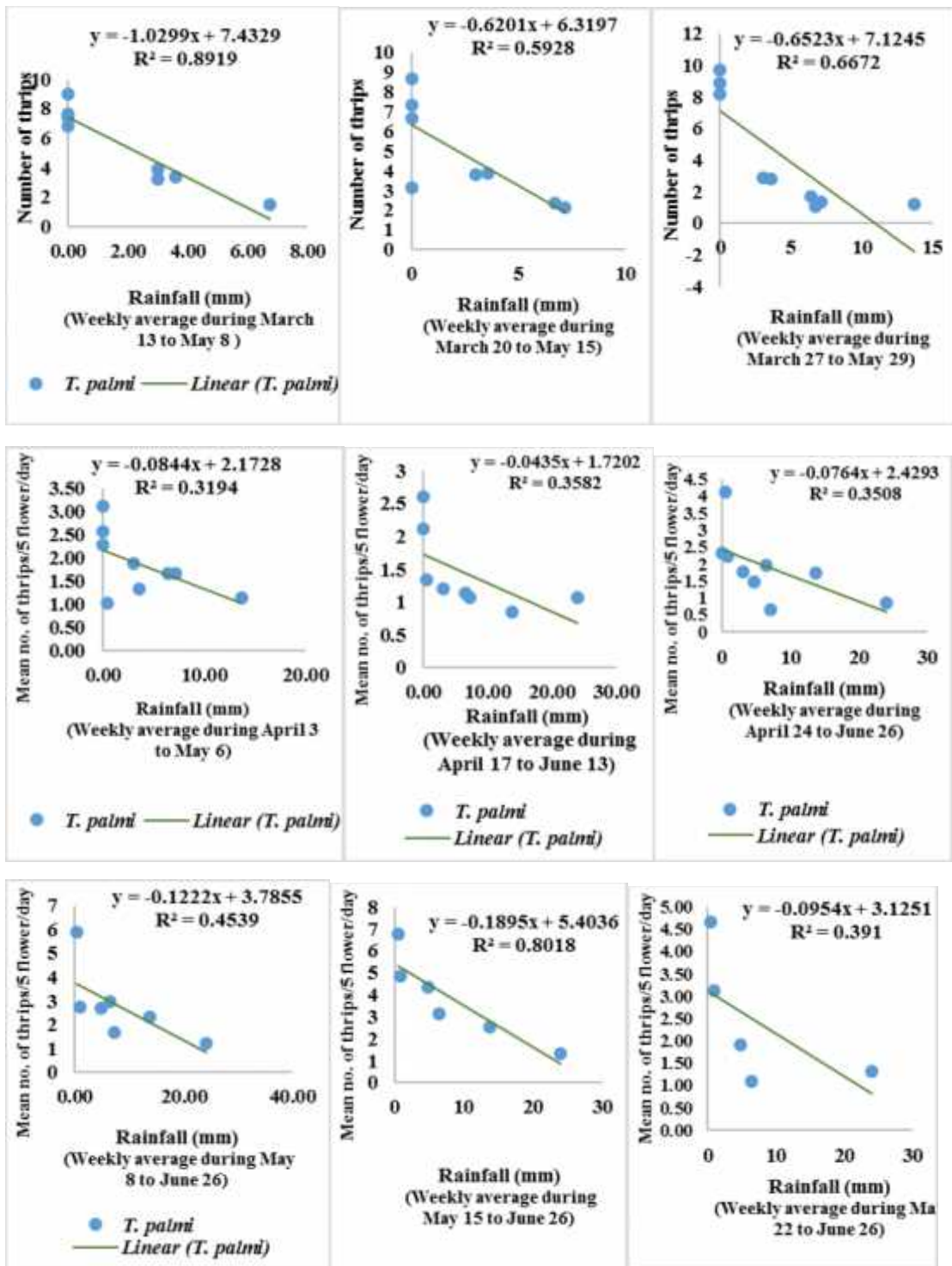
Figure 18. Relationship between rainfall and *T. palmi* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T$_1$ = 10 February, T$_2$ = 20 February, T$_3$ = 1 March, T$_4$ = 11 March, T$_5$ = 21 March, T$_6$ = 31 March, T$_7$ = 10 April, T$_8$ = 20 April, T$_9$ = 30 April].

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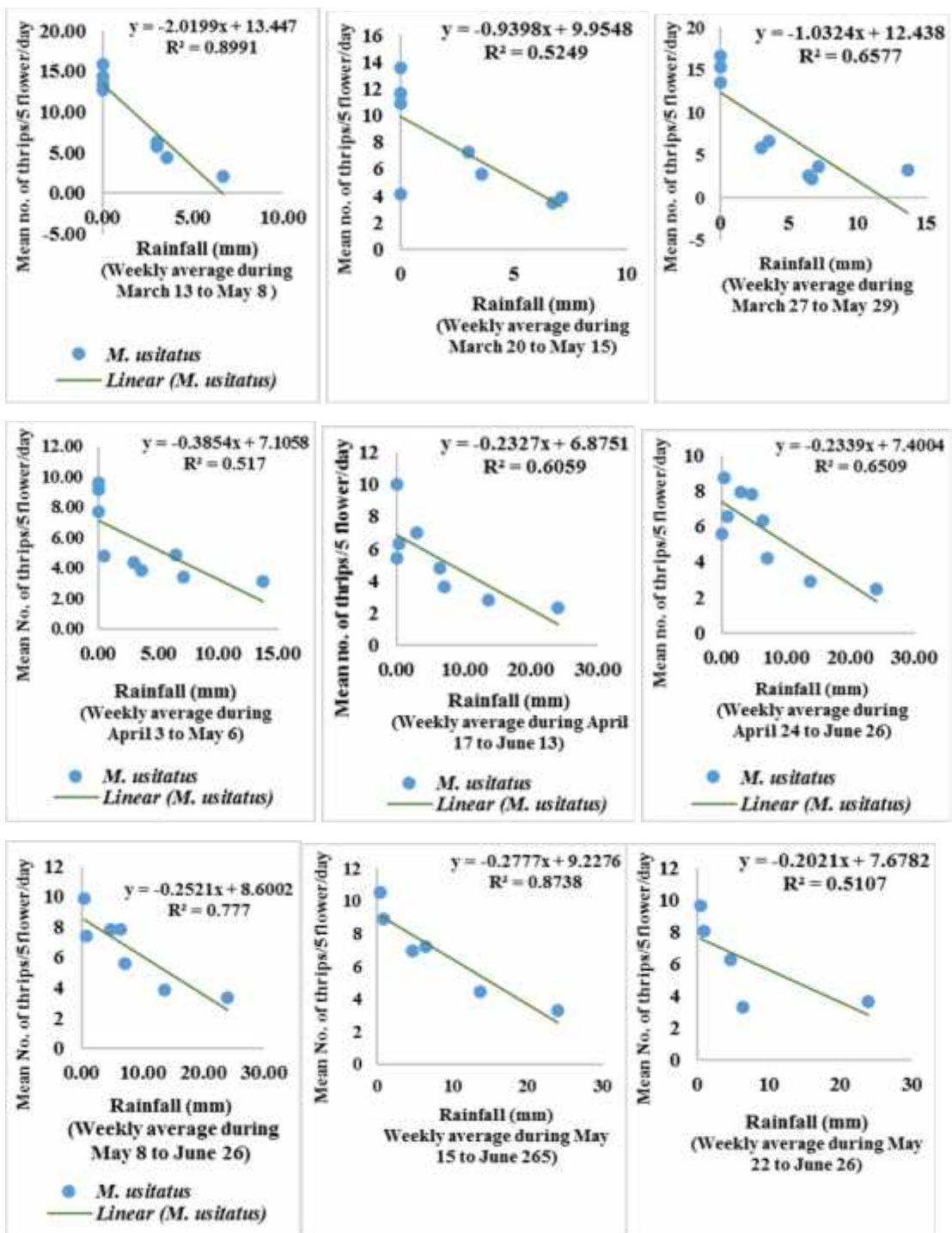
Figure 19. Relationship between rainfall and *M. usitatus* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T₁ = 10 February, T₂ = 20 February, T₃ = 1 March, T₄ = 11 March, T₅ = 21 March, T₆ = 31 March, T₇ = 10 April, T₈ = 20 April, T₉ = 30 April].

120
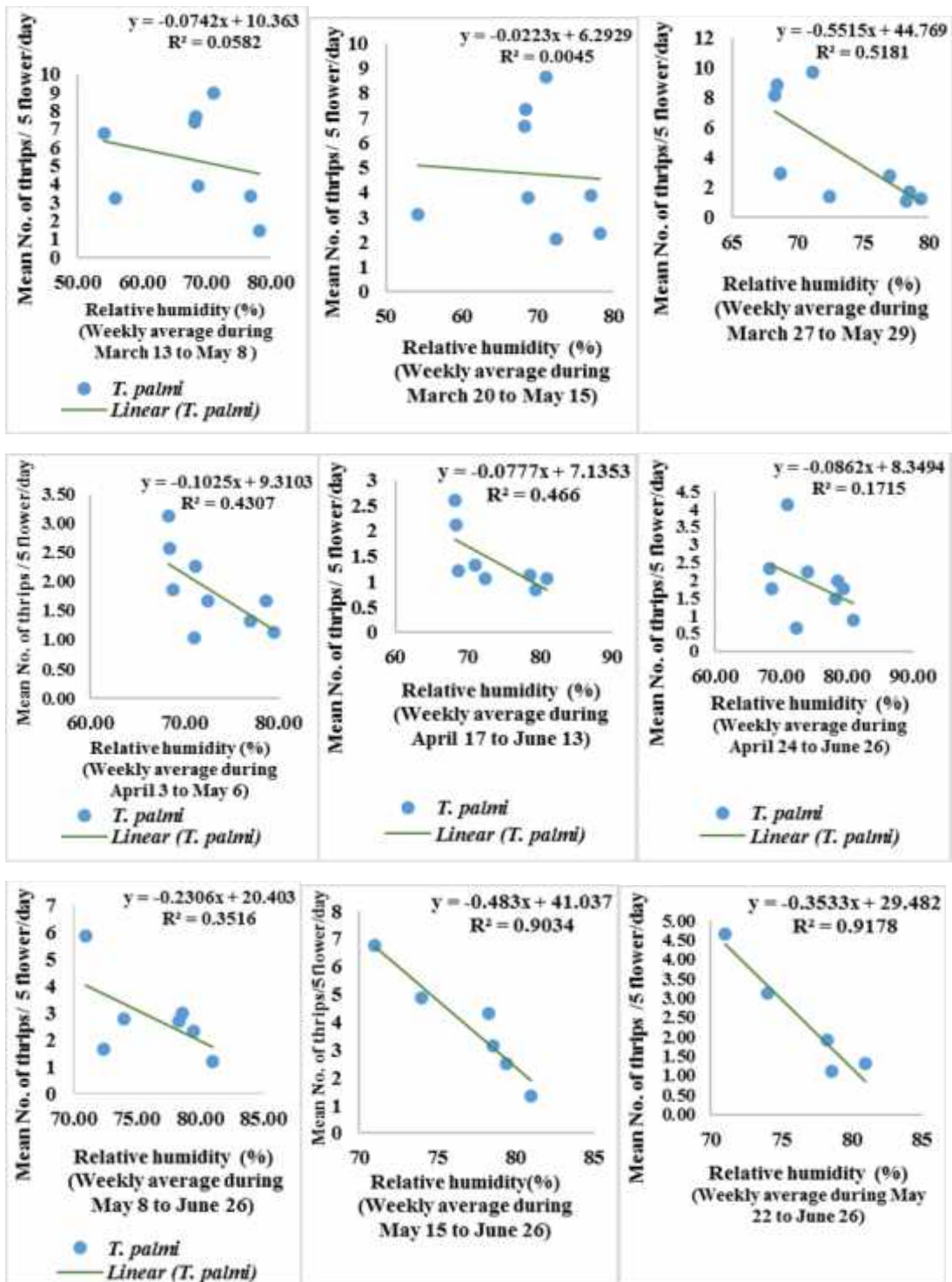
Figure 20. Relationship between relative humidity and *T. palmi* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T$_1$ = 10 February, T$_2$ = 20 February, T$_3$ = 1 March, T$_4$ = 11 March, T$_5$ = 21 March, T$_6$ = 31 March, T$_7$ = 10 April, T$_8$ = 20 April, T$_9$ = 30 April].

121
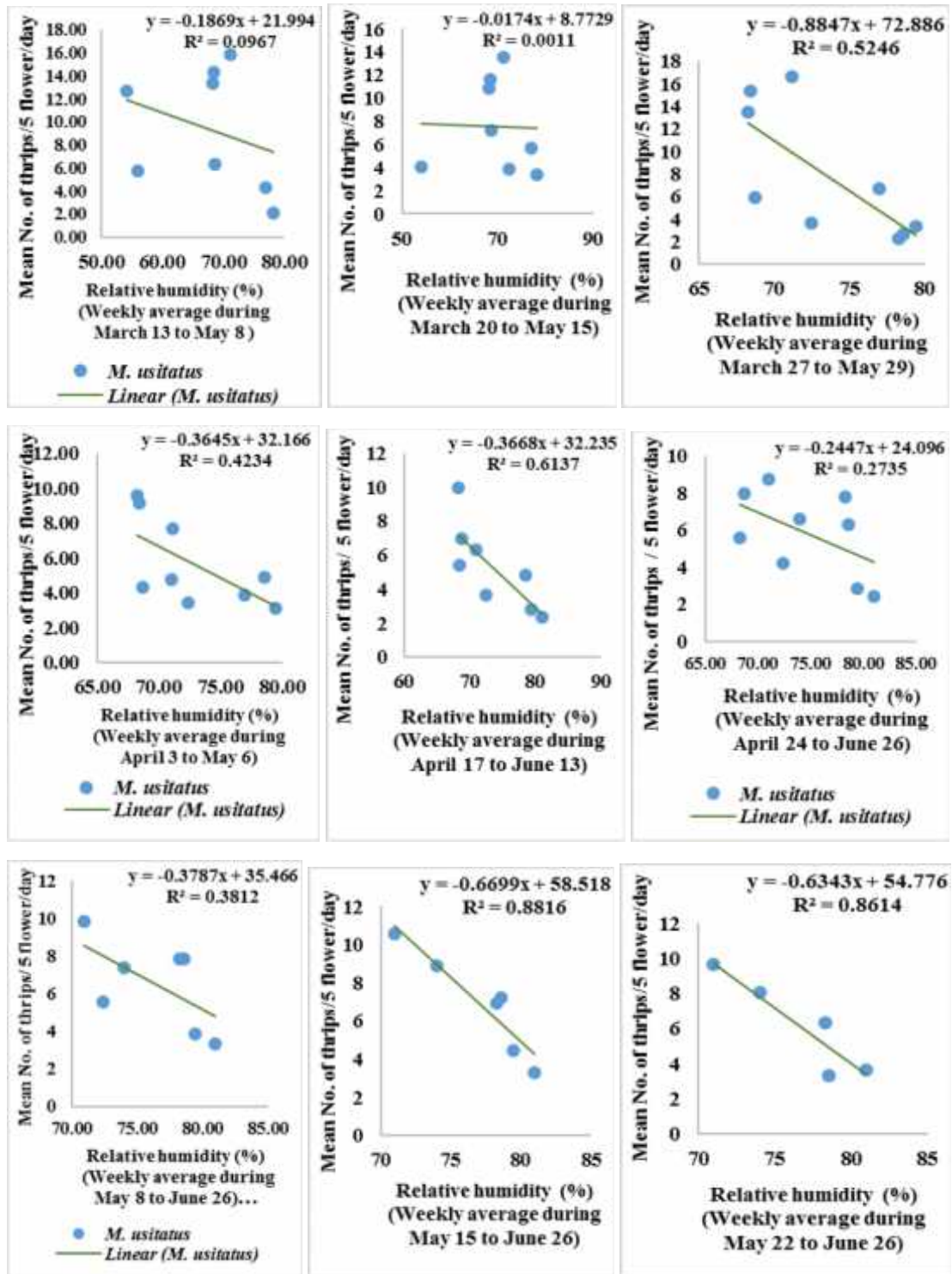
Figure 21. Relationship between relative humidity and *M. usitatus* population on different sowing dates (T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈ and T₉) during cropping period Kharif-1, 2016.

[T₁ = 10 February, T₂ = 20 February, T₃ = 1 March, T₄ = 11 March, T₅ = 21 March, T₆ = 31 March, T₇ = 10 April, T₈ = 20 April, T₉ = 30 April].

The results of the study revealed that both the thrips (*M. usitatus and T. palmi*) population on mungbean showed significantly positive relationship with average tempetature and sunshine hour but negative relationship with rainfall and relative humidity. Some other authors also found similar results. Thongjua and Thongjua (2015) reported the simple correlation coefficient (r) analysis which revealed that the relative humidity had moderately relationship and negative effect (r = -0.50) on thrips population and the relative humidity had relation to the direction of the rainfall. These two factors greatly impact the outbreak of thrips. They suggested an applicable method for controlling outbreaks of thrips by spray water from knapsack sprayer on canopy of mangosteen tree to control the humidity inside canopy, made it unsuitable for the growth of thrips and reduce popuation. The other method, to provide water at the top of canopy with four meters of water pipe, this method can reduce thrips damage well too. It was also found that, the correlation analysis of temperature with thrips population had low relationships (r = 0.30) and positive correlation effect. The average temperature in Nakhon Si Thammarat province was 25-29°C. Leite *et al.* (2005) reported that the increase in relative humidity and rainfall had a deleterious effect on the *Thrips tabaci* population. This may be due to the fact that the results at 40 mm rainfall and 80% relative humidity. However, the study strongly suggested that the population of thrips increases up to 78% relative humidity with the maximum level of 1.504 while decreases at 80% relative humidity. Temperatures above 35°C and drought have been reported to be unfavorable to the survival of thrips (Waiganjo *et al.* 2008). Heavy rain has been reported to wash thrips off plants down to the soil surface, causing sharp declines in their population density (Harris *et al.* 1936). The effects of weather factors that influence these population changes is essential in predicting thrips population.

4.3.11. Effect of sowing dates on yield contributing characters and yield of mungbean

4.3.11.1. Number of pods plant^{-1}

Results presented in Table 17 revealed that the number of pod plant^{-1} was significantly influenced by the effect of dates of sowing where, maximum number (34.00) of pod plant^{-1} was produced in 21 March sown crop which was followed by 11 March (31.67 pod plant^{-1}) and March 31 (29.33 pod plant^{-1}) sown crop. This was followed by April sowings crop. The number of pod plant^{-1} was found in 10 April (28.33), 20 April (28.00) and 30 April (27.67) sown crop, respectively. The minimum number (24.33) of pod plant^{-1} was produced in 10 February sown crop which was followed by 20 February (26.33 pod plant^{-1}) and 1 March (27.00 pod plant^{-1}) sown crop.

4.3.11.2. Pod length

The pod length (8.59 cm) was found maximum in 21 March sown crop, which was followed by 11 March sown crop (8.12 cm) and 31 March sown crops (8.02 cm). The minimum pod length was observed in 10 February sown crop (7.47 cm), which was followed by 20 February (7.70 cm) and 1 March (7.79 cm) sowings mungbean (Table 17).

4.3.11.3. Number of seeds pod^{-1}

A significant variation was found in the number of seed pod^{-1} due to the effect of dates of sowing on thrips population infesting mungbean. Among the different dates of sowing, the maximum number (11.87) of seeds pod^{-1} was found when mungbean was sown on 21 March, which was followed by 11 March sown crop (11.03 seeds pod^{-1}) and 31 March sown crop (10.86 seeds pod^{-1}). This was followed by April sowings crop. In 10 April sown crop (10.76 seeds pod^{-1}), in 20 April sown crop (10.67 seeds pod^{-1}) and in 30 April sown crop (10.70 seeds pod^{-1}) were found which were statistically identical. On the other hand, the minimum number of seeds pod^{-1} was recorded when mungbean was sown on 10 February (9.92 seed pod$^{-1)}$, which was followed by 20 February (10.03 seeds pod^{-1}) and 1 March (10.37 seeds pod^{-1}) sown crops (Table 17).

4.3.11.4. 1000 Seed weight (g)

The maximum 1000 seed weight (50.88 g) was recorded in 21 March sown mungbean crop which was followed by 11 March sown crop (49.74 g) and 31 March sown crop (48.78 g). The maximum number of thrips infesting in 10 February sown crop resulted minimum seed weight (43.33 g) which was followed by 20 February (44.97 g) and 1 March (45.52 g) sowings crop (Table 17). In April sowings mungbean, moderate weight of 1000 seed was found and this was in 10 April sowing 47.77 g, in 20 April sowing 47.22 g and in 30 April sowing mungbean 46.33 g, respectively.

4.3.11.5. Yield kg ha^{-1}

Grain yield of mungbean varied due to the variation of sowing dates and insect pest infestation (Table 17). It was observed that both the early (10 February to 01 March) and late sown (10 April to 30 April) crops received higher thrips infestation and provided lower yield. But mid sown (11 March to 31 March) crops received less thrips infestation and produced higher yield. The highest yield ha^{-1} (1176.80 kg) was obtained when mungbean was sown on 21 March which was followed by 11 March sown crop (1094.60 kg ha^{-1}), 31 March sown crop (1079.30 kg ha^{-1}) and 10 April sown crop (1074.20 kg ha^{-1}). This was followed by 20 April and 30 April sowings crop, where yield (1025.40 and 994.3 kg ha^{-1}, respectively) was found. The lowest yield (966.70 kg ha^{-1}) was obtained when mungbean was sown on 10 February which was statistically identical with 20 February (971.30 kg ha^{-1}) sowing and 1 March (976.10 kg ha^{-1}) sowing crop (Table 17).

Table 17. Effect of different sowing dates on yield contributing characters and yield of mungbean

Treatments (sowing dates)	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	1000 seed weight (g)	(Yield (kg ha^{-1})
T$_1$ (10 Feb)	24.33 e	7.47 f	9.92 e	43.33 f	966.70 d
T$_2$ (20 Feb)	26.33 de	7.70 e	10.03 e	44.97 ef	971.30 d
T$_3$ (1 March)	27.00 d	7.79 de	10.37 d	45.52 def	976.10 d
T$_4$ (11 March)	31.67 b	8.12 b	11.03 b	49.74 ab	1090.60 b
T$_5$ (21 March)	34.00 a	8.59 a	11.87 a	50.88 a	1176.80 a
T$_6$ (31 March)	29.33 c	8.02 bc	10.86 bc	48.78 abc	1079.30 b
T$_7$ (10 April)	28.33 cd	7.90 cd	10.76 c	47.77 bcd	1074.20 b
T$_8$ (20 April)	28.00 cd	7.89 cd	10.67 c	47.22 cde	1025.40 c
T$_9$ (30 April)	27.67 cd	7.81 de	10.70 c	46.33 cde	994.3 cd
S$\bar{x}$	0.71	0.05	0.06	0.79	12.37
CV (%)	4.33	1.03	1.02	2.90	2.06

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that grain yield of mungbean varied significantly depending on the seasonal variation in different sowing dates and incidence of thrips population. In early sown crops, pod number per plant, pod length, seeds number per pod, 1000 seed weight and yield of mungbean per ha was lowest with higher thrips infestation. Thrips population was higher in early season, may be due to lower rainfall in that period. However, in mid sown (11 March to 31 March) crops optimum temperature and rainfall favoured the optimum growth of plant with higher pod setting and less thrips incidence. In late (April) sown crops, thrips population increased than mid sown crops but was less than early sown crops which affected on yield of mungbean. In case of very late (30 April) sown crop, higher rainfall not only affected the thrips population but also the plant growth with less pod setting which resulted lower yield. Hossain *et al.* (2012) also supported the present findings. It was observed that both early (February) and late sown (April to May) crops encountered higher insect pest infestation and resulted lower yield. But mid sown (March) crops received less insect pest infestation and produced higher yield.

4.3.12. Relationship between thrips on flower and yield of mungbean

The yield of mungbean was significantly affected by thrips. Figure 22 showed a negative relationship (y = -22.25x + 1260, R^2 = 0.640) between number of thrips in flower and yield of mungbean. For every 1% increase of thrips populatin in flower, there was a decrease of yield by 22.25% and the correlation coefficient (r) was 0.80.
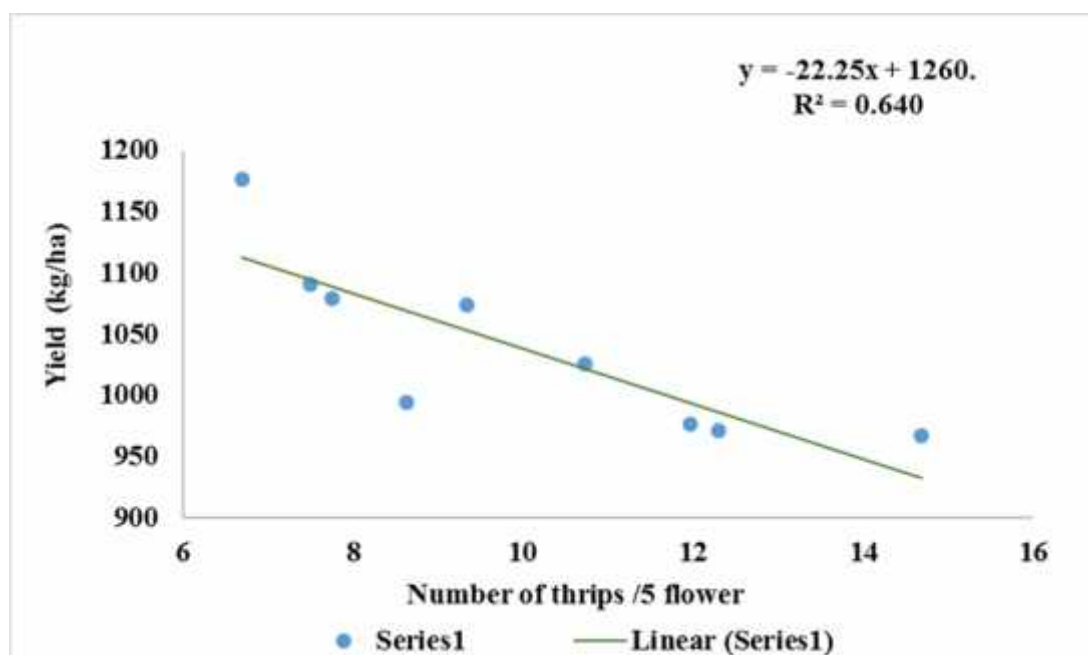
Figure 22. Relationship between incidence of thrips population (in flowers) and yield of mungbean.

The results from the above findings showed that the yield of mungbean decreased with the increase of thrips population in flower. Similar observation was found by Hossain *et al*. (2009) who also reported that the increase of thrips population in flower causes a progressive loss in yield. Duff (2012) reported that in Tasmania green beans suffered severe pod damage by thrips with on average 50% of pods marketable. Higher numbers of *M. usitatus* in the flowers with between 1.9-3.3 thrips per 10 flowers during the autumn 2008 trial and 1.9-5.5 per 10 flowers during the autumn 2010 trial were observed than other thrips species. The results suggested that *M. usitatus* might be more responsible for pod damage than *F. occidentalis*.

127

4.4 Experiment 4: Screening of some Mungbean Varieties against Thrips to explore the Resistant Source(s)

A field trial was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from 20 February to 3 May 2018 (Kharif-1) to screen some mungbean varieties against thrips. The causes of higher or lower incidence of thrips on different mungbean varieties have been discussed with interpretations and furnished under the following sub-headings:-

4.4.1. Varietal influence on incidence of thrips on top trifoliate leaves of mungbean

Eleven mungbean varieties (Table 18) were screened against thrips under field condition during 2018, Kharif-1 season. The lowest mean number of *M. usitatus* and *T. palmi* (0.77 and 0.22, respectively) at pre-flowering stage was observed in BARI Mung-7 (T_8) with cumulative mean number of both the thrips species 0.99 per 10 top trifoliate leaves, which was followed by BARI Mung-8 (T_9) (0.71 *M. usitatus* and 0.46 *T. palmi*, respectively with cumulative mean number of both the species 1.17 per10 top trifoliate leaves). This was followed by BU mug 2 (T_2), Binamoog-6 (T_5) and BU mug 1 (T_2), in which varieties the number of *M. usitatus* was (1.18, 1.56 and 1.47, respectively) and *T. palmi* was (0.66, 0.77 and 0.86, respectively) with cumulative mean number of both the thrips species (1.84, 2.33 and 2.33, respectively). The intermediate level of cumulative mean number of both the thrips species was found in BARI Mung-6 (T_7) (2.65) and Binamoog-8, (T_6) (2.99), respectively per 10 top trifoliate leaves. On the other hand, the highest mean number of *M. usitatus* and *T. palmi* (3.01 and 2.14, respectively) was found on Barishal local (T_{11}) variety with cumulative mean number of both the thrips species 5.15 per 10 top trifoliate leaves, which was followed by BARI Mung-2/Kanti (T_{10}) in which variety, the number of *M. usitatus* and *T. palmi* (2.68 and 1.97, respectively) was noticed with cumulative mean number of both the thrips species (4.65) per 10 top trifoliate leaves. This was followed by BU Mug 4 (T_3) (*M. usitatus* and *T. palmi* were 2.14 and 1.45, respectively with cumulative mean number of both the thrips species 3.59) and BU mug 5 (T_4) (*M. usitatus* and *T. palmi* were 2.00 and 1.33, respectively with cumulative mean number of both the thrips species 3.33). Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 top trifoliate leaves of all the varieties tested (Table 18), i.e., *M. usitatus* was found the dominant species

of the crop. In BARI Mung-7 (T_8), the incidence of *M. usitatus* was 77.69% and *T. palmi* was 22.31% whereas, in Barishal local variety, the incidence of *M. usitatus* was 58.51% and *T. palmi* was 41.49%, respectively.

Table 18. Mean number of *M. usitatus* and *T. palmi* on top trifoliate leaves at pre-flowering stage of eleven mungbean varieties

Treatments	Mean number of thrips per 10 top trifoliate leaves		Cumulative mean number of two thrips species per 10 top trifoliate leaves	Comparative incidence of *M. usitatus* and *T. palmi* on 10 top trifoliate leaves	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T_1	1.47 cde	0.86 e	2.33 de	63.00 b	37.00 a
T_2	1.18 def	0.66 f	1.84 e	63.61 b	36.39 a
T_3	2.14 bc	1.45 c	3.59 b	58.29 b	41.71 a
T_4	2.00 bc	1.33 c	3.33 bc	58.85 b	41.15 a
T_5	1.56 cd	0.77 ef	2.33 de	66.43 b	33.57 a
T_6	1.87 cd	1.12 d	2.99 bcd	62.52 b	37.48 a
T_7	1.60 cd	1.05 d	2.65 cd	59.90 b	40.10 a
T_8	0.77 ef	0.22 h	0.99 f	77.69 a	22.31 b
T_9	0.71 f	0.46 g	1.17 f	60.31 b	39.69 a
T_{10}	2.68 ab	1.97 b	4.65 a	57.66 b	42.34 a
T_{11}	3.01 a	2.14 a	5.15 a	58.51 b	41.49 a
Sx	**0.24**	**0.17**	**0.65**	**3.51**	**3.51**
CV (%)	**23.65**	**9.24**	**13.80**	**9.74**	**16.18**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

From the above findings it was revealed that the lowest incidence of thrips was found in BARI Mung-7 (T_8) but the highest incidence of thrips was found in Barishal local variety (T_{11}). The performance of mungbean varieties in respect of lower incidence of adult thrips on top trifoliate leaves was BARI Mung-7 > BARI Mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI mung-6 > Binamoong-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Percent incidence of *M. usitatus* was

higher than *T. palmi* per 10 top trifoliate leaves of all the varieties tested. Sinha (2013) reported that significantly lowest thrips population per sample (6 leaves i.e., 2 upper+2 middle+2 lower per sample) was recorded in mungbean variety K-851 (1.25 thrips per sample) followed by mungbean variety PDM-11 (1.38), Pusa Vishal (1.38) and LGG-460 (1.61) that were at par. Highest thrips population per sample was recorded in mungbean varieties TM37 (2.06) and TJM-3 (1.89). Nadeem *et al.* (2014) reported that population of thrips (numbers per leaf) showed significant variations among the tested mungbean cultivars. Population trend of thrips (4.0) observed the lowest on the MH 3153 whereas, the highest thrips (12.3) on MH 34143. Population of thrips on other lines was observed as 8.7, 5.3, 9.3, 7.7, 7.3, 9, 5.7 and 7.3 in MH 5251, MH 5254, MH 5255, MH 34144, MH 34164, MH 34241, NM 2006 (Check 1) and AZRI 2006 (Check 2), respectively. Complete resistance against thrips was not observed in any of the tested cultivar, except MH 3153 which showed comparatively better resistance among the tested genotypes.

4.4.2. Varietal influence on incidence of thrips on terminal shoots of mungbean

Statistically significant variations among different mungbean varieties were observed in respect of incidence of both *M. usitatus* and *T. palmi* population on terminal shoots (Table 19). The lowest mean number of *M. usitatus* and *T. palmi* (2.22 and 0.77, respectively) was observed at pre-flowering stage stage on BARI Mung-7 (T_8) with cumulative mean number of both the thrips species (2.99) per 10 terminal shoots, which was statistically identical with BARI Mung-8 (T_9) (*M. usitatus* and *T. palmi* were 2.16 and 0.97, respectively with cumulative mean number of both the thrips species was 3.13 per 10 terminal shoots), and followed by BU mug 2 (T_2) (*M. usitatus* and *T. palmi* were 5.09 and 1.05, respectively with cumulative mean number of both the thrips species was 6.14 per 10 terminal shoots), Binamoog-6 (*M. usitatus* and *T. palmi* were 5.42 and 1.33, respectively with cumulative mean number of both the thrips species was 6.75 per 10 terminal shoots). On the other hand, the highest mean number of *M. usitatus* and *T. palmi* (4.96 and 4.17, respectively) was recorded with cumulative mean number of both the thrips species 9.13 per 10 terminal shoots on Barishal local (T_{11}), which was statistically identical with BARI Mung-2/Kanti (T_{10}) (*M. usitatus* and *T. palmi* were 5.21 and 3.76, respectively with cumulative mean number of both the thrips species 8.97 per 10 terminal shoots) and followed by BU mug 4 (T_3) (*M. usitatus* and *T. palmi* were 5.63 and 3.14, respectively with

cumulative mean number of both the thrips species 8.77 per 10 terminal shoots) and BU mug 5 (T_4) (*M. usitatus* and *T. palmi* were 5.42 and 2.98, respectively with cumulative mean number of both the thrips species 8.41 per 10 terminal shoots). The intermediate level of cumulative mean number of both the thrips species was found on BU mug 1 (T_1) (7.33), BARI Mung-6 (T_7) (7.88) and Binamoog-8, (T_6) (8.12), respectively. Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 terminal shoots of all the varieties tested i.e., *M. usitatus* was found the dominant species of the crop (Table 4.4.2). In BARI Mung-7 (T_8), the incidence of *M. usitatus* was 74.40% and *T. palmi* was 25.60% whereas, in Barishal local variety, the incidence of *M. usitatus* was 54.20% and *T. palmi* was 45.80%, respectively.

Table 19. Mean number of *M. usitatus* and *T. palmi* on terminal shoots at pre-flowering stage of eleven mungbean varieties

Treatments	Mean number of thrips per 10 terminal shoots		Cumulative mean number of two thrips species per 10 terminal shoots	Comparative incidence of *M. usitatus* and *T. palmi* on 10 terminal shoots	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T_1	5.35 a	1.98 c	7.33 cd	72.49 cd	27.51 de
T_2	5.09 a	1.05 de	6.14 e	82.80 a	17.20 g
T_3	5.63 a	3.14 b	8.77 ab	64.13 ef	35.87 bc
T_4	5.42 a	2.98 b	8.41 ab	64.48 ef	35.52 bc
T_5	5.42 a	1.33 d	6.75 de	80.18 ab	19.82 fg
T_6	5.34 a	2.78 b	8.12 abc	65.68 de	34.32 cd
T_7	5.54 a	2.34 c	7.88 bc	70.45 cde	29.55 cde
T_8	2.22 b	0.77 e	2.99 f	74.40 bc	25.60 ef
T_9	2.16 b	0.97 de	3.13 f	68.51 cde	31.49 cde
T_{10}	5.21 a	3.76 a	8.97 a	58.09 fg	41.91 ab
T_{11}	4.96 a	4.17 a	9.13 a	54.20 g	45.80 a
Sx	0.34	0.14	0.32	2.30	2.30
CV (%)	12.30	10.84	7.76	5.80	12.72

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

The above results revealed that among the different mungbean varieties the lowest incidence of cumulative mean population of thrips per 10 terminal shoots was found in BARI Mung-7, followed by BARI Mung-8 in field condition. Thus, the rank of efficacy of the varietal performance against incidence of adult *M. usitatus* and *T. palmi* with cumulative mean population of both thrips species was BARI Mung-7 > BARI mung-8 > BU mug 2 > Binamoog-6 > BU mug-1 > BARI mung-6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Other authors also found thrips in terminal shoot of different varities of same or other crops. Gadad *et al.* (2014) reported that among twenty groundnut varieties screened, none of them was immune to thrips, whereas, one variety TGLPS-3 was resistant to thrips by recording lower mean thrips population (3.2 per terminal bud) at vegetative stage. Seven varieties viz., DH-86, DH86-15Kr-18-1, DH-2000-1, ICGV-86699TAN, TAG-24, NRCG-CS-268 and NRCG-CS-281 had shown intermediate resistance by recording mean thrips population between 5.4 to 5.9 thrips per terminal bud at vegetative stage. Seven varieties viz., Chintamani-2, DTG-17 X ICGV-86699-5, DH-218, DH-221, GPBD-5, ICGV-00350 and ICGV-86590 were moderately susceptible to thrips with mean thrips population between 6.1 to 7.2 thrips per terminal bud at vegetative stage. Similarly, three varieties viz., DH-86 X DH-102-29, GPBD-4 X R8808-6 and JL-24 showed susceptible reaction with 8.6 to 9.0 thrips per terminal bud and two varieties viz., DH-216 and TMV-2 were highly susceptible to thrips incidence by recording higher thrips population of 10.3 and 9.9 thrips per terminal bud, respectively at vegetative stage.

4.4.3. Varietal influence on incidence of thrips on flower buds of mungbean

Significant differences were observed among different varietal treatments used in this study in terms of incidence of thrips population on flower bud of mungbean (Table 20). The lowest mean number of *M. usitatus* and *T. palmi* (4.32 and 0.98, respectively) was observed during flowering stage on BARI Mung-7 (T_8) with cumulative mean number of both the thrips species (5.30) per 10 flower buds, which was followed by BARI Mung-8 (T_9) (the mean number of *M. usitatus* and *T. palmi* was 4.45 and 1.33, respectively with cumulative mean number of both the thrips species was 5.79), and BU mug 2 (T_2) (the mean number of *M. usitatus* and *T. palmi* was 5.18 and 1.69, respectively with cumulative mean number of both the thrips species was 6.87), Binamoog-6 (T_5) (the mean number of *M. usitatus* and *T. palmi* was 5.47 and 1.87, respectively with cumulative mean number of both the thrips species was 7.33). On the other hand, the highest mean number of *M. usitatus* and *T. palmi* (5.94 and 5.68, respectively) was recorded with cumulative mean number of both the thrips species 11.62 per 10 flower buds on Barishal local (T_{11}), which was statistically identical with BARI Mung-2/Kanti (T_{10}) (the mean number of *M. usitatus* and *T. palmi* was 5.21 and 5.12, respectively with cumulative mean of both number the thrips species was 10.33) and followed by BU mug 4 (T_3) (the mean number of *M. usitatus* and *T. palmi* was 5.33 and 4.34, respectively with cumulative mean number of both the thrips species was 9.67) and BU mug 5 (T_4) (the mean number of *M. usitatus* and *T. palmi* was 5.35 and 3.79, respectively with cumulative mean number of both the thrips species was 9.15). The intermediate level of cumulative mean number of both the thrips species was found on BU mug 1 (T_1) (7.38), BARI mung-6 (T_7) (8.33) and Binamoog-8, (T_6) (8.86). Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 flower buds of all the varieties tested i.e., *M. usitatus* was found the dominant species of the crop. In BARI Mung-7 (T_8), the incidence of *M. usitatus* was 81.27% and *T. palmi* was 18.73% whereas, in Barishal local variety, the incidence of *M. usitatus* was 51.10% and *T. palmi* was 48.90%, respectively (Table 4.4.3).

Table 20. Mean number of *M. usitatus* and *T. palmi* on flower buds of eleven mungbean varieties

Treatments	Mean number of thrips per 10 flower buds		Cumulative mean no. of two thrips species per 10 flower buds	Comparative incidence of *M. usitatus* and *T. palmi* on 10 flower buds	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T_1	5.45 ab	2.32 ef	7.78 def	70.24 c	29.76 d
T_2	5.18 ab	1.69 fg	6.87 fgh	75.43 b	24.57 e
T_3	5.33 ab	4.34 b	9.67 bc	55.14 e	44.86 b
T_4	5.35 ab	3.79 bc	9.15 bcd	58.61 e	41.39 b
T_5	5.47 ab	1.87 fg	7.33 efg	74.40 b	25.60 e
T_6	5.64 ab	3.22 cd	8.86 cdef	63.79 d	36.21 c
T_7	5.46 ab	2.87 de	8.33 cdef	65.39 d	34.61 c
T_8	4.32 b	0.98 h	5.30 h	81.27 a	18.73 f
T_9	4.45 b	1.33 gh	5.79 gh	76.71 b	23.29 e
T_{10}	5.21 ab	5.12 a	10.33 ab	50.45 f	49.55 a
T_{11}	5.94 a	5.68 a	11.62 a	51.10 f	48.90 a
S$\bar{x}$	0.40	0.21	0.54	1.35	1.35
CV (%)	13.14	12.05	11.22	3.55	6.80

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

From the above findings it was revealed that among the different mungbean varieties the lowest incidence of cumulative mean population of thrips per 10 flower buds was found in BARI Mung-7, followed by BARI Mung-8 in field condition. Thus, the rank of efficacy of the varietal performance against incidence of adult *M. usitatus* and *T. palmi* with cumulative mean population of both thrips species on flower bud was BARI Mung-7 > BARI mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI mung-6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local.

4.4.4. Varietal influence on incidence of thrips on flowers of mungbean

Statistically significant variations among different mungbean varieties were observed in respect of incidence of both *M. usitatus* and *T. palmi* population on flowers (Table 21). The lowest mean number of *M. usitatus* and *T. palmi* (6.01 and 1.66, respectively) was observed during flowering stage on BARI Mung-7 (T_8) with cumulative mean number of both the thrips species (7.69) per 10 flowers, which was statistically identical with BARI Mung-8 (T_9) (*M. usitatus* and *T. palmi* were 5.68 and 2.45, respectively with cumulative mean number of both the thrips species was 8.13 per 10 flowers), and followed by BU mug 2 (T_2) (*M. usitatus* and *T. palmi* were 10.21 and 2.92, respectively with cumulative mean number of both the thrips species was 13.14 per 10 flowers), Binamoog-6 (*M. usitatus* and *T. palmi* were 11.22 and 3.66, respectively with cumulative mean number of both the thrips species was 14.88 per 10 flowers). The intermediate level of cumulative mean number (17.33, 18.33 and 19.48, respectively) of both the thrips species per 10 flowers was found in BU mug 1 (T_1), BARI mung-6 (T_7) and Binamoog-8, (T_6), respectively. On the other hand, the highest mean number of *M. usitatus* and *T. palmi* (14.27 and 8.40, respectively) was recorded with cumulative mean number of both the thrips species 22.68 per 10 flowers on Barishal local variety (T_{11}), which was statistically identical with BARI Mung-2 (T_{10}) (*M. usitatus* and *T. palmi* were 14.34 and 7.12, respectively with cumulative mean number of both the thrips species 21.47 per 10 flowers). This was next followed by BU mug 4 (T_3) (*M. usitatus* and *T. palmi* was 13.87 and 6.95, respectively with cumulative mean number of both the thrips species 20.77) and BU mug 5 (T_4) (the mean number of *M. usitatus* and *T. palmi* were 13.87 and 6.47, respectively with cumulative mean number of both the thrips species 20.34 per 10 flowers). Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 flowers of all the varieties tested i.e., *M. usitatus* was found the dominant species of the crop. In BARI Mung-7 (T_8), the incidence of *M. usitatus* was 78.44% and *T. palmi* was 21.56 % whereas, in Barishal local variety, the incidence of *M. usitatus* was 62.94% and *T. palmi* was 37.06%, respectively (Table 21).

Table 21. Mean number of *M. usitatus* and *T. palmi* in flowers of eleven mungbean varieties

Treatments	Mean number of thrips per 10 flowers		Cumulative mean no. of two thrips species per 10 flowers	Comparative incidence of *M. usitatus* and *T. palmi* on 10 flowers	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T_1	13.22 a	4.11 cd	17.33 d	76.43 ab	23.57 de
T_2	10.21 b	2.92 ef	13.14 e	77.59 ab	22.41 de
T_3	13.82 a	6.95 b	20.77 ab	66.59 de	33.41 ab
T_4	13.87 a	6.47 b	20.34 bc	68.28 d	31.72 b
T_5	11.22 b	3.66 de	14.88 e	75.55 ab	24.45 de
T_6	14.45 a	5.03 c	19.48 bc	74.32 ab	25.68 de
T_7	13.47 a	4.85 c	18.33 cd	73.50 bc	26.50 cd
T_8	6.01 c	1.66 g	7.67 f	78.44 a	21.56 e
T_9	5.68 c	2.45 fg	8.13 f	69.62 cd	30.38 bc
T_{10}	14.34 a	7.12 b	21.47 ab	66.78 de	33.22 ab
T_{11}	14.27 a	8.40 a	22.68 a	62.94 e	37.06 a
S͞x	0.46	0.38	0.70	1.48	1.48
CV (%)	6.66	13.52	7.26	9.10	3.57

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

From the above findings it was revealed that among the different mungbean varieties the lowest incidence of *M. usitatus* and *T. palmi* with cumulative mean population of thrips per 10 flowers was found in BARI Mung-7, followed by BARI Mung-8 in field condition. Thus, the rank of efficacy of the varietal performance against incidence of adult *M. usitatus* and *T. palmi* with cumulative mean population of both thrips species in flower was BARI Mung-7 > BARI mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI Mung-6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Kooner *et al*. (2004) recorded observations on the population of thrips which were taken by randomly collecting 10 flowers per replication per entry at

flowering stage of mungbean. Each flower was thoroughly shaken on a white paper and carefully examined for the population of thrips. The population of thrips in Final yield trial (FYT) in summer 2002 ranged from 17.00-34.67 per 10 flowers against 31.33-32.00 and 42.00 on the checks and the Infester, respectively. Entries SML 9, SML1, and NM 92 had less thrips infestation. In summer 2003, the incidence of thrips was low and varied between 0.33-2.67 on the test entries, while it was 1.33 and 5.00 per 10 flowers on the checks and Infester, respectively. Entries BMC 29, HUM 16, PDM 11, TM 99-37 were identified least susceptible.

4.4.5. Varietal influence on top trifoliate leaves and terminal shoots infestation by thrips at pre-flowering stage of mungbean

Significant variations were observed in respect of top trifoliate leaves and terminal shoots infestation by thrips among the eleven tested varieties and none of the variety was found free from the thrips attack (Table 22). The lowest number of infested top trifoliate leaves and terminal shoots (2.50 and 4.83, respectively) per 10 top trifoliate leaves and terminal shoots, lowest percent infestation of top trifoliate leaves and terminal shoots (25.00% and 48.33%, respectively) were recorded in BARI Mung-7 (T_8). The results were statistically different from other varieties and followed by BARI mung-8 (T_9), BU mug 2 (T_2) and Binamoog-6 (T_5), respectively where the number of infested top trifoliate leaves (3.00, 3.17 and 3.17, respectively) per 10 top trifoliate leaves with percent top trifoliate leaves infestation (30.00%, 31.70% and 31.70%, respectively) and the number of infested terminal shoots (5.17, 5.50 and 5.67, respectively) per 10 terminal shoots with percent infestation of terminal shoots (51.70%, 55.00% and 56.70%, respectively) were recorded. Intermediate level of infested top trifoliate leaves (3.50, 3.50, 3.67 and 3.67 per 10 top trifoliate leaves) with percent top trifoliate leaves infestation (35.00%, 35.00%, 36.70% and 36.70%) was observed in BU mug 1 (T_1), BARI Mung-6 (T_7), Binamoog-8 (T_6) and BU mug 5 (T_4), respectively. Similarly, intermediate level of infested terminal shoots (5.83, 5.83, 6.00 and 6.50 per 10 terminal shoots) with percent terminal shoot infestation (58.30%, 58.30%, 60.00% and 65.00%) was recorded in BU mug 1(T_1), BARI Mung-6 (T_7), Binamoog-8 (T_6) and BU mug 5 (T_4), respectively. On the other hand, the highest number of infested top trifoliate leaves (5.00 per 10 top trifoliate leaves) with 50.00% top trifoliate leaves infestation and infested terminal shoots (8.17 per 10 terminal shoots) with 81.67% terminal shoot infestation were recorded in Barishal local (T_{11})

variety. This was followed by BARI Mung-2 (Kanti) (T_{10}) and BU mug 4 (T_3) variety where the number of infested top trifoliate leaves (4.83 and 4.00, respectively per 10 top trifoliate leaves) with percent top trifoliate leaves infestation (48.33% and 40.00%, respectively) and the number of infested terminal shoots (7.33 and 6.83, respectively per 10 terminal shoots) with percent terminal shoots infestation (73.33% and 68.30%, respectively) of terminal shoots were recorded (Table 22).

Table 22. Top trifoliate leaves and terminal shoot infestation by thrips at pre-flowering stage of eleven mungbean varieties

Treatments	Mean no. of infested top trifoliate leaves per 10 top trifoliate leaves	% infestation of top trifoliate leaves	Mean no. of infested terminal shoot per 10 terminal shoots	% infestation of terminal shoots
T_1	3.50 c	35.00 c	5.83 ef	58.30 ef
T_2	3.17 d	31.70 d	5.50 g	55.00 g
T_3	4.00 b	40.00 b	6.83 c	68.30 c
T_4	3.67 c	36.70 c	6.50 d	65.00 d
T_5	3.17 d	31.70 d	5.67 fg	56.70 fg
T_6	3.67 c	36.70 c	6.00 e	60.00 e
T_7	3.50 c	35.00 c	5.83 ef	58.30 ef
T_8	2.50 e	25.00 e	4.83 i	48.33 i
T_9	3.00 d	30.00 d	5.17 h	51.70 h
T_{10}	4.83 a	48.33 a	7.33 b	73.33 b
T_{11}	5.00 a	50.00 a	8.17 a	81.67 a
S$\bar{x}$	0.08	0.83	0.10	0.74
CV (%)	3.94	3.94	2.81	2.09

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

From the above findings it was revealed that among the different mungbean varieties the lowest percent infestation of top trifoliate leaves and terminal shoots was found in

BARI Mung-7, followed by BARI Mung-8. The rank of efficacy of the varietal performance against top trifoliate leaves and terminal shoots infestation by thrips was BARI Mung-7 > BARI Mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI Mung-6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Percent leaves or shoots infestation by thrips may vary from crop to crop for many reasons, i.e., thrips species, crop type, crops phenology, crops availability and suitability, weather factors etc. The results of the present study was supported by Gadad (2014), who reported that among twenty groundnut varieties screened for resistance, none of the variety was free from the thrips damage and their leaf damage level varied above 10 percent up to 60 percent. However, TGLPS-3 recorded damage score of "2" (>10 % and <20% leaf damage) thus falling under resistant category. Eight varieties viz., Dh-103, Dh-86, Dh86-15Kr-18-1, DH-2000-1, DTG-17X ICGV-86699-5, ICGV-86699TAN, Dh-330 and TAG24 recorded damage score of "3" (>20 % and <30% leaf damage) and hence belonged to moderately resistant category. While six varieties were moderately susceptible by scoring leaf damage score of "4" (>30 % and <40% leaf damage) which included Chintamani-2, Dh-218, Dh221, GPBD-5, ICGV-00350 and ICGV-86590. Whereas, three genotypes namely, Dh-86 X Dh-102-29, GPBD-4 X R8808-6 and JL-24 recorded leaf damage score of "5" (>40 % and <50% leaf damage), which fell under susceptible category and two varieties Dh-216 and TMV2 were categorized as highly susceptible as they recorded more than "5" leaf damage score.

4.4.6. Varietal influence on flower bud infestation and shedding by thrips at flowering stage of mungbean

Significant variations were observed among the eleven mungbean varieties in respect of flower bud infestation and shedding by thrips and none of the variety was found free from the thrips incidence on flower buds (Table 23). The total number of flower bud (45.51 plant^{-1}) was found maximum in BARI Mung-7 (T_8) which was followed by BU mug 2 (T_2), BARI Mung-8 (T_9) and Binamoog-6 (T_5), respectively in which the total number of flower bud (41.67, 41.07 and 38.85, plant^{-1}), respectively was observed. Whereas, the intermediate level of total flower bud (37.67, 36.22, 33.11 and 33.59 plant^{-1}), respectively was observed in BU mug 1 (T_1), BARI Mung-6 (T_7), Binamoog-8 (T_6) and BU mug 5 (T_4), respectively. The minimum number of total flower bud (17.81 plant^{-1}) was found in Barishal local (T_{11}) variety, which was statistically identical with BARI Mung-2 (Kanti) (T_{10}), in which the total number of flower bud was (21.56 plant^{-1}). This was followed by BU mug 4 (T_3) in which the total number of flower bud was (30.67 plant^{-1}). The lowest number of infested and shedding flower bud (9.57 and 2.76 plant^{-1}), respectively was observed in BARI Mung-7 (T_8), which was followed by BARI Mung-8 (T_9), BU mug 2 (T_2), and Binamoog-6 (T_5), respectively, in which the number of infested flower bud (10.25, 10.40, and 11.33 plant^{-1}, respectively) with percent flower bud infestation (24.92%, 24.91%, and 29.15%, respectively) and shedding flower bud (1.80, 2.23 and 2.51 plant^{-1}, respectively) with percent flower bud shedding (4.36%, 5.39% and 6.45%, respectively) was found. The intermediate number of infested flower bud (11.84, 12.62, and 12.29, respectively) with flower bud infestation (31.45%, 34.72% and 36.98%, respectively) and shedding flower bud (3.27, 3.35 and 3.62 plant^{-1}, respectively) with percent flower bud shedding (8.66%, 9.22% and 11.87%, respectively) was recorded in BU mug 1 (T_1), BARI Mung-6 (T_7) and Binamoog-8 (T_6) variety, respectively. On the other hand, the highest number of infested flower bud (13.89 plant^{-1}) with 77.76% flower bud infestation and shedding flower bud (8.67 plant^{-1}) with 48.67% flower bud shedding were recorded in Barishal local (T_{11}) variety, which was followed by BARI Mung-2 (Kanti) (T_{10}) variety in which the number of infested flower bud (13.24 plant^{-1}) with 62.43% flower bud infestation and shedding flower bud (6.70 plant^{-1}) with 31.81% flower bud shedding were recorded. This was followed by BU mug 4 (T_3) and BU mug 5 (T_4), in which the number of infested flower bud (13.36 and 12.85 plant^{-1}, respectively) with 43.12% and 38.29%

flower bud infestation, respectively and shedding flower bud (4.73 and 4.51 plant^{-1}) with 15.34% and 13.49% flower bud shedding, respectively were found (Table 23).

Table 23. Flower bud infestation and shedding by thrips at flowering stage of eleven mungbean varieties

Treatments	Total no. of flower bud plant^{-1}	No. of infested flower bud plant^{-1}	% infestation of flower bud	No .of shedding flower bud plant^{-1}	% shedding of flower bud
T$_1$	37.67 bcd	11.84 abc	31.45 def	3.27 de	8.66 def
T$_2$	41.67 ab	10.40 bc	24.92 fg	2.23 efg	5.39 efg
T$_3$	30.67 f	13.26 a	43.17 c	4.73 c	15.34 c
T$_4$	33.59 def	12.85 ab	38.29 cd	4.51 c	13.49 cd
T$_5$	38.85 bc	11.33 abc	29.15 efg	2.51 def	6.45 efg
T$_6$	33.11 ef	12.29 ab	36.98 cde	3.62 cd	11.87 cde
T$_7$	36.22 cde	12.62 ab	34.72 de	3.35 de	9.22 def
T$_8$	45.51 a	9.57 c	21.00 g	1.26 g	2.76 g
T$_9$	41.07 b	10.25 bc	24.91 fg	1.80 fg	4.36 fg
T$_{10}$	21.56 g	13.24 a	62.43 b	6.70 b	31.81 b
T$_{11}$	17.81 g	13.89 a	77.76 a	8.67 a	48.67 a
S$\bar{x}$	1.45	0.83	2.66	0.38	1.73
CV (%)	7.33	11.96	11.94	16.83	20.96

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = BU mug 1, T$_2$ = BU mug 2, T$_3$ = BU mug 4, T$_4$ = BU mug 5, T$_5$ = Binamoog-6, T$_6$ = Binamoog-8, T$_7$ = BARI Mung-6, T$_8$ = BARI Mung-7, T$_9$ = BARI Mung-8, T$_{10}$ = BARI Mung-2 (Kanti) and T$_{11}$ = Barishal local].

From the above findings it was revealed that among the different mungbean varieties the lowest percent flower bud infestation and flower bud shedding were found in BARI Mung-7, followed by BARI Mung-8 and BU mug 2. The rank of efficacy of the varietal performance against flower bud infestation and flower bud shedding by thrips was BARI Mung-7 > BARI Mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI mung-6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local.

4.4.7. Varietal influence on flower infestation and shedding by thrips at flowering stage of mungbean

Significant variations were observed among the eleven mungbean varieties in respect of flower infestation and flower shedding by thrips and none of the variety was found free from the thrips attack on mungbean flowers (Table 24). The total number of flowers (16.62 $plant^{-1}$) was found maximum in BARI Mung-7 (T_8) which was followed by BARI Mung-8 (T_9), BU mug 2 (T_2) and Binamoog-6 (T_5), respectively, in which the total number of flowers (16.36, 15.41 and 14.77, $plant^{-1}$), respectively was observed. Whereas, the intermediate level of total flower (13.78, 13.19 and 12.71 $plant^{-1}$), was observed in BU mug 1 (T_1), BARI Mung-6 (T_7) and Binamoog-8 (T_6), respectively. The lowest number of total flowers (10.45 $plant^{-1}$) was found in Barishal local (T_{11}) variety, which was statistically identical with BARI Mung-2 (Kanti) (T_{10}), in which the total number of flowers was (11.47 $plant^{-1}$). This was followed by BU mug 4 (T_3) and BU mug 5 (T_4), in which the total number of flowers (11.77 and 12.31 $plant^{-1}$, respectively) was found. The lowest number of infested flower and shedding flower (4.89 and 2.33 $plant^{-1}$), respectively was observed in BARI Mung-7 (T_8), which was followed by BARI Mung-8 (T_9), BU mug 2 (T_2), and Binamoog-6 (T_5), respectively, in which the number of infested flower (5.18, 5.33, and 5.81 $plant^{-1}$, respectively) with percent flower infestation (31.68%, 34.59%, and 39.31%) and shedding flower (2.67, 2.87 and 3.13 $plant^{-1}$, respectively) with percent flower shedding (16.32%, 18.62% and 21.19%), respectively were recorded. The intermediate number of infested flower (5.99, 6.15, and 6.25, respectively) with percent flower infestation (43.47%, 46.60% and 49.17%, respectively) and shedding flower (3.37, 3.63 and 3.77 $plant^{-1}$, respectively) with percent flower shedding (24.46%, 27.52% and 29.69%) were recorded in BU mug 1(T_1), BARI Mung-6 (T_7) and Binamoog-8 (T_6) variety, respectively. On the other hand, the highest number of infested flower (6.92 $plant^{-1}$) with 66.25% flower infestation and shedding flower (4.10 $plant^{-1}$) with 39.20% flower shedding were recorded in Barishal local (T_{11}) variety. This was followed by BARI Mung-2 (Kanti) (T_{10}), BU mug 4 (T_3) and BU mug 5 (T_4) variety, in which the percent infestation of flower (57.95%, 57.66% and 54.83%, respectively) and percent shedding of flower (35.25%, 33.92% and 32.49%), respectively were observed (Table 24)

Table 24. Flower infestation and shedding by thrips at flowering stage of eleven mungbean varieties

Treatments	Number of total flower plant^{-1}	Number of infested flower plant^{-1}	% infestation of flower	Number of shedding flower plant^{-1}	% shedding of flower
T$_1$	13.78 bcd	5.99 d	43.47 f	3.37 bcd	24.46 f
T$_2$	15.41 ab	5.33 ef	34.59 h	2.87 def	18.62 h
T$_3$	11.77 def	6.79 ab	57.66 b	4.00 ab	33.98 bc
T$_4$	12.31 def	6.75 ab	54.83 c	4.00 ab	32.49 c
T$_5$	14.77 abc	5.81 de	39.31 g	3.13 cde	21.19 g
T$_6$	12.71 cde	6.25 bcd	49.17 d	3.77 abc	29.69 d
T$_7$	13.19 cde	6.15 cd	46.60 e	3.63 abc	27.52 e
T$_8$	16.62 a	4.89 f	29.42 i	2.33 f	14.02 j
T$_9$	16.36 a	5.18 f	31.68 i	2.67 ef	16.32 i
T$_{10}$	11.47 ef	6.65 abc	57.95 b	4.04 a	35.25 b
T$_{11}$	10.45 f	6.92 a	66.25 a	4.10 a	39.20 a
S$\bar{x}$	0.67	0.19	0.89	0.21	0.70
CV (%)	8.62	5.43	3.33	10.38	4.54

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = BU mug 1, T$_2$ = BU mug 2, T$_3$ = BU mug 4, T$_4$ = BU mug 5, T$_5$ = Binamoog-6, T$_6$ = Binamoog-8, T$_7$ = BARI Mung-6, T$_8$ = BARI Mung-7, T$_9$ = BARI Mung-8, T$_{10}$ = BARI Mung-2 (Kanti) and T$_{11}$ = Barishal local].

From the above findings it was revealed that among the different mungbean varieties the lowest percent flower infestation and flower shedding were found in BARI Mung-7, followed by BARI Mung-8 and BU mug 2. The rank of efficacy of the varietal performance against flower infestation and flower shedding by thrips was BARI Mung-7 > BARI mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI mung-6 > Binamoog-8 > BU mug-5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Percent flower infestation by thrips may vary for many reasons, i.e., thrips species, crop type, weather factors, suitability of planting time of different varieties, availability of flower etc. Variety is one of the important factors, which is related to crop phenology, nutrition, bio-physical and bio-chemical constituents, availability of vegetation or inflorescence etc. as well as intensity of insect pest incidence.

4.4.8. Variations in morphological traits in different mungbean varieties

The type of trichome hair on midrib of lower surface of top fully opend trifoliate leaves of eleven tested mungbean varieties were found spiny and curved (Plate 75, 76, 77 and 78) but density differed significantly (Table 25). The density of leaf trichome hair was highest (32.67 per 0.5 cm midrib) in BARI Mung-7 (T_8) which was statistically identical with BARI Mung-8 (T_9), BU mug 2 (T_2) and Binamoog-6 (T_5), respectively, in which the density of leaf trichome hair (31.67, 31.67 and 30.33 per 0.5 cm midrib, respectively) was recorded. The intermediate level of leaf trichome hair density (27.33, 26.11 and 21.33 per 0.5 cm midrib, respectively) was found in BU mug 1 (T_1), BARI Mung-6 (T_7) and Binamoog-8 (T_6), respectively. On the other hand, the density of leaf trichome hair (15.67 per 0.5 cm midrib) was lowest in Barishal local (T_{11}) variety which was statistically identical with BARI Mung-2 (Kanti) (T_{10}), BU mug 4 (T_3) and BU mug 5 (T_4) variety, in which the density of leaf trichome hair (18.67, 19.00 and 21.00 per 0.5 cm midrib), respectively was observed. No significant variations were observed in length of leaf trichome hair on midrib of lower surface of eleven tested mungbean varieties. Comparatively, maximum length (0. 117 cm) of leaf trichome hair was found in BARI Mung-7 while the minimum length (0.067 cm) of leaf trichome hair was found in Barishal local (T_{11}) variety. Other authors also found more or less similar results on trichome density in contributing resistance or preventing attack of insect pests in different varieties of same or different crop. Tamang *et al.* (2017) screened five mungbean genotypes for their resistance against insect pests during 2013 and found that Sukumar (WBM-29) had less susceptibility to the attack of thrips in which the maximum density (33.50 per 0.5 cm^2) of trichomes was observed on the leaves. While trichome density was lowest (18.0 per 0.5 cm^2) in Samrat (PDM 24-139) had relatively higher thrips incidence. Chakraborti (2006) reported that among 24 mungbean genotypes tested against thrips, trichome density per cm^2 on lower surface of mungbean leaf ranged 26.37-52.24. In resistant genotypes i.e., Sb1-17(a)-1/4, Sb1-17(a)-6/2, MLD-95-21, A33, A228, the trichome density on lower surface of leaf was 52.25, 50.00, 40.05, 42.29, 38.91 per cm^2, respectively, whereas, in susceptible genotypes i.e., A-267, Pusa vishal, PDM-84-143, Pusa-Baishakhi, A228, the trichome density on lower surface of leaf was 37.81, 30.84, 40.05, 26.37 per cm^2, respectively. Taggar and Gill (2012) reported that trichome density and angle were negatively correlated to with whitefly eggs, nymphs

and adults in blackgram. Ali (2008) found negative relationship between mungbean leaf trichome density and incidence of whitefly. Aheer *et al.* (1999) evaluated nine cotton genotypes for relative resistance against leafhopper and reported that the genotype N-86-ph showed highest population i.e., 3.96 per leaf, while the genotype, N-92 showed lowest population i.e., 1.66 per leaf. Hair density on mid rib and lamina showed significantly negative correlation with leafhopper.

Table 25. Type, density and length of trichome hairs on top trifoliate leaves of eleven mungbean varieties

Treatments	Type of leaf trichome hair on midrib (lower surface)	Leaf trichome hair on midrib (25 DAS)	
		Density (No. / 0.5 cm)	Length (cm)
T_1	Spiny, curved	27.33 ab	0.083 a
T_2	Spiny, curved	31.67 a	0.087 a
T_3	Spiny, curved	19.00 c	0.070 a
T_4	Spiny, curved	21.00 bc	0.077 a
T_5	Spiny, curved	30.33 a	0.087 a
T_6	Spiny, curved	21.33 bc	0.077 a
T_7	Spiny, curved	26.33 ab	0.083 a
T_8	Spiny, curved	32.67 a	0.117 a
T_9	Spiny, curved	31.67 a	0.100 a
T_{10}	Spiny, curved	18.67 c	0.070 a
T_{11}	Spiny, curved	15.67 c	0.067 a
$S\bar{x}$	-	2.03	NS
CV(%)	-	14.05	-

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

(a) BU mug 1

(b) BU mug 2

(c) BU mug 4

Plate 75.   Trichome hairs on lower surface (0.5 cm midrib) of mungbean varieties (a) BU mug 1, (b) BU mug 2 and (c) BU mug 4.

146
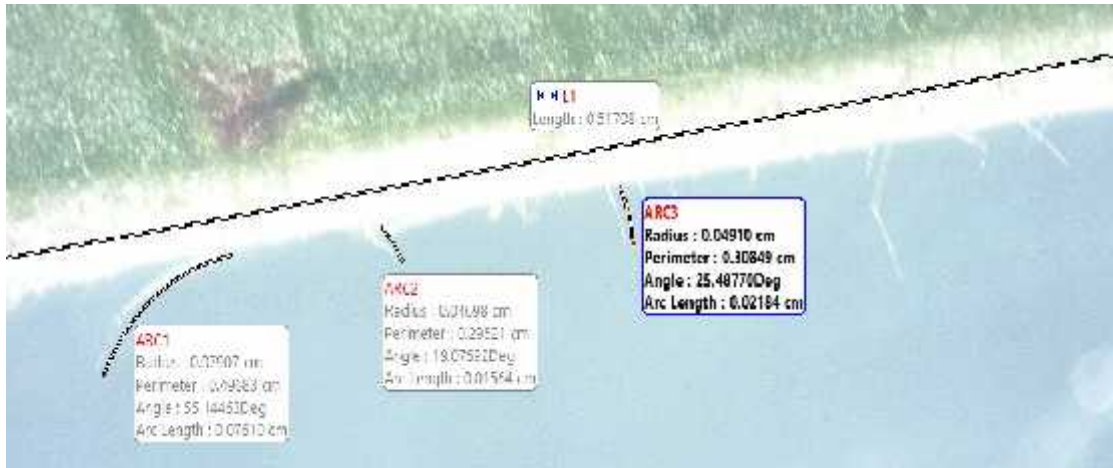
(d) BU mug 5
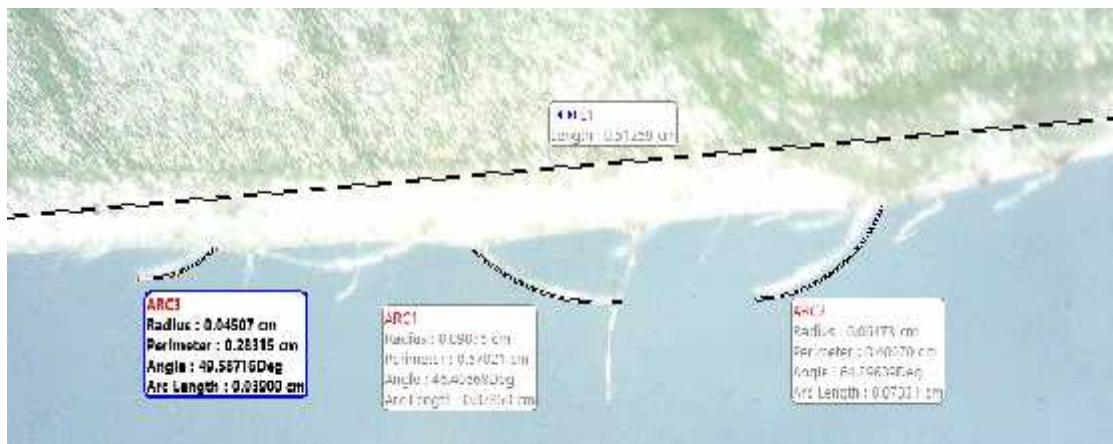
(e) Binamoog-6

(f) Binamoog-8

Plate 76. Trichome hairs on lower surface (0.5 cm midrib) of mungbean varieties (d) BU mug 5, (e) Binamoog-6 and (f) Binamoog-8.

(g) BARI Mung-6
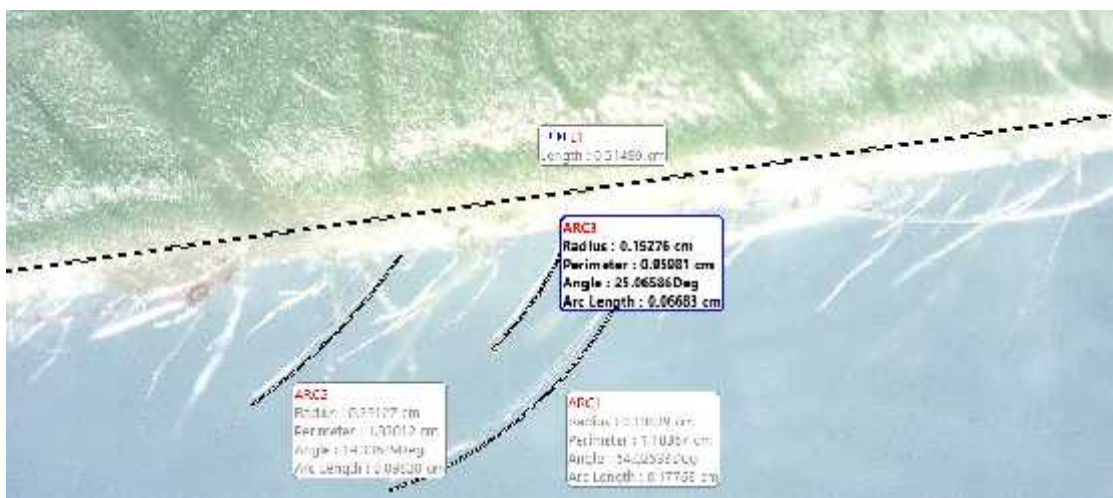
(h) BARI Mung-7
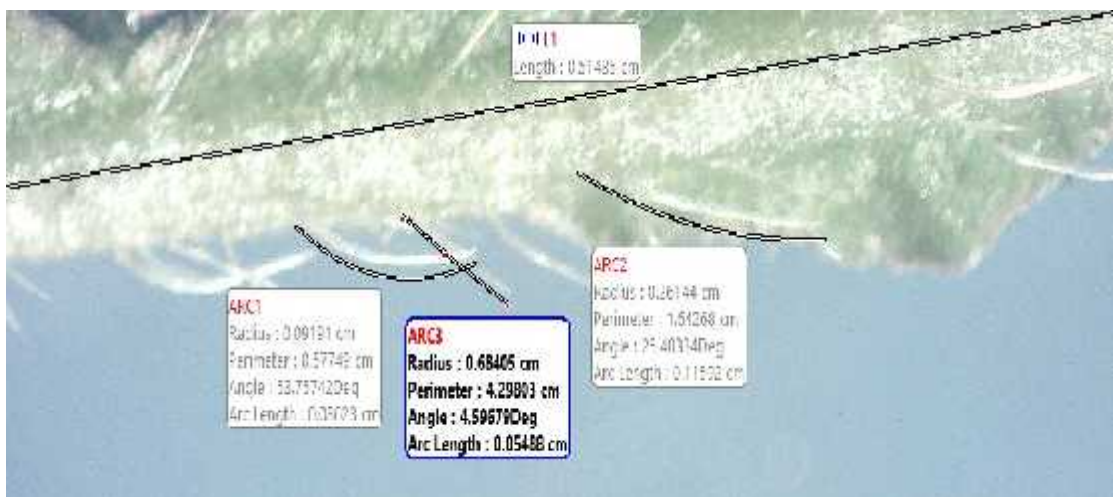
(i) BARI Mung-8

Plate 77. Trichome hairs on lower surface (0.5 cm midrib) of mungbean varieties (g) BARI Mung-6 (h) BARI Mung-7 and (i) BARI Mung-8.

(j) BARI Mung-2 (Kanti)
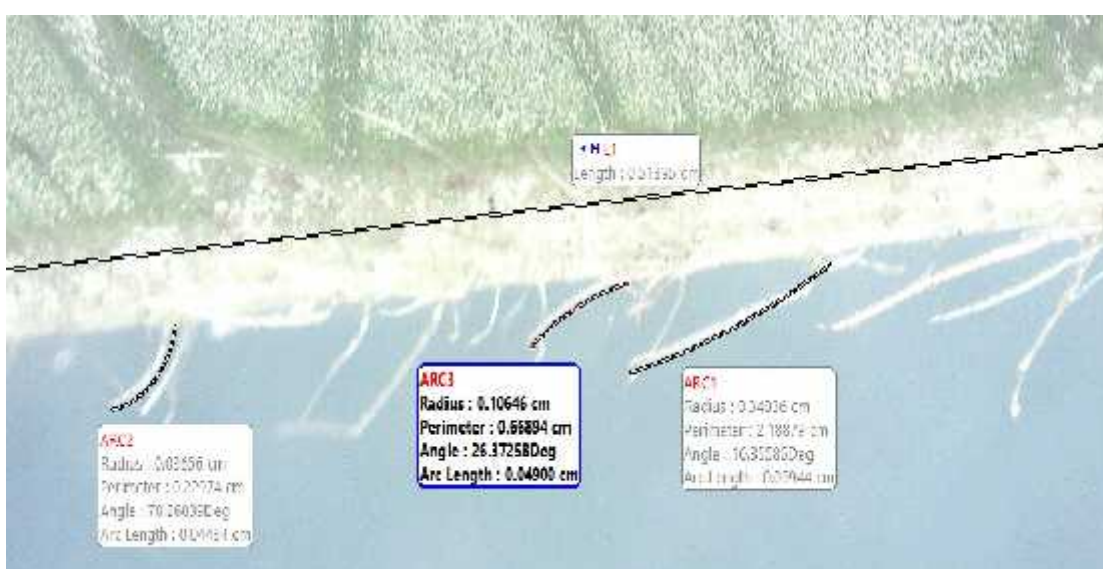
(k) Barishal local

Plate 78. Trichome hairs on lower surface (0.5 cm midrib) of mungbean varieties (j) BARI Mung-2 (Kanti) and (k) Barishal local.

4.4.8.1 Relationship between leaf trichome density and incidence of thrips

The leaf trichome density had a negative relationship (r = 0.947) with the incidence of adult thrips (Figure 23)
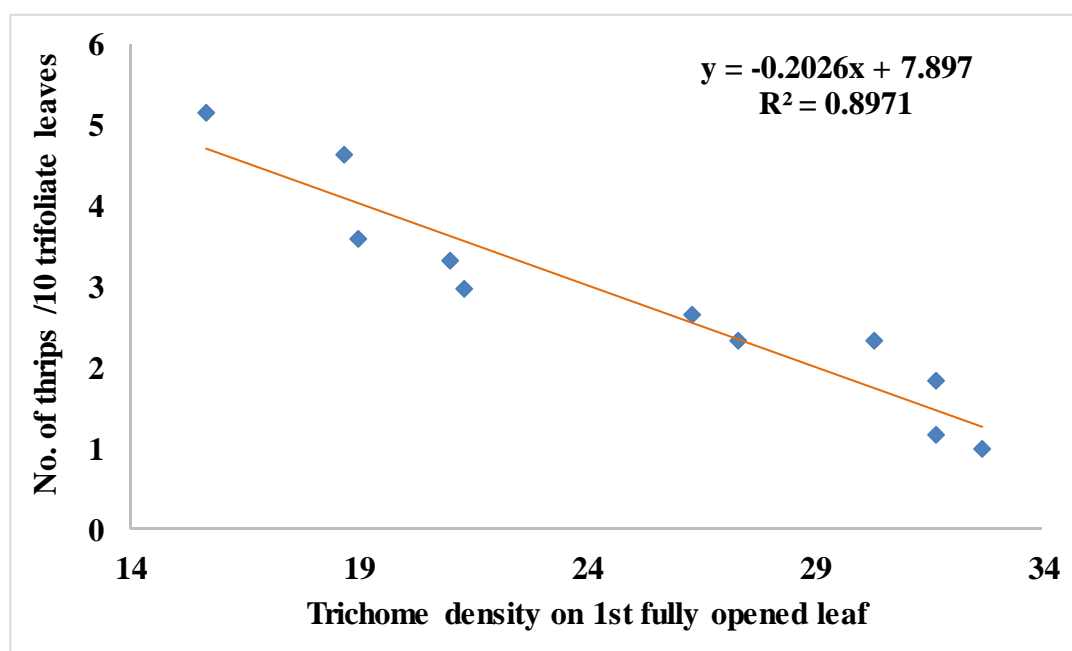
Figure 23. Relationship between trichome hair density and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.9. Variations in chemical constituents (moisture percentage and chlorophyll content of leaves) in different mungbean varieties

Significant variations in chemical contituents especially moisture and chlorophyll$_{(a+b)}$ content of leaves (25 DAS) were observed among eleven tested mungbean varieties. The maximum leaf moisture content (84.19%) and chlorophyll$_{(a+b)}$ content (1.11 mg per 100 g) was measured in BARI Mung-7 (T$_8$) which was statistically identical with BARI Mung-8 (T$_9$) and BU mug 2 (T$_2$) in which leaf moisture content (84.10% and 83.83%, respectively) and leaf chlorophyll$_{(a+b)}$ content (1.07 and 1.07 mg per 100 g, respectively) were recorded. This was followed by Binamoog-6 (T$_5$), BU mug 1 (T$_1$), BARI Mung-6 (T$_7$) and Binamoog-8, (T$_6$) in which leaf moisture content (83.43%, 83.67%, 82.87% and 82.75%, respectively) and leaf chlorophyll$_{(a+b)}$ content (1.04, 1.03, 1.02 and 1.02 mg per 100 g, respectively) were recorded. The minimum leaf moisture content (81.61%) and leaf chlorophyll$_{(a+b)}$ content (0.86 mg per100 gm) were found in Barishal local (T$_{11}$) variety which was followed by BARI Mung-2 (T$_2$), BU mug 4 (T$_3$) and BU mug 5 (T$_4$), respectively in which leaf moisture (81.69%, 81.95%

150

and 82.53%, respectively) and chlorophyll$_{(a+b)}$ content (0.94, 0.99 and 1.00 mg per100 g, respectively) were recorded (Table 26). Other authors also found more or less similar results in case of moisture and chlorophyll content in resistant and susceptible vatieties against thrips or other sucking pests of same or other crops. Gadad *et al.* (2014) screened twenty groundnut varieties for resistance against thrips and found none of the variety free from the thrips damage and their leaf damage level varied above 10 percent up to 60 percent. Leaf water content varied 58 to 92 percent. The correlation between leaf water content and thrips population indicated the existence of negative and non significant relation in groundnut crop. Vijayalakshmi (2013) screened seventeen onion genotypes against *T. tabaci* and found that the leaf water content varied from 70.00 to 91.58 % among the onion genotypes. There was a highly significant and negative correlation between leaf water content and thrips population (-0.866). Ali (2008) reported that comparatively, in the resistant variety (BU mug 1) against whitefly, the amount of chlorophyll A (0.1789 mg per 100 g) and chlorophyll B (0.0689 mg per 100 g) was found higher than the susceptible variety Barishal local (Chl A 0.1033 and Chl B 0.0389 mg per 100 g) and there was negative correlation between chlorophyll content and incidence of adult whitefly.

Table 26. Moisture and chlorophyll content in leaves among eleven mungbean varieties

Treatments	% Leaf moisture (25 DAS)	Chlorophyll $_{(a+b)}$ (mg per 100 g) (25 DAS)
T_1	83.67 abc	1.03 bc
T_2	83.83 ab	1.07 ab
T_3	81.95 def	0.99 cd
T_4	82.53 cdef	1.00 c
T_5	83.43 abc	1.04 bc
T_6	82.75 bcde	1.02 bc
T_7	82.87 bcd	1.02 bc
T_8	84.19 a	1.11 a
T_9	84.10 a	1.07 ab
T_{10}	81.69 ef	0.94 d
T_{11}	81.61 f	0.86 e
$S\overline{x}$	0.36	0.02
CV(%)	0.74	1.78

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = BU mug 1, T_2 = BU mug 2, T_3 = BU mug 4, T_4 = BU mug 5, T_5 = Binamoog-6, T_6 = Binamoog-8, T_7 = BARI Mung-6, T_8 = BARI Mung-7, T_9 = BARI Mung-8, T_{10} = BARI Mung-2 (Kanti) and T_{11} = Barishal local].

From the above findings it was revealed that maximum leaf moisture and chlorophyll$_{(a+b)}$ content were measured in BARI Mung-7 (T_8) followed by BARI Mung-8 (T_9) and BU mug 2 (T_2) in which thrips incidence was found lower while minimum leaf moisture and chlorophyll$_{(a+b)}$ content were measured in Barishal local variety (T_{11}) followed by BARI Mung-2 (T_2), BU mug 4 (T_3) and BU mug 5 (T_4), respectively in which thrips incidence was found higher.

4.4.9.1. Relationship between leaf moisture content and incidence of adult thrips

The leaf moisture content had a negative relationship (r = 0.969) with the number of adult thrips (Figure 24)
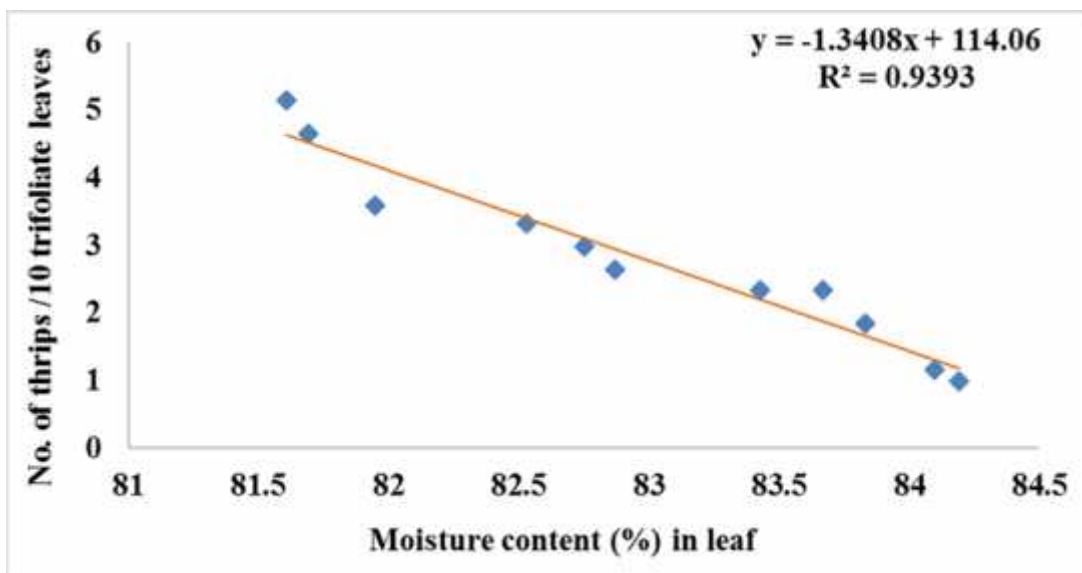
Figure 24. Relationship between moisture content (%) in leaves and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.9.2. Relationship between leaf chlorophyll $_{(a+b)}$ content and incidence of adult thrips

The leaf chlorophyll $_{(a+b)}$ content had a negative relationship (r = 0.95) with the number of adult thrips (Figure 25)
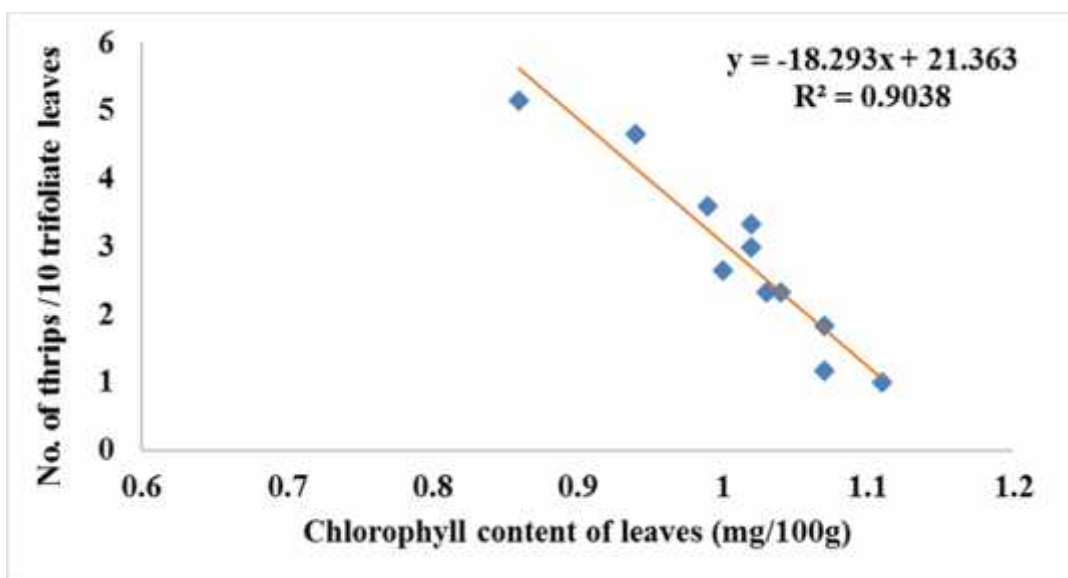
Figure 25. Relationship between chlorophyll content (mg per 100 g) in leaves and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.10. Variations in chemical constituents (phosphorous, potassium, phenol and total soluble sugar content of leaf) in different mungbean varieties

The data illustrated in Table 27 revealed that no significant variations were observed in phosphorous content of the eleven mungbean varieties tested in this study. However, the lowest phosphorous content (0.11%) was measured in BARI Mung-7 (T_8) while the highest phosphorous content (0.15%) was measured in Barishal local variety. Significant variations were observed in other chemical constituents especially potassium, phenol and total soluble sugar contents. The maximum potassium (2.34%), phenol (8.39 mg g^{-1}), but minimum total soluble sugar (2.12 mg g^{-1}) contents were measured in BARI Mung-7 (T_8) variety which were followed by BARI Mung-8 (T_9), BU mug 2 (T_2), Binamoog-6 (T_5) and BU mug 1 (T_1), respectively in which potassium content (2.29%, 2.13%, 2.09% and 1.96%, respectively), phenol content (7.49, 7.37, 6.99 and 6.92 mg g^{-1}, respectively) and total soluble sugar content (2.40, 2.75, 3.17 and 3.84 mg g^{-1}, respectively) were recorded. Statistically similar results were found in respect of potassium content (1.88%, 1.84%, 1.81%, 1.79%, respectively) in BARI Mung-6 (T_7), Binamoog-8 (T_6), BU mug 5 (T_4) and BU mug 4 (T_3) varieties, respectively but significant variations were found in phenol content (6.96, 6.23, 6.47, 6.22 mg g^{-1}) and total soluble sugar (4.13, 4.20, 4.41, 5.50 mg g^{-1}) content. The minimum potassium (1.50%), phenol (5.64 mg g^{-1}), but maximum total soluble sugar (5.87 mg g^{-1}) were recorded in Barishal local variety which were followed by BARI Mung-2 (Kanti) in which potassium (1.50%), phenol (5.64 mg g^{-1}) and total soluble sugar (5.87 mg g^{-1}) were measured.

Table 27. Phosphorus, potassium, phenol and total soluble sugar content in leaves among eleven mungbean varieties

Treatments	Phosphorus (%)	Potasssium (%)	Phenol (mg g^{-1})	Total soluble sugar (mg g^{-1})
T$_1$	0.13 a	1.96 abc	6.92 c	3.84 e
T$_2$	0.12 a	2.13 ab	7.37 b	2.75 g
T$_3$	0.12 a	1.79 bcd	6.22 e	5.50 b
T$_4$	0.12 a	1.81 bcd	6.47 d	4.41 c
T$_5$	0.12 a	2.09 ab	6.99 c	3.17 f
T$_6$	0.13 a	1.84 bcd	6.23 e	4.20 cd
T$_7$	0.12 a	1.88 bcd	6.96 c	4.13 d
T$_8$	0.11 a	2.34 a	8.39 a	2.12 i
T$_9$	0.12 a	2.29 a	7.49 b	2.40 h
T$_{10}$	0.13 a	1.67 cd	6.19 e	5.78 a
T$_{11}$	0.15 a	1.50 d	5.64 f	5.87 a
S$\bar{x}$	NS	0.12	0.07	0.08
CV(%)	-	11.12	1.82	3.21

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = BU mug 1, T$_2$ = BU mug 2, T$_3$ = BU mug 4, T$_4$ = BU mug 5, T$_5$ = Binamoog-6, T$_6$ = Binamoog-8, T$_7$ = BARI Mung-6, T$_8$ = BARI Mung-7, T$_9$ = BARI Mung-8, T$_{10}$ = BARI Mung-2 (Kanti) and T$_{11}$ = Barishal local].

From the above findings it was revealed that phenol and potassium content was higher comparatively, in resistant varieties i.e. BARI Mung-7, BARI Mung-8 and BU mug 2 but total soluble sugar content was lower. No significant variations were observed in phosphorous content among the eleven tested varieties in this study. Phenols are extremely abundant plant allelo-chemicals often associated with feeding deterrence or growth inhibition of herbivores. The present findings of decreased intensity of thrips attack with increased total phenol and potassium content in comparatively resistant varieties, though no variety was found free from thrips attack. Other authors also found more or less similar results in the same or other crops. Chakraborty (2006) reported that phenol was found to be negatively correlated with the thrips (*M. distalis*) population and the OD-Phenol also showed negative correlation indicating higher level of phenol was responsible for low thrips population. Among twenty four genotypes of mung bean, percent potassium content ranged 1.22-2.34 % and percent

phosphorous content ranged 0.05-0.20% were found. No significant correlations were found between the thrips population and P and K content although contradictory result was reported by Rawat and Shaw (1983). Gadad *et al.* (2014) reported that the total phenol content in selected groundnut varieties ranged from 0.20 to 0.56 mg g^{-1}. The correlation between thrips population and phenol content was negative and significant (r=-0.850). Naik (2005) observed that thrips population was strongly associated with phenols showing significant and negative relationship in groundnut. Vijayalakshmi (2013) screened seventeen onion genotypes against *Thrips tabaci* and found that the total phenol content in selected varieties ranged from 2.00 to 5.10 mg g^{-1}. The correlation between thrips population and phenol content was negative and significant (-0.961). The data on total sugars content in selected varieties revealed that the quantities of sugars varied from 4.12 to 8.75 mg g^{-1}. The correlation between thrips population and total sugar content was positive and significant (0.972).

4.4.10.1. Relationship between potassium content and incidence of thrips in leaves

There was a strong negative relationship (r = 0.9748) between potassium content and number of thrips on leaves (Figure 26).
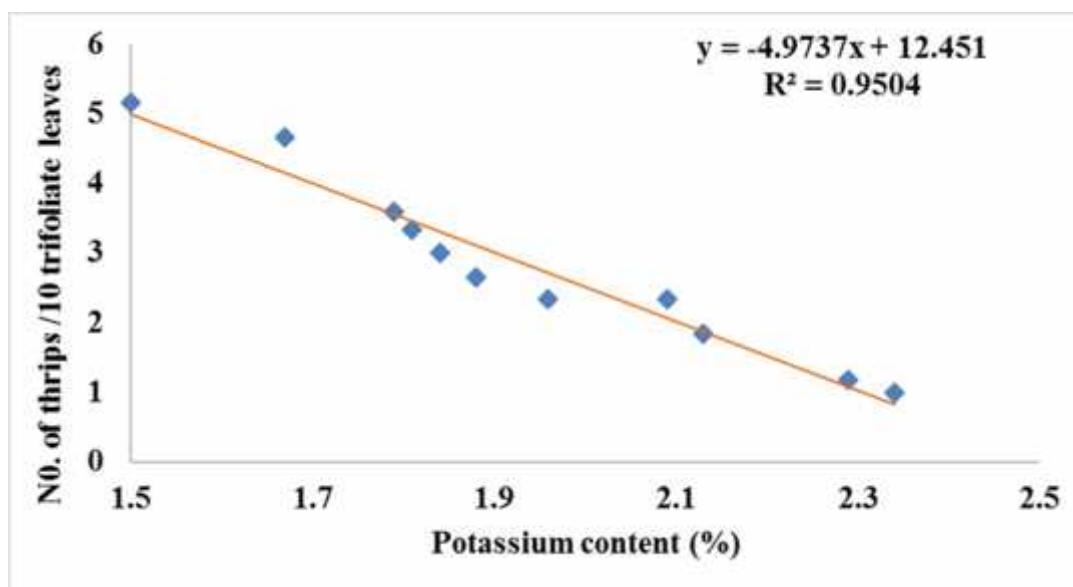
Figure 26. Relationship between Potassium content (%) in leaves and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.10.2. Relationship between phenol content and incidence of thrips in leaves

There was a negative relationship (r = 0.925) between phenol content and number of thrips on leaves (Figure 27).
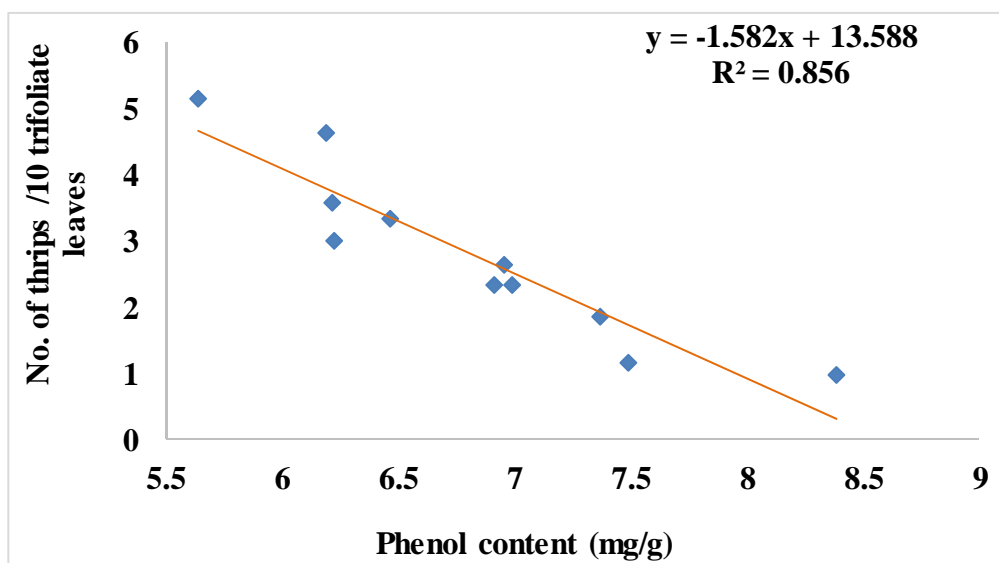
Figure 27. Relationship between phenol content (mg g^{-1}) in leaves and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.10.3. Relationship between total soluble sugar content and incidence of adult thrips in leaves

There was a positive relationship (r = 0.967) between total soluble content and number of thrips on leaves (Figure 28).
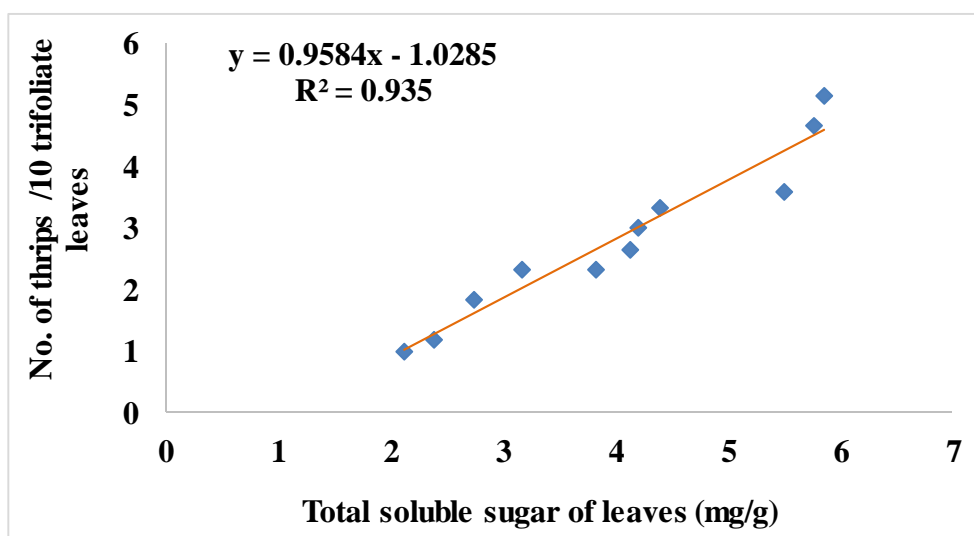
Figure 28. Relationship between total soluble sugar content (mg g^{-1}) in leaves and incidence of thrips population on top trifoliate leaves of mungbean.

4.4.11. Yield contributing characteristics and yield of different mungbean varieties

4.4.11.1. Number of pod plant^{-1}

Significant variations were observed among different mungbean varieties in respect of number of pods plant^{-1}. The highest pod number (26.77 plant^{-1}) was recorded in BARI Mung-7 (T_8) which was statistically identical with BU mug 2 (T_2), BARI Mung-8 (T_9) and Binamoog-6 (T_5) in which number of pod (26.34, 25.66 and 24.32 plant^{-1}, respectively) was found. The intermediate level of pod number (23.78, 22.34 and 21.45 plant^{-1}) was observed in BU mug 1 (T_1), BARI Mung-6 (T_7) and Binamoog-8 (T_6), respectively. On the other hand, the lowest number of pods (16.34 plant^{-1}) was recorded in Barishal local (T_{11}) variety which was statistically identical with BARI Mung-2 (T_2) (17.78 pods plant^{-1}). This was followed by BU mug 4 (T_3) and BU mug 5 (T_4) (20.67 and 21.11 pods plant^{-1}) respectively (Table 28).

4.4.11.2. Pod length

Significant variations were observed among different mungbean varieties in respect of pod length. The maximum pod length (8.84 cm) was observed in BARI Mung-7 (T_8) which was followed by BU mug 2 (T_2), Binamoog-6 (T_5) and BU mug 1 (T_1), in which pod length (7.93, 7.90 and 7.64 cm, respectively) was measured. The intermediate level of pod length (7.59, 7.34, 7.31 and 7.22 cm) was recorded in BARI Mung-6 (T_7), Binamoog-8 (T_6), BU mug 5 (T_4) and BU mug 4 (T_3), respectively. The minimum pod length (6.42 cm) was found in Barishal local (T_{11}) variety. This was followed by BARI Mung-2 (T_2) and BARI Mung-8 (T_9) (6.65 and 6.68 cm, respectively) (Table 28).

4.4.11.3. Number of seeds pod^{-1}

Data presented in Table 4.4.11 revealed that significant variations were observed among different mungbean varieties in case of seed number pod^{-1}. However, the maximum seed (11.20 pod^{-1}) was observed in BARI Mung-7 (T_8) and the minimum seed number (9.97 pod^{-1}) was found in Barishal local (T_{11}) variety. In other varieties i.e., BU mug 2 (T_2), Binamoog-6 (T_5), BU mug 1 (T_1), BARI Mung-6 (T_7), Binamoog-8 (T_6), BU mug 5 (T_4), BU mug 4 (T_3), BARI Mung-8 (T_9) and BARI Mung-2 (T_2), the seed number pod^{-1} (10.97, 10.87, 10.83, 10.53, 10.36, 10.27, 10.23, 10.21 and 10.13, respectively) was recorded (Table 28).

4.4.11.4. 1000 Seed weight (g)

Significant variations were observed among different mungbean varieties in case of 1000 seed weight. The highest 1000 seed weight (48.26 g) was observed in BARI Mung-7 (T_8). This was followed by BU mug 2 (T_2), Binamoog-6 (T_5) and BU mug 1 (T_1), in which 1000 seed weight (47.66 g, 47.33 g and 46.33 g, respectively) was observed. Intermediate level of 1000 seed weight (45.81 g, 44.44 g, 43.55 g and 42.70 g) was observed in BARI Mung-6 (T_7), Binamoog-8 (T_6), BU mug 5 (T_4) and BU mug 4 (T_3), respectively. On the contrary, the lowest 1000 seed weight (26.45 g) was observed in Barishal local (T_{11}) variety. This was followed by BARI Mung-2 (T_{10}) and BARI Mung-8 (T_9) (29.69 g and 31.09 g, respectively) (Table 28).

4.4.11.5. Yield (kg ha^{-1})

The data illustrated in Table 28 revealed that significant variations were observed among different mungbean varieties in case of yield (kg ha^{-1}). The highest yield (1323.44 kg ha^{-1}) was observed in BARI Mung-7 (T_8). This was followed by BU mug 2 (T_2), Binamoog-6 (T_5) and BU mug 1 (T_1), in which the yield (1308.66, 1287.61 and 1264.07 kg ha^{-1}, respectively) was observed. Intermediate level of yield (1203.99, 1187.06, 1165.51, 1124.87 and 1105.47 kg ha^{-1}) was observed in BARI Mung-6 (T_7), Binamoog-8 (T_6), BARI Mung-8 (T_9), BU mug 5 (T_4) and BU mug 4 (T_3), respectively. On the contrary, the lowest yield (754.89 kg ha^{-1}) was observed in Barishal local (T_{11}) variety. This was followed by BARI Mung-2 (T_{10}) (982.74 kg ha^{-1}).

Table 28. Effect of thrips incidence on yield contributing characters and yield of eleven mungbean varieties

Treatment	Number of pod plant^{-1}	Pod length (cm)	Number of seed pod^{-1}	1000 seed weight (g)	Yield (kg ha^{-1})
T$_1$	23.78 bcd	7.64 b	10.83 ab	46.33 abc	1264.07 b
T$_2$	26.34 ab	7.93 b	10.97 ab	47.66 ab	1308.66 ab
T$_3$	20.67 e	7.22 bcd	10.23 ab	42.70 d	1105.47 e
T$_4$	21.11 e	7.31 bc	10.27 ab	43.55 d	1124.87 de
T$_5$	24.32 abc	7.90 b	10.87 ab	47.33 ab	1287.61 ab
T$_6$	21.45 de	7.34 bc	10.37 ab	44.44 cd	1187.06 c
T$_7$	22.34 cde	7.59 b	10.53 ab	45.81 bc	1203.99 c
T$_8$	26.77 a	8.84 a	11.20 a	48.26 a	1323.44 a
T$_9$	25.66 ab	6.68 cd	10.21 ab	31.09 e	1165.51 cd
T$_{10}$	17.78 f	6.65 cd	10.13 ab	29.69 e	982.74 f
T$_{11}$	16.34 f	6.42 d	9.97 b	26.45 f	754.89 g
S$\bar{x}$	0.84	0.26	0.32	0.71	14.81
CV (%)	2.41	6.01	5.29	2.10	2.22

 In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = BU mug 1, T$_2$ = BU mug 2, T$_3$ = BU mug 4, T$_4$ = BU mug 5, T$_5$ = Binamoog-6, T$_6$ = Binamoog-8, T$_7$ = BARI Mung-6, T$_8$ = BARI Mung-7, T$_9$ = BARI Mung-8, T$_{10}$ = BARI Mung-2 (Kanti) and T$_{11}$ = Barishal local].

From the above findings, it was revealed that though the maximum pod number was recorded in BARI Mung-7 (T$_8$), BU mug 2 (T$_2$), BARI Mung-8 (T$_9$) and Binamoog-6 (T$_5$) varieties, respectively, the yield was found higher in BARI Mung-7 (T$_8$), BU mug 2 (T$_2$), Binamoog-6 (T$_5$) and BU mug 1 (T$_1$) varieties, respectively. The variations were found due to variations in thrips incidence and other yield contributing characters i.e., pod number, 1000 seed weight etc. The order of varietal performance in respect of yield was BARI Mung-7 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI Mung-6 > Binamoog-8 > BARI Mung-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local. Other authors also more or less supported the

present findings. Ali (2008) screened ten mungbean varieties against whitefly and found that the maximum yield (968.0 kg ha^{-1}) was recorded in BU mug 1 followed by BU mug 2 (892.3 kg ha^{-1}) , BARI Mung-6 (807.3 kg ha^{-1}), BARI Mung-5 (719.0 kg ha^{-1}), Binamoog-5 (625.3 kg ha^{-1}) while lowest yield (414.3 kg ha^{-1}) was found in Barishal local variety followed by BARI Mung-2 (536.7 kg ha^{-1}) in Gazipur district during Kharif-1. The yield of same varieties varied in other districts i.e. in Jessore and Barishal. Maximum yield of same varieties was observed in Jessore and then Barishal district. In Jessore highest yield was recorded in BU mug 1 (1960 kg ha^{-1}) whereas, the lowest yield was observed in Barishal local (1160 kg ha^{-1}), respectively. The yield varied due to many reasons i.e., the varieties, sowing time, location, weather factors, pest incidence, management etc.

4.5 Experiment 5: Performance of different Colored Sticky Board Traps against Mungbean Thrips

A field trial was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from 4 April to 26 June, 2017 (Kharif-1) to evaluate the color preference by thrips so as to evolve a more attractive color which can be used as effective sticky traps under mungbean ecosystem. Six color sticky board traps (blue, white, yellow, violet, pink and orange) were evaluated with an untreated control treatment and the number of trapped thrips was recorded in windward direction throughout the cropping period. The results of the present study that was carried out regarding the color preference of thrips and their effect on mungbean production have been discussed with interpretations and furnished under the following sub headings:-

4.5.1. Population of adult thrips and percent incidence of *M. usitatus* and *T. palmi* captured by different colored sticky board traps in mungbean field

The mean number of adult thrips captured per color sticky trap varied significantly among the tested color traps (Table 29). The highest mean number of adult *M. usitatus* (9.23) and *T. palmi* (3.88) with cumulative mean number (13.11) of both the thrips species was caught on blue sticky board trap which was followed by violet and orange sticky board traps where mean number of adult *M. usitatus* (6.66 and 6.22 trap^{-1}, respectively) and *T. palmi* (3.22 and 2.66 trap^{-1}, respectively) with cumulative mean number (9.88 and 8.88 trap^{-1}, respectively) of both the adult thrips species was recorded. In white and yellow sticky board traps intermediate level of adult *M. usitatus* (5.56 and 6.22 trap^{-1}, respectively) and *T. palmi* (2.67 and 1.77 trap^{-1}, respectively) was caught with cumulative mean number (8.23 and 7.99 trap^{-1}, respectively) of both the thrips species was recorded. The lowest number of thrips was caught on pink sticky board trap where mean number of adult *M. usitatus* (4.01 trap^{-1}) and *T. palmi* (1.11 trap^{-1}) with cumulative mean number (5.12 trap^{-1}) of both the thrips species was found. Between the two species, comparatively the percent incidence of *M. usitatus* captured per color sticky board trap was found higher in all the traps than *T. palmi* (Table 4.5.1). On blue color sticky board trap, percent incidence of *M. usitatus* and *T. palmi* 70.35% and 29.65%, respectively, whereas, on pink color sticky board trap 78.23% and 21.77%, respectively was found.

Table 29. Mean number of adult *M. usitatus* and *T. palmi* captured by different colored sticky board traps in mungbean field

Treatment	Mean no. of adult thrips captured color sticky board trap[-1]		Cumulative mean no. of two thrips species captured color sticky board trap[-1]	Comparative incidence of *M. usitatus* and *T. palmi* captured color sticky board trap[-1]	
	M. usitatus	*T. palmi*		*M. usitatus* (%)	*T. palmi* (%)
T$_1$ (Blue)	9.23 a	3.88 a	13.11 a	70.35 b	29.65 b
T$_2$ (White)	5.56 c	2.67 c	8.23 cd	67.52 c	32.48 a
T$_3$ (Yellow)	6.22 bc	1.77 d	7.99 d	77.81 a	22.19 c
T$_4$ (Violet)	6.66 b	3.22 b	9.88 b	67.38 c	32.62 a
T$_5$ (Pink)	4.01 d	1.11 e	5.12 e	78.23 a	21.77 c
T$_6$ (Orange)	6.22 bc	2.66 c	8.88 c	70.00 b	30.00 b
T$_7$ (Control)	0.00 e	0.00 f	0.00 f	0.00 d	0.00 d
S$\bar{x}$	**0.23**	**0.06**	**0.23**	**0.82**	**0.82**
CV (%)	**7.26**	**4.71**	**5.22**	**2.31**	**5.91**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings, it was revealed that the maximum number of adult thrips was captured by blue sticky board trap. Overall, the order of thrips number caught on colored sticky board traps was blue > violet > orange > white > yellow > pink. The results confirm the reported findings of other researchers that blue sticky traps are more effective against *M. usitatus* and *T. palmi*. Tang *et al.* (2016) reported that more *M. usitatus* was caught by blue, light blue, white and purple traps than by yellow, green, pink, gray, red, or black traps in cowpea ecosystem. Kaas (2005) stated that different hues of colors, possibility of trap materials, reflectance and other factors next to color as recorded by the human eye could be playing some part in the effect which colored sticky traps exhibit. Vernon and Gillespie (1990) found that *F. occidentalis* alighted preferentially on traps of bright blue, violet, yellow and purple, whereas green, orange and UV reflecting white hues were not attractive. They suggested that flower thrips have three photoreceptors tuned to 350 to 360 nm in UV, 440 to 450 nm in blue and 540 to 570 nm in the yellow wavelength. If assumed to have the same type

of photoreceptors in the present thrips species, it would help to explain their preference to blue, violet, orange, over the colors such as white, yellow, pink. Other authors also found blue sticky trap more effective on thrips (Elimem *et al.* 2014; Harbi *et al.* 2013; Covaci *et al.* 2012; Muvea 2011). Background colors of traps can also increase or decrease the attractiveness of a trap depending on trap color and thrips species (Czencz 1987).

The response of the thrips species to the different colors may be explained by their feeding site preference and their adaptation could have resulted in differences in their visual system. Although both of *M. usitatus* and *T. palmi* are polyphagous species, and both could feed on leaves and pollen as well, they may have a preference towards inflorescence than vegetative parts of mungbean plants. Mungbean leaves are light green or dark green and flowers are usually pale yellow mingled with violet and/or purple; thus, blue and violet traps were more attractive to *M. usitatus* and *T. palmi* than other colored traps.

4.5.2 Population dynamics of thrips captured by different colored sticky board traps

Figure 29 showed that the colors used in the study significantly affected catches of thrips. Mean number of thrips captured by blue sticky board trap was significantly greater than by all the other color sticky board traps. Blue was the most attractive color followed by violet and orange than white, yellow and pink. Thrips captured by color sticky board traps gradually increased from 25 DAS till 39 DAS. After 39 DAS thrips number caught on color sticky board traps started to decline till 46 DAS may be due to rainfall (15.86 mm) during that period (Appendix II). Peak incidence of thrips caught on color sticky board traps was observed on 53 DAS. Presence of flowers in that stage of mungbean crop and lower rainfall (0.29 mm) may facilitated thrips population build up and attractive to colored board traps. Further, decrease in thrips captured by colored sticky board traps appeared till 60 DAS may be due to rainfall (8.00 mm) throughout the week (Appendix II). However, thrips captured by colored sticky board traps again started to increase till 67 DAS and the number of captured thrips by colored sticky board traps was attained near about maximum may be due to low rainfall (0.86 mm) during that period and thrips present in flowers attracted and fly to color traps easily. Then again thrips captured by colored sticky board traps declined till 81 DAS may be due to heavy rainfall throughout the week that washed

off thrips causing a decline in population density (North and Shelton 1986), the flowers availability was also lower during the last stage of the crop. The Rainfall data during the cropping period is documented in Appendix II.
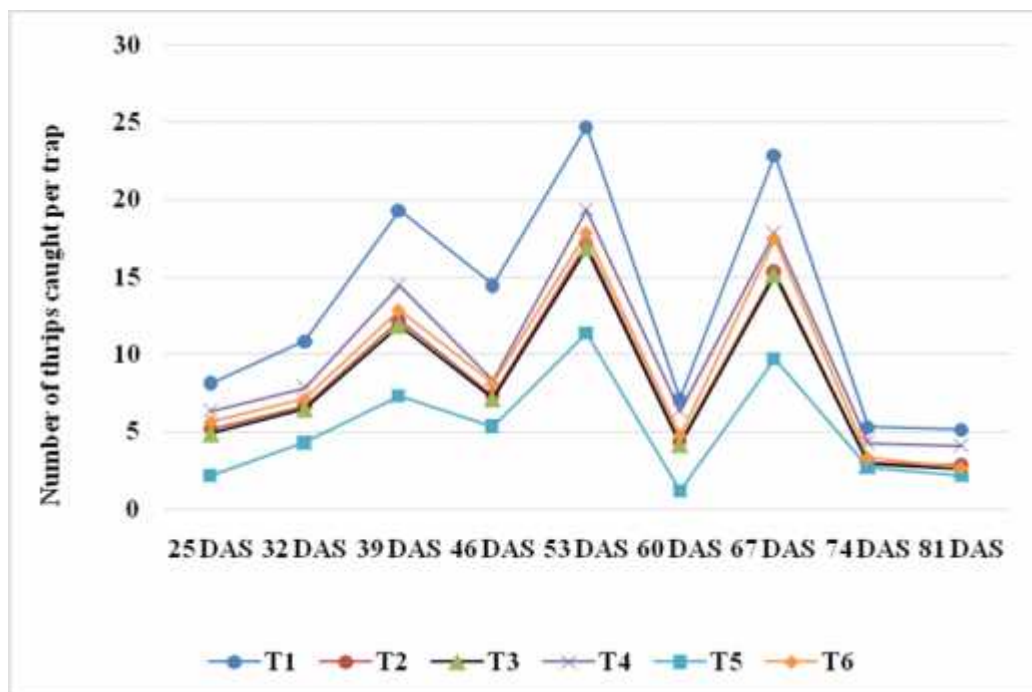
[T_1 = Blue trap, T_2 = White trap, T_3 = Yellow trap, T_4 = Violet trap, T_5 = Pink trap, T_6 = Orange trap].

Figure 29. Population dynamics of adult thrips captured on different colored sticky board traps in mungbean field.

From the above results, it was clearly revealed that thrips infestation of mungbean starts before flowering (Figure 29). At this stage of crop development, the thrips can only forage on the vegetative plant parts i.e., young leaves and terminal shoots. Thrips likes to hinder in terminal shoots. As insect always has the innate characteristics to get attracted to colors, so this innate character was mainly used here for mass trapping under field condition using color traps. This could be the reason of trapping adult thrips before flowering stage of the crop. The thrips population gradually increased with increase of plant age from vegetative to flowering stage. So, the captured number of thrips by traps varied due to plant growth stage and preferences of its feeding and oviposition sources.   As adults are known to prefer flowers (Kirk 1997), they probably lay their eggs and then fly to flowering plants. Peak thrips trapping coincided with peak flowering, when thrips are expected in large numbers. Bean flower thrips usually prefer flowers than vegetation. Rainfall was also an important factor to inhibit flight of thrips to attractive colored traps. Most researchers therefore,

165

concentrate on the trapped pests on the colored sticky traps rather than the impact on population dynamics of the pests. This study indicated that, for the suppression of thrips, colored traps would be useful to monitor thrips on mungbean plants. Tang *et al.* (2016) reported that the blue stickt trap caught more *M. usitatus* but yellow sticky trap only caught a small number of thrips throughout the study period. Kasina *et al.* (2009) reported that early crop infestation may create a pool of thrips that can readily migrate to flowers. Peak thrips trapping coincided with peak flowering, when thrips are expected in large numbers. Nagaraju (2008) reported that the differences in weekly catches of thrips per color trap was influenced by the age of the crop. The trap caught (6.9 thrips per trap) started from 29th standard week i.e., 15 DAS and increased during 30th standard week (17.1 thrips per trap). However, thrips caught by traps declined during 31st standard week coinciding with heavy rainfall (126 mm) during the week. Further increasing in thrips number caught by colored traps appeared subsequently with advance in the age of the crop upto 35th standard week and there after, the catches declined gradually. The percentage of *T. palmi* attracted towards a particular colour trap (pink trap) in *kharif*, 2007 indicated that thrips had strong colour preference. The data also showed that irrespective of the trap colour the peak build up of *T. palmi* was coincided with the six weeks age of the crop, which in turn coincided with the beginning of the flowering period. This means the level of intensity might vary seasonally, but the peak occurrence happens always with the onset of flowering.

4.5.3 Thrips population on top trifoliate leaves of mungbean as influenced by colored sticky board traps

Thrips population found in mungbean ecosystem included *M. usitatus* and *T. palmi* (Table 30). The significant differences were observed among different treatments used in this study in terms of mean population of thrips and percent incidence of *M. usitatus* and *T. palmi* population present on top trifoliate leaves at pre-flowering stage of mungbean. The lowest mean number of *M. usitatus* (2.23) and *T. palmi* (1.64) with cumulative mean number of both the thrips species 3.87 per 5 top trifoliate leaves was observed in blue color sticky board trapped plots which was followed by violet color sticky board trapped plots where mean number of *M. usitatus* and *T. palmi* was 2.87 and 2.26, respectively with cumulative mean number of both the thrips species 5.13 per 5 top trifoliate leaves. Next to violet trapped plots, mean number of *M. usitatus*

(3.07) and *T. palmi* (2.71) with cumulative mean number of both the thrips species 5.78 per 5 top trifoliate leaves was observed in orange color trapped plots. In white and yellow color sticky board trapped plots intermediate level of *M. usitatus* (3.67 and 3.87, respectively)) and *T. palmi* (2.64 and 3.00, respectively) with cumulative mean number (6.31 and 6.87, respectively) of both the thrips population was observed. The highest mean number of *M. usitatus* (5.13) and *T. palmi* (3.74) with cumulative mean number (8.87) of both the thrips species per 5 top trifoliate leaves was observed in untreated control plots which was followed by pink color sticky board trapped plots where mean number of *M. usitatus* and *T. palmi* (4.67 and 2.45, respectively) was observed with cumulative mean number of both the thrips species 7.12 per 5 top trifoliate leaves. Blue sticky board trap reduced maximum i.e., 56.40% *M. usitatus* and 56.27% *T. palmi* population on top trifoliate leaves. Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 top trifoliate leaves in all the treatments. In blue trapped plots the occurrence of *M. usitatus* and *T. palmi* was 57.63% and 42.37%, respectively per 5 top trifoliate leaves whereas, in pink color sticky board trapped plots, the occurrence of *M. usitatus* and *T. palmi* was 65.53% and 34.47%, respectively per 5 top trifoliate leaves (Table 30).

Table 30. Mean number of *M. usitatus* and *T. palmi* on top trifoliate leaves at pre-flowering stage of mungbean

Treatment	Mean number of *M. usitatus* and *T. palmi* per 5 top trifoliate leaves and reduction of population over untreated control				Cumulative mean no. of two thrips species per 5 top trifoliate leaves	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 5 top trifoliate leaves	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T₁ (Blue)	2.23 d	56.40 a	1.64 d	56.27 a	3.87 e	56.30 a	57.63 b	42.37 a
T₂ (White)	3.67 b	27.83 c	2.64 bc	28.86 c	6.31 bc	28.42 cd	58.13 b	41.87 a
T₃ (Yellow)	3.87 b	24.30 c	3.00 b	19.05 d	6.87 b	22.14 de	56.35 b	43.65 a
T₄ (Violet)	2.87 c	43.58 b	2.26 c	39.46 b	5.13 d	41.82 b	55.95 b	44.05 a
T₅ (Pink)	4.67 a	9.03 d	2.45 c	34.52 bc	7.12 b	19.76 e	65.53 a	34.47 b
T₆ (Orange)	3.07 c	39.64 b	2.71 bc	27.38 cd	5.78 cd	34.66 bc	53.12 b	46.88 a
T₇ (Control)	5.13 a	-	3.74 a	-	8.87 a	-	57.80 b	42.20 a
Sx̄	0.19	2.94	0.14	2.73	0.26	2.38	1.72	1.72
CV (%)	8.88	15.23	9.39	13.82	7.23	12.15	5.15	7.04

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the lowest number of *M. usitatus* and *T. palmi* with cumulative mean population of both the thrips species per five top trifoliate leaves was observed in blue color sticky board trapped plots followed by violet and orange trapped plots. In white and yellow color sticky board trapped plots, mean population of thrips of both the species was in intermediate level. On the other hand, the highest number of *M. usitatus* and *T. palmi* with cumulative mean population of thrips per five top trifoliate leaves was observed in untreated control plots followed by pink color trapped plots. Blue sticky trap reduced maximum thrips population. The percent incidence of *M. usitatus* was higher than *T. palmi* per 5 top trifoliate leaves in all the treatments. Thrips was found on top trifoliate leaves during vegetative stage as thrips preferred to suck juices or chlorophyll contents from lush green young leaves. Both *M. usitatus* and *T. palmi* occurs in mungbean before pre-flowering stage of the crop, when plant was light green or dark green in color. In the present study, blue and violet sticky color boards were comparatively dark in color than other color boards used as traps. Colour preference of different Thysanoptera species has been investigated in several studies in different crops. Prema *et al*. (2018) reported that thrips catches were high on yellow trap followed by blue trap during the vegetative stage of the cotton crop. Performance of coloured traps with regard to thrips catches was in the order of yellow > blue > white > green > red. Roth (2016) reported that the host-plant type could significantly influence the response of some Thysanoptera species to colours. It was also shown that differences in the shades of the same colour and the interaction between thrips and their host plants, may account for differences in color preference for a given thrips species in different experiments (Brødsgaard, 1989). Western flower thrips possess either trichromatic vision with peak spectral sensitivities in the greenish-yellow (540-570 nm), bluish-green (440-450 nm) and also in the UV-A region (350-360 nm), or dichromatic vision with peak sensitivities in the greenish-yellow (540570 nm) and in the UV-A region (350-360 nm) and blue colour is perceived through the simultaneous excitation of both receptors, as suggested by Matteson *et al.* (1992).

4.5.4 Thrips population on terminal shoots of mungbean as influenced by different colored sticky board traps

Significant variations were observed among different treatments used in this study in terms of mean number of thrips and percent incidence of *M. usitatus* and *T. palmi* population present on terminal shoot at pre-flowering stage of mungbean. Data presented in Table 31 clearly revealed that the lowest mean number of *M. usitatus* and *T. palmi* (2.50 and 1.50, respectively) with cumulative mean number of both the thrips species (4.00) per 5 terminal shoots was found in blue color sticky board trapped plots. This was followed by violet sticky board trapped plots where the mean number of *M. usitatus* and *T. palmi* was 3.10 and 2.43, respectively with cumulative mean number of both the thrips species 5.53 per 5 terminal shoots. This was followed by orange color sticky board trapped plots, where mean number of *M. usitatus* (3.07) and *T. palmi* (2.53) with cumulative mean number (5.60) of both the thrips species per 5 terminal shoots was observed which was statistically identical with violet trapped plots. On the contrary, the highest mean number of *M. usitatus* (5.57) and *T. palmi* (3.57) with cumulative mean number (9.13) of both the thrips species per 5 terminal shoots was found in untreated control plots which was followed by pink, yellow and white color sticky board trapped plots where the mean number of *M. usitatus* (4.10, 4.10 and 3.57, respectively) and *T. palmi* (3.10, 3.07 and 3.10, respectively) with cumulative mean number of both the thrips species was 7.20, 7.17 and 6.67, respectively per 5 terminal shoots of mungbean. Blue sticky board trap reduced maximum i.e., 54.94% *M. usitatus* and 57.81% *T. palmi* population on terminal shoot of mungbean. Between the two species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 terminal shoots in all the treatments. In blue color sticky board trapped plots, the occurrence of *M. usitatus* and *T. palmi* was 62.53% and 37.47%, respectively whereas, in pink trapped plots the occurrence of *M. usitatus* and *T. palmi* was 56.99% and 43.01%, respectively per 5 terminal shoots (Table 31).

Table 31. Mean number of *M. usitatus* and *T. palmi* on terminal shoots at pre-flowering stage of mungbean

Treatment	Mean number of *M. usitatus* and *T. palmi* per 5 terminal shoots and reduction of population over untreated control				Cumulative mean no. of two thrips species per 5 terminal shoots	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 5 terminal shoots	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T₁ (Blue)	2.50 b	54.94 a	1.50 d	57.81 a	4.00 d	56.06 a	62.53 a	37.47 c
T₂ (White)	3.57 b	35.93 c	3.10 ab	13.07 c	6.67 b	27.00 c	53.49 c	46.51 a
T₃ (Yellow)	4.10 ab	25.64 d	3.07 ab	13.20 c	7.17 b	20.79 c	57.22 bc	42.78 ab
T₄ (Violet)	3.10 b	44.16 b	2.43 c	30.85 b	5.53 c	38.96 b	56.01 c	43.99 a
T₅ (Pink)	4.10 ab	26.34 d	3.10 ab	12.34 c	7.20 b	20.87 c	56.99 bc	43.01 ab
T₆ (Orange)	3.07 b	44.75 b	2.53 bc	28.80 b	5.60 c	38.53 b	54.84 c	45.16 a
T₇ (Control)	5.57 a	-	3.57 a	-	9.13 a	-	60.95 ab	39.05 bc
S$\bar{\text{x}}$	0.54	2.33	0.19	1.83	0.32	2.28	1.45	1.45
CV (%)	8.03	10.43	12.16	12.16	8.55	11.69	4.36	5.88

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the lowest number of both the thrips species i.e., *M. usitatus* and *T. palmi* per 5 terminal shoots was found in blue color sticky board trapped plots followed by violet and orange trapped plots. The highest number of *M. usitatus* and *T. palmi* population per 5 terminal shoots was found in untreated mungbean plots followed by pink, yellow and white color sticky board trapped plots. Blue sticky trap reduced maximum *M. usitatus* and *T. palmi* thrips population on terminal shoot. Thrips are very cryptic in nature and has the innate characteristic to get attracted to colors. This innate character was mainly used here for mass trapping of thrips under field condition using colored sticky traps. Though thrips feed and oviposit on young leaves, they also likes to hinder in terminal shoots and feed on there during vegetative stage. Babu *et al.* (2004) recorded significantly higher number of *T. palmi* population on mungbean in all the cropping season than other species of Thysanoptera captured included *F. schultzei* (Trybom), *S. dorsalis* (Hood), *M. distalis* (Bagnall) which is contradictory to the present study. In all color traps, like yellow, blue and green sticky traps, the maximum number of *T. palmi* occurred in kharif, followed by rabi and summer seasons.

4.5.5. Thrips population on flower buds of mungbean as influenced by different colored sticky board traps

The data presented in Table 32 clearly revealed that the population of thrips per 5 flower buds varied significantly among different treatments used in this study. The lowest mean number of *M. usitatus* and *T. palmi* (4.13 and 2.20, respectively) with cumulative mean number (6.33) of both the thrips species per 5 flower buds was found in blue color sticky board trapped plots which was followed by violet color sticky board trapped plots where mean number of *M. usitatus* and *T. palmi* (4.21 and 2.44, respectively) was observed with cumulative mean number (6.65) of both the thrips species per 5 flower buds. Next to violet trapped plots, mean number of *M. usitatus* (4.33) and *T. palmi* (2.72) with cumulative mean number (7.05) of both the thrips species per 5 flower buds was observed in orange color sticky board trapped plots. In white color sticky board trapped plots, intermediate number of cumulative mean population (7.98) of thrips was found per 5 flower buds. On the contrary, the highest mean number of *M. usitatus* and *T. palmi* (7.18 and 4.21, respectively) with cumulative mean number (11.39) of both the thrips species per 5 flower buds was recorded in untreated control plot which was followed by pink color sticky board trapped plot where mean number of *M. usitatus* and *T. palmi* (5.46 and 3.98, respectively) was observed with cumulative mean number (9.44) of both the thrips species per 5 flower buds. Blue sticky board trap reduced maximum i.e., 42.23% *M. usitatus* and 47.71% *T. palmi* population on flower bud of mungbean. Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flower buds in all the treatments. In blue color sticky board trapped plots, the incidence of *M. usitatus* and *T. palmi* was 65.24% and 34.76%, respectively whereas, in pink color sticky board trapped plots, the incidence of *M. usitatus* and *T. palmi* was 57.87% and 42.13%, respectively per 5 flower buds (Table 32).

Table 32. Mean number of *M. usitatus* and *T. palmi* on flower buds at flowering stage of mungbean

Treatment	Mean number of *M. usitatus* and *T. palmi* per 5 flower buds and reduction of population over untreated control				Cumulative mean no. of two thrips species per 5 flower buds	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 5 flower buds	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T₁ (Blue)	4.13 e	42.23 a	2.20 d	47.71 a	6.33 e	44.37 a	65.24 a	34.76 c
T₂ (White)	4.71 cd	34.41 bc	3.27 b	22.93 c	7.98 c	29.95 c	59.04 cd	40.96 ab
T₃ (Yellow)	5.04 bc	29.46 cd	3.82 a	8.88 d	8.86 b	22.13 d	56.89 d	43.11 a
T₄ (Violet)	4.21 de	41.25 ab	2.44 cd	42.21 a	6.65 de	41.61 ab	63.38 ab	36.62 bc
T₅ (Pink)	5.46 b	23.63 d	3.98 a	5.25 d	9.44 b	17.00 e	57.87 cd	42.13 a
T₆ (Orange)	4.33 de	39.58 ab	2.72 c	35.31 b	7.05 d	38.14 b	61.43 bc	38.57 abc
T₇ (Control)	7.18 a	-	4.21 a	-	11.39 a	-	63.00 ab	37 bc
Sx̄	0.17	2.11	0.15	1.80	0.21	1.50	1.18	1.46
CV (%)	5.76	10.40	8.31	11.53	4.37	8.07	4.14	6.48

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings, it was revealed that the lowest mean population of thrips per five flower buds was observed in blue color board trapped plot followed by violet and orange color sticky board trapped plots. In white color sticky board trapped plots, intermediate population of thrips of both the species was observed. On the other hand, the highest mean population of thrips per five flower buds was observed in untreated control plot followed by pink and yellow sticky board trapped plots. Blue sticky board trap reduced maximum *M. usitatus* and *T. palmi* population on flower bud of mungbean. The percent incidence of *M. usitatus* was higher than *T. palmi* per five flower buds in all the treatments. Thrips is associated mostly with the damage of tender buds and flowers of mungbean (Lal, 1985). When inflorescence initiation starts in mungbean, mostly adult thrips start to migrate to inflorescence and feed and oviposit there. So, during that period different colored sticky board traps were effective for monitoring or mass trapping of thrips.

4.5.6. Thrips population in flowers of mungbean as influenced by different colored sticky board traps

The population of thrips per 5 flowers varied significantly influenced by different colored sticky board traps at flowering stage of mungbean (Table 33). The lowest mean number of *M. usitatus* and *T. palmi* (3.23 and 1.24), respectively with cumulative mean number (4.47) of both the thrips species per 5 flowers was observed in blue color sticky board trapped plots which was followed by violet color trapped plots where mean number of *M. usitatus* and *T. palmi* (5.81 and 2.48, respectively) with cumulative mean number (8.29) of both the thrips species per 5 flowers was recorded. Next to violet, the mean number of *M. usitatus* and *T. palmi* (6.31 and 2.78, respectively) with cumulative mean number (9.09) of both the thrips species per 5 flowers was recorded in orange color sticky board trapped plot. Intermediate number (10.28) of cumuilative mean population of both the thrips species was observed in white trapped plot. On the other hand, the highest number of *M. usitatus* (9.02) and *T. palmi* (5.20) with cumulative mean number (14.22) of both the thrips species per 5 flowers was observed in untreated control plot which was followed by pink color sticky board trapped plot where mean number of *M. usitatus* and *T. palmi* was 8.43 and 4.89, respectively with cumulative mean number (13.33) of both the thrips species per 5 flowers. Blue sticky board trap reduced maximum i.e., 64.19% *M. usitatus* and 76.12% *T. palmi* population on flowers of mungbean. Between the two species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 5 flowers in all the treatments. In blue color sticky board trapped plot the incidence of *M. usitatus* and *T. palmi* was 72.26% and 27.74%, respectively whereas, in pink trapped plot the incidence of *M. usitatus* and *T. palmi* was 63.21% and 36.79%, respectively per 5 flowers.

Table 33. Mean number of *M. usitatus* and *T. palmi* in flowers at flowering stage of mungbean

Treatment	Mean number of *M. usitatus* and *T. palmi* per 5 flowers and reduction of population over untreated control				Cumulative mean no. of two thrips species per 5 flowers	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* in 5 flowers	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T$_1$ (Blue)	3.23 d	64.19 a	1.24 e	76.12 a	4.47 g	68.59 a	72.26 a	27.74 b
T$_2$ (White)	6.51 c	27.79 c	3.77 c	27.43 c	10.28 d	27.68 c	63.33 b	36.67 a
T$_3$ (Yellow)	7.72 b	14.28 d	4.44 b	14.08 d	12.16 c	14.51 d	63.46 b	36.54 a
T$_4$ (Violet)	5.81 c	35.60 b	2.48 d	52.08 b	8.29 f	41.67 b	70.08 a	29.92 b
T$_5$ (Pink)	8.43 ab	6.54 e	4.89 ab	5.77 e	13.33 b	6.31 e	63.21 b	36.79 a
T$_6$ (Orange)	6.31 c	29.86 bc	2.78 d	46.32 b	9.09 e	36.02 b	69.41 a	30.59 b
T$_7$ (Control)	9.02 a	-	5.20 a	-	14.22 a	-	63.44 b	36.56 a
S$\bar{x}$	0.29	2.25	0.18	1.99	0.25	1.83	1.67	1.67
CV (%)	7.44	13.13	8.93	9.31	4.20	9.77	4.32	8.57

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the lowest mean population of *M. usitatus* and *T. palmi* per five flowers was observed in blue color sticky board trapped plot followed by violet and orange colored sticky board trapped plots. In white trapped plot, intermediate population of both the thrips species per five flowers was observed. On the other hand, the highest mean population of thrips per five flowers was observed in untreated control plot followed by pink and yellow color sticky board trapped plots. Blue sticky board trap reduced maximum *M. usitatus* and *T. palmi* population on flowers of mungbean. Comparatively, the percent incidence of *M. usitatus* was higher than *T. palmi* per five flowers in all the treatments. Other authors more or less supported the present findings of the study. Roth *et al.* (2016) reported that the flowers of cross-pollinated plants attractive for insects often have blue, violet and yellow colour in the nature. The whole area of the petals in these flowers often looks homogenous for the human eye, but their UV reflection is usually different on the internal and external area of the petal. Sticky colored traps are suitable tools to understand the preference of a given thrips species to different colors and to study the response of insects to visual stimulus since they exclude the effect of other stimuli (biochemical, physiological, etc.), which may also modify insect behavior.

4.5.7 Effect of different colored traps on top trifoliate leaves and terminal shoots infestation by thrips at pre-flowering stage of mungbean

Different colored sticky board traps caused significant (p<0.05) reduction of mungbean top trifoliate leaves infestation by thrips in comparison to untreated control (Table 34). The lowest number of infested top trifoliate leaves and terminal shoots (2.00 and 2.33) per 5 top trifoliate leaves and 5 terminal shoots respectively, lowest percent infestation of top trifoliate leaves and terminal shoots (40.00% and 46.67%, respectively,) were recorded in blue trapped mungbean plot, at par with violet color trapped mungbean plot and significantly different from remaining color trapped plots. Next to violet color sticky board trap, the lower number of infested top trifoliate leaves and terminal shoots (2.50 and 2.67) with (50.00% and 53.33%) percent infestation, respectively per 5 top trifoliate leaves and terminal shoots was observed in orange trapped mungbean plot. On the other hand, the highest number of infested top trifoliate leaves and terminal shoots (3.33 and 3.83, respectively) per 5 top trifoliate leaves and 5 terminal shoots with highest percent infestation (66.67% and 76.67%, respectively) of top trifoliate leaves and terminal shoots was recorded in untreated control plots, which was significantly different from other treatments and followed by pink trapped plots where the number of infested top trifoliate leaves and terminal shoots (3.00 and 3.33, respectively) with (60.00% and 66.67% infestation, respectively per 5 top trifoliate leaves and 5 terminal shoots was recorded in pink color sticky board trapped plots. This was followed by white and yellow color sticky board trapped mungbean plots where the mean number of infested top trifoliate leaves (2.83 and 2.83) per 5 top trifoliate leaves and infested terminal shoots (2.67 and 3.00) per 5 terminal shoot with (56.67% and 56.67%) infestation, respectively of top trifoliate leaves and (53.33% and 60.00%) infestation, respectively of terminal shoots were recorded. Blue sticky board trap reduced maximum top trifoliate leaves and terminal shoot infeatation (39.92% and 39.10%, respectively) by thrips which was statistically similar with violet color sticky board traps. On the other hand, pink sticky board trap reduced minimum top trifoliate leaves and terminal shoot infeatation (9.21% and 12.93%, respectively) by thrips.

Table 34. Top trifoliate leaves and terminal shoots infestation by thrips at pre-flowering stage of mungbean

Treatment	Per 5 top trifoliate leaves			Per 5 terminal shoots		
	Mean no. of infested top trifoliate leaves by thrips	% infestation of top trifoliate leaves by thrips	% reduction infestation of top trifoliate leaves	Mean no. of infested terminal shoot by thrips	% infestation of terminal shoot by thrips	% reduction infestation of terminal shoot
T$_1$ (Blue)	2.00 d	40.00 d	39.92 a	2.33 e	46.67 e	39.10 a
T$_2$ (White)	2.83 b	56.67 b	14.76 c	2.67 d	53.33 d	30.42 b
T$_3$ (Yellow)	2.83 b	56.67 b	14.60 c	3.00 c	60.00 c	21.54 c
T$_4$ (Violet)	2.00 d	40.00 d	39.92 a	2.33 e	46.67 e	39.10 a
T$_5$ (Pink)	3.00 b	60.00 b	9.21 d	3.33 b	66.67 b	12.93 d
T$_6$ (Orange)	2.50 c	50.00 c	24.76 b	2.67 d	53.33 d	30.44 b
T$_7$ (Control)	3.33 a	66.67 a	-	3.83 a	76.67 a	-
S$\overline{x}$	0.09	1.83	1.58	0.08	1.69	2.20
CV (%)	6.00	6.00	11.47	5.07	5.07	13.25

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings it was revealed that the highest percent infestation reduction of top trifoliate leaves and terminal shoots was recorded in blue color sticky board trapped plots followed by violet color trapped plots. The lowest percent infestation reduction of top trifoliate leaves and terminal shoot was observed in pink color sticky board trapped plots.

4.5.8. Effect of colored sticky traps on percent flower bud infestation and flower bud shedding by thrips of mungbean

Data in Table 35 revealed that there were significant variations in different colored sticky board trapped mungbean plots in case of flower bud infestation as well as shedding of flower bud by thrips. Among the different color sticky board traps, the highest number of total flower bud (49.87 plant^{-1}) and the lowest number of infested flower bud (8.67 plant^{-1}) with 17.37% flower bud infestation and 2.67% flower bud shedding were observed in blue color sticky board trapped plot which were followed by violet trapped plot where total number of flower bud (48.31 plant^{-1}), number of infested flower bud (10.86 plant^{-1}), percent flower bud infestation 22.49% and percent flower bud shedding 3.46% were found. Next to violet trapped plots, total number of flower bud (46.78 plant^{-1}), infested number of flower bud (13.31 plant^{-1}) with 28.44% percent flower bud infestation and percent flower bud 4.81% shedding were observed in orange trapped plots. Intermediate level of total flower bud (44.23 and 42.32 plant^{-1}) and infested flower bud (12.87 and 13.12 plant^{-1}) with (29.08% and 31.04%) percent flower bud infestation and (4.84% and 5.78%) percent flower bud shedding were recorded in white and yellow color sticky board trapped plots, respectively. On the other hand, the lowest number of flower bud (38.78 plant^{-1}) and highest percent flower bud infestation (34.86%) and percent flower bud shedding (6.68%) of flower were observed in control plot which were followed by pink trapped plot where total number of flower bud was (41.67 plant^{-1}) and percent flower bud infestation and percent flower bud shedding were 33.38% and 6.67%, respectively. Blue sticky board trap reduced maximum percent flower bud infeatation and percent flower bud shedding (50.18% and 60.11%, respectively) by thrips. On the other hand, pink sticky board trap reduced minimum percent flower bud infeatation and percent flower bud shedding (4.25% and 0.14%, respectively) by thrips.

Table 35. Flower bud infestation and shedding by thrips at flowering stage of mungbean

Treatments	Total no. of flower bud Plant^{-1}	No. of infested flower bud plant^{-1} by thrips	% flower bud infestation by thrips	% reduction of flower bud infestation	No. of shedding flower bud plant^{-1} by thrips	% flower bud shedding by thrips	% reduction of flower bud shedding
T$_1$ (Blue)	49.87 a	8.67 c	17.37 e	50.18 a	1.33 f	2.67 d	60.11 a
T$_2$ (White)	44.23 bc	12.87 a	29.08 bc	16.66 c	2.13 d	4.84 c	27.36 c
T$_3$ (Yellow)	42.32 cd	13.12 a	31.04 b	10.94 d	2.44 bc	5.78 b	13.42 d
T$_4$ (Violet)	48.31 a	10.86 b	22.49 d	35.49 b	1.67 e	3.46 d	48.19 b
T$_5$ (Pink)	41.67 cd	13.92 a	33.38 a	4.25 e	2.78 a	6.67 a	0.14 e
T$_6$ (Orange)	46.78 ab	13.31 a	28.44 c	18.47 c	2.25 cd	4.81 c	27.99 c
T$_7$ (Control)	38.78 d	13.52 a	34.89 a	-	2.58 ab	6.68 a	-
S$\bar{x}$	1.31	0.48	0.71	0.92	0.09	0.29	1.32
CV (%)	5.10	6.70	4.36	7.03	6.98	10.00	7.76

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings, it was revealed that the highest reduction of percent flower bud infestation and flower bud shedding was observed in blue color sticky board trapped plots followed by violet and orange trapped plots. Whereas, the lowest reduction of percent flower bud infestation and percent flower bud shedding was observed in pink colored sticky board trapped plots.

4.5.9. Effect of colored sticky board traps on percent flower infestation and flower shedding of mungbean by thrips

Significant variations were observed in different colored sticky board trapped mungbean plots in case of flower infestation as well as flower shedding by thrips (Table 36). Among the different colored sticky board traps, the highest number of total flower (15.22 plant^{-1}) and the lowest number of infested flower (4.88 plant^{-1}) were observed in blue colored sticky board trapped plot with 32.23% flower infestation and 8.57% flower shedding which were followed by violet and orange colored sticky board trapped plots where total number of flower was (14.33 and 13.67 plant^{-1}, respectively), number of infested flower was (5.13 and 5.67 plant^{-1}, respectively), percent flower infestation (35.80% and 41.60%) and percent flower shedding (10.02% and 11.26%), respectively were found. In white and yellow sticky board trapped plots intermediate level of total flower (13.13 and 12.77 plant^{-1}, respectively) and infested number of flower (6.13 and 6.57 plant^{-1}, respectively) with (46.69% and 51.46%, respectively) percent flower infestation and (12.05% and 12.88%, respectively) percent flower shedding was found. On the other hand, the lowest number of flower (10.22 plant^{-1}), number of infested flower (7.76 plant^{-1}), highest percent flower infestation (76.24%) and percent flower shedding (21.84%) were observed in control plot which was followed by pink sticky board trapped plot, where total number of flower (11.13 plant^{-1}), number of infested flower (6.88 plant^{-1}), percent flower infestation and percent flower shedding (62.12% and 18.96%, respectively) were observed (4.5.8). Blue sticky board trap reduced maximum percent flower infeatation and percent flower shedding (57.77% and 60.68%, respectively) by thrips which was statistically similar with violet sticky board trapped plots, where reduction of percent flower infeatation and percent flower shedding was (52.75% and 54.00%, respectively). On the other hand, pink sticky board trap reduced minimum flower infeatation and flower shedding (18.62% and 13.25%, respectively) by thrips.

Table 36. Flower infestation and shedding by thrips at flowering stage of mungbean

Treatments	Total no. of flower Plant^{-1}	No. of infested flower plant^{-1} by thrips	% flower infestation by thrips	% reduction of flower infestation	No. of shedding flower plant^{-1} by thrips	% flower shedding by thrips	% reduction of flower shedding
T$_1$ (Blue)	15.22 a	4.88 f	32.23 f	57.77 a	1.30 e	8.57 e	60.68 a
T$_2$ (White)	13.13 b	6.13 cd	46.69 cd	38.39 cd	1.58 c	12.05 c	44.66 c
T$_3$ (Yellow)	12.77 b	6.57 bc	51.46 c	32.13 d	1.64 c	12.88 c	40.87 c
T$_4$ (Violet)	14.33 ab	5.13 ef	35.80 ef	52.75 ab	1.43 d	10.02 de	54.00 ab
T$_5$ (Pink)	11.13 c	6.88 b	62.12 b	18.62 e	2.10 b	18.96 b	13.25 d
T$_6$ (Orange)	13.67 ab	5.67 de	41.60 de	44.92 bc	1.53 cd	11.26 cd	48.09 bc
T$_7$ (Control)	10.22 c	7.76 a	76.24 a	-	2.23 a	21.84 a	-
S$\bar{x}$	0.50	0.19	2.35	2.72	0.04	0.60	2.35
CV (%)	6.75	5.40	8.24	11.55	3.85	7.56	9.33

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings, it was revealed that the highest reduction of percent flower infestation and flower shedding was observed in blue sticky board trapped plot followed by violet and orange sticky board trapped plots. Whereas, the intermediate level of percent reduction of flower infestation and flower shedding was observed in white and yellow sticky boad trapped plots. The lowest reduction of percent flower infestation and flower shedding was observed in pink sticky board trapped plot.

4.5.10. Effect of different colored sticky board traps on incidence of adult thrips on top trifoliate leaves of mungbean

The colors used in the study significantly affected catches of thrips from top trifoliate leaves. Figure 30 showed that when blue color sticky board trap (T_1) captured maximum number of thrips, the incidence of thrips on top trifoliate leaves was lowest. In white (T_2) and yellow (T_3) trapped plots, the incidence of thrips increased because these color traps caught lower number of thrips than blue traps, but in violet (T_4) trapped plots, the incidence of thrips again declined because of more thrips caught on that trap. In pink (T_5) trapped plots, the incidence of thrips increased due to lower number of thrips was caught on this trap. In orange (T_6) trapped plots, the occurrence of thrips decreased but in control plots (T_7) its occurrence was maximum than all color trapped plots.
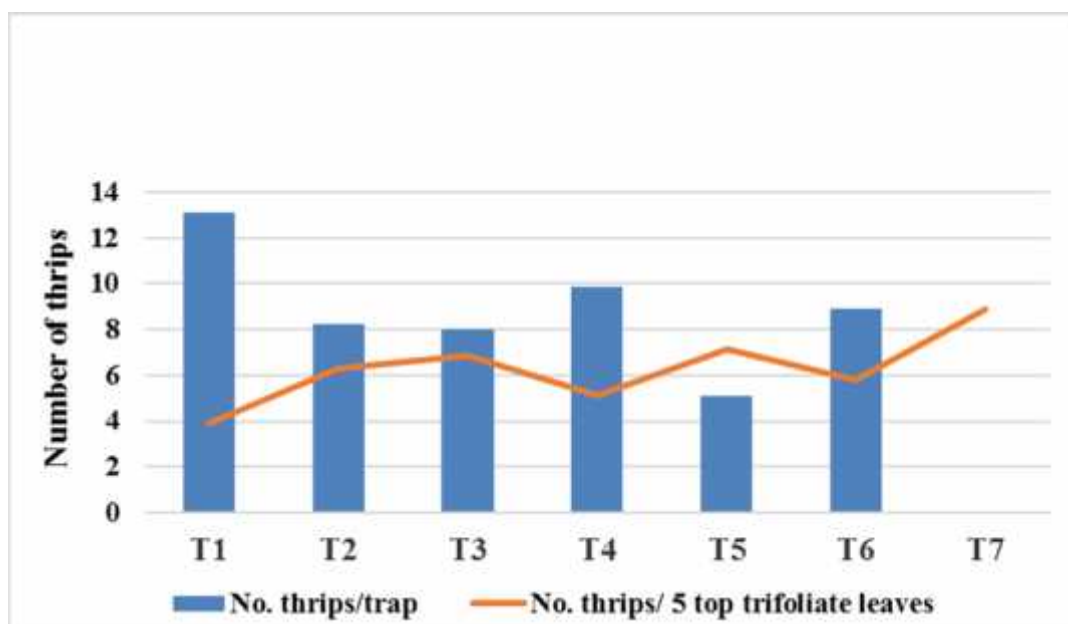
Figure 30. Effect of different colored sticky traps on incidence of adult thrips per 5 top trifoliate leaves.

From the above results it was revealed that the plots in which color traps had been mounted, the incidence of thrips was lower on top trifoliate leaves compared with the control plots. Among the tested color traps, the presence of blue color sticky board traps in the mungbean field resulted to the more reduction of thrips than violet, orange white, yellow or pink color sticky board traps. Muthuram *et al.* (2017) reported that green colour sticky boards were found effective in attracting *Thrips tabaci* in onion than yellow boards. Violet, orange and white sticky boards were found on par with each other which was contradictory to the present findings. Ranamukhaarachchi and Wickramarachchi (2007) reported that the significant correlation between cumulative thrips catches on color cards and level of infestation in the field support the utility of color cards in estimating the abundance of thrips (*Ceratothripoides claratris*) in tomato leaves. As *C. claratris* preferentially attacks leaves of tomato than fruits and stem, change in thrips counts on color cards could be used as an indicator of the change in abundance of *C. claratris* in tomato foliage.

4.5.11. **Effect of different colored sticky board traps on incidence of adult thrips on terminal shoots of mungbean**

Figure 31 showed that when blue colored sticky board traps (T_1) captured maximum number of thrips, the incidence of thrips in terminal shoots was lowest. In white (T_2) and yellow (T_3) trapped plots, the incidence of thrips increased because these color traps caught lower number of thrips than blue traps, but in violet (T_4) trapped plots, the incidence of thrips declined because of more thrips caught on that trap than white and yellow trapped plots. In pink (T_5) trapped plots, the incidence of thrips increased due to lower number of thrips caught on the trap. In orange (T_6) trapped plots, the occurrence of thrips decreased but in control plots (T_7), thrips occurrence was maximum than all colored trapped plots.
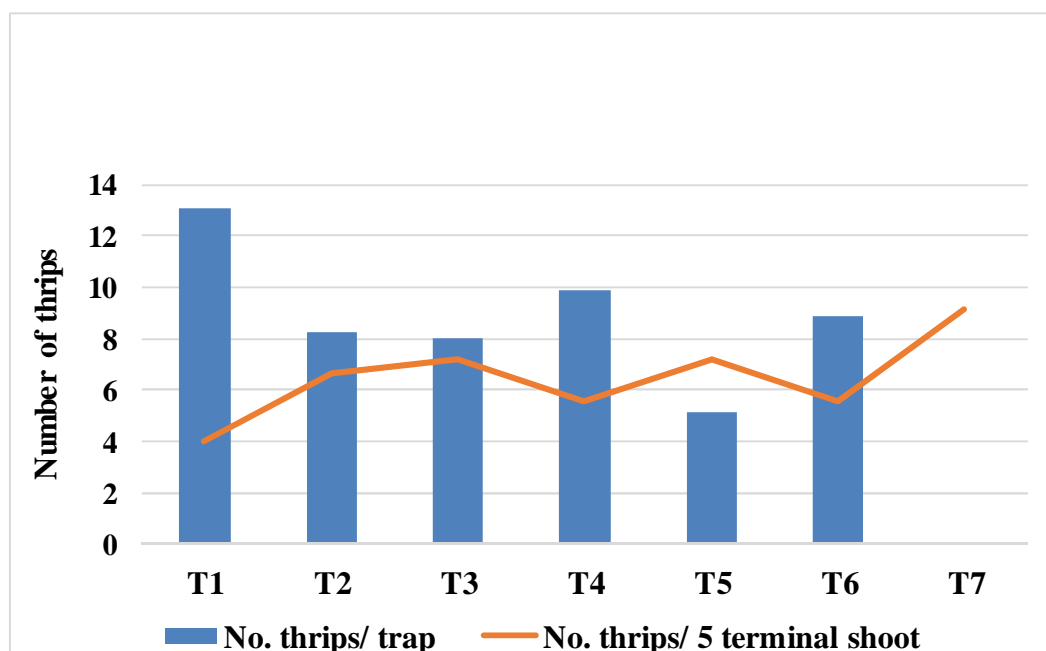
Figure 31. Effect of different colored sticky traps on incidence of adult thrips per 5 terminal shoots.

From the above results, it was revealed that the plots in which colored traps had been mounted, the incidence of thrips was lower in terminal shoots compared with the control plots. Among the tested colored traps, the presence of blue colored sticky board traps in the mungbean field resulted to the more reduction of thrips in terminal shoots than violet, orange white, yellow or pink colored traps.

4.5.12. **Effect of different colored sticky traps on incidence of adult thrips on flower buds of mungbean**

Figure 32. demonstrated that blue trap (T_1) mounted in mungbean plots captured maximum number of thrips and the incidence of thrips on flower buds found lowest in that plots. In white (T_2) and yellow (T_3) trapped plots, the incidence of thrips increased because these colored traps caught lower number of thrips than blue trap, but in violet trapped plot (T_4), the incidence of thrips declined because of more thrips caught on that trap after blue trap. In pink trapped plot (T_5), the incidence of thrips increased due to lower number of thrips caught on this trap. In orange trapped plot (T_6), the occurrence of thrips on flower bud decreased but in control plot (T_7), thrips occurrence increased than all other treatments.
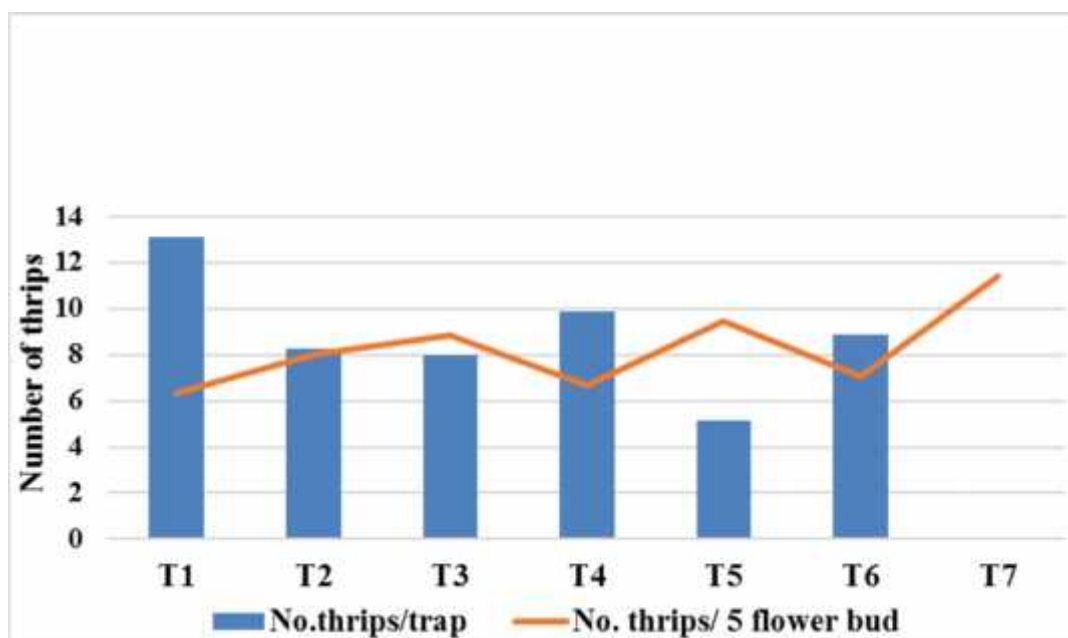
Figure 32. Effect of different colored sticky traps on incidence of adult thrips per 5 flower buds.

4.5.13. **Effect of different colored sticky traps on incidence of adult thrips in flowers of mungbean**

Figure 33 showed that there was a relation between the number of thrips caught on colored traps and the number of thrips in flowers. Different colored sticky traps had different responses on the capture of thrips on mungbean flower. The incidence of thrips on flowers was lowest in blue (T_1) trapped mungbean plot, where maximum number of thrips was captured. In white (T_2) and yellow (T_3) trapped plots, the

188

incidence of thrips increased because these color traps caught lower number of thrips than blue traps, but in violet (T_4) trapped plot, the incidence of thrips declined because of more thrips caught on that trap. In pink (T_5) trapped plot, the incidence of thrips increased due to lower number of thrips caught on this trap. In orange (T_6) trapped plot, the occurrence of thrips in flowers decreased but in control plot (T_7), thrips occurrence was maximum than all the color sticky board trapped plots.
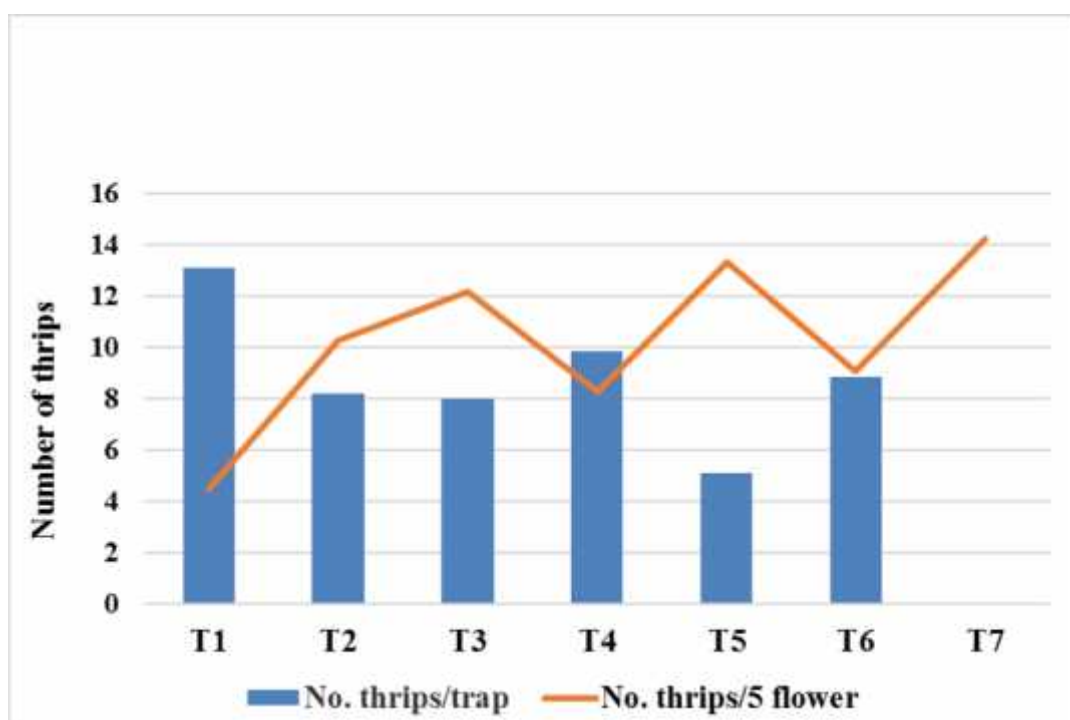
Figure 33. Effect of different colored sticky traps on incidence of adult thrips per 5 flowers.

From the above results, it was revealed that the plots in which colored traps had been used to monitor thrips, the incidence of thrips was found lower in mungbean flowers compared with the control plots. Among the six tested colored traps, the presence of blue colored sticky board trap in the mungbean field resulted to the more reduction of thrips in flowers than violet, orange white, yellow or pink color traps. Mungbean leaves are light green or dark green and flowers, buds or inflorescence are usually light yellow mingled with violet, purple, green, white (Plate 27). Therefore, based on the results, it can be recommend that blue traps are more effective followed by violet and orange color traps for monitoring and/or controlling thrips in mungbean, Tang *et al*. (2016) also found a strong correlation between blue trap catches and the number of thrips in flower dissection samples ($r = 0.929$, $p < 0.001$), whereas, there was a poor

and not significant correlation between yellow trap catches and flower dissection samples (r = 0.139, p = 0.702). Mwangi (2015) reported that the presence of blue or yellow sticky traps in the French bean field resulted to the reduction of both the *M. sjostedti* and *F. occidentalis.* The French bean plots mounted with blue sticky traps had significantly lower mean number of thrips (58) compared to the yellow traps (83) (p<0.05) whereas, the control had the maximum mean number of thrips (204). The results obtained in the study showed that colored sticky traps were able to reduce the number of thrips on the flowers of French beans. There was a positive effect of blue and yellow traps in reducing the number of thrips and that blue traps were slightly better than other traps. Lewis (1997) reported that *F. tritici* was shown to coincide its flight activities with the flowering of the blueberry plants, given that blueberry flowers are white and thought to be the most attractive to this species.

4.5.14. Effect of colored sticky board traps on yield contributing characters and yield of mungbean

4.5.14.1. Number of pod plant^{-1}

Data presented in Table 37 showed that the number of pod plant^{-1} was significantly influenced by attracting thrips as affected by different colored sticky board traps which lowering the incidence of thrips and shedding of flower bud or flower. The maximum number of pods plant^{-1} and percent increase of pods plant^{-1} over untreated control (29.57 and 30.48%, respectively) were recorded in blue colored sticky board trapped mungbean plots which was followed by violet colored trapped plots (28.10 and 24.05%, respectively). In orange, white and yellow trapped plots intermediate number of pods plant^{-1} and percent increase of pods plant^{-1} over control (26.20 and 15.75%, 26.10 and 14.62%, 25.50 and 12.53%, respectively) were found. The minimum number of pods plant^{-1} (22.77) was recorded in control plot which was followed by pink trapped plot (23.23 pods plant^{-1}). The lowest increase (2.22%) of pod number was observed in pink trapped mungbean plots.

4.5.14.2. Pod length

The maximum pod length and percent increase of pod length over untreated control (8.48 cm and 15.66%) were found in blue color sticky trapped plot which were followed by violet, orange and white color trapped plots (8.23 cm and 12.04%, 8.13 cm and 10.66%, 8.03 cm and 9.33%, respectively). Whereas, the minimum pod length was observed in control plot (7.35 cm), which was followed by pink and yellow

trapped plots (7.87 and 7.93 cm, respectively). The lowest increase of pod length over untreated control (7.16%) was found in pink trapped plot (Table 37).

4.5.14.3. Number of seed pod^{-1}

A significant variation was found in the number of seeds pod^{-1} due to the effect of different color sticky board traps on thrips population infesting mungbean. Among the different color sticky board traps, the maximum number of seed pod^{-1} and percent increase of seed pod^{-1} over untreated control (11.83 and 28.85%) was found when mungbean plots were trapped with blue colored sticky board trap, which was followed by violet, white and orange colored trapped plots (11.03 and 20.36%, 10.83 and 18.58% and 10.70 and 16.82%, respectively). On the other hand, the minimum number of seeds pod^{-1} was recorded in control plots (9.20 seeds pod$^{-1)}$, which was followed by pink and yellow trapped plots (10.10 and 10.23 seeds pod^{-1}, respectively). The lowest increase of seed pod^{-1} over untreated control (9.90%) was found in pink trapped plots (Table 37).

4.5.14.4. 1000 Seed weight (g)

Data presented in Table 37 showed that there was significant differences in terms of 1000 seed weight in seven treatments. The maximum 1000 seed weight and percent increase of 1000 seed weight over untreated control (47.53 g and 10.03%) were recorded in blue colored sticky board trapped plots. Whereas, the minimum 1000 seed weight (43.20 g) was found in control plot. The lowest percent increase of 1000 seed weight over untreated control (3.26%) was found in pink trapped plots followed by yellow trapped plots (3.71%).

4.5.14.5. Yield (kg ha^{-1})

Grain yield of mungbean varied due to the variation in the effect of colored sticky board traps and thrips infestation (Table 37). The highest yield and percent increase of yield over untreated control (1212.30 kg ha^{-1} and 19.14%) were obtained when mungbean plots were trapped with blue colored sticky board trap which was followed by violet and orange trapped plots (1195.00 kg ha^{-1} and 17.34%, 1152.00 kg ha^{-1} and 13.23%, respectively). On the other hand, the lowest yield (1022.32 kg ha^{-1}) was obtained in untreated control plot which was followed by pink, yellow and white trapped plots (1093.00, 1093.43 and 1120.67 kg ha^{-1}, respectively). The lowest increase of yield over untreated control (6.99%) was found in pink trapped plots followed by yellow trapped plots (7.45%).

Table 37. Effect of different colored sticky board traps on incidence of thrips and its impact on yield contributing characters and yield of mungbean

Treatment	Number of pod plant^{-1}	% increase over control	Pod length (cm)	% increase over control	Number of seed pod^{-1}	% increase over control	1000 seed weight (g)	% increase over control	Yield (kg ha^{-1})	% increase over control
T$_1$ (Blue)	29.57 a	30.48 a	8.48 a	15.66 a	11.83 a	28.85 a	47.53 a	10.03 a	1212.30 a	19.14 a
T$_2$ (White)	26.10 b	14.62 cd	8.03 a	9.33 bcd	10.83 ab	18.58 b	45.60 ab	5.57 cd	1120.67 ab	9.85 cd
T$_3$ (Yellow)	25.50 bc	12.53 d	7.93 ab	8.13 cd	10.23 bc	11.39 c	44.80 ab	3.71 d	1093.43 ab	7.45 d
T$_4$ (Violet)	28.10 ab	24.05 b	8.23 a	12.04 b	11.03 ab	20.36 b	46.73 a	8.18 ab	1195.00 a	17.34 ab
T$_5$ (Pink)	23.23 c	2.11 e	7.87 ab	7.16 d	10.10 bc	9.90 c	44.60 ab	3.26 d	1093.00 ab	6.99 d
T$_6$ (Orange)	26.20 b	15.75 c	8.13 a	10.66 bc	10.70 b	16.82 b	46.23 a	7.10 bc	1152.00 a	13.23 bc
T$_7$ (Control)	22.77 c	-	7.35 b	-	9.20 c	-	43.20 b	-	1022. 32 b	-
S$\bar{x}$	0.91	0.69	0.20	0.91	0.34	1.53	0.87	0.71	37.95	1.47
CV (%)	6.06	7.18	4.3	15.05	5.52	15.03	3.30	19.52	5.83	20.59

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

From the above findings, it was revealed that among the six colored sticky board traps tested in this study, blue color sticky board was the most effective color trap in mass trapping of thrips as well as contributing higher yield of mungbean producing maximum pod number with maximum pod length, seed number, 1000 seed weight etc. Next to blue trap, violet sticky board was the second effective and orange sticky board was the third effective color trap for mass trapping and/or suppressing of thrips. The rank of effectiveness of colored sticky board trap against thrips as well as contributing higher yield was blue > violet > orange > white > yellow > pink. Other authors also supported more or less the present findings in mungbean or other crop. Mwangi (2015) reported that there was no significant differences in the yield of french beans between the plots with blue and yellow traps and there was no significant difference in the yields between plots with clear traps and the control. Untreated control had the least yield 600 g (740 kg ha^{-1}). Muthuram (2017) found that there was 11.48% increase in yield by using green sticky boards placed in onion plots to monitor or suppress thrips than control plots. Colored traps may be used against thrips for several purposes- for monitoring the presence or absence of a species, for early detection of infestation and in some cases for suppressing by mass trapping. Obviously, the most attractive color is the most appropriate to use for monitoring and suppressing insect pests.

4.6. Experiment 6: Evaluation of some Bio-pesticides and Chemical Insecticides against Thrips on Mungbean

A field trial was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from 2 November 2017 to 15 February, 2018 to evaluate some bio-pesticides and chemical insecticides against thrips on mungbean. The results of the effectiveness of different bio-pesticides and chemical insecticides applied against thrips on mungbean have been discussed with interpretations and furnished under the following sub-headings:-

4.6.1. Effect of different bio-pesticides and chemical insecticides on the incidence of thrips population on top trifoliate leaves of mungbean

Significant variations in efficacy of different bio-pesticides and chemical insecticides were observed in respect of thrips (*M. usitatus* and *T. palmi*) incidence per 10 top trifoliate leaves at pre-flowering stage of mungbean in comparison to untreated control. Stargate 48SC (T_2) treatment was found very effective to control thrips. No thrips population (0.00) was recorded on top trifoliate leaves of mungbean in Stargate 48SC (T_2) treated plot (Table 38). A small number of adult *M. usitatus* and *T. palmi* (1.25 and 0.25, respectively) with cumulative mean number (1.50) of both the thrips species per 10 top trifoliate leaves was observed in Confidor 70WG (T_3) treated plot followed by Actara 25WG (T_4) treated plot where the number of adult *M. usitatus* and *T. palmi* was (1.50 and 0.74, respectively) with cumulative mean number (2.24) of of both the thrips species. On the other hand, the highest incidence of *M. usitatus* and *T. palmi* (5.76 and 2.25) with cumulative mean number (8.01) of both the thrips species per 10 top trifoliate leaves was recorded in untreated control (T_8) plot. In Bioneem plus 1EC (T_7) treatment the mean number of *M. usitatus* and *T. palmi* was (5.26 and 1.49, respectively) with cumulative mean number of both the thrips species 6.75. This was followed by Tracer 45SC (T_5) treated plot where the mean number of *M. usitatus* and *T. palmi* was (4.73 and 1.5, respectively) with cumulative mean number of both the thrips species 6.24. Among Bio-pesticides, Ecomec 1.8EC performed better in lowering *M. usitatus* (3.24 per 10 top trifoliate leaves) and *T. palmi* (1.25 per 10 top trifoliate leaves).

The data represented in Table 38 revealed that Stargate 48SC (T_2) showed the best performance in reducing of both *M. usitatus* and *T. palmi* population over untreated control (100%) followed by Confidor 70WG (78.26% and 88.83%, respectively) and Actara 25WG (73.76% and 67.15%, respectively) on top trifoliate leaves. Bioneem plus 1EC showed poor performance in reducing *M. usitatus* and *T. palmi* population (8.41% and 33.77%, respectively) over untreated control. Though the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 top trifoliate leaves in all the treatments, in Stargate 48SC (T_2) treated plots percent incidence of both *M. usitatus* and *T. palmi* was (0.00), i.e., the insecticide was very effective to control thrips among other neonicotinoids (Confidor 70WG and Actara 25WG) as well as other insecticides.

Table 38. Mean number of *M. usitatus* and *T. palmi* on top trifoliate leaves at pre-flowering stage of mungbean in different treatments

Treatments	Mean number of *M. usitatus* and *T. palmi* per 10 top trifoliate leaves and reduction of population over untreated control				Cumulative mean no. of two thrips species per 10 top trifoliate leaves	% reduction of both the thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 10 top trifoliate leaves	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T_1	2.76 d	51.64 c	0.99 d	55.87 d	3.75 e	52.92 d	73.56 bc	26.44 bc
T_2	0.00 f	100.00 a	0.00 g	100.00 a	0.00 h	100.00 a	0.00 e	0.00 e
T_3	1.25 e	78.26 b	0.25 f	88.83 b	1.50 g	81.25 b	83.21 a	16.79 d
T_4	1.50 e	73.76 b	0.74 e	67.15 c	2.24 f	71.94 c	66.93 d	33.07 a
T_5	4.73 c	17.73 e	1.51 b	32.85 f	6.24 c	21.95 f	75.80 bc	24.20 bc
T_6	3.24 d	43.28 d	1.25 c	44.20 e	4.49 d	43.60 e	72.18 c	27.82 b
T_7	5.26 b	8.41 f	1.49 b	33.77 f	6.75 b	15.35 g	77.87 b	22.13 c
T_8	5.76 a	-	2.25 a	-	8.01 a	-	71.86 c	28.14 b
S$\bar{x}$	0.17	2.11	0.05	2.62	6.88	1.71	1.53	1.53
CV (%)	9.45	6.86	9.19	7.51	0.16	5.36	4.07	11.89

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1.0 ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4 ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2 g L^{-1} of water, T_4 = Actara 25WG @ 0.2 g L^{-1} of water, T_5 = Tracer 45SC @ 0.4 ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1.0 ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1.0 ml L^{-1} of water, T_8 = Untreated control].

From the above findings it was revealed that no thrips population was observed on top trifoliate leaves in Stargate 48SC (T_2) treated plot. The next effective treatment was Confidor 70WG (T_3) followed by Actara 25WG (T_4) treatment to control thrips population. On the other hand, the highest mean population of thrips per 10 top trifoliate leaves was observed in untreated control plot followed by Bioneem plus 1EC (T_7) and Tracer 45SC (T_5) treated plots. The percent incidence of *M. usitatus* was higher than *T. palmi* per 10 top trifoliate leaves in all the treatments. The order of performance of treatments against thrips was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8). Other authors also supported more or less the findings of the present study. Ahirwar *et al.* (2016) reported that the effect of thiamethoxam on thrips population 1.54 per 6 trifoliate mungbean leaves was more followed by imidacloprid (2.11) and triazophos (2.19) in comparison to acephate (3.82), malathion (3.10), and monocrotophos (3.07). Significant reduction in thrips population was observed in all the treatments in comparison to control. Kaushik *et al.* (2015) evaluated thiamethoxam + imidacloprid spray against thrips resulted significant reduction of thrips in cowpea. Seal (2011) reported that various insecticides of the neonicotinoid group provided 42% to 75% control of *T. palmi*. Among these insecticides, clothianidin (Belay®) provided higher level (>70%) of *T. palmi* control than the others. These insecticides are nicotinic acetylcholine receptor agonists. Abamectin provided over 60% reduction of *T. palmi* on bean. Abamectin is neuroactive and affects ion transfer through cell membrane. Spinosad and spinetoram were highly effective insecticides commonly used by commercial growers in controlling *T. palmi* on all vegetable hosts. These two products are also neuroactive and their mode of action is similar to nicotinoids. Afzal *et al*. (2002) observed that imidacloprid 25WP @ 200 g acre[-1], proved to be the best treatment against black thrips, *Caliothrips indicus* (2.75 black thrips per leaf). Azam *et al*. (2008) reported that the incidence of thrips on mungbean was noticed during vegetative and flowering stage. Furadan 5G, Cruiser 70WS, Neem seed oil @ 10 ml of water + Trix @ 5 ml L^{-1} of water, Cymbush 10EC, Ekalux 25EC and Shobicron 425EC were sprayed in assigned plots. Among the treatments, spraying of Shobicron 425EC @ 2 ml L^{-1} of water (at 20 DAS and at 35 DAS) treatment had the lowest number of thrips (2.5 per 5 leaves) whereas, the highest number of thrips (5.2 per 5 leaves) was recorded on untreated control plot.

4.6.2. Effect of different bio-pesticides and chemical insecticides on the incidence of thrips population on terminal shoots of mungbean

Significant variations in efficacy of different bio-pesticides and chemical insecticides were observed in respect of thrips (*M. usitatus* and *T. palmi*) incidence per 10 terminal shoots at pre-flowering stage of mungbean in comparison to untreated control. The lowest number of adult *M. usitatus* and *T. palmi* (0.99 and 0.02) with cumulative mean number (1.01) of both the thrips species per 10 terminal shoot was observed in Stargate 48SC (T_2) treated plot which was followed by Confidor 70WG (T_3) and Actara 25WG (T_4) treated plots where the mean number of adult *M. usitatus* and *T. palmi* was (1.26 and 0.39) and (1.74 and 1.00), respectively with cumulative mean number (1.65 and 2.74), respectively of both the species of thrips. On the other hand, the highest incidence of *M. usitatus* and *T. palmi* (6.77 and 2.78, respectively) with cumulative mean number (9.55) of both the species of thrips per 10 terminal shoots was recorded in untreated control (T_8) plot which was followed by Bioneem plus 1EC (T_7) and Tracer 45SC (T_5) treated plots where the mean number of *M. usitatus* and *T. palmi* was (5.25 and 2.14) and (4.83 and 1.42), respectively with cumulative mean number (7.39 and 6.25), respectively of both the thrips species (Table 39). Among Bio-pesticides, Ecomec 1.8EC performed better in controlling *M. usitatus* (3.85 per 10 terminal shoots) and *T. palmi* (1.23 per 10 terminal shoots). Stargate 48SC (T_2) showed the best performance in reducing of both *M. usitatus* and *T. palmi* population over untreated control (85.23% and 99.28%, respectively) followed by Confidor 70WG (81.04% and 85.89%, respectively) and Actara 25WG (74.22% and 63.81%, respectively). Bioneem plus 1EC showed poor performance in reducing *M. usitatus* and *T. palmi* population (20.55% and 22.37%, respectively) over untreated control on terminal shoots. Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 terminal shoots in all the treatments. In Stargate 48SC (T_2) treated plot percent incidence of *M. usitatus* and *T. palmi* was (98.00% and 2.00%, respectively) (Table 39).

Table 39. Mean number of *M. usitatus* and *T. palmi* on terminal shoots at pre-flowering stage of mungbean in different treatments

Treatments	Mean number of *M. usitatus* and *T. palmi* per 10 terminal shoots and reduction of population over untreated control				Cumulative mean no. of two thrips species per 10 terminal shoots	% reduction of both the thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 10 terminal shoots	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T_1	3.18 c	52.17 c	1.10 d	60.08 cd	4.28 e	54.87 d	74.14 bc	25.86 bc
T_2	0.99 d	85.23 a	0.02 f	99.28 a	1.01 g	89.40 a	98.00 a	2.00 d
T_3	1.26 d	81.04 ab	0.39 e	85.89 b	1.65 g	82.61 b	76.31 bc	23.69 bc
T_4	1.74 d	74.22 b	1.00 d	63.81 c	2.74 f	71.23 c	63.39 d	36.61 a
T_5	4.83 b	26.93 e	1.42 c	48.67 e	6.25 c	33.94 f	77.26 b	22.74 c
T_6	3.85 c	42.56 b	1.23 cd	55.85 d	5.08 d	46.65 e	75.77 bc	24.23 bc
T_7	5.25 b	20.55 e	2.14 b	22.37 f	7.39 b	21.90 g	70.96 bc	29.04 bc
T_8	6.77 a	-	2.78 a	-	9.55 a	-	70.64 c	29.36 b
S$\bar{x}$	0.28	2.72	0.08	2.12	0.25	1.23	2.01	2.01
CV (%)	13.84	8.62	11.24	5.89	8.97	3.72	4.60	14.41

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2g L^{-1} of water, T_4 = Actara 25WG @ 0.2g L^{-1} of water, T_5 = Tracer 45SC @ 0.4ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1ml L^{-1} of water, T_8 = Untreated control].

From the above findings it was revealed that Stargate 48SC was the most effective insecticide against thrips population per 10 terminal shoots. Among bio-pesticides, Ecomec 1.8EC was most effective but less than chemical insecticides. The rank of pesticides in efficacy of controlling thrips population in terminal shoots was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8).

4.6.3. Effect of different bio-pesticides and chemical insecticides on the incidence of thrips population on flower buds of mungbean

Data in Table 40 revealed that there were significant variations observed in efficacy of different bio-pesticides and chemical insecticides in respect of thrips (*M. usitatus* and *T. palmi*) incidence per 10 flower buds of mungbean in comparison to untreated control. The lowest number of adult *M. usitatus* (1.66) was recorded per 10 flower buds in Stargate 48SC (T_2) treated plot. There was no *T. palmi* observed on flower buds in this Stargate 48SC treated mungbean plot. The result was followed by Confidor 70WG (T_3) and Actara 25WG (T_4) treated plots where the mean number of adult *M. usitatus* and *T. palmi* was (4.25 and 0.33) and (4.38 and 1.54), respectively with cumulative mean number (4.58 and 5.92), respectively of both the thrips species. On the other hand, the highest population of *M. usitatus* and *T. palmi* (8.98 and 3.08) with cumulative mean number of both the thrips species (12.06) per 10 flower buds was recorded in untreated control (T_8) plot which was followed by Bioneem plus 1EC (T_7) and Tracer 45SC (T_5) treated plots where the mean number of *M. usitatus* and *T. palmi* was (6.63 and 2.83) and (6.11 and 1.97), respectively with cumulative mean number of both the thrips species 9.46 and 8.08, respectively. Stargate 48SC (T_2) reduced the highest percent of *M. usitatus* and *T. palmi* population over untreated control (81.21% and 100.00%, respectively). Among Bio-pesticides, Ecomec 1.8EC (T_6) showed comparatively better result in controlling *M. usitatus* and *T. palmi* (35.91% and 46.03%, respectively) on flower buds. Bioneem plus 1EC (T_7) showed poor performance in reducing *M. usitatus* and *T. palmi* population (25.28% and 7.97%, respectively) over untreated control. Comparatively, the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 flower buds in all the treatments.

Table 40. Mean number of *M. usitatus* and *T. palmi* on flower buds of mungbean in different treatments

Treatments	Mean number of *M. usitatus* and *T. palmi* per 10 flower buds and reduction of population over untreated control				Cumulative mean no. of two thrips species per 10 flower buds	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 10 flower buds	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T$_1$	4.83 cd	45.99 b	1.62 c	46.66 c	6.45 de	46.14 c	74.77 d	25.23 b
T$_2$	1.66 e	81.23 a	0.00 e	100.00 a	1.66 g	86.04 a	100.00 a	0.00 e
T$_3$	4.25 d	52.48 b	0.33 d	89.27 b	4.58 f	61.89 b	92.79 b	7.21 d
T$_4$	4.38 d	51.00 b	1.54 c	49.82 c	5.92 e	50.70 c	73.93 d	26.07 b
T$_5$	6.11 b	30.90 cd	1.97 b	35.22 d	8.08 c	32.01 e	75.63 cd	24.37 bc
T$_6$	5.73 bc	35.91 c	1.66 bc	46.03 c	7.39 cd	38.50 d	77.58 c	22.42 c
T$_7$	6.63 b	25.28 d	2.83 a	7.97 e	9.46 b	20.70 f	70.06 e	29.94 a
T$_8$	8.98 a	-	3.08 a	-	12.06 a	-	74.44 d	25.56 b
S$\bar{x}$	0.35	2.45	0.11	3.51	0.45	2.20	0.91	0.91
CV (%)	11.53	9.20	11.91	11.35	11.14	7.95	1.97	7.83

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = Novastar 56EC @ 1ml L^{-1} of water, T$_2$ = Stargate 48SC @ 0.4ml L^{-1} of water, T$_3$ = Confidor 70WG @ 0.2g L^{-1} of water, T$_4$ = Actara 25WG @ 0.2g L^{-1} of water, T$_5$ = Tracer 45SC @ 0.4ml L^{-1} of water, T$_6$ = Ecomec 1.8EC @ 1ml L^{-1} of water, T$_7$ = Bioneem plus 1EC @ 1ml L^{-1} of water, T$_8$ = Untreated control].

From the above findings it was revealed that Stargate 48SC was the most effective insecticide against thrips population on flower buds. Among bio-pesticides, Ecomec 1.8EC was most effective but less than chemical insecticides. The rank of pesticides in efficacy of controlling thrips population on flower buds was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8). The findings of the present study are in partial agreement with the findings of Yadav *et al*. (2017), who found fipronil followed by imidacloprid were very effective against *M. sjostedti* in flower bud of cowpea and the observation at 7 days after application of treatments indicated that significantly highest reduction (63.23 %) in thrips population was observed in the seed treatment with fipronil @ 3ml/kg + spray with fipronil @ 5 ml L^{-1} with thrips population 2.80 thrips/flower bud/plant followed by the seed treatment with imidacloprid 17.8SL @ 10ml/kg + spray with imidacloprid 17.8SL @ 5 ml $L^{-1)}$ (51.87%) with thrips population 3.60 thrips/flower bud/plant at 7 days of application. The lowest percent reduction of thrips was recorded in monocrotophos 36SL @ 2ml L^{-1} with 21.06 % (6.20 thrips/flower bud/plant).

4.6.4. Effect of different bio-pesticides and chemical insecticides on the incidence of thrips population in flowers of mungbean

Data in Table 41 illustrated that there was significant variations observed in the efficacy of different bio-pesticides and chemical insecticides in respect of thrips (*M. usitatus* and *T. palmi*) population occurrence per 10 flowers of mungbean in comparison to untreated control. The lowest number of adult *M. usitatus and T. palmi* (1.87 and 0.11, respectively) per 10 flowers was recorded in Stargate 48SC (T_2) treated plot. The result was followed by Confidor 70WG (T_3) and Actara 25WG (T_4) treated plots, where the mean number of adult *M. usitatus* and *T. palmi* was (4.52 and 0.75) and (5.03 and 1.43), respectively with cumulative mean number of both the thrips species 5.27 and 6.46, respectively per 10 flowers. On the other hand, the highest population of *M. usitatus* and *T. palmi* (9.23 and 4.90) with cumulative mean number (14.13) of both the thrips species per 10 flowers were recorded in untreated control (T_8) plot which was followed by Bioneem plus 1EC (T_7) and Tracer 45SC (T_5) treated plots, where the mean number of *M. usitatus* and *T. palmi* was (7.89 and 3.97) and (6.87 and 2.38), respectively with cumulative mean number of both the thrips species 11.86 and 9.27, respectively. Stargate 48SC (T_2) reduced maximum *M. usitatus* and *T. palmi* population (79.64% and 97.75%, respectively) over untreated control. Whereas, Bioneem plus 1EC reduced minimum *M. usitatus* and *T. palmi* population (14.22% and 18.44%, respectively) over untreated control. Among Bio-pesticides, Ecomec 1.8EC showed better result in controlling *M. usitatus* and *T. palmi* on mungbean flowers (27.91% and 53.98%, respectively) over untreated control. Between the two thrips species, comparatively the percent incidence of *M. usitatus* was higher than *T. palmi* per 10 flowers in all the treatments. In Stargate 48SC (T_2) treated plots, the percent incidence of *M. usitatus* and *T. palmi* was 94.38% and 5.62%, respectively while in untreated control plots the percent incidence of *M. usitatus* and *T. palmi* was 65.22% and 34.78%, respectively (Table 41).

Table 41. Mean number of *M. usitatus* and *T. palmi* in flowers of mungbean in different treatments

Treatments	Mean number of *M. usitatus* and *T. palmi* per 10 flowers and reduction of population over untreated control				Cumulative mean no. of two thrips species per 10 flowers	% reduction of two thrips species	Comparative incidence of *M. usitatus* and *T. palmi* on 10 flowers	
	M. usitatus	% reduction of *M. usitatus*	*T. palmi*	% reduction of *T. palmi*			*M. usitatus* (%)	*T. palmi* (%)
T_1	5.13 d	44.11 b	2.10 c	56.85 d	7.23 d	48.72 c	70.93 de	29.07 bc
T_2	1.87 e	79.64 a	0.11 f	97.75 a	1.98 f	85.95 a	94.38 a	5.62 f
T_3	4.52 d	50.53 b	0.75 e	84.53 b	5.27 e	62.56 b	85.67 b	14.33 e
T_4	5.03 d	44.84 b	1.43 d	70.48 c	6.46 d	54.01 c	77.81 c	22.19 d
T_5	6.87 c	25.29 c	2.38 c	51.28 d	9.25 c	34.45 d	74.13 cd	25.87 cd
T_6	6.62 c	27.91 c	2.25 c	53.98 d	8.87 c	37.13 d	74.56 cd	25.44 cd
T_7	7.89 b	14.22 d	3.97 b	18.44 e	11.86b	15.77 e	66.53 ef	33.47 ab
T_8	9.23 a	-	4.90 a	-	14.13 a	-	65.22 f	34.78 a
S$\bar{x}$	0.34	2.18	0.13	1.95	0.32	1.96	1.53	1.53
CV (%)	10.00	9.21	10.10	5.45	6.85	7.03	3.49	11.13

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2g L^{-1} of water, T_4 = Actara 25WG @ 0.2g L^{-1} of water, T_5 = Tracer 45SC @ 0.4ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1ml L^{-1} of water, T_8 = Untreated control].

From the above findings it was revealed that Stargate 48SC was the most effective insecticide against thrips population in flowers. Among bio-pesticides, Ecomec 1.8EC was comparatively effective but less than chemical insecticides. The order of pesticides in efficacy of controlling thrips population on flowers was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8). Other authors more or less supported the present findings. Better performance of clothianidin against thrips infesting mungbean tend to support the findings of Patil *et al.* (2007) who proved effectiveness of these insecticides against thrips infesting cotton. Dalwadi (2005) showed superior performance of Imidacloprid insecticide against *M. distalis* infesting Indian bean. Nadeem *et al.* (2016) reported that Mospilan 20SP treated plot comparatively showed least population of thrips (5.08) per infloresence throughout the study period followed but not significantly different to Actara 25WG with 5.75 thrips per infloresence. Population of thrips per infloresence found in Actara 25WG (5.75) and Confidar 200SL (6.75) treated plots was found statistically similar with each other. Among neem oil concentrations tested, although, all the concentrations (1, 2 and 3%) showed comparatively low per infloresence population of thrips than control plot but neem oil 3% showed comparatively least population of thrips (10.83) per inflorescence. Kar *et al.* (2018) recorded the mean data of two years (2015 and 2016) thrips population ranged from 6.2 to 23.2 numbers per 10 flowers of mungbean among the treatments as against 38.3 numbers per 10 flowers in untreated control. The percent reduction over control was higher, 83.8% in seed treatment with imidacloprid 48FS @ 5 ml kg^{-1} seed + spraying of thiamethoxam 25WG @ 50 g a.i. ha^{-1} followed by 73.6% reduction in seed treatment with imidacloprid 48FS @ 5 ml kg^{-1} seed + spraying of spinosad 45SC @ 73 g a.i. ha^{-1}. Singh *et al.* (2016) reported that after first spray, acetamiprid 180g a.i. ha^{-1} was most effective treatment against thrips which reduced thrips population 69.85 percent over control while triazophos 400g a.i. ha^{-1} was found least effective which reduced population 14.96 percent over control. Similar trend was also found after second spray. Jensen (1995) reported that spinosad showed very little thrips control, although other tests had shown it to be active against other types of thrips, it did not appear to have much activity on the onion thrips, which also supported the present findings.

4.6.5. Incidence of thrips under different treatments on different plant parts of mungbean

The average population of thrips of mungbean under different treatments has been shown in Figure 34. The highest average thrips population was observed in flowers of mungbean than flowerbuds, terminal shoots and top trifoliate leaves in all the treatments. On the other hand, the lowest population of thrips was observed on top trifoliate leaves in all the treatments. Among different treatments, Stargate 48SC (T_2) was very effective in lowering thrips in all the plant parts observed in this study followed by Confidor 70WG (T_3) and Actara 25WG (T_4). The highest incidence of thrips was found in untreated control (T_8) plots on the observed plant parts (top trifoliate leaves, terminal shoots, flower buds and flowers) followed by Bio-neem plus 1EC treated plots. From the results, it was clearly revealed that thrips infestation of mungbean started before flowering on vegetative plant parts i.e. young leaves and terminal shoots and quickly migrate to flower buds and flowers once formed as they prefer flowers than vegetative plant parts. The high thrips number in flowers, could be due to upward migration of thrips from lower in the canopy in addition to new infestations from nearby host plants (Reitz 2002, Chellemi *et al.* 1994). However, it is also possible that their presence on flowers would be a preferred site for taking off to other fields. Some other findings also supports the present findings. Urías-López *et al.* (2007) stated that the most important factor that affects thrips population level is the phenological stage of the plant. Indeed, this is so because many thrips species strongly prefer flowers and young buds. Prema *et al.* (2018) reported that high chlorophyll content during the vegetative stage attracted more number of thrips towards cotton which was contradictory to the present findings. The results of the present study suggests that when early infestation occurs in vegetative plant parts, Stargate 48 SC would be the most effective treatment to suppress thrips population during that time as well as the remaining cropping period.
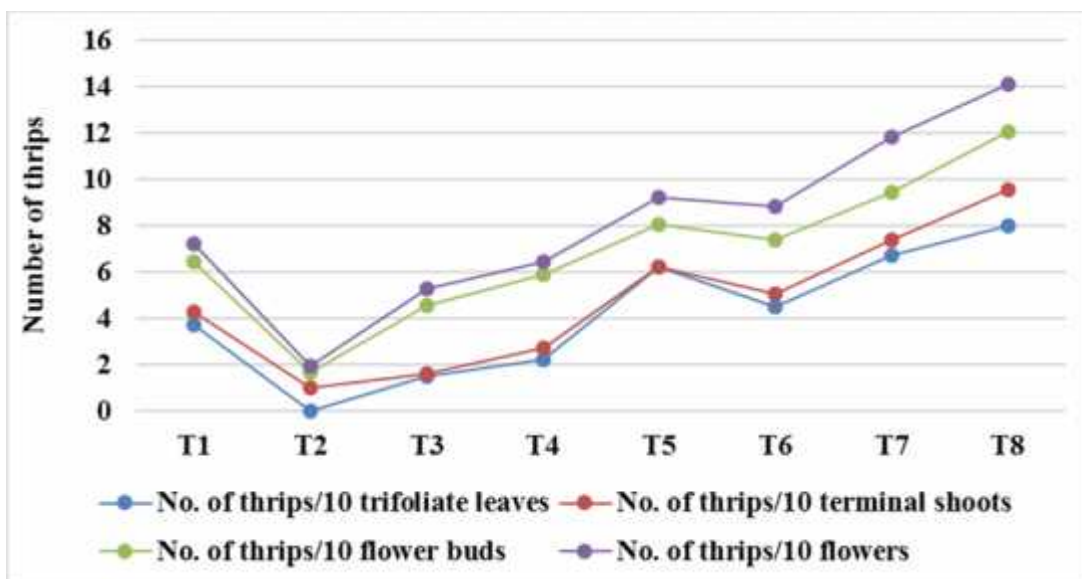
Figure 34. Mean number of thrips under different treatments on different plant parts of mungbean.

4.6.6. Effect of different bio-pesticides and chemical insecticides on top trifoliate leaves infestation by thrips at pre-flowering stage of mungbean

Different bio-pesticides and chemical insecticides caused significant ($p<0.05$) reduction of mungbean top trifoliate leaves infestation by thrips in comparison to untreated control (Table 42). There was no infested top trifoliate leaves (0.00) observed in the Stargate 48SC (T_2) treated plot and top trifoliate leaves infestation reduction over control was (100.00%) which was significantly different from other treatments. Next, the lower number of infested top trifoliate leaves per 10 top trifoliate leaves, percent infestation of top trifoliate leaves and percent reduction of top trifoliate leaves over untreated control (0.26, 2.60% and 85.20%, respectively) was found in Confidor 70WG (T_3) treated plot, which was followed by Actara 25WG (T_4) treated plot, where number of infested top trifoliate leaves per 10 top trifoliate leaves, percent infestation of top trifoliate leaves and percent reduction of top trifoliate leaves over control (0.51, 5.10% and 70.71%, respectively) were observed. On the other hand, the highest number of infested top trifoliate leaves (1.76) per 10 top trifoliate leaves and highest percent infestation of top trifoliate leaves (17.60%) were recorded in untreated control plot, which were significantly different from other treatments and followed by Bioneem plus 1EC (T_7), where percent infestation of top trifoliate leaves was 15.17% and percent reduction of top trifoliate leaves over control was 13.53%. Ecomec 1.8EC (T_6) and Tracer 45SC (T_5) were statistically identical in

respect of percent top trifoliate leaf infestation (12.60% and 12.40%), respectively by thrips while, Ecomec 1.8EC reduced 31.95% top trifoliate leaf infestation and Tracer 45SC (T_5) reduced 28.62% top trifoliate leaf infestation by thrips.

Table 42. Effect of bio-pesticides and chemical insecticides on top trifoliate leaf infestation by thrips at pre-flowering stage of mungbean

| Treatments	No. of infested top trifoliate leaf per 10 top trifoliate leaves	% infestation of top trifoliate leaf	% reduction infestation over control
T_1	1.01 d	10.13 d	42.10 d
T_2	0.00 g	0.00 g	100.00 a
T_3	0.26 f	2.60 f	85.20 b
T_4	0.51 e	5.10 e	70.71 c
T_5	1.26 c	12.60 c	28.62 e
T_6	1.24 c	12.40 c	31.95 e
T_7	1.52 b	15.17 b	13.53 f
T_8	1.76 a	17.60 a	-
S$\bar{x}$	0.07	0.72	3.15
CV (%)	13.12	13.12	10.28

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1 ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4 ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2 g L^{-1} of water, T_4 = Actara 25WG @ 0.2 g L^{-1} of water, T_5 = Tracer 45SC @ 0.4 ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1 ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1 ml L^{-1} of water, T_8 = Untreated control].

From the above results it was revealed that Stargate 48SC was very effective in reducing infestation of top trifoliate leaves, followed by Confidor 70WG and Actara 25WG treatments. Among bio-pesticides, Ecomec 1.8EC and Tracer 45SC were statistically identical in case of percent top trifoliate leaves infestation by thrips. Maximum infestation was found in untreated control plot followed by Bioneem plus 1EC.

4.6.7. Effect of different bio-pesticides and chemical insecticides on terminal shoots infestation by thrips at pre-flowering stage of mungbean

Data presented in Table 43 revealed that different bio-pesticides and chemical insecticides caused significant (p<0.05) reduction of mungbean terminal shoot infestation by thrips in comparison to untreated control. The lowest number (1.00) of infested terminal shoot per 10 terminal shoot, lowest percent infestation of terminal

shoot (10.00 %) and the maximum infestation reduction of terminal shoot over untreated control (75.54%) were recorded in the Stargate 48SC (T_2) treated plot, which were significantly different from other treatments and followed by Confidor 70WG (T_3) and Actara 25WG (T_4) treatments, where the number of infested terminal shoot 1.75 and 2.50, respectively per 10 terminal shoots, percent infestation of terminal shoots 17.50% and 25.00%, respectively and the infestation reduction of terminal shoots over untreated control 57.18% and 38.51%, respectively were found. On the other hand, the highest number of infested terminal shoot (4.08) per 10 terminal shoots and highest percent infestation of terminal shoots (40.83%) were recorded in untreated control plot, which were significantly identical with Bioneem plus 1EC (T_7), where the number of infested terminal shoots (3.75) with 37.50% infestation of terminal shoot and percent reduction of terminal shoot infestation 8.19% were observed (Table 43).

Table 43. Effect of bio-pesticides and chemical insecticides on terminal shoot infestation by thrips at pre-flowering stage of mungbean

Treatments	No. of infested terminal shoot per 10 terminal shoots	% infestation of terminal shoot	% reduction infestation over control
T_1	3.00 c	30.00 c	26.15 d
T_2	1.00 f	10.00 f	75.54 a
T_3	1.75 e	17.50 e	57.18 d
T_4	2.50 d	25.00 d	38.51 c
T_5	3.50 b	35.00 b	14.32 e
T_6	3.50 b	35.00 b	14.32 e
T_7	3.75 ab	37.50 ab	8.19 e
T_8	4.08 a	40.83 a	-
$S\bar{x}$	0.13	1.29	1.99
CV (%)	7.75	7.75	10.32

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1 ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4 ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2g L^{-1} of water, T_4 = Actara 25WG @ 0.2 g L^{-1} of water, T_5 = Tracer 45SC @ 0.4 ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1ml L^{-1} of water, T_8 = Untreated control].

4.6.8. Effect of bio-pesticides and chemical insecticides on flower bud infestation by thrips at flowering stage of mungbean

Flower bud infestation by thrips was significantly affected by the application of bio-pesticides and chemical insecticides (Table 44). Among the treatments, the highest number of total flower bud (41.33 plant^{-1}) and the lowest number of infested flower bud (2.97 plant^{-1}) with 7.22% flower bud infestation and maximum 49.50% reduction of flower bud infestation over untreated control were recorded in Stargate 48SC (T$_2$) treated plot which were followed by Confidor 70WG (T$_3$) and Actara 25WG (T$_4$) treated plots where the total number of flower bud (40.67 and 40.13 plant^{-1}, respectively), infested number of flower bud (3.33 and 3.67 plant^{-1}, respectively) with (8.20% and 9.17%, respectively) flower bud infestation and (42.58% and 35.87%, respectively) reduction of flower bud infestation over untreated control were observed. On the other hand, the lowest number of total flower bud (35.87 plant^{-1}) and highest number of infested flower bud (5.13 plant^{-1}) with 14.29% flower bud infestation were recorded in untreated control plot (T$_8$) which were followed by Bioneem plus 1EC (T$_7$) and Tracer 45SC (T$_5$) treated plots where the number of total flower bud (36.87 and 37.13 plant^{-1}, respectively) and the number of infested flower bud (4.93 and 4.57 plant^{-1}, respectively) with (13.38% and 12.39%, respectively) flower bud infestation and (6.33% and 13.31%, respectively) reduction of flower bud infestation over untreated control were recorded. Other treatments also showed significant variations in flower bud infestation. In Novastar 56EC (T$_4$) and in Ecomec 1.8EC (T$_6$) treatment, percent flower bud infestation (9.94% and 10.85%, respectively) with percent reduction of flower bud infestation over control (30.41% and 24.07%, respectively) were observed (Table 44).

Table 44. Effect of bio-pesticides and chemical insecticides on flower bud infestation by thrips on mungbean

Treatments	No. of total flower bud plant^{-1}	No. of infested flower bud by thrips plant^{-1}	% infestation of flower bud by thrips	% reduction infestation over control
T$_1$	39.67 ab	3.93 cd	9.94 cd	30.41 cd
T$_2$	41.33 a	2.97 e	7.22 e	49.50 a
T$_3$	40.67 ab	3.33 de	8.20 de	42.58 ab
T$_4$	40.13 ab	3.67 cd	9.17 cde	35.87 bc
T$_5$	37.13 ab	4.57 ab	12.39 ab	13.31 e
T$_6$	38.33 ab	4.13 bc	10.85 bc	24.07 d
T$_7$	36.87 ab	4.93 a	13.38 a	6.33 e
T$_8$	35.87 b	5.13 a	14.29 a	-
S$\bar{x}$	1.53	0.20	0.65	3.05
CV (%)	6.82	8.63	10.62	18.28

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = Novastar 56EC @ 1 ml L^{-1} of water, T$_2$ = Stargate 48SC @ 0.4 ml L^{-1} of water, T$_3$ = Confidor 70WG @ 0.2 g L^{-1} of water, T$_4$ = Actara 25WG @ 0.2 g L^{-1} of water, T$_5$ = Tracer 45SC @ 0.4 ml L^{-1} of water, T$_6$ = Ecomec 1.8EC @ 1 ml L^{-1} of water, T$_7$ = Bioneem plus 1EC @ 1 ml L^{-1} of water, T$_8$ = Untreated control].

The above results of the study revealed that all the insecticides significantly reduced flower bud infestation in mungbean. Stargate 48SC was the most effective insecticide against thrips which cause flower bud infestation and Confidor 70WG was second effective insecticide, Actara 25WG was third effective insecticide. Other chemical treatment i.e., Novastar 56EC also showed significant variation in reducing of flower bud infestation. Among bio-pesticides Ecomec 1.8EC treated plots showed better result in reduction of flowerbud infestation (24.07%). Comparatively, other bio-pesticides i.e., Tracer 45SC and Bioneem plus 1EC performed poorly against thrips resulting lower flower bud infestation reduction (13.29% and 6.37%, respectively) of mungbean in field condition. The order of effectiveness of treatments was Stargate 48SC (T$_2$) > Confidor 70WG (T$_3$) > Actara 25WG (T$_4$) > Novastar 56EC (T$_1$) > Ecomec 1.8EC (T$_6$) > Tracer 45SC (T$_5$) > Bioneem plus 1EC (T$_7$) > Untreated control (T$_8$).

4.6.9. Effect of bio-pesticides and chemical insecticides on flower bud shedding by thrips at flowering stage of mungbean

Flower bud shedding by thrips was significantly affected by the application of bio-pesticides and chemical insecticides (Table 45). Among the treatments, the lowest number of shedding flower bud (1.74 plant^{-1}) with 4.21% flower bud shedding was observed in Stargate 48SC (T$_2$) treated plot which was followed by Confidor 70WG (T$_3$) and Actara 25WG (T$_4$) treated plots, where the percent flower bud shedding (4.96% and 5.28%, respectively) was found. On the other hand, the highest number of shedding flower bud (3.34 plant^{-1}) with 9.38% flower bud shedding was recorded in control plots (T$_8$) which was statistically identical with Bioneem plus 1EC (T$_7$) and Tracer 45SC (T$_5$) treated plots, where the number of shedding flower bud (3.12 and 2.97 plant^{-1}) with (8.50% and 8.08%) flower bud shedding, respectively was observed. Stargate 48SC, Confidor 70WG and Actara 25WG reduced above 40% flower bud shedding (54.03%, 46.15% and 42.95%, respectively). Among bio-pesticides, Ecomec 1.8EC reduced maximum (28.83%) of flower bud shedding, whereas, Tracer 45SC (T$_5$) and Bioneem plus 1EC (T$_7$) reduced flower bud shedding 13.82% and 9.39%, respectively (Table 45).

Table 45. Effect of bio-pesticides and chemical insecticides on flower bud shedding by thrips on mungbean

Treatments	No. of total flower bud plant^{-1}	No. of shedding flower bud plant^{-1}	% flower bud shedding	% reduction of flower bud shedding over control
T$_1$	39.67 ab	2.38 bc	6.01 c	35.14 cd
T$_2$	41.33 a	1.74 d	4.21 d	54.03 a
T$_3$	40.67 ab	2.02 cd	4.96 cd	46.15 ab
T$_4$	40.13 ab	2.12 cd	5.28 cd	42.95 bc
T$_5$	37.13 ab	2.97 a	8.08 ab	13.82
T$_6$	38.33 ab	2.53 b	6.66 bc	28.83 d
T$_7$	36.87 ab	3.12 a	8.50 a	9.39 e
T$_8$	35.87 b	3.34 a	9.38 a	-
S$\bar{x}$	1.53	0.13	0.54	3.07
CV (%)	6.82	8.83	14.05	16.14

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = Novastar 56EC @ 1 ml L^{-1} of water, T$_2$ = Stargate 48SC @ 0.4 ml L^{-1} of water, T$_3$ = Confidor 70WG @ 0.2 g L^{-1} of water, T$_4$ = Actara 25WG @ 0.2 g L^{-1} of water, T$_5$ = Tracer 45SC @ 0.4 ml L^{-1} of water, T$_6$ = Ecomec 1.8EC @ 1 ml L^{-1} of water, T$_7$ = Bioneem plus 1EC @ 1 ml L^{-1} of water, T$_8$ = Untreated control].

The above results of the study revealed that Stargate 48SC reduced maximum flower bud shedding and Confidor 70WG was second effective insecticide, Actara 25WG was third effective insecticide in reducing flower bud shedding. Other chemical treatment i.e., Novastar 56EC also showed significant variation in reducing of flower bud shedding. Among bio-pesticides Ecomec 1.8EC showed better result in reduction of flower bud shedding. Comparatively, other bio-pesticides i.e., Tracer 45SC and Bioneem plus 1EC performed poorly against thrips resulting lower reduction of flower bud shedding in mungbean field. The order of effectiveness of treatments was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8).

4.6.9.1. Relationship between incidence of thrips population and flower bud shedding

Rate of flower bud shedding percentage was significantly affected by thrips. Figure 35 showed a proportional relationship between number of thrips and rate of flower bud shedding. There was a positive relationship between number of thrips and rate of flower bud shedding. The result showed that the flower bud shedding percentage increase with the increase of thrips population but pesticide reduce the thrips population and flower bud shedding.
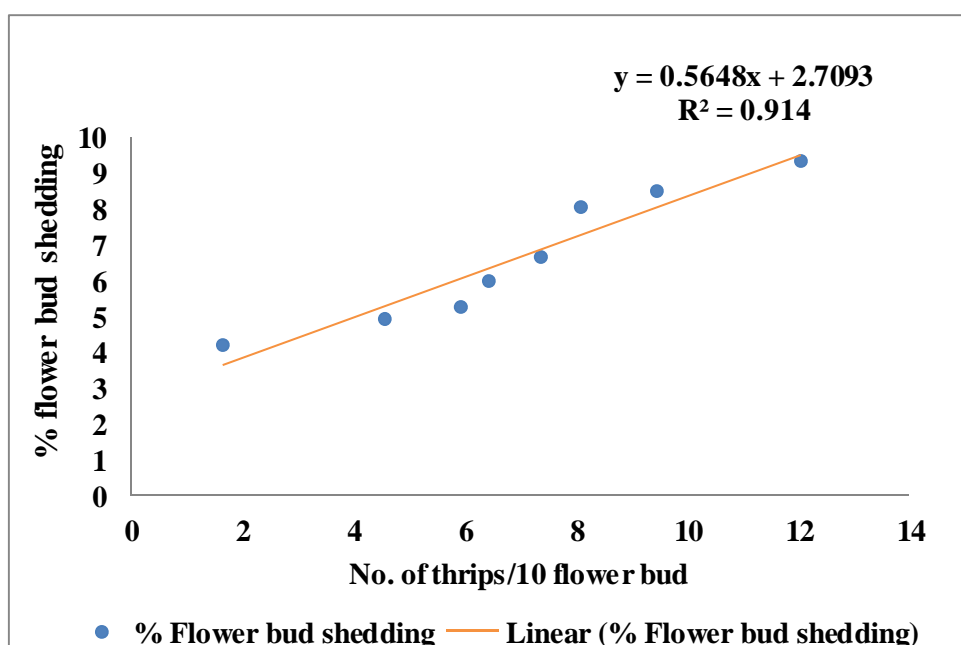
Figure 35. Relationship between incidence of thrips population and flower bud shedding of mungbean.

213

4.6.10. Effect of bio-pesticides and chemical insecticides on flower infestation by thrips at flowering stage of mungbean

Data presented in Table 46 revealed that different bio-pesticides and chemical insecticides significantly affected the flower infestation of mungbean by thrips. Among the treatments, the maximum number of total flower (12.33 plant^{-1}) and the lowest number of infested flower (0.42 plant^{-1}) with 3.41% flower infestation were observed in Stargate 48SC (T$_2$) treated plots which were followed by Confidor 70WG (T$_3$), Actara 25WG (T$_4$) and Novastar 56EC (T$_1$), where the total number of flower (11.11, 10.87 and 10.13 plant^{-1}, respectively) and infested number of flower (1.33, 1.97 and 2.11 plant^{-1}, respectively) with (12.07%, 18.20% and 21.03%, respectively) flower infestation by thrips. On the other hand, the lowest number of total flower (7.12 plant^{-1}) and highest number of infested flower (3.34 plant^{-1}) with 47.22% flower infestation were recorded on untreated control plot (T$_8$) and which were followed by Bio-neem plus 1EC (T$_7$) and Tracer 45SC (T$_5$), where the total number of flower (7.33 and 8.54 plant^{-1}, respectively) and infested number of flower (3.04 and 2.87 plant^{-1}, respectively) with (41.63% and 33.65%, respectively) of flower infestation by thrips were found. Stargate 48SC and Confidor 70WG reduced above 70% flower infestation (92.71% and 73.98%, respectively). Other chemical treatment i.e., Novastar 56EC also reduced (55.48%) flower infestation. On the contrary, Bioneem plus 1EC and Tracer 45SC reduced 10.34% and 27.80% flower infestation, respectively. Among bio-pesticides Ecomec 1.8EC reduced maximum (43.69%) flower infestation.

Table 46. Effect of bio-pesticides and chemical insecticides on flower infestation by thrips on mungbean

Treatments	Total No. of flower plant^{-1}	No. of infested flower plant^{-1}	% infestation of flower	% reduction infestation over control
T_1	10.13 bc	2.11 d	21.03 e	55.48 c
T_2	12.33 a	0.42 f	3.41 g	92.71 a
T_3	11.11 ab	1.33 e	12.07 f	73.98 b
T_4	10.87 ab	1.97 d	18.20 e	61.28 c
T_5	8.54 cd	2.87 b	33.65 c	27.80 e
T_6	9.14 c	2.43 c	26.59 d	43.07 d
T_7	7.33 d	3.04 b	41.63 b	10.34 f
T_8	7.12 d	3.34 a	47.22 a	-
S$\bar{x}$	0.53	0.09	1.64	2.66
CV (%)	9.59	7.49	11.14	8.84

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1 ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4 ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2 g L^{-1} of water, T_4 = Actara 25WG @ 0.2 g L^{-1} of water, T_5 = Tracer 45SC @ 0.4 ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1 ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1 ml L^{-1} of water, T_8 = Untreated control].

From the above findings it was revealed that all the insecticides significantly reduced flower infestation of mungbean. Stargate 48SC was the most effective insecticide against thrips which infest flower and Confidor 70WG was second effective insecticide, Actara 25WG was the third effective insecticide. Comparatively, among bio-pesticides Ecomec 1.8EC showed better result than Tracer 45SC and Bioneem plus 1EC that performed poorly against thrips resulting higher flower infestation of mungbean by thrips in field condition. The order of effectiveness of treatments was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8). This reuslts similar to the findings of Hossain (2015) who reported that application of imidacloprid at different growth stages of mungbean suppressed thrips population and flower infestation significantly. He recorded the lowest number of thrips (2.00) and infested flowers (1.67) 20 flowers^{-1} in Imitaf 20SL sprayed plots which was statistically identical to Regent, Nitro, Ripcord, Voliam flexi and Tafgor.

More than 80% flower infestation reduction was observed in Imitaf and Regent sprayed plots.

4.6.11. Effect of bio-pesticides and chemical insecticides on flower shedding by thrips at flowering stage of mungbean

Flower shedding by thrips was significantly affected by the application of bio-pesticides and chemical insecticides (Table 47). Among the treatments, the lowest number of shedding flower (0.13 plant^{-1}) with 1.06% flower shedding was observed in Stargate 48SC (T_2) treated plot which was followed by Confidor 70WG (T_3), Actara 25WG (T_4) and Novastar 56EC (T_1) treated plots, where the number of shedding flower (0.67, 0.97 and 1.12 plant^{-1}, respectively) with (6.08%, 9.02% and 11.06%, respectively) flower shedding was found. On the other hand, the highest number of shedding flower (2.03 plant^{-1}) with 28.69% flower shedding was recorded from untreated control plot (T_8) which was followed by Bioneem plus 1EC (T_7) and Tracer 45SC (T_5) treated plots where the number of shedding flower (1.87 and 1.63 plant^{-1}, respectively) with (8.50% and 8.08%, respectively) flower shedding was observed. Stargate 48SC reduced maximum 96.25% flower shedding followed by Confidor 70WG (T_3), Actara 25WG (T_4) and Novastar 56EC (T_1), which reduced above 60% flower shedding (78.55%, 68.64% and 61.11%, respectively). Among bio-pesticides, Ecomec 1.8 EC reduced maximum (45.59%) flower shedding (Table 47).

216

Table 47. Effect of bio-pesticides and chemical insecticides on flower shedding by thrips on mungbean

| Treatments	Total No. of flower plant^{-1}	No. of shedding flower plant^{-1}	% shedding flower	% reduction of flower shedding over control
T_1	10.13 bc	1.12 d	11.06 e	61.11 d
T_2	12.33 a	0.13 f	1.06 g	96.25 a
T_3	11.11 ab	0.67 e	6.08 f	78.55 b
T_4	10.87 ab	0.97 d	9.02 e	68.64 c
T_5	8.54 cd	1.63 b	19.12 c	32.62 f
T_6	9.14 c	1.41 c	15.49 d	45.59 e
T_7	7.33 d	1.87 a	25.53 b	10.28 g
T_8	7.12 d	2.03 a	28.69 a	-
$\overline{Sx}$	0.53	0.06	0.80	2.20
CV (%)	9.59	8.64	9.50	6.79

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T_1 = Novastar 56EC @ 1 ml L^{-1} of water, T_2 = Stargate 48SC @ 0.4 ml L^{-1} of water, T_3 = Confidor 70WG @ 0.2 g L^{-1} of water, T_4 = Actara 25WG @ 0.2 g L^{-1} of water, T_5 = Tracer 45SC @ 0.4 ml L^{-1} of water, T_6 = Ecomec 1.8EC @ 1 ml L^{-1} of water, T_7 = Bioneem plus 1EC @ 1 ml L^{-1} of water, T_8 = Untreated control].

From the above findings it was revealed that all the insecticides significantly reduced flower shedding of mungbean by controlling thrips. Stargate 48SC reduced maximum flower shedding whereas, Bioneem plus 1EC reduced minimum flower shedding. The rank of effectiveness of treatments was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8) in respect of flower shedding. Some other authors also more or less supported the above findings. Tamo *et al.* (1993) reported that thrips was an important pest of the reproductive structures (flower bud and flowers) of cowpea, with early feeding leading to flower bud and flower shedding and consequently poor pod setting. Mumutaj (2014) reported that Talstar 2WP (85.04%) showed the best performance in reducing of flower shedding over control followed by Confidor 70WG (83.77%), Dursban 20EC (83.37%) and Actara 25WG (80.36%). Neem oil showed poor performance (56.35%) in reducing flower shedding over control.

4.6.11.1. Relationship between incidence of thrips population and flower shedding of mungbean

Rate of flower shedding percentage was significantly affected by thrips. Figure 36 showed a proportional relationship between number of thrips and rate of flower shedding. There was a positive relationship between number of thrips and rate of flower shedding. The result showed that the flower shedding percentage increase with the increase of thrips population but pesticide reduce the thrips population and flower shedding.

$$y = 2.4791x - 5.652$$
$$R^2 = 0.9749$$
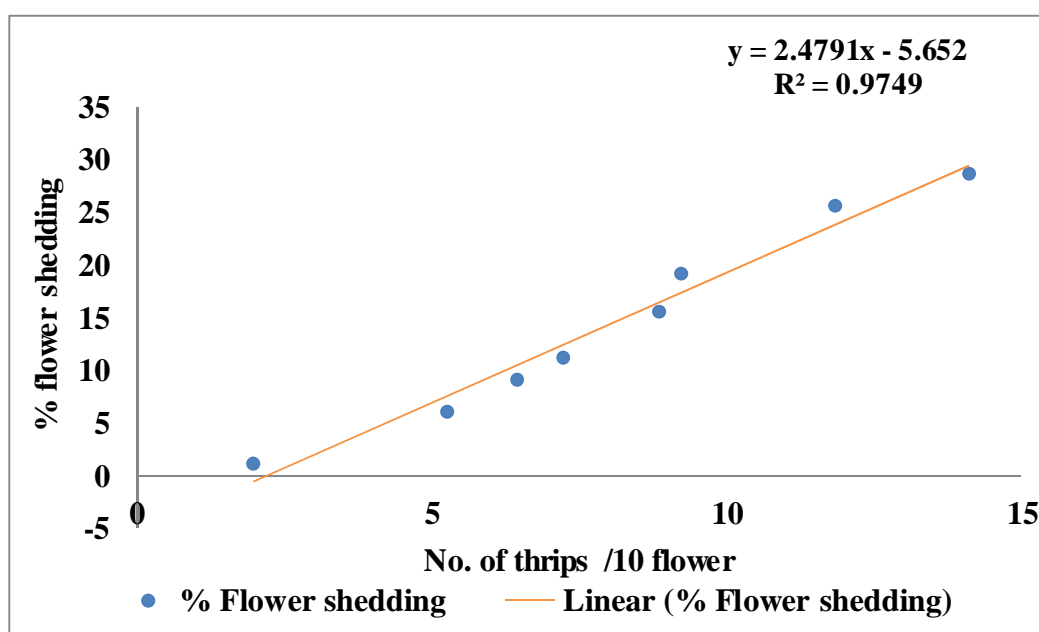
Figure 36. Relationship between incidence of thrips population and flower shedding of mungbean.

4.6.12. Effect of bio-pesticides and chemical insecticides on pod, seed and yield of mungbean

The Effect of bio-pesticides and chemical insecticides on pod, seed and yield of mungbean has been described under the following subheadings-

4.6.12.1. Number of pods plant^{-1}, pod length and their percent increase over control

The average number of pods and pod length of mungbean under different treatments have been shown in Table 48. The highest number of pod (23.80 plant^{-1}) and pod length (8.03 cm) was observed in Stargate 48SC (T_2) treated plot followed by Confidor 70WG (T_3), Actara 25WG (T_4) and Novastar 56EC (T_1) treated plots, where the number of pods (22.40, 21.20 and 20.70 plant^{-1}, respectively) and pod length

218

(7.82, 7.36 and 7.22 cm, respectively) were observed. However, the lowest number of pods and pod length (16.40 plant^{-1} and 5.84 cm) was found in untreated control plot (T$_8$) which was followed by Bioneem plus 1EC (T$_7$) and Tracer 45SC (T$_5$) treated plots, where the pods number (17.20 and 18.80 plant^{-1}, respectively) and pod length (6.34 and 6.84 cm, respectively) were observed. Stargate 48SC (T$_2$) showed the best performance in increasing the number of pods plant^{-1} (45.89%) and pod length (37.95%) over untreated control followed by Confidor 70WG (T$_3$) (36.78% and 33.92%, respectively) and Actara 25WG (T$_4$) (29.84% and 26.11%, respectively). Bioneem plus 1EC (T$_7$) showed poor performance in increasing pod number and pod length (4.90% and 8.59%, respectively) over untreated control plot followed by Tracer 45SC (T$_5$) (14.82% and 17.74%, respectively).

Table 48. Effect of bio-pesticides and chemical insecticides on number of pods and pod length of mungbean

Treatments	Number of pods plant^{-1}	% increase over control	Pod length (cm)	% increase over control
T$_1$	20.70 abc	26.88 c	7.22 ab	23.68 b
T$_2$	23.80 a	45.89 a	8.03 a	37.95 a
T$_3$	22.40 ab	36.78 b	7.82 a	33.92 a
T$_4$	21.20 abc	29.84 c	7.36 ab	26.11 b
T$_5$	18.80 cd	14.82 d	6.84 abc	17.74 c
T$_6$	19.70 bcd	20.24 d	7.13 ab	22.05 bc
T$_7$	17.20 d	4.90 e	6.34 bc	8.59 d
T$_8$	16.40 d	-	5.84 c	-
S$\overline{x}$	1.07	2.01	0.38	1.78
CV (%)	9.26	13.59	9.28	12.71

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = Novastar 56EC @ 1 ml L^{-1} of water, T$_2$ = Stargate 48SC @ 0.4 ml L^{-1} of water, T$_3$ = Confidor 70WG @ 0.2 g L^{-1} of water, T$_4$ = Actara 25WG @ 0.2 g L^{-1} of water, T$_5$ = Tracer 45SC @ 0.4 ml L^{-1} of water, T$_6$ = Ecomec 1.8EC @ 1 ml L^{-1} of water, T$_7$ = Bioneem plus 1EC @ 1 ml L^{-1} of water, T$_8$ = Untreated control].

The above results revealed that all the insecticides significantly increaseed pod number and pod length in mungbean. Stargate 48SC (T_2) was the most effective insecticide in increasing the rate of pod formation and pod length and Confidor 70WG (T_3) was the second effective insecticide, Actara 25WG (T_4) was the third effective insecticide. Among bio-pesticides, Ecomec 1.8EC showed better performance in increasing pod number (20.12%) and pod length (22.09%) over untreated control. The order of effectiveness of treatments was Stargate 48SC (T_2) > Confidor 70WG (T_3) > Actara 25WG (T_4) > Novastar 56EC (T_1) > Ecomec 1.8EC (T_6) > Tracer 45SC (T_5) > Bioneem plus 1EC (T_7) > Untreated control (T_8). These results partially agreed with the report of Ali (2008), who recorded that pods plant^{-1} and pod length of mungbean varied significantly among different insecticides and found that the number of pod plant^{-1}, pod length and their increase over control was maximum in admire 200SL followed by ripcord 10EC. The order of effectiveness of insecticides was Admire 200SL > Ripcord 10EC > Neemarin1500 > Marshal 20EC > Abatin 1.8EC.

4.6.12.2. Relationship between flower shedding and pod number of mungbean

Rate of flower shedding percentage was significantly affected on pod number of mungbean plant. Figure 37 showed a proportional relationship between rate of flower shedding and pod number /plant. There was a negative relationship between rate of flower shedding and pod number /plant. The result showed that the pod number decreased with the increase of flower shedding percentage but pesticide reduce the thrips population and flower shedding.

$$y = -0.2631x + 23.842$$
$$R^2 = 0.9949$$
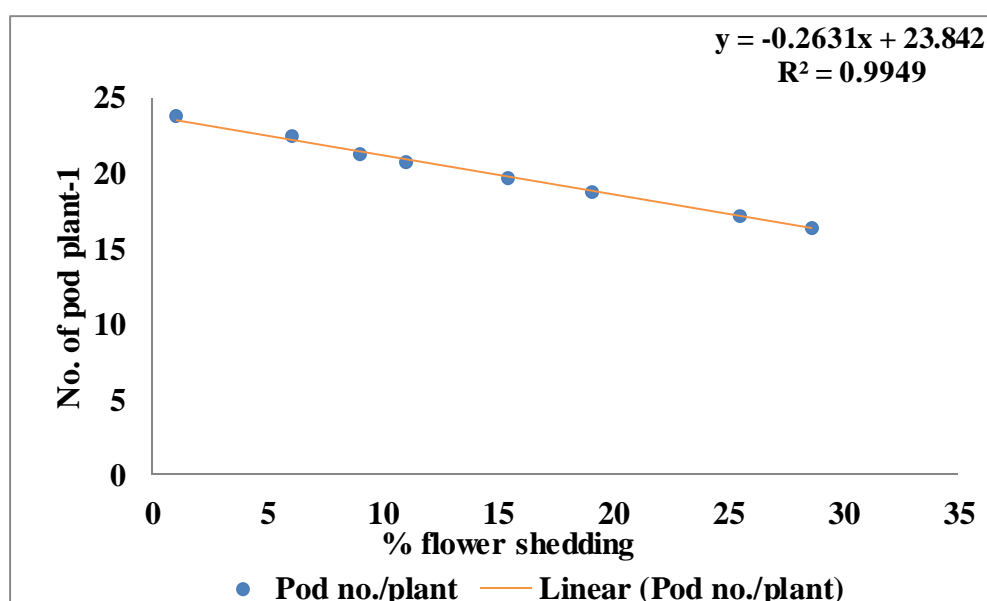
Figure 37. Relationship between flower shedding and pod number of mungbean

4.6.12.3. Number of seed pod[-1], 1000 seed weight, yield of mungbean and their percent increase over control

Significant variations were found in the number of seeds pod[-1], 1000 seed weight and yield due to the effect of different bio-pesticides and chemical insecticides applied against thrips infesting mungbean (Table 49). Among the treatments, Stargate 48SC (T_2) produced the maximum number of seeds (10.20 seeds pod[-1]), 1000 seed weight (48.40 g, respectively) and yield (1026.91 kg ha^{-1}) which was statistically identical with Confidor 70WG (T_3) (9.30 seeds pod[-1], 1000 seed weight 47.10 g and yield 991.26 kg ha^{-1}) and Actara 25WG (T_4) (9.00 seeds pod[-1], 1000 seed weight 46.40 g and yield 970.22 kg ha^{-1}, respectively) treated plots. Whereas, the minimum number of seeds (6.97 seeds pod[-1]), 1000 seed weight (37.30 g) and yield (532.24 kg ha^{-1}) was recorded in untreated control plot (T_8), which was followed by treatment Bioneem plus 1EC (T_7) (7.80 seeds pod[-1], 1000 seed weight 40.70 g and yield 691.37 kg ha^{-1}, respectively) (Table 4.6.12). Other treatments gave intermediate level of seeds pod[-1], 1000 seed weight and yield and they were i.e., Novastar 56EC (T_1) (8.70 seeds pod[-1], 1000 seed weight 45.20 g and yield 871.43 kg ha^{-1}, respectively), Ecomec 1.8EC (T6) (8.50 seeds pod[-1], 1000 seed weight 44.70 g and yield 792.80 kg ha^{-1}, respectively) and Tracer 45SC (T_5) (8.10 seeds pod[-1], 1000 seed weight 44.10 g and yield 774.12 kg ha^{-1}, respectively). The results of the study revealed that all the insecticides increased seeds pod[-1], 1000 seed weight and yield in mungbean. Stargate 48SC (T_2) showed the best performance in increasing of seeds pod[-1] (47.22%), 1000 seed weight (30.05%) and yield (93.68%), respectively over untreated control plot followed by Confidor 70WG (T_3) (33.56%, 26.60% and 86.74%, respectively and Actara 25WG (T_4) (29.65%, 24.43% and 82.31%, respectively). Bioneem plus 1EC (T_7) showed poor performance in increasing seeds pod[-1], 1000 seed weight and yield (12.15%, 9.45% and 29.94%, respectively) followed by Tracer 45SC (T_5) (16.99%, 18.55% and 45.93%, respectively) over untreated control plot (Table 49).

Table 49. Effect of bio-pesticides and chemical insecticides to manage thrips and its impact on yield of mungbean

Treatment	Seed No. pod^{-1}	% increase over control	1000 seed weight (g)	% increase over control	Yield (kg ha^{-1})	% increase over control
T$_1$	8.70 bcd	25.64 cd	45.20 b	21.21 cd	871.43 b	64.18 b
T$_2$	10.20 a	47.22 d	48.40 a	30.05 a	1026.91 a	93.68 a
T$_3$	9.30 ab	33.56 b	47.10 ab	26.60 ab	991.26 a	86.74 a
T$_4$	9.00 bc	29.65 bc	46.40 ab	24.43 bc	970.22 a	82.31 a
T$_5$	8.10 cd	16.99 ef	44.10 b	18.55 d	774.12 bc	45.93 c
T$_6$	8.50 bcd	22.79 de	44.70 b	19.99 cd	792.80 b	48.83 c
T$_7$	7.80 de	12.15 f	40.70 c	9.45 e	691.37 c	29.94 d
T$_8$	6.97 e	-	37.30 d	-	532.24 d	-
S$\bar{x}$	0.36	2.12	1.01	1.61	32.38	4.21
CV (%)	7.34	13.68	3.94	12.97	6.75	11.29

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[T$_1$ = Novastar 56EC @ 1 ml L^{-1} of water, T$_2$ = Stargate 48SC @ 0.4 ml L^{-1} of water, T$_3$ = Confidor 70WG @ 0.2 g L^{-1} of water, T$_4$ = Actara 25WG @ 0.2 g L^{-1} of water, T$_5$ = Tracer 45SC @ 0.4 ml L^{-1} of water, T$_6$ = Ecomec 1.8EC @ 1 ml L^{-1} of water, T$_7$ = Bioneem plus 1EC @ 1 ml L^{-1} of water, T$_8$ = Untreated control].

From the above findings, it was revealed that Stargate 48SC (T$_2$) was the most effective insecticide in increasing seeds pod^{-1}, 1000 seed weight and yield of mungbean and Confidor 70WG (T$_3$) was second effective insecticide, Actara 25WG (T$_4$) was third effective insecticide. Among bio-pesticides, Ecomec 1.8EC showed better performance than other bio-pesticieds. The order of effectiveness of treatments was Stargate 48SC (T$_2$) > Confidor 70WG (T$_3$) > Actara 25WG (T$_4$) > Novastar 56EC (T$_1$) > Ecomec 1.8EC (T$_6$) > Tracer 45SC (T$_5$) > Bioneem plus 1EC (T$_7$) > Untreated control (T$_8$). Singh *et al.* (2016) reported that all the insecticides tested in the experiment were effective in increasing yield of mungbean over control. The insecticide clothianidin 60 g a.i. ha^{-1} produced maximum yield 6.67 q ha^{-1} while the control plot yielded 3.39 q ha^{-1}. Mumutaj (2014) also found that the yield per plot of mungbean was affected by the application of different insecticidal treatments. The highest yield per plot was obtained by the application of Talstar 2WP (2.05 kg)

followed by Confidor 70WG (1.96 kg). The lowest yield per plot was obtained in untreated control plot (1.06 kg) followed by Neem oil (1.27 kg). Other treatments gave intermediate levels of yield and they were Decis 5EC (1.68 kg), Ripcord 10EC (1.52 kg), Marshal 20EC (1.83 kg), Sevin 85SP (1.55 kg), Dursban 20EC (1.94 kg) and Actara 25WG (1.91 kg). Ali (2008) found that seeds pod^{-1}, 1000 seed weight and yield of mungbean were highest in admire 200SL treated plots among the tested insecticides. The order of effectiveness of insecticides was Admire 200SL > Ripcord 10EC > Neemarin 1500 > Marshal 20EC > Abatin 1.8EC.

4.6.12.4. Relationship between number of thrips in flower and yield of mungbean
Number of thrips in flower was significantly affected on yield of mungbean. Figure 38 showed a negative relationship between thrips number in flower and yield of mungbean. The result showed that the yield decreased with the increase of thrips number in flower. Nabirye *et al.* (2003) found a significant negative relationship between thrips densities and cowpea grain yield.
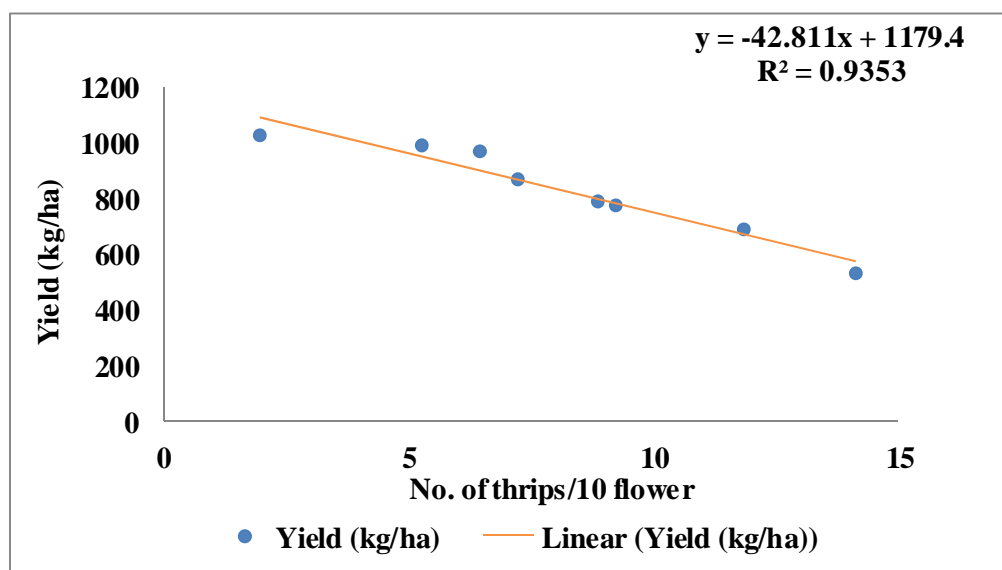
Figure 38. Relationship between incidence of thrips (in flowers) and yield of mungbean.

CHAPTER V
SUMMARY

Six experiments were conducted, two of which in the Laboratory of Department of Entomology and four in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during February 2016 to May 2018 to study bio-ecology, taxonomic characterization, varietal screening, color traps and management of thrips infesting mungbean. Based on the findings of the six experiments, the results have been summarized below:

Two species of thrips were identified on mungbean and they were *Megalurothrips usitatus* and *Thrips palmi*. Study on the morphological features revealed that the adult females of *M. usitatus* were mainly dark brown in color with striped abdominal segments and macroptera (fully winged). Antennae were eight segmented and the segment III was yellow. The antennal segments III–IV were with forked sensorium and VIII was almost twice as long as VII. The ocellar setae III was long, arising just inside triangle ocelli. 2 pairs of long postero-angular setae and 1 pair of antero-angular setae were prominent on pronotum. The first vein setal row of forewing was incomplete, but second vein setal row was complete, with closely and uniformly spaced setae. Abdomianl segment VIII beared postero-marginal comb of small microtrichia. Sternites had three pairs of long marginal setae. The male of *M. usitatus* was similar to female but was smaller and paler. Legs were almost yellow in color, Pronotum was usually more yellow than head which was deepest in colour and abdominal segment X was never tubular.

Adult females of *T. palmi* were yellow in color with numerous dark setae on the head, thorax and abdomen. Antennae were 7 segmented and transluscent forked sense cones were present on segments III and IV. A pair of ocellar setae was located outside the triangular formation. Three ocelli beared red pigment. The wings had some dark pigments, first vein of forewing was found with a gap in the setal row followed by 3 well-spaced distal setae and second vein with row of near about 15 setae. Pronotum beared only two pairs of large setae at posterolateral angle and metanotum with median setae arising behind anterior margin was found. There were four lateral marginal setae on abdominal tergite II and three pairs of marginal setae were present each on abdominal sternite of III–VII.

Adult females of *M. usitatus* were larger than males and average body length of female and male was 1.97 ± 0.13 mm and 1.42 ± 0.12 mm, respectively and that of antenna was 0.36 ± 0.03 mm and 0.32 ± 0.02 mm, respectively. The average head length and width of female were 0.18 ± 0.02 mm and 0.18 ± 0.01 mm, respectively where in male, were 0.13 ± 0.01 mm and 0.16 ± 0.01 mm, respectively. The average thoracic length was 0.60 ± 0.04 mm and 0.48 ± 0.03 mm in female and male, respectively. The width of prothorax and mesothorax was 0.24 ± 0.01 mm and 0.43 ± 0.03 mm, respectively in female, where 0.22 ± 0.01 mm and 0.32 ± 0.03 mm, respectively, in male. The abdominal length and width were 1.18 ± 0.08 mm and 0.45 ± 0.03 mm, respectively in female, where 0.79 ± 0.07 mm and 0.28 ± 0.02 mm, respectively in male.

T. palmi was smaller than *M. usitatus.* The average body length of female *T. palmi* was 1.20 ± 0.02 mm and length of antenna was 0.23 ± 0.01 mm. The head was wider than length and the average length and width were 0.12 ± 0.01 mm and 0.14 ± 0.01 mm, respectively. The average thoracic length was 0.39 ± 0.01 mm. The prothoracic and mesothoracic width were 0.19 ± 0.01 mm and 0.26 ± 0.01 mm, respectively. The average abdominal length and width were 0.69 ± 0.02 mm and 0.28 ± 0.01 mm, respectively.

The results for the study on biology of thrips revealed that eggs of *M. usitatus* had taken 3.13 ± 0.06 days to hatch after oviposition in mungbean pod. The larvae of *M. usitatus* resembled the adults in general body form though they were smaller, apterous and different in color. Between two larval instars, the first instar was pale yellow in color and developed in 1.48 ± 0.05 days. The second instar was deep yellow to orange in color and larger, and needed 2.30 ± 0.08 days to develop. Two instars were noticed during the pupal period and the wing pads of the prepupae were shorter than that of the pupae. The antennae of prepupa was erect but was found bent in pupa. The prepupal period was 1.30 ± 0.07 days and that of the pupal stage was 2.26 ± 0.13 days. The pupa moulted to adult which was dark brown in color. Taken together, the developmental time from egg to adult was 10.54 ± 0.15 days on mungbean pod. In case of pre-adult mortality percentage of *M. usitatus,* mortality of the first larval instar was 14.41%, second larval instar 22.77%, pre-pupa 14.10% and pupa 65.67%. The total pre-adult mortality was 80.51%. The longevity of adult males was shorter (6.42 ± 0.44 days) than adult females (12.07 ± 1.56 days) reared on mungbean pod.

The incidence of *M. usitatus* was higher than *T. palmi* on all the plant parts (top trifoliate leaf, terminal shoot, flower bud and flower) in different sowing dates during kharif season, 2016. Among the different dates of sowing the lowest number of *M. usitatus* and *T. palmi* (2.21 and 1.02, respectively per 5 top trifoliate leaves, 2.67 and 1.43, respectively per 5 terminal shoots, at pre-flowering stage and 4.22 and 2.18, respectively per 5 flower buds, 5.28 and 1.42, respectively per 5 flower at flowering stage) was recorded on 21 March sown crop. The highest population of *M. usitatus* and *T. palmi* (5.04 and 2.51, respectively per 5 top trifoliate leaves, 5.53 and 3.48, respectively per 5 terminal shoots at pre-flowering stage and 8.41 and 4.40, respectively per 5 flower buds, 9.34 and 5.34, respectively per 5 flowers at flowering stage) was recorded when crop was sown on 10 February. Thrips population was higher at early (10 February to 01 March) and late (10 April to 30 April) sown crops than mid (11 March to 31 March) sown crops. Similarly, at pre-flowering stage, the lowest percent infestation of top trifoliate leaves (50.07%) and terminal shoots (50.73%) by thrips was recorded in 21 March sown crop while the highest percent infestation of top trifoliate leaves (76.20 %) and terminal shoots (77.13%) by thrips was recorded in 10 February sown crop. At flowering stage, the lowest percent infestation and shedding of flower bud (22.44% and 10.36%, respectively) and flower (38.23% and 20.92%, respectively) were recorded in 21 March sown crop while the highest percent infestation and shedding of flower bud (60.08% and 26.06%, respectively) and flower (75.81% and 45.61 %, respectively) were recorded in 10 February sown crop. There was positive relationship between number of thrips and flower shedding (y = 2.914x + 2.341, R^2 = 0.891) of mungbean.

The population dynamics of thrips in different dates of sowing was significantly related to weather factors. In 10 February, 2016 (T_1) sown mungbean, the population of *M. usitatus* and *T. palmi* on flower (5.73 and 3.19 per 5 flowers, respectively) was first observed at 39 DAS and reached to a peak level (15.83 *M. usitatus* and 8.97 *T. palmi* per 5 flowers) on 67 DAS. Thereafter, both the thrips population decreased gradually but was active till 88 DAS. In 20 February (T_2) sown mungbean, the population of *M. usitatus* and *T. palmi* (13.59 and 8.65 per 5 flowers, respectively) attained peak on 57 DAS. After that, the population of both the thrips species decreased gradually and found up to 85 DAS (15 May). In 1 March (T_3) sown mungbean, the population of *M. usitatus* (16.67 per 5 flowers) and *T. palmi* (9.67 per

5 flowers) attained peak on 17 April (48 DAS) when no rainfall was occurred and flowers also available for inhabiting thrips. In 11 March (T_4) sown mungbean, the peak incidence of *M. usitatus* and *T. palmi* (9.57 and 3.12 per 5 flowesr, respectively) was recorded on 51 DAS. In March 21 (T_5) sown crop, the population *M. usitatus* and *T. palmi* was recorded in flower from 24 April (34 DAS) to 13 June (83 DAS). The maximum population of *M. usitatus* and *T. palmi* (9.98 and 2.61 per 5 flowers, respectively) was found on 1 May (41 DAS). In 31 March (T_6) sown crop, the population of both *M. usitatus* and *T. palmi* was appeared in flower on 1 May (31 DAS) and attained peak on 66 DAS (5 June), when rainfall was only 0.43 mm but the thrips population decreased drastically on 13 June (73 DAS) when rainfall was 24 mm during that week. In 10 April (T_7) sown mungbean, the incidence of *M. usitatus* and *T. palmi* in flower was initiated from 15 May (35 DAS) and reached its peak (*M. usitatus* 9.87 and *T. palmi* 5.87 per 5 flowers, respectively) on 5 June (56 DAS) and was active till 26 June (77 DAS). In April 20 (T_8) sown mungbean, the population of *M. usitatus* and *T. palmi* in flowers was recorded from 22 May (32 DAS) to 26 June, (67 DAS). In April 30 sown crop (T_9) the population of *M. usitatus* and *T. palmi* was started to appear in flower from 29 May (29 DAS) and attained its peak (9.63 and 4.67 per 5 flowers, respectively) on 36 DAS (5 June). In the next week, the population of both the species declined drastically when rainfall was 24.00 mm. But the population of both the thrips species increased again on 26 June (57 DAS) when rainfall 0.86 mm, average temperature $30.59^{o}C$ and relative humidity 74.00% were recorded.

The population of *T. palmi* and *M. usitatus* in mungbean flower showed significantly positive relationship with temperature and bright sunshine hour but negatively related with rainfall and relative humidity.

Exploring yield contributing parameters, the highest pod number (34.00 $plant^{-1}$), pod length (8.59 cm), seed number (11.87 pod^{-1}), 1000 seed weight (50.88 g) and yield (1176.80 kg ha^{-1}) of mungbean were recorded in 21 March sown crop. Whereas, the lowest pod number (24.33 $plant^{-1}$, pod length (7.47 cm), seed number (9.92 pod^{-1}), 1000 seed weight (43.33 g) and yield (966.70 kg ha^{-1}) were recorded in 10 February sown mungbean. The yield of mungbean was significantly affected by thrips and found a negative relationship (y = - 22.25x + 1260, R^2 = 0.640) between number of thrips and yield of mungbean.

The results for the study on varietal screening against thrips revealed that among eleven mungbean varieties, no variety was found free from thrips attack but in BARI Mung-7 (T_8), comparatively lower incidence of *M. usitatus* and *T. palmi* (0.77 and 0.22), respectively per 10 top trifoliate leaves, 2.22 and 0.77, respectively per 10 terminal shoots at pre-flowering stage, 4.32 and 0.98, respectively per 10 flower buds and 6.01 and 1.66, respectively per 10 flowesr at flowering stage of the crop) was observed. On the other hand, in Barishal local variety, the highest incidence of *M. usitatus* and *T. palmi* (3.01 and 2.14, respectively per 10 top trifoliate leaves, 4.96 and 4.17, respectively per 10 terminal shoots at pre-flowering stage, 5.94 and 5.68, respectively per 10 flower buds and 14.27 and 8.40, respectively per 10 flowers at flowering stage of the crop) was found. Similarly, the lowest percent infestation of top trifoliate leaves (25.00 %) and terminal shoots (48.33 %) at pre-flowering stage and lowest percent infestation and shedding of flower bud (21.00 % and 2.76 %, respectively), and lowest percent infestation and shedding of flower (29.42 % and 14.02 %, respectively) at flowering stage were recorded in BARI Mung-7 (T_8). On the other hand, the highest percent infestation of top trifoliate leaves (50.00 %) and terminal shoots (81.67 %) at pre-flowering stage and highest percent infestation and shedding of flower bud (77.76 % and 48.67 %, respectively) and highest percent infestation and shedding of flower (66.25 % and 39.20 %, respectively) at flowering stage were recorded in Barishal local variety. In respect of lower incidence of thrips and lower infestation of different plant parts of mungbean, the rank of the varieties was BARI Mung-7 > BARI Mung-8 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI Mung -6 > Binamoog-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local.

Among different morphological traits and chemical constituents in leaf of eleven mungbean varieties responsible for resistance against thrips, leaf trichome hair was found spiny and curved, and the highest leaf trichome density (32.67 per 0.5 cm midrib) from lower surface was observed in BARI Mung-7 (T_8) followed by BARI mung-8 (T_9), BU mug 2 (T_2) and Binamoog-6 (T_5), respectively in which leaf trichome density was (31.67, 31.67 and 30.33 per 0.5 cm midrib, respectively). Whereas, the lowest leaf trichome density (15.67 per 0.5 cm midrib) was observed in Barishal local variety (T_{11}). There was no significant difference in length of leaf trichome hair of 11 tested varieties. Negative relationship (y= -0.2026x + 7.897, R^2 =

0.8971) was found between leaf trichome density and incidence of thrips. There was no significant variation in phosphorous (P) content in leaf of eleven mungbean varieties, but significantly maximum leaf moisture (84.19%), chlorophyll$_{(a+b)}$ (1.11 mg/100 g), potassium (K) (2.34%), phenol (8.39 mg g^{-1}) and minimum total soluble sugar (2.12 mg g^{-1}) content were measured in BARI Mung-7 (T$_8$). On the other hand, minimum leaf moisture (81.61%), chlorophyll$_{(a+b)}$ (0.86 mg per 100 g), potassium (K) (1.50%), phenol (5.64 mg g^{-1}) and maximum total soluble sugar (5.87 mg g^{-1}) content were measured in Barishal local variety. Negative relationship was found between leaf moisture content and number of thrips (y = -1.3408x + 114.06, R^2 = 0.9393), chlorophyll$_{(a+b)}$ content and number of thrips (y = -18.293x + 21.363, R^2 = 0.9038), K content and number of thrips (-4.9737x + 12.451, R^2 = 0.9504), phenol content and number of thrips on leaf (y = -1.582x + 13.588, R^2 = 0.856) but positive relationship was found (y = 0.9584x – 1.0285, R^2 = 0.935) between total soluble sugar content and number of thrips on leaf.

The maximum pod number (26.77 plant^{-1}), pod length (8.84 cm), seed number (11.20 pod^{-1}), 1000 seed weight (48.26 g) and yield (1323.44 kg ha^{-1}), were recorded in BARI Mung-7 (T$_8$) whereas, the lowest yield was found in Barishal local variety (754.89 kg ha^{-1}) with lowest pod number (16.34 plant^{-1}), pod length (6.42 cm), seed number (9.97 pod^{-1}), 1000 seed weight (26.45 g). Due to variations in thrips incidence and different yield contributing characters, the order of varietal performance in respect of yield was BARI Mung-7 > BU mug 2 > Binamoog-6 > BU mug 1 > BARI Mung-6 > Binamoog-8 > BARI Mung-8 > BU mug 5 > BU mug 4 > BARI Mung-2 (Kanti) > Barishal local.

Performance of colored trap study revealed that the blue colored sticky board trap caught the maximum mean number of *M. usitatus* and *T. palmi* (9.23 and 3.88, respectively) followed by violet (6.66 and 3.22, respectively) and orange (6.22 and 2.66, respectively) colored sticky board traps. The minimum mean number of *M. usitatus* and *T. palmi* (4.01 and 1.11, respectively) was caught on pink color sticky board trap. The incidence of thrips was lower in colored sticky board trapped plots in comparison with control plot. The lowest mean number of *M. usitatus* and *T. palmi* (2.23 and 1.64, respectively per 5 top trifoliate leaves, 2.50 and 1.50, respectively per 5 terminal shoots at pre-flowering stage, 4.13 and 2.20, respectively per 5 flower buds, 3.23 and 1.24, respectively per 5 flowers at flowering stage) was found in blue

colored sticky board trapped plot whereas, the highest mean number of *M. usitatus* and *T. palmi* (5.13 and 3.74, respectively per 5 top trifoliate leaves, 5.57 and 3.57, respectively per 5 terminal shoots, 7.18 and 4.21, respectively per 5 flower buds, 9.02 and 5.20, respectively per 5 flowers) was observed in control plot. Blue sticky board trap reduced maximum thrips population (56.30%, 56.06%, 44.37% and 68.59%) on top trifoliate leaves, terminal shoots, flower buds and flowers, respectively. At pre-flowering stage, the lowest percent infestation of top trifoliate leaves and terminal shoots (40.00% and 46.67%, respectively) and at flowering stage, the lowest percent infestation and shedding of flower bud (17.37% and 2.67%, respectively) and the lowest percent infestation and shedding of flower (32.23% and 8.57%, respectively) were found in blue trapped plot. On the other hand, at pre-flowering stage, the highest percent infestation of top trifoliate leaves and terminal shoots (66.67% and 76.67%, respectively) and at flowering stage, the highest percent infestation and shedding of flower buds (34.89 % and 6.68 %, respectively) and the highest percent infestation and shedding of flowers (76.24% and 21.84%, respectively) were found in control plot. The maximum pod number (29.57 plant^{-1}), pod length (8.48 cm), seed number (11.83 pod^{-1}), 1000 seed weight (47.53 g) and yield (1212.30 kg ha^{-1}) were recorded in blue color trapped plot whereas, the minimum pod number (22.77 plant^{-1}), pod length (7.35 cm), seed number (9.20 pod^{-1}), 1000 seed weight (43.20 g) and yield (1022.32 kg ha^{-1}) were found in control plot.

In the management study, among different bio-pesticides and chemical insecticides treated plots, the lowest mean number of *M. usitatus* and *T. palmi* in different plant parts (0.00 and 0.00, respectively per 10 top trifoliate leaves, 0.99 and 0.02, respectively per 10 terminal shoots at pre-flowering stage, 1.66 and 0.00, respectively per 10 flower buds, 1.87 and 0.11, respectively per 10 flowers at flowering stage) was found in Stargate 48SC (T_2) treated plot. On the other hand, the highest mean number of *M. usitatus* and *T. palmi* (5.76 and 2.25, respectively per 10 top trifoliate leaves, 6.77 and 2.78, respectively per 10 terminal shoots at pre-flowering stage, 8.98 and 3.08, respectively per 10 flower buds, 9.23 and 4.90, respectively per 10 flowers at flowering stage) was observed in control plot (T_8). Stargate 48SC (T_2) reduced 100.00 thrips population on top trifoliate leaves and also reduced maximum *M. usitatus* and *T. palmi* population (85.23% and 99.28%, respectively) on terminal shoots, (81.23% and 100.00%, respectively) on flower buds and (79.64% and 97.75%, respectively) on

flowers of mungbean. On the other hand, Bioneem plus 1EC (T_7) reduced the lowest percent of *M. usitatus* and *T. palmi* population (8.41% and 33.77%, respectively) on top trifoliate leaves, (20.55% and 22.37%, respectively) on terminal shoots, (25.28% and 2.83%, respectively) on flower buds and (14.22% and 18.44%, respectively) on flowers of mungbean. At pre-flowering stage, the highest percent reduction infestation of top trifoliate leaves and terminal shoots (100.00% and 75.54%, respectively) and at flowering stage, the highest percent reduction infestation and shedding of flower bud (49.50% and 54.01%, respectively) and highest percent reduction infestation and shedding of flower (92.78% and 96.25%, respectively) were found in Stargate 48SC (T_2) treated plot. On the other hand, the lowest percent reduction infestation of top trifoliate leaves and terminal shoots (13.53% and 8.19%, respectively) and the lowest percent reduction infestation and shedding of flower bud (6.33 % and 9.39%, respectively) and the lowest percent reduction infestation and shedding of flower (10.34% and 10.28%, respectively) were found in Bioneem plus 1EC (T_7). Among bio-pesticides, Ecomec 1.8EC showed better performance. The maximum pod number (23.80 plant^{-1}), pod length (8.03 cm), seed number (10.20 pod^{-1}), 1000 seed weight (48.40 g) and yield (1026.91 kg ha^{-1}) were found in Stargate 48SC (T_2) treated plot while, the minimum pod number (16.40 plant^{-1}), pod length (5.84 cm), seed number (6.97 pod^{-1}), 1000 seed weight (37.30 g) and yield (532.24 kg ha^{-1}) were found in untreated control plot.

CONCLUSION AND RECOMMENDATION

CONCLUSIONS

Based on the findings of the six experiments, the following conclusions can be made-

Two species of thrips i.e., *Megalurothrips usitatus* and *Thrips palmi* were identified on mungbean. The adult female of *M. usitatus* was mainly dark brown, antennae were 8-segmented and the segment III was yellow. The ocellar setae III was long, arising just inside triangle. Two pairs of long posteroangular setae and one pair of anteroangular setae were present on pronotum. The legs of males of *M. usitatus* were sometimes almost yellow and pronotum was usually yellow than head. Adult female of *T. palmi* was yellow, antennae were 7-segmented. A pair of ocellar setae was located outside the triangular red pigmented ocelli. Pronotum beared only two pairs of large setae at posterolateral angle. *T. palmi* was smaller than *M. usitatus.*

The incubation period, first instar larva, second instar larva, prepupa and pupal period were 3.13 ± 0.06 days, 1.48 ± 0.05 days, 2.30 ± 0.08 days, 1.30 ± 0.07 days and 2.26 ± 0.13 days, respectively of *M. usitatus* reared on mungbean pod. Taken together, the developmental time from egg to adult was 10.54 ± 0.15 days.

The larvae of *M. usitatus* resembled the adults in general body form though they lacked wings and were smaller and different in color. The first instar was pale yellow and the second instar was deep yellow to orange and larger in size. The wing pads of the prepupae were shorter than that of the pupae. The antennae of prepupa was erect but was found bent in pupa.

In case of pre-adult mortality percentage of *M. usitatus,* mortality of the first instar larva was 14.41%, second instar larva 22.77%, pre-pupa 14.10% and pupa 65.67%. The total pre-adult mortality was 80.51%. The longevity of adult males was shorter (6.42 days) than adult females (12.07 days).

Both *M. usitatus* and *T. palmi* were recorded from top trifoliate leaf and terminal shoot at pre-flowering stage. After initiation of inflorescence, thrips started to migrate in flower bud and flower of mungbean. In March 21 sown crop, thrips population of both the species, percent infestation of top trifoliate leaf, terminal shoot, flower bud, flower, percent shedding of flower bud and flower was found lowest, but pod number, pod length, seed number in pod, 1000 seed weight and yield was highest.

Thrips population was higher in early (February 10 to March 01) and late sown (10 April to April 30) crops than mid sown (March 11 to March 31) crops in different plant parts of mungbean. Population fluctuation of thrips was very much dependent on prevailing climatic conditions. *M. usitatus* and *T. palmi* on mungbean showed significantly positive relationship with temperature and bright sunshine hours but negatively related with rainfall and relative humidity. There was positive relationship between thrips number and flower bud /flower shedding and negative relationship between population of thrips in flower and yield of mungbean.

Among eleven mungbean varieties, no variety was found free from thrips attack but in BARI Mung-7, BARI Mung-8 and BU mug 2, both *M. usitatus* and *T. palmi* incidence were comparatively lower in different plant parts. Percent infestation of top trifoliate leaf, terminal shoot, flower bud, flower, percent shedding of flower bud and flower was found lowest in BARI Mung-7 followed by BARI Mung-8, BU mug 2 and Binamoog-6. Thrips population showed significantly negative relationship with leaf trichome density, moisture, chlorophyll, potassium and phenol content but positive relationship with total soluble sugar content in leaf. Highest yield was found in BARI Mung-7 followed by BU mug 2, Binamoog-6.

Blue colored sticky board trap caught maximum number of *M. usitatus* and *T. palmi* followed by violet and orange color sticky board traps whereas, pink sticky board trap was found least effective.

Stargate 48SC (clothianidin) was found most effective chemical insecticide against thrips, Confidor 70WG was found second effective and Actara 25WG was found third effective insecticide. Among bio-pesticides, Ecomec 1.8EC was found more effective against thrips but lower than chemical insecticides.

RECOMMENDATIONS

Based on the findings of the present studies, the following recommendations can be made:-

⌐ Two major thrips species i.e., *M. usitatus, T. palmi* was identified on different plant parts of mungbean causing damage to plants and responsible for flower shedding. So, control measures should be taken to manage thrips population.

⟩ In early sown (February) mungbean, thrips incidence was higher due to lower rainfall and control measures should be taken during that period.

⟩ In Mid sown (11 March-21 March) mungbean optimum temperature and rainfall favoured optimum growth of the crop and received less thrips infestation and can be recommended as best sowing time for ensuring higher yield.

⟩ BARI Mung-7, BARI Mung-8 and BU mug 2 contains higher curved trichome hairs, K, moisture, chlorophyll, phenol and lower total soluble sugar and thrips incidence was lower in these varieties. So, more research in depth may be undertaken to confirm these resistant factor(s) for developing resistant varieties in breeding program.

⟩ It may be recommend that blue sticky trap is more effective for monitoring and/or mass trapping of *M. usitatus* and *T. palmi* in mungbean. Further investigation is needed with more number of traps per plot.

⟩ Stargate 48SC (clothianidin) @ 0.4 ml L^{-1} of water may be recommended for suppressing thrips. Among bio-pesticides, Ecomec 1.8 EC @ 1 ml L^{-1} of water may be used.

⟩ Further investigation is needed for validation of these research findings.

CHAPTER VI

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