BIOLOGY AND MANAGEMENT OF GRAPE THRIPS *Scirtothrips dorsalis* HOOD (THRIPIDAE : THYSANOPTERA)

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Bangalore **July, 2008**

Affectionately dedicated to

My Mother Late. Smt.

Jayamma, Family Members,

Guide and

Dr. C.T. Ashok Kumar

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
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CERTIFICATE

This is to certify that the thesis entitled "**BIOLOGY AND MANAGEMENT OF GRAPE THRIPS, *Scirtothrips dorsalis* Hood (THRIPIDAE : THYSANOPTERA)"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** of the University of Agricultural Sciences, Bangalore, is a bonafide record of research work done by **Mr. NIRANJANA, N.S., ID No. PAK 6107,** during the period of his study in the University under my guidance and supervision and that no part of this thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

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THESIS ABSTRACT

Four species of thrips belonging to two different families *viz,* Thripidae and phlaeothripidae were recorded in the grape orchards of Bangalore. Among these, *Scirtothrips dorsolis* Hood was the most common species. The insect was found to damage the leaves, petioles and berries and sucked the sap results in silvery white scarchy patches on the leaves and scars on the berries. In severe infestations, the leaves withered, ultimately fell down. Further, scarring and cracks on fruit surface was observed. When the crop was in tender leaf stage and flowering was initiated, the peak density of *S.dorsalis* was 13.93 during Kharif at 30-40 days after pruning. Similarly, in summer also the peak populations of 17.43 individuals were seen. Effect of crop growth stages on thrips density, fully matured leaves, small, medium and large size fruits except tender leaves have negative effect. The pest number attained a peak of 13.93 per shoot during the last week of July and second week of March 17.43 per shoot in kharif and summer season, respectively. Effect of weather parameters namely, Relative humidity, rainfall and wind speed except temperature were found to have negative effect on *S. dorsalis* infestation. The egg was kidney or oval shape, glassy white in colour, laids singly in the tissues mostly on the tender parts, occasionally on older parts. An average of 12.60±1.51 days to complete the life cycle. On an average each stage *Viz.,* Egg, first, second instar larva, prepupa and pupa lasted for 3.73±0.66 days, 1.15±0.21 days, 2.83±0.49 days, 1.03±0.30 days and 3.83±0.53 days, respectively. The oviposition lasted for 1.93±0.68 days. Mean fecundity was 2.3±0.94 eggs per day and lived for 4.88±1.35days. the efficacy of new insecticide molecules including bio-pesticide Viz, fipronil 80 WG (40 g.a.i/ha), fipronil 80 WG (50 g.a.i/ha), fipronil 5 SC, spinosad 2.5 SC, Imidacloprid 17.8 EC, Dimethoate 30 EC, Quinolphos 25 EC, Monocrotophos 36 SL, Acephate 75 SP, Azadiachtin 1% and Fish oil rosin soap were evaluated against S.dorsalis on grapes in the form of two foliar applications at 10 days interval. Of these, fipronil 80 WG (50 g.a.i/ha),followed by Spinosad, Acephate and imidacloprid proved effective in the control of *S.dorsalis*.

Signature of the Student   Signature of the Major Advisor

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Introduction

I. INTRODUCTION

Grapes (*Vitis vinifera* L.) is one of the most important commercial fruit crops of the temperate region. This crop can also be grown successfully in tropical and sub tropical regions of the world. Grapes is said to have originated from Asia Minor and then spread to Greece, Germany, the United States of America and the Philippines. Grapes seems to have been introduced to India from Iran and Afghanistan in 1300 AD (Bose *et al*., 1999).

Grapes rank first among fruits both in area (7.39 m. ha) and production (68.95 m. tonnes) with a productivity of 9.31 tonnes per hectare. Italy, France, erstwhile USSR, Spain and USA are the important grape growing countries (Anon., 2006)

In India, grapes are commercially grown in about 0.6 lakh ha with an annual production of 10.83 lakh tonnes (Anon., 2006). Grape cultivation in India acquires great significance due to its high productivity (25.68 tonnes/ha) as compared to many grape producing countries. The main grape growing states are Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Karnataka is one of the important states growing different varieties of grapes and grapes are grown in 9,700 ha and the estimated production is about 1.67 lakh tonnes (Anon, 2007).

The important Grape growing districts in Karnataka are Bangalore, Kolar, Bijapur, Bagalkot, Belgaum, Koppal and Gulbarga (Anon., 2007). The Common varieties grown in the state are Thomson seedless, Anab-e-Shahi, Bangalore Blue and Gulabi. Of these, Bangalore Blue is the most popular cultivar of southern districts of Karnataka. It is believed to be a natural hybrid of *V. vivifera* and *V. labrusca* L. It is a moderate yielder and the vines are medium in vigour. Bunches are medium to small in size and compact. The berries are medium sized, bluish black or dark purple in colour, seeded and spherical in shape. Pulp is green and juicy. The juice is purple coloured, foxy flavoured having total soluble solids of about 16 to 18 percent and about 0.8 to 1.0 percent acidity (Winkler *et al*., 1974).

Extensive and intensive cultivation of grape tend to attract number of insect pests to the vineyard (Alexandri, 1973). Bournier (1977) listed 132 insect pests attacking grapes in the world. In India, as many as 94 species of insects and mites have been reported (Tandon and Verghese, 1994). Common pests so far reported are flea beetle (*Scelodonta strigicolis* (Motschulsky)), mealy bugs (*Maconellicoccus hirsutus* Green), thrips (*Ripiphorothrips cruentatus* Hood and *Scirtothrips dorsalis* Hood) and Shot hole borer (*Xyleborus crassiusculus* (Motschulsky)).

Among sucking pests, thrips are considered as serious on grapes. Recently, this pest has assumed major pest status on grapes as the scab caused on fruits reduces yield and marketability. *Ripiphorothrips cruentatus* and *Scirtothrips dorsalis* Hood are the species recorded infesting the leaves and berries (Butani., 1979). Among them, *S. dorsalis*, a key pest of chilli, is also a major pest in Karnataka. This insect has been found to infest about 20 hosts in India, including important crops like tea, cotton, castor and mango (Ananthakrishnan, 1971).

Bangalore Blue, meant for making juice and wine (with export potential) remains as one of the popular varieties among the grape growers especially in and around Bangalore and Kolar districts. Its popularity may further be attributed to the double bearing character in a single year and low production cost compared to other varieties. Farmers in Bangalore and adjacent districts complain that they have difficulty in managing thrips infestation on grapes and very little information is available on the bio-ecology and control of thrips on grapes.

Therefore, considering the importance of the crop and the problem posed by insect pests, an in depth study on the species complex, distribution, nature of damage, seasonal incidence, biology and management of thrips on Bangalore Blue grapes was initiated .

The present investigation was undertaken to study *Scirtothrips dorsalis* Hood a major species of thrips on grapes with following objectives:

1. To study the thrips complex on grapes in and around Bangalore,
2. To study the incidence of thrips in relation to growth parameters of grape vines,
3. To study the biology of *S. dorsalis* infesting grapes,
4. To evaluate the efficacy of selected new insecticide molecules including bio-pesticides against thrips.

Review of Literature

II. REVIEW OF LITERATURE

Thrips are important pests of grapes. A review of available literature on species of thrips occurring on grapes in India and elsewhere reveales the records of *Rhipiphorothrips cruentatus* Hood, *Scirtothrips dorsalis* Hood, *Drepanothrips reuteri* UIzel, *Frankliniella occidentalis* Pergande, *Frankliniella cestrum* Mouiton, *Thrips tabaci* Lindeman, *Thrips meridionalis* Priesn, *Scirtothrips aurantii* Faure, *Scirtothrips citri* (Moulton), *Heliothrips sylvsnus* Faure and *Taeniothrips pallidivestis* (Krat.). Thus, the available literature on species complex of thrips on grapes and symptomatology, seasonal incidence, biology and chemical control with special reference to *S. dorsalis* has been reviewed and presented under the following headings. Further, wherever necessary the work done on *S. dordalis* mainly on chillies, groundnut, castor, rose and tea has also been reviewed and presented to support the present state of knowledge on the species.

2.1 Common names

Scirtothrips dotrsalis is known by many common names It has been called “chilli thrips” (Rao, 1929), “Dreaded chilli thrips” (Singh, 1944) , “Scab thrips of grapes” (Reddy, 1959), “Assam thrips” and “Tea thrips” (Dev, 1964). It is also called “Yellow thrips” because of its colour, and in Japan it is known as “Yellow tea thrips” (Hashimoto *et al*., 1984).

2.1.1 Systematic position

Scirtothrips dorsallis belongs to the family Thripidae of the suborder Terebrantia of the order Thysanoptera. The pest was first collected by Ramakrishna Ayyar on castor shoots and chillies in Coimbatore (India) in 1916 and was sent to hood, who described it as a new species in 1919 under the name *Scirtothrips dorsalis*. Since then, there has been no nomenclature change in this thrips.

2.1.2 Species Complex, seasonal variation in the incidence and distribution

Rahman Bharadwaj (1937) reported *Rhipiphorothrips cruentatus* Hood as a serious pest of grapevines in India. Anathakrishnan (1971) reported that the chilli thrips, *S. dorsalis* in addition to *R. cruentalis* cause damage to grapevines in Tamil Nadu, Andhra Pradesh and Maharashtra. He observed that the infestation on flower bunches and young fruits of grape resulted in reduced fruit set and development of corky layer with cracks on the fruit surface.

Butani (1979) reported that apart from grape thrips, *R. cruentatus*, chilli thrips, *S. dorsalis* and two other species of thrips were known to attack grapes. According to Batra *et al* . (1980) *R. cruentatus* sucked sap from the lower surface of leaves and caused rossetting and scarring of grapes. Nair (1986) reported *R. cruentatus* as a pest of grapevine, producing silvery patches on leaves and corky layers on fruit surface. Maximum number of *Thrips tabaci* was recorded on grapes during the blossom stage in South Africa (Schwartz, 1988).

Flowers (1989) reported that among several species of Thysanoptera collected from grape foliage and flowers, *Scirtothrips citri* (Moulton), a serious pest of citrus was recorded for the first time in Florida. Investigations in Vineyards in eastern Switzerland in 1986-88 revealed 23 species of thrips (of which three were beneficial) on vines. It was reported that the most frequently occurring species was *Drepanothrips reuteri* Uzel which was the only species preferring vines and was invariably dominant when there was damage symptoms accompanied by high number of thrips per leaf (Remund and Boller, 1989).

Schwartz (1989) reported the incidence of *Heliothrips sylvanus* Faure on grapes in Western cape province of South Africa during 1985-88. Similarly, severe damage to grapes caused by thrips species was recorded in southern Italy by Ciampolini *et al*. (1990). They reported *Frankliniella ocidentalis* Pergande as the most harmful and widespread species. *Taeniothrips pallidivestis* (Krat) and *D. reuteri* were sporadic in their appearance and less damaging.

Ripa *et al*. (1993) studied the relationship between scarring of grapes and the presence of thrips species, *T. tabaci* and *Frankliniells cestrum* Moulton during flowering and concluded that the adults of *T. tabaci* colonized in clusters during anthesis and nymphs fed on pollen and internal tissues of the calyptra.

The direct damage caused by *F. occidentalis* to tomatoes, peppers, aubergines, Cucumbers, melons, Strawberries, peaches, apples, and grapes in France was described by Grassell (1996). Similarly, infestation of the western flower thrips, *F.occidentalis* on grapes was observed in Chile (Gonzalez, 1996). Shibao (1996) reported the damage to grape (cv.Delaware) caused by *S. dorsalis* in vineyards of Japan.

The grape thrips *D. reuteri* was dominant in all vineyards of western and southern Switzerland (Linder and Jermini, 1998) and in Italy (Zandigiacomo and Frausin, 1998). Dubois and Quilici (1999) recorded *S. aurantii* Faure as the principal grape insect pest in Reunion Island. Whereas, *F. ocidentalis*, *T. tabaci* and *Thrips meridionalis* Priesn were observed on grapes in France (Baldacchino, 1999). Gal *et al*. (2000) observed the damage caused by western flower thrips, *F. occidentalis* on grapes in Northern California.

Harish (2002) reported five species of thrips belonging to three different families viz, *Scirtothrips dorsalis* Hood (Thripidae), *Streothrips arorai* Bhatti (Aeolothripidae), *Haplothrips tenuipennis* Bagnall (Phlaeothripidae), *Karnyothrips flavipes* Jones (Phlaeothripidae), *Xylaplothrips* sp. (Phlaeothripidae) on grapes.

2.2 Seasonal incidence and ecology of *S. dorsalis*

Ayyar *et al*. (1935) described the crop season and rainfall in Guntur (Andhra Pradesh) and Periyakulam (Tamil Nadu) areas. In both areas the rainfall occurred mainly during North-East monsoon. However, it was early in Guntur and late in Periyakulam. At both the places the thrips population was low during rainy season. In North-eastern region of India, S. *dorsalis* occurred on tea bush almost throughout the year. The thrips appeared on pruned tea with the development of new growth. They multiplied and attained peak during May. With the onset of mansoon, the population reached a minimum level and the pest prevailed in minimum numbers form August to October. The thrips virtually disappeared during cold weather (Dev, 1964). Butani (1979) reported that peak infestation of thrips occurred during hot summer i.e., May to end of July in South India.

Raizada (1965) reported that the thrips were present throughout the year in Delhi, but reached its peak during spring and early summer. The damage was reduced in July – September with the onset of rains. But, the activity of thrips resumed in October causing severe damage. The author also observed considerable variation in abundance of *S. dorsalis* in different years.

According to Vevai (1969) the abundance of *S. dorsalis* on chilli was more during October in Andhra Pradesh, February to March in Bihar, August to November in Delhi, Mysore and Madhya Pradesh and throughout the year in Tamil Nadu and Maharashtra. In Karnataka, the pest was observed almost throughout the year on chilli. The population reached its peak during October and thereafter gradually declined from November onwards reaching the lowest level in May (Ningappa, 1972). Rangarajan *et al*. (1975) reported that the thrips appeared both in summer and winter in Tamil Nadu. Senapati and Mohanty (1980) observed the occurrence of *S. dorsalis* throughout the year in Orissa with higher populations during January – March with a peak in the first week of March.

In Taiwan, a higher population of S. dorsalis was found during dry season, though the pest was observed throughout the year (Lee and Wen, 1982). However, some adults were active on tea throughout the winter but disappeared totally in mid May. The adults and eggs of *S. dorsalis* were observed on the leaves of lime fruit in an orchard in Japan from mid May until the end of October. Larvae occurred from end of May until mid November (Sakakibara and Nishigaki, 1988). The authors also observed that the adults were most abundant in July when total number of young leaves in the orchard was highest.

Velayudhan *et al*. (1985) found that temperature and rainfall had a significant impact not only on numerical strength of thrips but also on their reproductive ability and soil pupation. Higher temperature and rainfall caused dramatic decline in population during May to June and November to December. Borthakur (1984) observed peak incidence of *S. dorsalis* from July to August on tea bushes in North eastern states of India, where as Sanap *et al.* (1985) recorded the appearance of *S. dorsalis* during first week of August in Maharastra on chillies and the population increased gradually till September and declined thereafter. He reported that an average temperature of 25.8^0C to 26.9^0C and 60 to 70 per cent relative humidity were congenial for multiplication of chilli thrips.

Patnaik *et al*. (1986) reported that the *S. dorsalis* population remained very low from August to December in the chilli crop and a steady rise in the pest population was recorded from December, with its peak during January after which the population declined. In cotton, thrips population was available throughout the observation period but in a lower threshold. Studies on the influence of climate revealed that temperature, rainfall and relative humidity were negatively correlated with thrips population but a diurnal temperature variation was positively correlated. Cool and drier months favoured the pest to inflict heavy damage throughout the year. Incidence was more pronounced from November till March and it remained at moderate density levels in the rest of the year on chilli crop.

Populations of *S. dorsalis* were observed on the new shoots of pomegranate in Gujarat from June to December. The thrips population was abundant during

June to August. Prolonged dry spell after rains favoured increase in population of thrips. The weekly average minimum and maximum temperatures had a highly significant positive correlation with the population of thrips, correlation coefficient values being r= 06519 and r = 0.527 respectively. Besides, relative humidity also showed positive correlation with the population of thrips, the 'r' value being 0.409. However, rainfall did not show any association with the population of thrips on pomegranate (Bagle, 1993).

Reddy (1997) reported that the population of *S. dorsalis* on rose was very severe during the summer season and reached peak during April. Shibao (1996) observed significant positive correlations between the density of *S. dorsalis* per grape fruit cluster and the damage to fruit clusters during the period from mid – June to mid –July.

According to Shibao (1990) the infestation by *S. dorsalis* occurred from June to September on grapes in Japan with population peaks in July and August. Shibao (1996) reported that the first and second peaks of *S. dorsalis* on grape occurred at about 550 and 851 degree days, respectively. Shibao (1997) observed four smaller peaks of *S. dorsalis* on grape shoots in Japan during mid – July, early and late August and mid September. On fruit clusters, the number of adults peaked in early July. The relationship between the density of *S. dorsalis* and the number of lateral shoots on two grape cultivars (Neo Muscat and Delware) was studied in Japan. The results for each cultivar suggested that the quantity of available resource (lateral shoots) accounted for differences in the population density of *S. dorsalis*, including seasonal fluctuations (Shibao, 1997).

Lingeri *et al*. (1998) observed that the incidence of *S.dorsalis* on chillies was more pronounced during December and January. Further, they reported that the population increased during dry periods with maximum temperature and lower intensity of rainfall.

Murugan (2000) reported that thrips population gradually increased during the observation period and reached its peak during first fortnight of April. He found severe infestations during April – May and decline in population from June with the onset of rains. The fortnight average maximum temperatures and sunshine hours had a significantly positive correlation with the population of thrips, correlation coefficient values being r = 0.8039 and r = 0.530 respectively. Besides, minimum temperature also showed positive correlation with the population of thrips, the 'r' value being 0.1908. However, relative humidity, total rainfall and wind velocity were negatively correlated with the thrips population, correlation coefficients values being r = -0.7366, r = -0.2375 and r = -0.2602, respectively.

Harish (2002) studied the incidence of *S. dorsalis*, accordingly the incidence prevailed throughout the cropping period, except during fruiting season on grapes. The pest number attained peak during the first week of November and third week of May in winter and summer season respectively.

2.3 Biology of *S. dorsalis*

Rao (1929) and Ayyar *et al*. (1935) studied the biology of *S. dorsalis* on chilli. However, more detailed observations on the biology of this thrips were made by Dev (1964) on tea, Raizada (1965) on castor, Amin and Palmer (1985) on groundnut, Patnaik *et al.* (1986) on chilli and Murugan (2000) on rose. Mound (1996) found that life cycle of thrips on groundnut studied by Amin and Palmer (1985) was not of *S. dorsalis* as the identity was not confirmed.

2.3.1 Eggs

The eggs were white, very minute and laid in the tissues of the leaves and shoots (Rao, 1929; Ayyar *et al.* 1935). The eggs were bean-shaped, slightly narrower at one and glossy white in colour and laid singly in the tissues of buds and young leaves and occasionally in older leaves and the site could only be marked by the raised surface (Dev,1964; Raizada, 1965; Murugan, 2000). The egg measured on an average 0.25 mm in length and 0.10 mm in breadth (Dev, 1964; Murugan, 2000). Raizada (1965) observed that thrips preferred the veins of leaves for egg laying while they rarely oviposited in flowers.

Patnaik *et al.* (1986) reported that the eggs were laid internally in the leaf lamina and occasionally in the petioles. The ovipositional sites were characterized by light yellow dots with raised cap like structures. Onkarappa and Mallik (1998) observed maximum number of eggs on petals of completely exposed flower buds followed by tender leaves. Murugan (2000) observed that *S. dorsalis* showed distinct preference for oviposition on one half of the tender leaves (one side of midrib) whiles the other half was rarely oviposited upon. Harish (2002) recorded egg laying in the tissues mostly on the tender pods, occasionally on older pods of French beans.

According to Rao (1929), Ayyar et al. (1935) and Raizada (1965) the incubation period varied from four to six days, while Dev (1964) and Patnaik et al. (1986) noted it to be six to eight days. Murugan (2000) and Harish (2002) reported that incubation period ranged from three to five days.

2.3.2 Larvae

Two larval instars have been recorded in *S.dorsalis*. The total duration of the larval instars reported are slightly varied from seven to eight days (Rao,1929), four to five days (Ayyar *et al.* 1935), four to six days (Dev, 1964), five to six days (Patnaik *et al.* 1986) and three to six days (Muaugan, 2000) and two to five days (Harish, 2002). The newly hatched first instar larva was almost white and its colour gradually changed to pale yellow. It was 0.29-0.32 mm long and 0.09-0.10 mm wide. The antennae were seven segmented but the three distal segments were not distinct. The second stage larva was orange yellow in colour and the antennal segments were distinct and were pale orange in colour. It was 0.48-0.12 mm long and 0.13- 0.18 mm wide (Dev, 1964).

According to Murugan (2000) and Harish (2002) the abdomen of the first instar larvae gradually tapered posteriorly from the thorax, where the width was maximum.The duration of first instar larva ranged from 1.0-2.00 days. The abdomen of the second instar larvae was some what barrel shaped and the width was highest across the IV abdominal segment. The duration ranged from 3.00 to 4.00 days. They concluded that the two larval instars occurred simultaneously on rose flowers and pods. The total larval period lasted for 3.00 to 6.00 days.

2.3.3 Prepupa and pupa

The prepupa could be recognized by the antennae being directed forward and by the short wing pads. In the pupa, the antennae were however, directed backward over the head, while the wing pads were much longer (Dev, 1964). Murugan (2000) and Harish (2002) observed that prepupa could be recognized by the antennae being shorter, laterally directed and the segments being indistinct. The prepupal and pupal periods lasted 18 to 24 hours and 48 to 56 hours (Rao, 1929), 12 to 24 hours and 3 to 5 days (Ayyar *et al*., 1935), 2 to 3 days and 2 to 3 days (Raizada, 1965), 1 to 1.5 days and 2 to 2.5 days (Patnaik *et al.*, 1986), 0.75 to 1.5 days and 3.25 to 4.75 days (Murugan, 2000), and 0.5-1.75 days and 3-4.75 days (Harish, 2002).

Pupation took place largely in the leaf axils, in leaf curls, under the calyx of the flower and fruits and in other tenders parts of the plant (Ayyar *et al*., 1935). Raizada (1965) observed that late second instar larva pupated in the soil under field conditions, while it did so in the fallen dried leaves and decaying leaves under laboratory condition.

Patnaik *et al*. (1986) stated that in nature pupation took place in the crevices of dry and old leaves, but in the laboratory dried moss provided the best niche for pupation. Murugan (2000) observed that pupation occurred on the curled portion of the flower petals under laboratory conditions. He stated that pupa was found in leaf litter, surface soil and soil upto three inches below the ground surface. Harish (2002), observed in the curled portion of the bean stalk.

2.3.4 Adult

The adult female was orange yellow and the head was more or less rectangular. On the dorsal aspect of 2^{nd} to 7^{th} abdominal tergites there were are like pale brownish patches. It measured 1.05 mm long and 0.19 mm wide. Antenna measured 0.23 mm long and wing measured 0.54 mm long. Male was smaller than the female and are like brownish patches on the abdominal tergites were absent. It measured 0.71 mm long, 0.14 mm broad. Antenna measured 0.16 mm long and wing measured 0.38 mm long (Dev, 1964). Murugan (2000) found that three ocelli were placed in a triangle over the vertex. Antenna was filiform, eight segmented and measured 0.23 – 0.26 mm long. Similar observations were made by Harish (2002).

In field populations, the number of females is usually more than males (Dev, 1964; Raizada, 1965; Patnaik *et al*, 1986 and Murugan, 2000). Reproduction was both by sexual and parthenogenetic means (Raizada, 1965; Murugan, 2000; Harish, 2002).

According to Ayyar *et al.* (1935) a female thrips laid two to four eggs per day, while Dev (1964) recorded an average of three eggs per day for female and it was not possible to ascertain the total number of eggs laid by a female during its life owing to the mortality in captivity within three days. Patnaik *et al*, (1986) recorded on an average 12 ovipositional punctures per leaf. Adults lived for a period of two to five days. Murugan (2000) noticed that the adult lived for a period to five days. Murugan (2000) noticed that the adult lived for a period of three to seven days. The longevity of adult female thrips ranged from 3 to 6.75 days with an average of 4.78 days (Harish, 2002).

2.3.5 Life cycle

The life cycle from egg to adult ranged from 10 to 15 days (Ayyar *et al*, 1935), 13 to 18 days (Dev, 1964), 15 to 20 days (Raizada, 1965), 14 to 19 days (Patnaik *et al*, 1986), 10.25 to 17.25 days (Murugan, 2000) and 9.75 to 17.75 days (Harish, 2002).

2.4 Chemical control of *S. dorsalis*

Fish oil rosin soap, tobacco decoction, HCH and sulphur dusts were used in controlling the thrips before 1960's (Rao *et al*, 1950; Fernando and Peiris, 1957 and Puttarudraiah, 1959). Spraying 625 ml of fenitrothion 50 EC or 1250 ml of malathion 50 EC/ha was recommended by Ananthakrishnan (1971) for the control of chilli thrips.

Nawale and Pokharkar (1977) noticed that monocroptophos @ 0.5kg a.i./ha was the best and significantly superior to carbofuran granules @ 1.0 kg a.i./ha. According to Reddy and Jagadish (1980) monocrotophos @ 0.05 per cent in an emulsion gave greatest mortality of *S. dorsalis* infesting chilli followed by 0.03 per cent quinalphos, a mixture of malathion and fenitrothion @ 0.06 per cent and 0.04 per cent phosalone.

According to Jaganmohan *et al* (1980) foliar spraying of monocrotophos (0.4 kg a.i/ha) and dimethoate (0.3 kg a.i./ha) were found to be most effective for the control of thrips on sweet pepper with persistence lasting for more than 15 days. Dhandapani and Kumaraswami (1983) found that sprays containing 0.1 per cent monocrotophos gave high mortality upto 21 days after treatment. Patnaik *et al* (1985) reported that the population of *S. dorsalis* infesting chilli was effectively controlled by fenvalerate (0.002%), dimethoate (0.06%) sevisulf (0.12%) and formothion (0.05%).

Among several compounds evaluated methamidophos and acephate each @ 0.5 kg a.i./ha have reduced the population of *S. dorsalis* and persisted upto two weeks after spraying (Rao and Ahmed, 1986). The population of thrips infesting chilli was effectively controlled by phosalone @ 0.438 kg a.i./ha (Nandihalli and Thontadarya, 1986). According to Khaire and Naik (1986) spraying of monocrotophos @ 0.50 kg a.i./ha was found to be the most effective treatment against *S. dorsalis* followed by phosalone chlorfenvinphos and quinalphos which was on par. Sprays containing 0.05 per cent monocrotophos or 0.05 per cent bromophos methyl were the most effective in reducing the population of *S. dorsalis* on chilli (Khaire *et al*, 1989). Among several compounds evaluated 0.08 per cent monocrotophos recorded 94.97 per cent reduction in the population of thrips, followed by phosalone, carbosulfan and triazophos with 89.61, 85.92 and 84.64 per cent reduction respectively (Kandaswamy *et al.,* 1990).

Radke and Aherkar (1987) tested the efficacy of insecticides namely permethrin, cypermethrin, fenvalerate all @ 0.01 per cent, decamethrin @ 0.0025 per cent and monocrotophos @ 0.07 per cent against *S. dorsalis* on chilli. Among these monocrotophos was highly effective in the control of thrips. Mkwaila (1990) reported that Karate (Lamda – cyhalothrin) at 100 ml in 750 litres water / ha and 14 day intervals significantly suppressed thrips population on tea.

Nair *et al.* (1991) tested seven insecticides for the control of *S. dorsalis* on rose. The results indicated that monocrotophos, quinalphos or phosphamidon @ 0.05 per cent each effectively suppressed leaf damage while dimethoate and phosphamidon @ 0.05 per cent and monocrotophos and endosulfan @ 0.1 per cent reduced the flower bud damage effectively.

Bagle (1993) sprayed 0.05 per cent monocrotophos, phosphamidon, dimethoate and dichlorovos, 0.07 per cent endosulfan, 0.005 per cent fenvalerate and 0.0015 percent deltamethrin against *S. dorsalis* damaging flowers and leaves on pomegranate. Monocrotophos, dimethoate and phosphamidon were effective and consistent in their efficacy against thrips over a period of 15 days.

The optimum crop stage and number of applications of monocrotophos for the control of *S. dorsalis* on chillies (Capsicum annum) was studied in Gujarat. The results indicated that five sprays of monocrotophos at 0.5 kg a.i./ha at fortnightly intervals beginning 35 days after transplanting suppressed thrips damage and increased yield (Bagle, 1993). Mandge *et al.* (1993) observed lowest incidence of thrips with 0.1% monocrotophos during 1987-1989 in Maharastra.

Jarande and Dethe (1994) found that seed dressing with 15 g imidacloprid 70 WS per kg seeds followed by root dip of seedling with 0.03 per cent imidacloprid gave excellent control of *S. dorsalis* on chilli.

Sridharan *et al.* (1995) evaluated six insecticides and neem oil against *S. dorsalis* in rice fallow cotton during flowering and bolling phase. The results of the field trial revealed that spraying of either phosalone (2500 ml/ha) or methyl demeton (500 ml/ha) was effective in reducing the population significantly and the rest to the treatments, viz., dimethoate, endosulfan, quinalphos, neem oil and phosphamidon were in decreasing order of efficacy against thrips.

Keisa and Varatharajan (1995) tested the efficacy of neem derivatives namely Achook and Nimin along with the conventional pesticide monocrotophos 0.05 per cent against *S. dorsalis* on chilli. Though the density of thrips population decreased to some extent in the plots treated with Achook and Nimin, the average percentage control of thrips was higher in monocrotophos treated plots (79%) followed by the treatment of alternate sprays of Achook – Monocrotophos (65%).

However, the mean percentage control of thrips in Achook and Nimin treated plots was only 33 per cent and 45 percent, respectively.

Chandrasekaran and Veeravel (1998) evaluated the efficacy of plant products, viz., Achook (0.05%, 1.0%, 1.5%), neem oil (1%, 3%, 5%), neem cake (1%, 3%, 5%), tobacco leaf extract (1%, 3%, 5%) along with an insecticide monocrotophos (0.05%) against *S. dorsalis* on chilli. The results revealed that monocrotophos was the most effective treatment. Among the plant products tested Achook (1.5%) significantly reduced the thrips population, followed by neem oil (5%, 3%). Neem cake extract was the least effective one in reducing thrips population.

Bagle (1998) sprayed monocrotophos (0.03 and 0.05%), phosphamidon (0.03 and 0.05%), dimenthoate (0.03 and 0.05%), neem seed kernel extract (3.0 and 5.0%) and carbaryl (0.2%) against *S. dorsalis*. The results of the experiments revealed the effectiveness of all the treatments in reducing the incidence of thrips on chilli.

Patel *et al.* (1999) evaluated different spray schedules of several insecticides at different intervals for the control of *S. dorsalis* infesting chilli (*Capsicum frutescens*) cv. S-49. They found that soil application of carbofuran at 0.5 kg a.i/ha 15 days after transplanting followed by continuous spray of triazophos 0.04% at 10 day intervals 30 days after transplanting effectively controlled thrips and gave a higher green chilli fruit yield with a higher cost: benefit ratio. Mathirajan *et al.* (2000) evaluated the effectiveness of Lambda-cyhalothrin @ 10, 20 and 30 g.a.i./ha for the control of *S. dorsalis* on groundnut. Fenvalerate 20EC @ 50 g.a.i./ha and monocrotophos 35 EC @ 360 g a.i./ha were taken as standards for comparison. The study indicated that Lambda-cyhalothrin 30 g.a.i./ha was effective against thrips. The order of efficacy was Lambda-cyhalothrin (30>20>10g a.i./ha) > monocrotophos>fenvalerate.

Harish (2002) evaluated the efficacy of synthetic, contact and botanical insecticides *viz*., acephate 75% SP @ 0.075%, verticel 100 SP @ 0.2%, endosulfan 35 EC @ 0.07%, chlorpyriphos 20 EC @ 0.05%, carbaryl 50 % WDP, cartap hydrochloride 5% SP, fipronil 5% SC, fish oil rosin soap, azadirachtin 0.03 EC, endosulfan + azadirachtin and soil raking were evaluated against *S. dorsalis* on grapes in the form of two foliar applications at ten days interval. Of these endosulfan followed by cartap hydrochloride and cabaryl proved effective in the control of *S. dorsalis*. Whereas, fipronil, endosulfan + azadirachtin and acephate had moderate effect, verticel and soil raking were less effective in controlling *S. doasalis.*

Diafenthiuron 50 SC (POLO 50 SC) @ 400 g. a.i. /ha gave significant result in reducing thrips population over dimethoate @ 1 ml/lit, further recorded higher yield and safer to natural enemies (Kulkarni and Adsule, 2006). Similarly, Balikai (2007) evaluated the efficacy of diafenthiuron 50 SC against thrips (*Thrips palmi* Karny and *Scirtothrips dorsalis* Hood) in grapes. The results revealed that diafenthiuron 50 WP @ 600 g/ha, diafenthiuron 50 SC @ 600 ml/ha, diafenthiuron 50 SC @ 400 ml/ha were highly effective against thrips. Further, diafenthiuron @ 600 ml/ha recorded highest yield of 8.94 kg/vine and did not differ statistically from diafenthiuron 50 WP @ 600 g/ha, diafenthiuron 50 SC @ 400 ml/ha and standard check monocrotophos and dimethoate.

Material and Methods

III. MATERIAL AND METHODS

The present investigation was carried out to study the species complex of thrips on Bangalore Blue, their biology and management with special reference to *Scirtothrips dorsalis* Hood during 2007-08. Laboratory and field studies were carried out at the Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS) Bangalore. The vines were pruned during June 2007 and February 2008 and observations were taken in both seasons. Normal agronomical practices and fungicidal sprays were carried out as per recommended package of practice (Anon., 1999).

3.1 Species composition

Surveys were undertaken in grape orchards at GKVK and in and around Bangalore to know the species composition of thrips involved in causing damage to Bangalore blue grapes. Thrips occurring on grapes were collected at fortnightly interval throughout the cropping period by gently beating the canopy five times on to a stiff black paper board (30cm ×30cm). Thrips so collected were picked using a fine camel hairbrush, transferred to small glass vials containing 80 percent ethyl alcohol and were subsequently labeled (date of collection, host and locality) in the laboratory. Thrips were identified by Dr.A. Jagadish, Professor of Entomology, (Rtd) U.A.S, Bangalore.

3.1.1 Seasonal variation in the incidence and distribution of thrips

The study was undertaken during June–October (2007) and February–May (2008) were at GKVK. Observations were recorded fifteen days after pruning. Ten vines of uniform size and age were sampled throughout the cropping period. From each vine, 20 shoots were selected randomly, making a total of 200 shoots for estimation of thrips density at weekly intervals. Each shoot was gently tapped on to stiff black paper board (30 × 30 cm) and thrips number thus collected was counted. Initially, the data on thrips density were analysed for mean, variance and variance- mean ratio. Variance- mean ratio was the parameter used to understand the aggregation pattern of thrips (Southwood, 1978). Further, the data was subjected to analysis of variance (ANOVA) to find if the mean density of *S. dorsalis* differed significantly within the stages of the crop.

3.2 To study the incidence of thrips in relation to growth parameters of grape vines

The study was undertaken during June–October (2007) and February–May (2008) at GKVK. Observations were under taken fifteen days after pruning. The 20 randomly selected shoots from10 vines were selected and the incidence of thrips were recorded on each growth parameters of grape vines *viz*., tender leaves, half matured leaves, full matured leaves, flowers, pea sized berries, marble sized berries and large sized berries at weekly intervals *in situ* by counting visually using a hand lens and also by gently tapping the inflorescence five times on to a stiff black paper board (30cm ×30cm). The average number of thrips per shoot was worked out to know the relative abundance of the components of the species complex.

3.2.1 Seasonal incidence of *S. dorsalis*

The study was undertaken during June–October (2007) and February–May (2008) at GKVK. Observations were recorded fifteen days after pruning.The observations on thrips numbers were recorded as under 3.2.

Simultaneously, weather parameters *viz*., maximum temperature, minimum temperature, relative humidity, total rainfall and wind speed were collected from the meteorological section of GKVK. These were averaged for a week (except for rainfall, which was summed up for a week) and the mean number of thrips was correlated with the meteorological factors. For the correlation studies, weekly mean values of weather parameters *viz*., maximum and minimum temperature in degree Celsius, relative humidity in percentage, wind speed in km/hr and total rainfall in mm were considered.

3.3 Biology of *S. dorsalis* under laboratory

Studies on the biology of *S. dorsalis* were made in the laboratory from March - April, 2008 on grape vines and Frenchbean pods. Plastic jars (0.5 1or 1litre) covered with muslin cloth for ventilation were used for rearing. About 10 to 15 layers of coarse paper were placed on the bottom of each jar to provide a pupation site. Fresh bean pods (*Phaseolus vulgaris* L.) purchased from market were placed on the paper and smeared with 10% honey. Female adult thrips collected from the field were introduced into the jars with pods for oviposition. The eggs laid were identified by the oval translucent raised surface. Because of contamination risk, green beans brought into the laboratory were washed in warm soapy water and rinsed with tap water (Lowry et al., 1992) and dipped in fungicide (Steiner et al., 1995). They were then dried on paper toweling and stored in a plastic bag. Problems of bacteria and fungi were there by reduced but not eliminate.

After hatching, the larvae were individually reared on tender bean pods in jars for studying duration and development of instars, pre pupa and pupa. Pods were changed once in 2-3 days. Observations were recoded at intervals of 6 hrs. To study the longevity of adult’s pre oviposition, oviposition, post oviposition periods and fecundity, freshly emerged females were individually placed in small glass vials containing tender pods. New tender pods were provided every day after removing the old pods to record the data on number of eggs laid by each female and the incubation period. In *S. dorsalis*, males were rare and reproduction mainly occurred through thelotoky parthenogenesis.

3.3.1. Egg count

Lactophenol clearing method (Carlson and Hibbs., 1962) was followed to count the eggs. Clearing solution was prepared using one part of each of 85 percent lactic acid, phenol, distilled water and two parts of glycerin. This solution was brought to the boiling point in a beaker. Bean pods were immersed and boiled for 3 minutes in the clearing solution. Following this, the pods could be held submerged for an extended time in cold lactophenol, until eggs were counted. The same method was used to study the oviposition site of *S. dorsalis*.

3.3.2 Method of Mounting

To study the morphological characters and to measure the body dimensions, slides were prepared by adopting the method given by Mound and Pitkin (1972). The specimens were removed from the collecting or storage fluid and were placed in cavity block with 80 percent alcohol. The specimens were then dehydrated by placing in solutions with different alcohol concentrations: in 80 percent for 20 minutes, in 95 percent for 10 minutes, in 100 percent for 5 min or less. Then the specimens were kept in clove oil overnight till they cleared. This method was also used for clearing pods with eggs.

The specimens so cleared were mounted ventral side upon a 13mm cover slip in a drop of DPX mountant, the quantity depending on the size of the specimen but sufficient to support the cover slip without crushing the body. Then the cover slip with specimen was placed on a drop of DPX mountant on a 75mm long, 25mm wide and 1.3mm thick slide. The cover slip was gently tilted and gently pressed to spread the wings and arrange the specimen. The slides were dried and labeled (date, host, and locality).

3.3.3 Measurement of various stages of *S. dorsalis*

Measurement of the eggs, larval instars, pre pupae, pupae and adults were made using a calibrated ocular micrometer.

3.4 Evaluation of the efficacy of selected new insecticide molecules including bio-pesticides

To know the relative efficacy of different chemicals including bio-pesticides in controlling *S. dorsalis* on grapes, field experiments were laid out at GKVK. The trial was conducted during summer 2008. A randomized block design with 12 treatments and three replications was used for the experiment. Each vine was considered as a replication(Table 1). Two sprays were given by using a foot operated high volume sprayer at 25 and 35 days after pruning.

3.4.1 Observations

Observations on the number of thrips were recorded one day prior to spraying and three and ten days after spraying. Pre-treatment and post treatment counts on randomly selected shoots were taken by gently beating the shoots five times against black cardboard sheet and the number of thrips present on the black sheet was counted.

Observations were recorded on the total number of thrips per bunch. The data were analyzed to determine the efficacy of different chemicals in suppressing the thrips and effect of these chemicals on grape pests. To study the phytotoxicity of these chemicals, the observations on leaf injury on tips and leaf surface, wilting, vein clearing, necrosis and epinasty and hyponasty were made on 3 and 10 days after spray. The percentage phytotoxicity was recorded and transformed to 0-6 scale.

3.5 Statistical analysis

The simple correlation studies were made to find out the relationship between the weather parameters and seasonal incidence of *S. dorsalis*. The spatial distribution of thrips was analysed by calculating the variance-mean ratio. Further, data on thrips density were subjected to analysis of variance (ANOVA) to find the mean population density of thrips at different crop stages.

Table 1: List of Insecticides and bio-pesticides.

Treatment No.	Chemical name	Trade name	Dosage
1	Fipronil	Regent 80 WG	40 (g a.i./ha)
2	Fipronil	Regent 80 WG	50 (g a.i./ha)
3	Fipronil	Regent 5SC	40 (g a.i./ha)
4	Spinosad	Success 2.5SC	84.37 (g a.i./ha)
5	Imidacloprid	Confidor 17.8 EC	45 (g a.i./ha)
6	Dimethoate	Rogor 30 EC	300 (g a.i./ha)
7	Quinalphos	Ekalux 25 EC	250 (g a.i./ha)
8	Monocrotophos	Nuvacron 36 SL	500 (g a.i./ha)
9	Acephate	Asataf 75 SP	400 (g a.i./ha)
10	Azadirachtin	Nimbecidineplus 1%	2.25 (lit/ha)
11	Fish oil rosin soap	Fosco	1.87 (kg/ha)
12	Control	-	-

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the investigations carried out during 2007-08 at Gandhi Krishi Vignana Kendra (GKVK), Bangalore on the species complex, distribution, seasonal incidence, biology and management of *Scirtothrips dorsalis* Hood on grapes (cv. Bangalore blue) are presented here.

4.1 Species composition

In the present study, it was found that *Scirtothrips dorsalis* Hood (Plate 1), *Haplothrips ganglbaueri* Schmutz(Plate 2), *Haplothrips ceylonicus* Schmutz (Plate 3), and *Thrips hawaiensis* Morgan (Plate 4),were the four species of thrips recorded on Bangalore Blue grapes. Thrips species and the families to which they belong are presented in Table 2.

Of the four species of thrips recorded, only *S. dorsalis* was common and was occurred in large numbers, where as other three species were in negligible numbers during both study periods. In the season, peak thrips population coinciding with the initiation of new flush and flowering in grapes.

All the species of thrips were found throughout the cropping period during both the seasons. Of these, *S. dorsalis* was rasping and sucking sap from tender plant parts on grapes, while the remaining species were associated with the inflorescence.

4.1.1 Kharif pruning

Scirtothrips dorsalis could be identified in the field by its orange, yellow colour and presence of median triangular pale brownish patch tapering posteriorly from second to seventh abdominal tergites. *Scirtothrips dorsalis* was found to be maximum in number throughout the cropping period compared to other species of thrips (Table 3). During 29 days after pruning 94.80 per cent of total thrips number

Table 2: Thrips fauna on grapes (cv. Bangalore Blue) at Bangalore

Sl. No.	Thrips species	Sub order	Family
1	*Scirtothrips dorsalis* Hood	Terebrantia	Thripidae
2	*Thrips hawaiensis* Morgan	Terebrantia	Thripidae
3	*Haplothrips ganglbaueri* Schmutz	Tubulifera	Phlaeothripidae
4	*Haplothrips cylonicus* Schmutz	Tubulifera	Phlaeothripidae

Plate 1: ***Scirtothrips dorsalis*** **Hood (Thripidae:Thysanoptera)**

Plate 2: ***Haplothrips ganglbaueri*** **Schmutz (Phlaeothripidae:Thysanoptera)**

Plate 3: ***Haplothrips ceylonicus*** **Schmutz (Phlaeothripidae:Thysanoptera)**

Plate 4: ***Thrips hawaiensis*** **Morgan (Thripidae:Thysanoptera)**

Plate 1

Plate 2

Plate 3

Plate 4

Table 3: Species composition of thrips on grapes (cv. Bangalore Blue) during Kharif- 2007

Observation days after pruning (DAP)	Mean number of thrips/shoot		Proportion (%)	
	S. dorsalis	other sp.	*S. dorsalis*	other sp.
15	3.29	0.29	91.89	8.11
29	11.31	0.62	94.8	5.2
43	8.54	0.49	94.57	5.43
57	5.93	0.42	93.38	6.62
71	8.32	0.63	92.96	7.04
85	5.84	0.53	91.67	8.33
99	3.54	0.44	88.94	11.06
113	1.22	0.27	81.87	18.13

*Date of pruning: 25/06/2007, Mean of 200 shoots from 10 vines

Table 4: Species composition of thrips on grapes (cv. Bangalore Blue) during Summer- 2008

Observation days after pruning (DAP)	Mean number of thrips/shoot		Proportion (%)	
	S. dorsalis	other sp.	*S. dorsalis*	other sp.
15	5.82	0.47	92.52	7.48
29	10.6	0.93	91.93	8.07
43	11.71	0.63	94.89	5.11
57	9.53	0.54	94.63	5.37
71	9.78	0.89	91.65	8.35
85	12.15	1.24	90.73	9.27
99	5.27	0.51	91.17	8.83
113	2.14	0.31	87.34	12.66

*Date of pruning: 02/02/2008, Mean of 200 shoots from 10 vines was constituted by *S. dorsalis* alone, while the remaining species put together accounted for only 5.2 per cent. Thus, indicating the numerical dominance of *S. dorsalis.* Though, there was gradual decline in the number of *S. dorsalis* after the tender leaf stage (43days after pruning). Interestingly, there was little fluctuation in the number of other species of thrips and they did not decrease drastically in the same proportion as that of *S. dorsalis* towards the end of the season. However, the numbers of both gradually, declined with the crop growth and reached a low of 1.22 and 0.27 mean thrips per shoot, respectively, at harvest. The decline in other species of thrips was very gradual compared to *S. dorsalis.* Hence, the higher proportion of other thrips species (18.13%) towards the end of the season (Table 3).

4.1.2 Summer pruning

Scirtothrips dorsalis and other species of thrips were observed from the second week of February to third week of May, 2008 (Table 4). The number of *S. dorsalis* reached its peak during 43 days after prunning and remained numerically dominant throughout the cropping period. *Scirtothrips dorsalis* constituted 94.89 per cent of total thrips during 43 days after pruning. The number of other species of thrips gradually declined, but not in the same proportion as that of *S. dorsalis.* Hence, at the last date of observation other species of thrips constituted higher proportion (12.66%) (Table 4). Further, the density of *S. dorsalis* and other species of thrips reached a low of 2.14 and 0.31 mean thrips per shoot respectively, at harvest.

4.1.3 Seasonal variation in the incidence and distribution of S. *dorsalis*

The different parameters *viz.*, mean density (x) variance (S^2) and variance - mean ratio (S^2/X) representing within vine and overall distribution patterns of *S. dorsalis* were presented for both seasons in Tables 5&6. It is clear from the table that the variance exceeded the mean in all the stages (except ripening stages)

Table 5: Statistical parameters for seasonal variation and distribution of grape thrips during kharif 2007

Observation days after pruning	Mean (x)	Variance (s^2)	Variance -mean ratio (s^2/x)
08/07/2007	3.41	5.01	1.47
15/07/2007	9.29	17.09	1.84
22/07/2007	11.63	22.44	1.93
29/07/2007	13.94	33.17	2.38
05/08/2007	8.97	19.19	2.14
12/08/2007	7.26	12.77	1.76
19/08/2007	6.04	10.08	1.67
26/08/2007	5.25	1.89	1.53
02/09/2007	8.31	11.13	1.34
09/09/2007	8.98	9.68	1.39
16/09/2007*	5.94	6.4	1.3
23/09/2007*	5.61	6.02	1.31
30/09/2007*	3.44	3.85	1.12
07/10/2007*	2.13	1.98	0.93
14/10/2007*	1.24	0.88	0.71

* Observation recorded after berry maturation
Mean of 200 shoots from 10 vines

Table 6: Statistical parameters for seasonal variation distribution of grape thrips during summer 2008

Observation days after pruning (DAP)	Mean (x)	Variance (s^2)	Variance -mean ratio (s^2/x)
17/02/2008	6.09	7.55	1.24
24/02/2008	14.67	26.25	1.79
02/03/2008	11.63	23.6	2.03
09/03/2008	17.43	40.26	2.31
16/03/2008	12.53	19.9	1.89
23/03/2008	13.28	22.44	1.69
30/03/2008	10.43	5.82	1.53
06/04/2008	7.58	10.15	1.34
13/04/2008	11.04	13.35	1.21
20/04/2008	9.96	11.35	1.14
27/04/2008*	14.45	16.9	1.17
04/05/2008*	12.21	13.91	1.14
11/05/2008*	6.83	7.44	1.09
18/05/2008*	3.61	3.99	0.94
25/05/2008*	2.13	1.98	0.93

* Observation recorded after berry maturation
Mean of 200 shoots from 10 vines

Table 7: Distribution of thrips within vine at different growth stages during 2007-08

Crop stages	Mean number of thrips/shoot	
	Kharif	Summer
Vegetative stage-1(15 DAP)	3.30	5.94
Vegetative stage-2(22 DAP)	8.81	14.86
Vegetative stage-3(29 DAP)	11.84	11.86
Vegetative stage-4(36 DAP)	13.12	17.33
Flowering stage -1 (43 DAP)	8.63	10.367
Flowering stage -2 (50 DAP)	7.39	13.14
Flowering stage -3 (57 DAP)	6.25	3.65
Fruit set stage -1 (64 DAP)	1.18	7.42
Fruit set stage -2 (71 DAP)	8.36	10.99
Fruit set stage -3 (78 DAP)	6.94	9.84
Fruit set stage -4 (85DAP)	4.8	14.28
Veraison stage-1 (92 DAP)	4.58	12.10
Veraison stage-2 (99 DAP)	3.52	6.60
Ripening stage -1(106 DAP)	2.23	3.40
Ripening stage -2(113 DAP)	1.35	2.07
CD (P = 0.05%)	0.22	0.40

DAP = Days after pruning
Mean of 200 shoots from 10 vines

indicating a contagious or aggregated distribution of *S. dorsalis*. The variance-mean ratio has been the simplest method for showing the distribution pattern. From the vegetative stage 2 (i.e., 22 days after pruning) to flowering stage 3 (57 days after pruning) *S. dorsalis* showed an aggregated distribution. Thereafter, it tended to be random and at ripening stage 1 and 2, a near uniform distribution. Statistically, the significant differences in thrips density were observed among the different crop stages (Table 7). The highest density was recorded in vegetative stage 4 (36 days after pruning) during kharif (13.12) and summer (17.33 mean number of thrips/shoot*)*. It was significantly higher than all other stages of the crop. There were significant differences among all the stages of the crop in both the seasons. Predominantly, maximum density was observed from vegetative stage 2 (22 days after pruning) to flowering stage 2 (50 days after pruning) (Table 7). These have implications in management.

4.1.4 Symptoms and nature of damage

Scirtothrips dorsalis caused damage to all the stages of grapevine. The adults and larvae were relatively in large numbers on tender leaves. In the initial stages thrips rasp and suck the sap particularly from lower surface of tender leaves. Later, they move to leaf petiole, inflorescence and tiny berries. Extensive lacerations and punctures made by these thrips on leaves resulted in the initial development of silvery white patches with curly tips. The leaves which were initially puckered, under severe infestation gradually gets deformed and drop. Feeding by thrips at inflorescence stage resulted in shedding of individual flowers and formation of scar on the future berries. Later, the scar turned brown and coalesced, causing development of corky layer with cracks on surface of berries. The damage persisted with berry development and resulted in scabbed or malformed berries. These berries when matured were unfit for marketing. The pattern of feeding and nature of damage caused by *S. dorsalis* to Bangalore Blue grapes is presented in Table 8:Plate 5&6.

Table 8: Different stages of the vine and the damage symptoms caused by thrips

Crop stages	Symptoms
Bud/ sprout stage (15DAP)	-
Tender leaf stage (30-40 DAP)	Appearance of silvery white patches
Flowering stage (40-50 DAP)	Leaves shows curly tip and leaf petiole shows scars
Pea sized berries stage (60-70 DAP)	Development of scar
Marble sized berries stage (80-100 DAP)	Scar turn brown and coalesce
Large sized berries stage (100-130 DAP)	Scaring and cracks on fruit surface

- DAP = days after pruning

Plate 5:

A: Leaf showing silvery white scorchy Symptoms

B: Leaf showing curly tip Symptoms

C: Later leaves turn brown and coalesce

D: Leaf petiole showing scar symptoms

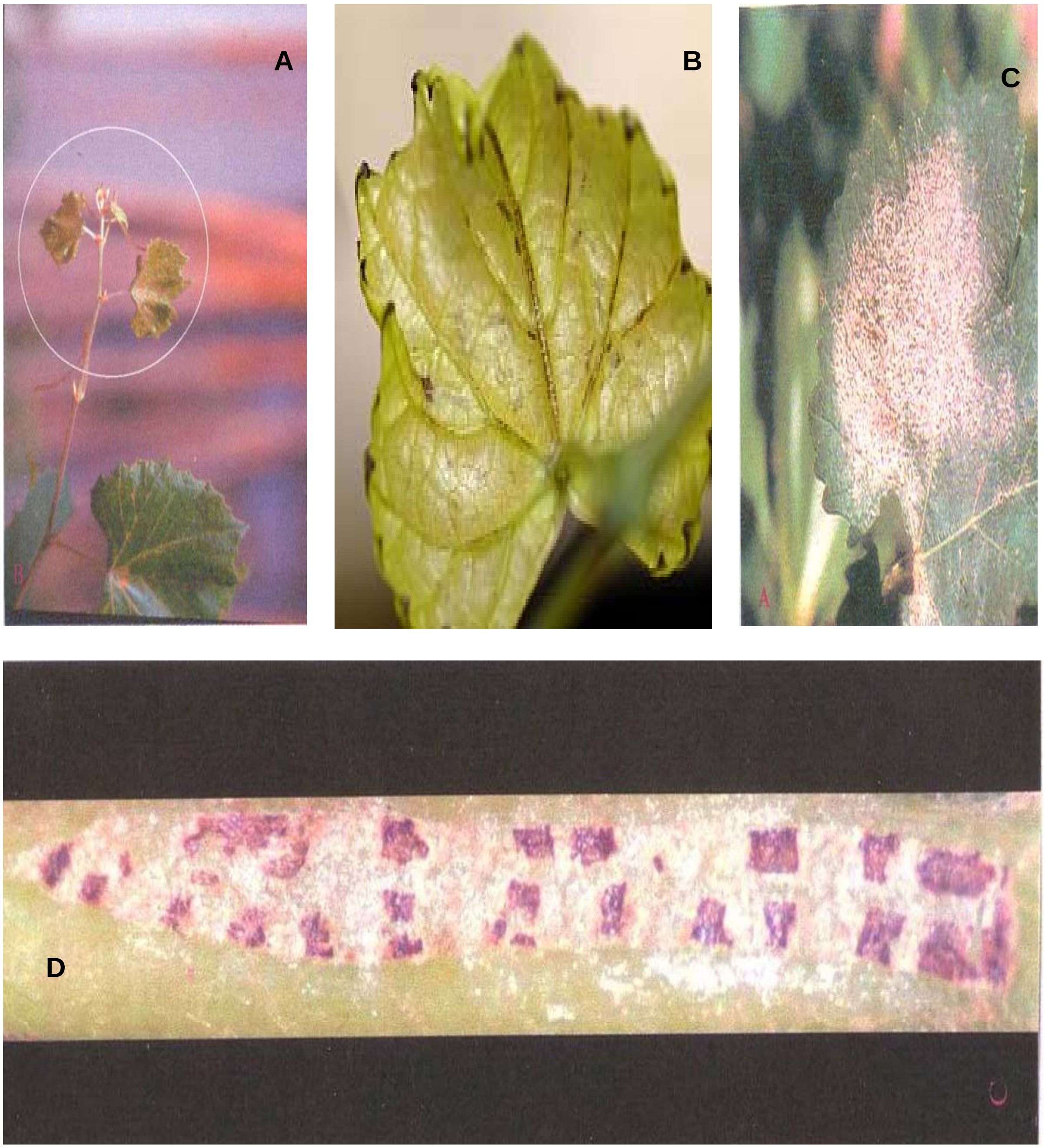


Plate 5

Plate 6:

A: Healthy bunch

B: Berries showing scar symptoms

C: Matured bunches showing scar symptoms

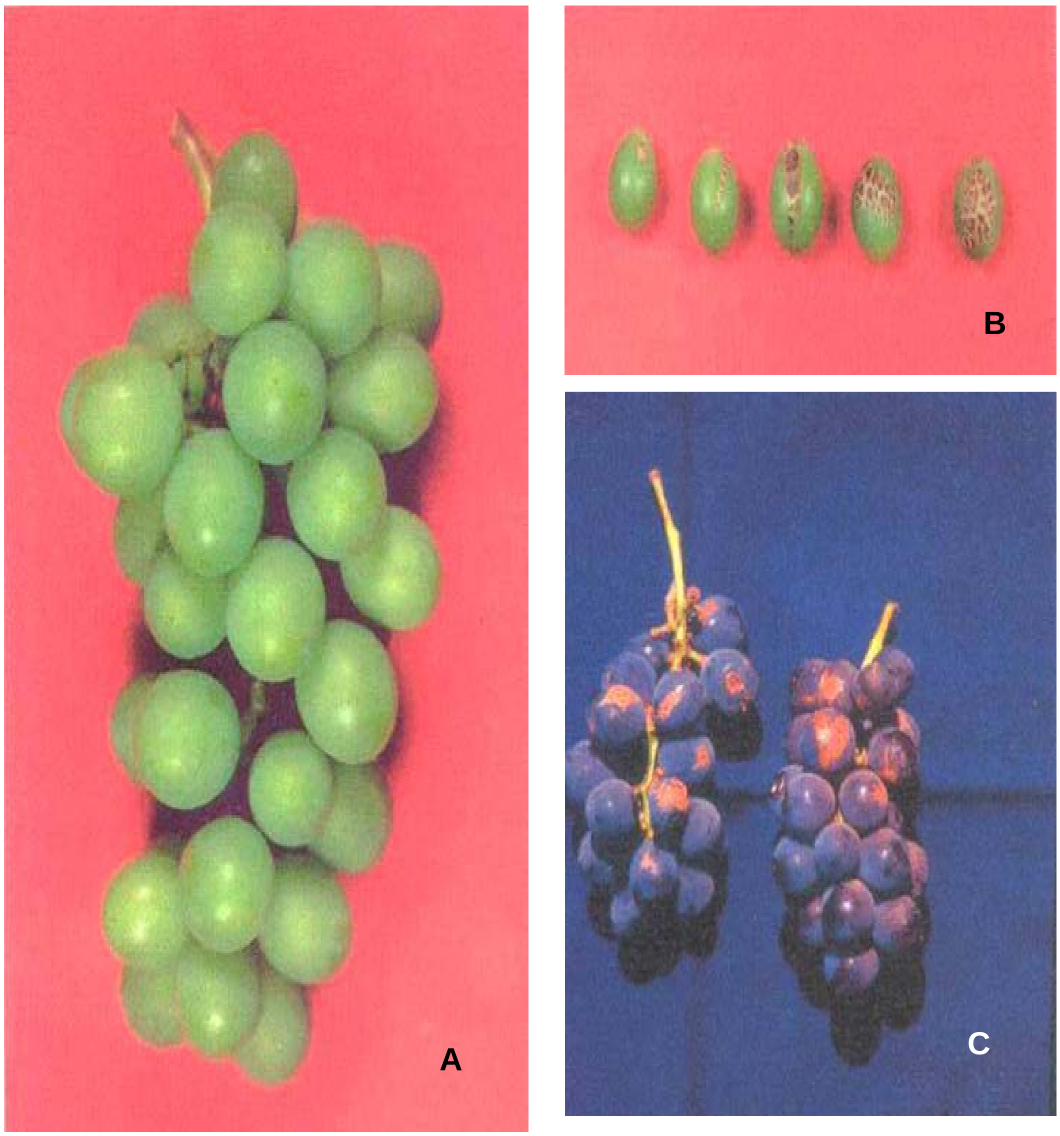


Plate 6

Table 9: Incidence of thrips on grapes (cv. Bangalore Blue) during 2007-08

Mean number of thrips per shoot			
Date of observation	**Kharif pruning**	**Date of observation**	**Summer pruning**
08/07/2007	3.43	17/02/2008	6.07
15/07/2007	9.29	24/02/2008	14.67
22/07/2007	6.62	02/03/2008	11.63
29/07/2007	13.93	09/03/2008	17.43
05/08/2007	6.97	16/03/2008	10.53
12/08/2007	6.24	23/03/2008	13.28
19/08/2007	6.04	30/03/2008	3.81
26/08/2007	1.24	06/04/2008	7.58
02/09/2007	8.3	13/04/2008	11.04
09/09/2007	5.97	20/04/2008	9.96
16/09/2007*	2.16	27/04/2008*	14.45
23/09/2007*	3.10	04/05/2008*	12.21
30/09/2007*	3.63	11/05/2008*	6.83
07/10/2007*	3.43	18/05/2008*	3.61
14/10/2007*	1.23	25/05/2008*	2.13

* Observation recorded after berry maturation

4.2 Incidence of thrips in relation to growth parameters of grape vines

Thrips number was low during the bud/sprouting stage (15 days after pruning) and increased with the initiation of new flush. The number of thrips species reached a peak 30-40 days after pruning (13.93 and 17.43 mean thrips per shoot during kharif and summer, respectively). However, the numbers of thrips started declining later reaching a low at 11 0-120 days after pruning (1.23 and 2.13 number of thrips/shoot during kharif and summer, respectively) (Table 9).

4.2.1 Relationship between crop growth parameters and the incidence of thrips

The incidence of thrips was recorded in relation to the mean number of each grape vine parts (growth) namely, tender leaves, half matured leaves, fully matured leaves, flowers, pea, marble and large sized berries. Results of the simple correlation analysis between the incidence of thrips and crop stages for both seasons are presented in Table 10.

4.2.1.1 Kharif pruning

The results showed a significant positive correlation between the incidence of thrips and tender leaves (r =+0.82). Secondly, the incidence was significantly, negatively correlated with fully matured leaves (r = -0.37) and large sized berries (r = -0.95). Half matured leaves (r = +0.19), flowers (r = +0.05), pea sized berries (r = -0.13) and marble sized berries (r = -0.52) had no significant correlation with thrips density (Table 10).

4.2.1.2 Summer pruning

On grapes, the incidence of thrips was significantly, positively correlated with tender leaves (r = +0.78) and showed significantly, negative correlation with fully matured leaves (r = -0.41) and large sized berries (r = -0.81), respectively. The incidence showed a positive trend with half matured leaves (r = +0.28),

Table 10: Correlation between the incidence of thrips and growth parameters of grape vines during 2007 -08

Parts of the vine	Correlation values	
	Kharif pruning	Summer pruning
Tender leaves	+0.82**	+0.78**
Half matured leaves	+0.19NS	+0.28NS
Fully matured leaves	-0.37*	-0.41*
Flowers	+0.05NS	+0.08NS
Pea sized berries	-0.13NS	-0.27NS
Marble sized berries	-0.52NS	-0.36NS
Large sized berries	-0.95**	-0.81**

** = Significant at P = 0.01%
* = Significant at P = 0.05%
NS = Non significant

flowers (r = +0.08) and negative trend with pea sized berries (r = -0.27) and marble sized berries (r = -0.36) which were however not significant (Table 10).

4.2.2 Seasonal incidence of thrips

The study revealed occurrence of thrips throughout the cropping period, except at the late fruiting stage. Observations on the incidence of thrips were recorded during both seasons at weekly interval (Table 9).

4.2.2.1 Kharif pruning

Weekly observations on the incidence of thrips were recorded from second week of July, 2007 to second week of October, 2007. A steep increase in the number of thrips was observed 22 days after pruning (9.29/shoot) compared to the first observation (3.43/shoot) recorded at 15 days after pruning (Table 9).The number reached the peak during last week of July, recording 13.93 thrips/shoot.

The thrips number gradually declined during the subsequent weeks recording a low of 1.24 mean number of thrips per shoot during the last week of August. However, the number increased from 1.24 to 8.30 and 5.97 in the subsequent two weeks. Thus, severe infestation of thrips occurred from second week of July to mid September. After berry maturation (mid September) thrips number decreased (2.16/shoot), there was a steady increase in number of thrips per shoot during the last week of September. Further, their number drastically declined in the following week recording 3.43 per shoot. Finally, it reached a low of 1.23 thrips per shoot by mid October.

4.2.2.2 Summer pruning

Incidence of *S. dorsalis* was recorded at weekly intervals from third week of February, 2008 to third week of May, 2008. A steep increase in the number of thrips was observed 22 days after pruning (14.67/shoot) compared to the first

Table 11: Seasonal incidence of thrips on grapes (cv. Bangalore Blue) and weather parameters during kharif, 2007

Date of observation	Number of thrips/shoot	Temparature(^{0}c)$^+$		Relative humidity (%)$^+$	Total rainfall (mm)$^{++}$	Wind speed (km/hr)
		Max	Min			
08/07/2007	3.43	29.2	20.3	88.28	0	17.4
15/07/2007	9.29	29.7	20.2	86.28	12.2	15.0
22/7/2007	6.62	27.0	19.8	92.14	84.4	9.6
29/07/2007	13.93	28.4	20.4	92.85	24.4	6.9
05/08/2007	6.97	26.3	18.9	92.42	66.6	10.8
12/08/2007	6.24	26.5	19.6	95.28	6.2	14.0
19/08/2007	6.04	28.8	20.1	91.85	0.6	7.2
26/08/2007	1.24	28.0	19.3	94.85	130.0	8.1
02/09/2007	8.3	26.9	18.8	94.42	21	9.1
09/09/2007	5.97	27.0	19.1	93.42	54	9.5
16/09/2007*	2.16	26.7	16.4	94.71	37.6	5.2
23/09/2007*	3.10	26.8	17.2	91.28	53.7	9.5
30/9/2007*	3.63	24.4	14.3	91.14	6.4	4.7
7/10/2007*	3.43	28.2	15.1	90.42	0	7.5
14/10/2007*	1.23	29.6	17.2	88.57	0	14.16

* Observation recorded after berry maturation
+= Average of 7 days
++= Total of 7 days

Table 12: Seasonal incidence of thrips on grapes (cv. Bangalore Blue) and weather parameters during summer, 2008

Date of observation	Number of thrips/shoot	Temparature(^{0}c)$^+$		Relative humidity (%)$^+$	Total Rain fall (mm)$^{++}$	Wind speed (km/hr)
		Max	Min			
17/2/2008	6.07	28.37	18.45	90.71	11.6	9.04
24/02/2008	14.67	30.08	20.20	89.28	0	4.48
02/03/2008	11.63	30.68	14.40	90.42	0	7.62
09/03/2008	17.43	31.17	19.97	85.28	0	4.23
160/3/2008	10.53	30.35	18.00	90.42	17	6.74
23/03/2008	13.28	29.68	18.34	93.14	2.2	4.90
30/03/2008	3.81	29.67	19.02	93.28	118	4.98
06/04/2008	7.58	29.40	19.65	90.71	0.4	4.41
13/04/2008	11.04	31.57	17.25	89.00	0	6.61
20/04/2008	9.96	34.68	19.97	85.42	0	5.65
27/04/2008*	14.45	32.40	20.48	88.14	1.4	5.14
04/05/2008*	12.21	32.20	20.300	85.14	0	8.60
11/05/2008*	6.83	33.90	21.10	85.57	1	8.47
18/05/2008*	3.61	34.70	21.00	86.85	0	9.61
25/05/2008*	2.13	34.81	20.40	87.14	21	6.94

* Observation recorded after berry maturation
+= Average of 7 days
++= Total of 7 days

observation (6.07/shoot) recorded at 15 days after pruning (Table 9). The number reached the peak during second week of March recording 17.43 thrips per shoot.

In the subsequent four weeks, the number gradually declined recording 10.53, 13.28, 3.81and 7.58 number of thrips per shoot, respectively. Later, there was an increase from 7.58 to 11.04 during the second week of April, but it again decreased to 9.96 during the third week of April. However, the severity of infestation of thrips was observed from last week of February to second week of May.

Further, there was an increase in the number of *S. dorsalis* during the first two weeks after berry maturation (second week of April). The number was 14.45 and 12.21 number of thrips per shoot, respectively. However, the number nearly halved in the subsequent two weeks recording 6.83 and 3.61 number of thrips per shoot, respectively. By the last week of May the numbers reached a low of 2.13 thrips/shoot.

4.2.3 Relationship between weather parameters and the incidence of thrips

The mean number of thrips at weekly intervals and weather parameters for kharif season are presented in Table 11. Similar observations recorded for summer season are presented in Table 12. The correlation coefficient between the seasonal incidence of thrips and various weather parameters during kharif, before and after berry maturation are presented in Table 13. Similar correlated values for summer are presented in Table 14.

4.2.3.1 Kharif pruning

On grapes, before berry maturation the incidence of thrips was significantly positively correlated with the maximum temperature (r = +0.12) and negatively correlated with the mean relative humidity (r = -0.12). The incidence showed a positive trend with minimum temperature (r = +0.32) and negative trend with total

Table 13: Correlation coefficient (r) between the incidence of thrips and weather parameters during kharif, 2007.

Weather parameters	Correlation values	
	Before berry maturation	**After berry maturation**
Maximum temperature (^{0}c)	+0.12**	-0.68**
Minimum temperature (^{0}c)	+0.32NS	-0.71NS
Mean relative humidity (%)	-0.12*	+0.10**
Total rainfall (mm)	-0.47NS	-0.11NS
Wind speed (k/hr)	-0.29NS	-0.67NS

** = Significant at P = 0.01%
* = Significant at P = 0.05%
NS = Non significant

Table 14: Correlation coefficient (r) between the incidence of thrips and weather parameters during summer, 2008.

Weather parameters	Correlation values	
	Before berry maturation	**After berry maturation**
Maximum temperature (^{0}c)	+0.27*	-0.97NS
Minimum temperature (^{0}c)	+0.06NS	-0.40NS
Mean relative humidity (%)	-0.52**	+0.02NS
Total rainfall (mm)	-0.53NS	-0.57NS
Wind speed (k/hr)	-0.36NS	-0.46**

** = Significant at P = 0.01%
* = Significant at P = 0.05%
NS = Non significant

rainfall (r = -0.47) and wind speed (r = -0.29). However, the correlations were not significant (Table 13).

After berry maturation (mid September), the incidence was significantly, negatively correlated with maximum temperature (r = -0.68) and positively correlated with mean relative humidity (r = +0.10). Further, the incidence showed negative trend with minimum temperature (r = -0.71), total rainfall (r = -0.11) and wind speed (r = -0.67) which, however were not significant (Table 13).

4.2.3.2 Summer pruning

The seasonal incidence of *S. dorsalis* during summer before berry maturation was significantly and positively correlated with the maximum temperature (r = +0.27) and negatively correlated with the mean relative humidity (r = -0.52). The incidence showed a positive trend with the minimum temperature (r = +0.06) and negative trend with total rainfall (r = -0.53) and wind speed (r = -0.36) though the correlations were not significant (Table 14).

However, after berry maturation (last week of April), the incidence was significantly and negatively correlated with wind speed (r = -0.46). The incidence showed a positive trend with the mean relative humidity (r = +0.02) and negative trend with maximum temperature (r = -0.97), total rainfall (r = -0.57) and minimum temperature (r = -0.40). However, the correlations were not significant (Table 14).

4.3 Biology of *Scirtothrips dorsalis* on French bean pods

4.3.1 Oviposition

Eggs were laid singly mostly on the tender pods, but occasionally on older pods. The eggs were laid scattered and oviposition was especially on tender/ hidden half of the tender pods while the upper/exposed half was rarely oviposited upon. The egg was entirely embedded in the tissue and the site could only be recognized by the translucent raised surface.

4.3.2 Eggs

The egg appeared kidney or oval shaped and glossy white in colour. It measured 0.23 to 0.26 mm in length with an average of 0.265mm. The width ranged from 0.10 to 0.12 mm with an average width of 0.11 mm. The incubation period ranged from 3.00 to 5.25 days with an average of 3.73±0.66 days (Table 15). The larval emergence site was recognized by the presence of a minute hole and the surrounding tissue turning brown.

4.3.3 Larva

4.3.3.1 First instar larva

The cuticle of the newly hatched larva was almost transparent. The colour of first stage larva gradually changed from white to pale yellow in about 12 hours. The antennae were seven segmented but the three distal segments were less distinct. The eyes were minute and pink in colour. The abdomen gradually tapered posteriorly from the thorax, where the width was maximum. This stage measured 0.28 to 0.32 mm in length (mean 0.30 mm) and 0.08 to 0.12 mm in width (mean 0.11 mm). The duration of the first instar larvae ranged from 1 to 1.75 days with an average of 1.15± 0.21 days (Table 15).

4.3.3.2 Second instar larva

It was orange yellow in colour. It measured 0.48 to 0.52 mm in length with a mean of 0.49 mm. Abdomen was nearly barrel shaped and the width was highest across the IV abdominal segment and ranged from 0.16 to 0.18 mm with an average of 0.17 mm. The antennal segments were distinct and they were pale orange in colour. The duration of the second instar larva ranged from 2.25 to 3.75 days with an average of 2.83± 0.49 days (Table 15).

Table 15: Duration of life stages of *Scirtothrips dorsalis* Hood under laboratory conditions (24.5- 26.5^0 c)

Stage of development	**Duration days**		
	Minimum	**Maximum**	***Mean ± SD**
Egg	3	5.25	3.73±0.66
I instar larva	1	1.75	1.15±0.21
II instar larva	2.25	3.75	2.83±0.49
Prepupa	0.75	1.5	1.03±0.30
Pupa	3.25	4.75	3.83±0.53
Total developmental period	10.5	17.25	12.60±1.51
Adult female longevity	3.25	6.75	4.88±1.35

* Mean of 20 replications

The two larval instars co-occurred on grape leaves and fed on leaves, stalk, petioles and shoots. Total larval period lasted 3.25 to 5.5 days with a mean of 3.98 ±0.70 days (Table 15).

4.3.4 Prepupa

It was a non-feeding intermediate stage between the larva and the pupa. The pre-pupa was yellow in colour. It could be recognized by the antennae being shorter, laterally directed, and the segments being indistinct. The wing pads were short, reaching only upto the third abdominal segment (later part of this stage). The prepupal period ranged from 0.75 to 1.5 days with a mean of 1.03±0.30 days (Table15). The prepupa measured about 0.59-0.61 mm (mean 0.59 mm) in length and 0.21 to 0.24 mm (mean 0.22 mm) in width.

4.3.5 Pupa

Pupa was dark yellow in colour with pinkish eyes. Antennae were directed backward over the head and thorax. The wing pads were much longer reaching almost the eighth abdominal segment. The pupa was 0.55 to 0.61 mm in length with an average of 0.59 mm and 0.21 to 0.25 mm in width (mean 0.23 mm). The pupal period ranged from 3.25 to 4.75 days with an average of 3.83±0.53 days (Table15). Like the prepupa this was a non-feeding stage. Under laboratory conditions, pupation occurred in the curled portion of the bean stalk. None could be observed in the soil below the ground surface. The average total duration of prepupal and pupal stages was 4.86± 0.83 days.

4.3.6 Total developmental period

The total developmental period from egg to adult was 10.5 to 17.25 days with a mean of 12.60 ± 1.51 days (Table 15: Plate 7).

Plate 7:

A: Egg stage of *Scirtothrips dorsalis*

B: First instar of *Scirtothrips dorsalis*

C: Second instar of *Scirtothrips dorsalis*

D: Prepupal stage of *Scirtothrips dorsalis*

E: Pupal stage of *Scirtothrips dorsalis*

F: Adult (female) stage of *Scirtothrips dorsaliss*

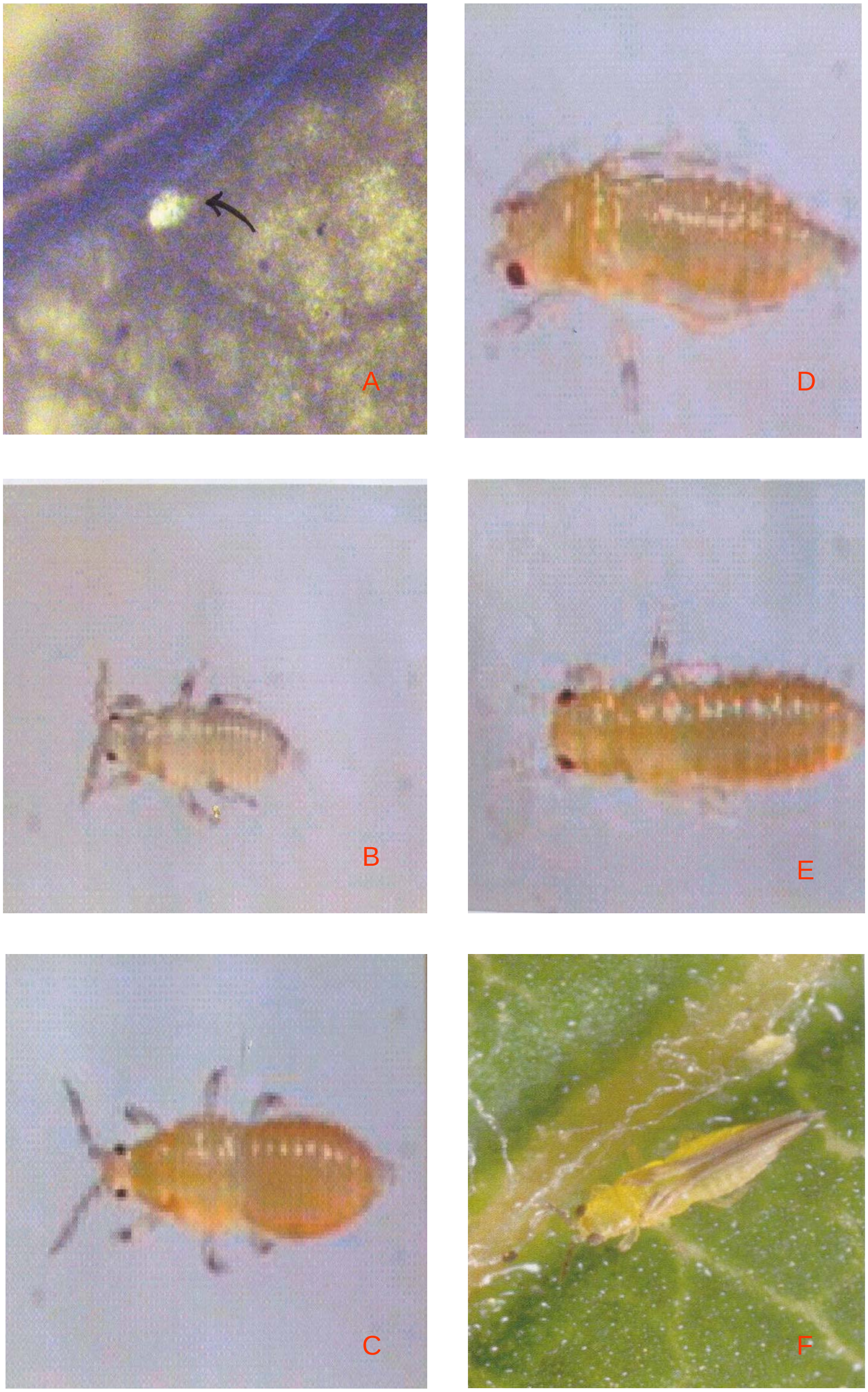


Plate 7

4.3.7 Adult

In the field, males were very rare and reproduction was mostly through thelytokous parthenogenesis. Hence, in the laboratory, freshly emerged females were used for oviposition studies. The adult female was orange yellow in colour and head more or less rectangular. Three ocelli were found in a triangle on vertex. Antennae were filiform and eight segmented and measured 0.23 to 0.26 mm in length (mean 0.24 mm). Forewing measured 0.49 to 0.55 mm long (mean 0.52 mm). On the median region of the second to seventh abdominal tergites there were triangular, pale brownish patches tapering posteriorly. The adult female thrips measured 0.91 to 0.93 mm in length (mean 0.92 mm) and 0.19 to 0.21 mm in width (mean 0.20 mm). Male was smaller than the female and the triangular patches on the abdominal tergite were indistinct. It measured 0.68 mm in length and 0.13 mm in width. Antennae measured 0.16 mm in length and the forewing measured 0.39 mm in length.

4.3.7.1 Pre-oviposition period

The pre-oviposition period ranged from 1 to 2 days with an average of 1.6 ± 0.49 days.

4.3.7.2 Oviposition period

The oviposition period lasted for 1 to 3 days with an average of 1.93 ± 0.68 days.

4.3.7.3 Fecundity per day

The maximum and minimum number of eggs laid by a female per day was 4 and 1, respectively, with an average of 2.3 ± 0.94 eggs per day.

4.3.7.4 Post-oviposition period

The duration of the post oviposition period ranged from 1 to 3 days with an average of 1.6 ± 0.61 days.

4.3.7.5 Longevity

The longevity of adult female thrips ranged from 3.25 to 6.75 days with an average of 4.88 ± 1.35 days (Table 15).

4.4 Evaluation of new insecticide molecules including bio-pesticides against grape thrips

Data on the efficacy of different insecticides against thrips infesting Bangalore blue grapes were presented in Table 16. The pre-treatment count of grape thrips during summer, 2008, ranged from 13.56 to 17.04 per shoot and the treatment differences were statistically non-significant (Table 16).

The number of thrips recorded three days after first spray in different treatments ranged from 6.17 to 16.71. All the insecticides and bio-pesticide treatments were better than control. Among them fipronil 80 WG (50 g.a.i. /ha) recorded least number of S. *dorsalis* (6.17 thrips/shoot) followed by fipronil 80 WG (40 g.a.i. /ha) (7.01), spinosad (7.11), acephate (7.63) and fipronil 5SC (7.81), all of them being on par. These were followed by quinalphos (8.52), imidacloprid (9.13 thrip/shoot), monocrotophos (10.41), dimethoate (10.51), fish oil rosin soap (12.57) and azadirachtin (12.64) which were on par.

Ten days after first spray, all treatments were superior to control. The least count was recorded in fipronil 80 WG (50 g.a.i./ha) (6.82thrips/shoot), which was on par with spinosad (8.11), acephate (9.16), fipronil 80 WG (40 g.a.i./ha) (9.61), imidacloprid (11.13), monocrotophos (11.13), fipronil 5 SC (11.19). Quinalphos (13.21) ranked next and was on par with fish oil rosin soap (13.83), dimethoate (14.25), and azadirachtin (15.23).

The count recorded three days after second spray ranged from 4.13 to 15.85. All the treatments were significantly better than control. Fipronil 80 WG (50 g.a.i./ha) and spinosad were the most effective insecticides in controlling

Table 16: Efficacy of selected new insecticide molecules including bio-pesticides against thrips on grapes (cv. Bangalore Blue) during summer 2008

Sl No.	Treatments	Dose (g.a.i./ha)	Number of thrips per shoot on different days					Bunch yield (tonnes/ha)	% increase in yield over control
			Pretreatment count	I Spray		II Spray			
				3DAS	10DAS	3DAS	10DAS		
1	Fipronil 80 WG	40	16.09	7.01^{ab}	9.61^{abcd}	6.47^{abc}	6.52^{abc}	27.17	60.48
2	Fipronil 80 WG	50	17.04	6.17^{a}	6.82^{a}	4.13^{a}	4.01^{a}	31.25	84.58
3	Fipronil 5SC	40	13.90	7.81^{abcde}	11.19^{abcdef}	7.93^{bcd}	8.21^{bcd}	24.19	42.88
4	Spinosad	84.375	15.38	7.11^{abc}	8.12^{ab}	4.63^{ab}	4.65^{ab}	29.08	71.76
5	Imidacloprid	45	16.52	$9.13^{abcdefg}$	11.13^{abcde}	8.42^{cdef}	8.63^{cdef}	23.39	38.15
6	Dimethoate	300	13.71	$10.51^{bcdefghi}$	14.25^{cdefg}	$11.02^{defghij}$	$11.62^{defghij}$	20.78	22.74
7	Quinalphos	250	15.09	8.52^{abcdef}	13.21^{bcdefg}	10.13^{defgh}	10.43^{cdefgh}	21.20	25.22
8	Monocrotophos	500	16.51	$10.41^{bcdefgh}$	11.13^{abcde}	8.91^{cdefg}	9.24^{cdefg}	22.46	35.66
9	Acephate	400	15.19	7.63^{abcd}	9.16^{abc}	8.15^{cde}	8.31^{bcde}	26.14	54.40
10	Azadirachtin	2.25lit/ha	16.39	12.64^{ghij}	15.23^{efg}	$10.34^{defghij}$	$10.91^{defghij}$	20.82	20.02
11	FORS	1.87Kg/ha	16.13	12.57^{ghij}	13.83^{cdefg}	10.20^{defghi}	$10.46^{cdefghi}$	18.96	11.99
12	Control	-	13.56	16.71^{k}	18.41^{g}	15.85^{k}	14.48^{j}	16.93	–
F - test			NS	*	*	*	*	*	
SEM±			1.45	1.33	1.89	1.17	1.35	0.85	
CD(P=0.05)			-	3.90	5.55	3.45	3.96	2.5	

DAS = Days after spray, * Significant; NS = Non significant

Figures in each column followed by same alphabet(s) are not significantly different thrips (4.13 and 4.63/shoot, respectively), and were on par. These were followed by fipronil 80 WG (40 g.a.i./ha) (6.47) was observed to be next in efficacy and was on par with fipronil 5 SC (7.93), acephate (8.16), imidacloprid (8.42*)*, monocrotophos (8.91), quinalphos (10.13), fish oil rosin soap (10.20), azadirachtin (10.34) and dimethoate (11.02 thrips/shoot).

Ten days after second spray, all the treatments were superior to control. Fipronil 80 WG (50 g.a.i. /ha) and spinosad were the best and equally effective recording 4.01 and 4.65 thrips per shoot, respectively. Fipronil 80 WG (40 g.a.i./ha) (6.52) ranked next and was on par with Fipronil 5 SC (8.21), acephate (8.32), imidacloprid (8.63*)*.These were followed by monocrotophos (9.24), quinalphos (10.43), fish oil rosin soap (10.46), azadirachtin (10.91) and dimethoate (11.62 thrips/shoot) which were on par.

From the data recorded on three and ten days after first and second sprays it is evident that treatments *viz.*, fipronil 80 WG (50 g.a.i./ha), spinosad and Fipronil 80 WG (40 g.a.i./ha) were comparatively more effective in controlling thrips*.* The moderately effective treatments were fipronil 5SC, acephate, imidacloprid, monocrotophos and quinalphos.

4.4.1 Phytotoxicity

The data pertaining to phytotoxicity, the results on the phytotoxicity test revealed that none of the insecticidal treatments showed any type of phytotoxic symptoms on grape vines at the dosage tried i.e., fipronil 80 WG (40 g.a.i./ha), fipronil 80 WG (50 g.a.i./ha), fipronil 5SC (40 g.a.i./ha), spinosad 2.5SC (84.375 g.a.i./ha), imidacloprid 17.8 EC (45 g.a.i./ha), dimethoate 30EC (300 g.a.i./ha), quinalphos 25EC (250 g.a.i./ha), monocrotophos 36SL (500 g.a.i./ha), acephate 75SP (400 g.a.i./ha), azadirachtin (2.25lit/ha) and fish oil rosin soap (1.87kg/ha).

4.4.2 Yield

Higher yield (31.25 tonnes/ha) was recorded in the plot treated with fipronil 80 WG (50 g.a.i. /ha) compared to all other treatments and this was followed by spinosad (29.08), fipronil 80 WG (40 g.a.i. /ha) (27.17), acephate (26.14), fipronil 5SC (24.19), imidacloprid 17.8 EC (23.39), monocrotophos 36 SL (22.46), quinalphos (21.20), dimethoate (20.78) and azadirachtin (20.82tonnes/ha). While fish oil rosin soap and untreated control recorded lower yield of 18.96 and 16.93 tonnes/ha, respectively (Table 16).

A maximum of 84.58 per cent increase in yield over untreated control was noticed in fipronil 80 WG (50 g.a.i. /ha) followed by spinosad (71.76), fipronil 80 WG (40 g.a.i. /ha) (60.48). A minimum of 11.99 per cent increase in yield over untreated control was recorded in fish oil rosin soap (Table 16).

Discussion

V. DISCUSSION

The results of the studies conducted on the species composition, seasonal incidence, biology and management of thrips on Bangalore Blue grapes for two seasons during 2007-08 at GKVK, Bangalore are discussed in this chapter.

5.1 Species composition

During the present investigation four species of thrips were found in the grape orchards under Bangalore conditions. These were *Scirtothrips dorsalis* Hood (Thripidae), *Haplothrips ganglbaueri* Schmutz (Phlaeothripidae), *Haplothrips ceylonicus* Schmutz (Phlaeothripidae), and *Thrips hawaiensis* Morgan (Thripidae). Of these, *S. dorsalis* was the major species of thrips to be phytophagous on grapes, which agrees with the findings of Ananthakrishnan (1971) and Butani (1979).

Ananthakrishnan (1971) reported *S. dorsalis* and *Rhipiphorothrips cruentatus* Hood affecting grapes in Tamil Nadu, Andhra Pradesh, Maharashtra and Karnataka. These two species were also recorded by Butani (1979). This study has recorded four additional species of thrips representing two families on grapes from India for the first time. The families and species recorded are *Aeolothripidae* (*S. arorai)* and *Phlaeothripidae (K. flavipes, H. tenuipennis and Xylaplothrips* sp.).

In the present study, *S. dorsalis* was the major species of thrips causing economic damage to Bangalore Blue variety (Fig; 1). As this variety is most commonly grown in and around Bangalore, studies on the bio-ecology and management were important. Precise management of thrips is crucial here, as sizeable segments of the grape growers are dependent on Bangalore Blue for subsistence (Anon., 1999).

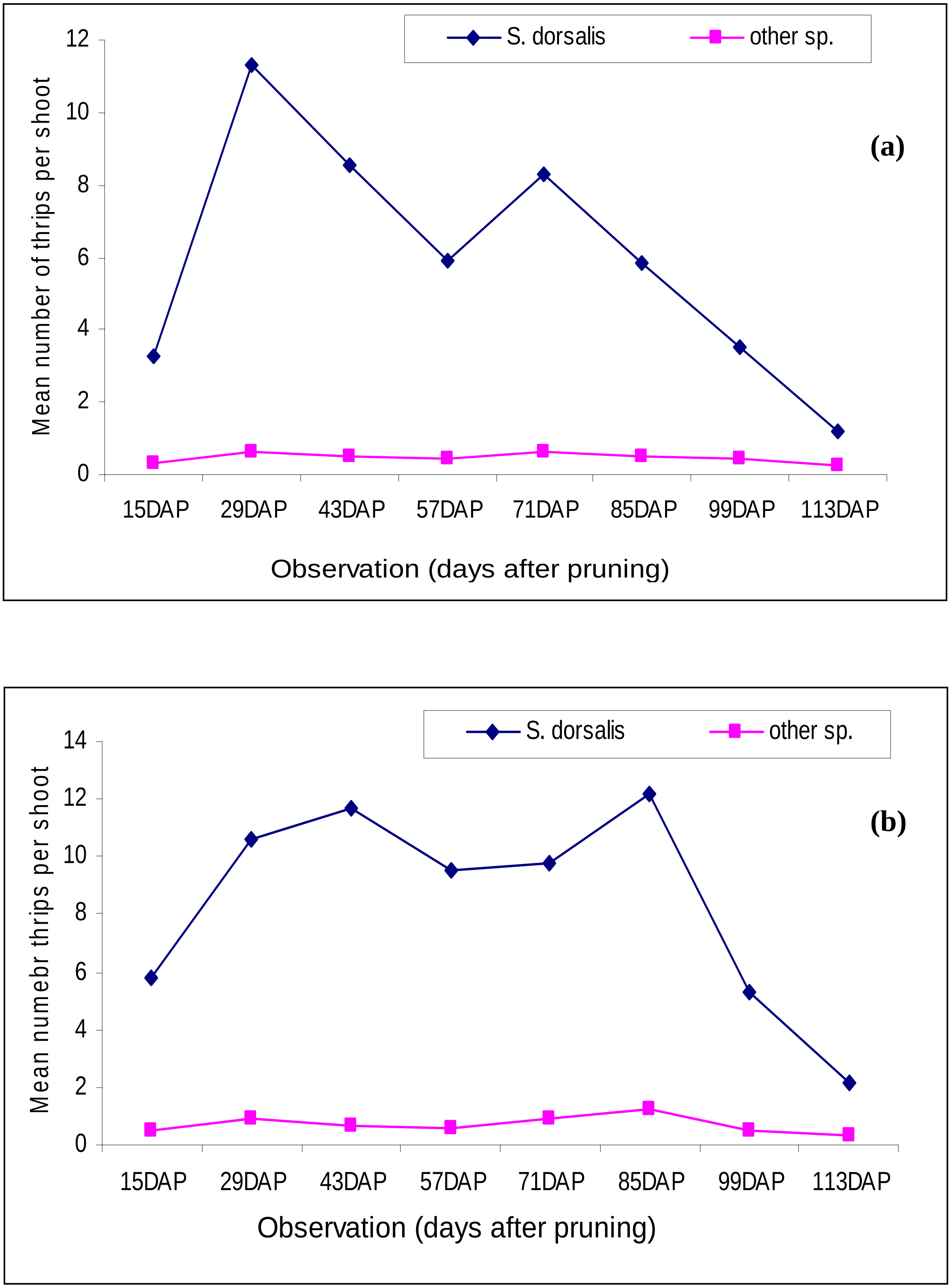


Fig. 1: Proportion of thrips species on grapes during (a) kharif and (b) summer seasons of 2007-08

5.1.1 Seasonal variation in the incidence and distribution of *S. dorsalis*

Spatial distribution is characteristic of insect species behaviour. The simplest and a reliable parameter to understand spatial distribution is variance-mean ratio (Southwood, 1978). When variance-mean ratio is > one (i.e., variance> mean) the insects are said to be aggregated. It is random when variance = mean and uniform when variance < mean (Southwood, 1966). The variance-mean ratio was > one between 15 days after pruning to 57 days after pruning, implying that *S. dorsalis* followed an aggregated pattern with higher mean densities. These results are comparable with the reports of Kirk (1985b).

Terry and Gardner (1990) and Milne (1997) who reasoned that, aggregations might be associated with finding common resources such as tender leaves and floral parts for food and or mating, thus aggregations takes place on such parts. They also reported aggregations on tender plant parts due to the concentration of eggs mostly on younger leaves and flowers. The reason for preference to tender plant parts might be because the new plant growth and opening of flowers provide more and better food as also reported by Kirk (1990). Further, there is a tendency for thrips to aggregate within leaf sheaths or deep within inflorescence to protect against rainfall, predators, parasitoids, adverse temperatures etc thus contributing for aggregation. This behaviour is in agreement with the findings of Kirk (1990) that this habit provides a microclimate with high relative humidity and allows easier access to food, besides giving protection from predators, parasitoids, solar radiation, rain and adverse temperatures. Thus, it is not surprising that there was an aggregated distribution on younger leaves (which fold easily upon thrips feeding) and within inflorescence. However, a few other factors such as tenderness of cells in young leaves and inflorescence may have also contributed for the contagious or aggregated distribution.

After fruit set, the variance-mean ratio was closer to one, manifesting a tendency to randomness by veraison stage 2 (99 days after pruning). This finding is comparable with the observations of Nugaliyadde and Heinrichs (1984) that fecundity almost halved between five leaf stages to six leaf stages. Thus, there was random distribution of *S. dorsalis* as the leaves got matured and berries were formed. Further, with onset of crop maturity the thrips showed under dispersion or uniform distribution with variance-mean ratio less than one (Table 5&6). This may be due to reduction in breeding niches.

The distribution within vine showed significant variation at different crop stages. This might be due to changes in position of thrips on the crop in response to sunlight and relative humidity as also observed by Steele (1935). This observation is in close agreement with the findings of Lewis (1997) that feeding activity of thrips can sometimes be greater during night and during day they retreat to concealed places, thus contributing for change in distribution. Further, other activity, such as oviposition, may also alter distribution, which is corroborated by Kirk (1985b) and Tamo *et al.* (1993) who observed changes in ovipositional preference by thrips over crop growth stages. Similarly, preference of thrips for different plant parts can also contribute to the variation within vine as also observed by Theunissen and Legutowska (1991).

The distribution of *S. dorsalis* on vines is of particular relevance for planning effective sampling strategies. If *S. dorsalis* are highly aggregated, more samples will be needed than when they are regularly distributed. The degree of aggregation may also reveal information about behaviour of *S. dorsalis* during different crop growth stages (Lewis, 1973).

The vegetative stages showed maximum density of *S. dorsalis*, and each of these stages significantly differed from others. From management point of view, vegetative stage 3(29 days after pruning) would be more appropriate for sampling of thrips. It is here, decisions for spray intervention need to be taken. The present investigation forms a basis for future studies of *S. dorsalis* on grapes, as distribution patterns helps in understanding sampling plan and relevant transformation (if necessary). Sampling is crucial for estimating pest density on a plant for scheduling pest management programs. This is all the more important when one studies thrips on grapes, where distribution varies with the growth stages of crop.

5.1.2 Symptoms and nature of damage

Scirtothrips dorsalis caused damage from the stage of new leaf emergence to berry maturation. The insect punctured the leaves, petioles and berries and sucked the sap resulting in silvery white scorchy patches on leaves and scars on berries. Under severe infestations, the leaves curled, withered and prematurely dropped. Further, scarring and cracking on fruit surface were observed. The affected mature berries were ugly and unfit for marketing. These observations are corroborated by Butani (1979) and Harish (2002).

5.2 Incidence of thrips in relation to growth parameters of grape vine

An indepth knowledge regarding the influence of crop growth parameters (tender leaves, half matured leaves, fully matured leaves, flowers, pea, marble and large sized berries) on the thrips is essential to know the critical growth stage that is susceptible to thrips damage. A perusal of the literature on the incidence of thrips revealed that it intensively feeds on tender leaves, flower bunches and young fruits, and the population starts building up with the initiation of new flush (Ananthakrishnan, 1971).

In this context, an attempt was made to understand the influence of crop growth stages on the incidence of thrips at GKVK, for two seasons during 2007-08. The number of *S. dorsalis* reached a peak 30-40 days after pruning (13.93 & 17.43 mean thrips/shoot during kharif and summer, respectively) (Figs, 2&3). In both seasons, the peak incidence of thrips occurred when the vines were in tender

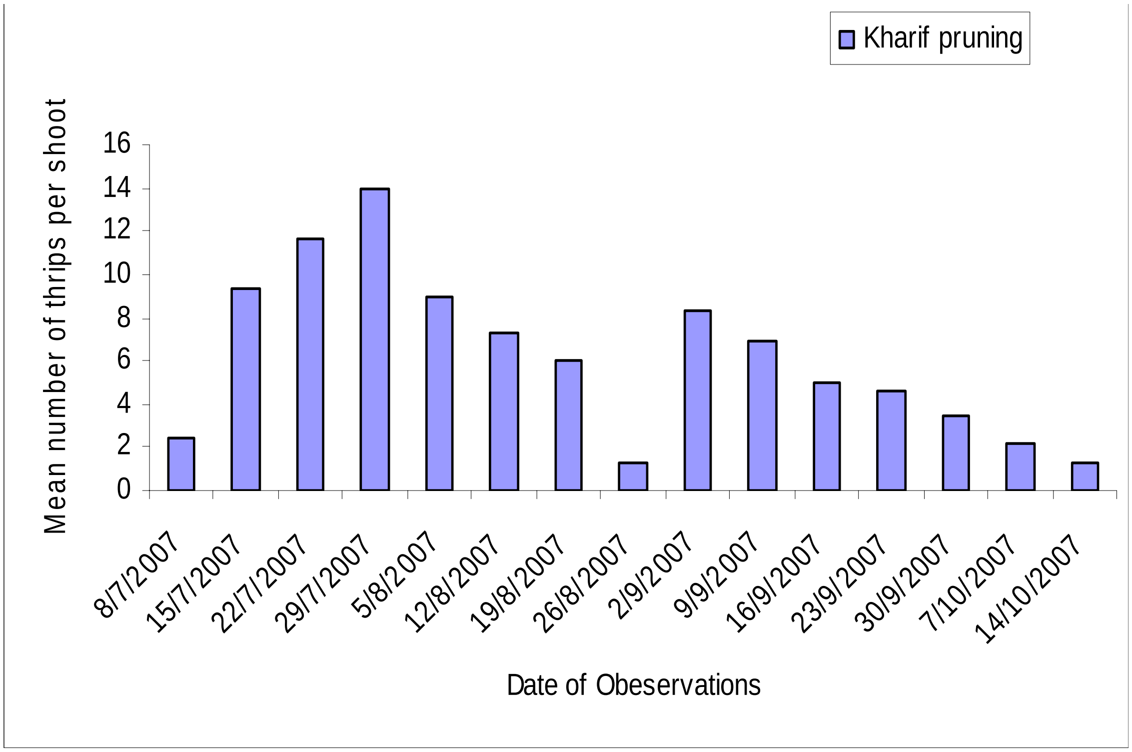


Fig 2: Incidence of thrips on grapes (cv. Bangalore Blue) during kharif, 2007

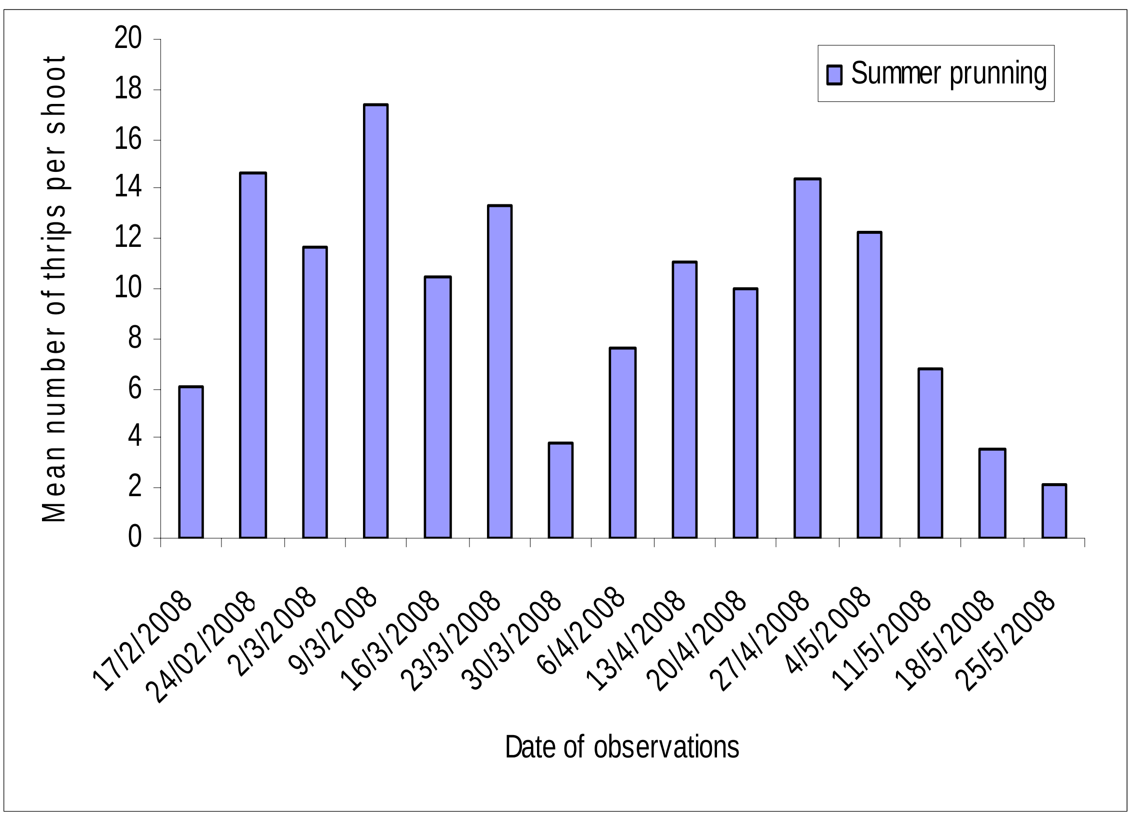


Fig 3: Incidence of thrips on grapes (cv. Bangalore Blue) during summer, 2008

leaf stage and the flowering had just initiated. This observation is in close agreement with the reports of Kirk (1990) that new plant growth and opening of flowers provide more and better food, thus increasing the rate of population growth.

The increase in the number of tender leaves favoured the multiplication of the pest in both seasons. Therefore, the peak incidence of the thrips was seen during this stage. This clearly showed that crop growth stages influenced thrips incidence. Similar studies were also recorded by Harish (2002) during winter and summer. The results indicated that pest prevailed throughout the cropping period, except during the late fruiting stage, further the pest number attain peak during the first week of November and third week of May in winter and summer, respectively.

5.2.1 Correlation studies between growth parameters of vine and incidence of *S. dorsalis.*

The correlation coefficients were worked out to know the effect of different crop stages on the incidence of thrips. Tender leaves were significantly, positively correlated with the thrips number during both seasons (Table 10). This clearly showed the preference of thrips for tender leaves. The incidence of thrips showed only a positive trend with half matured leaves and flowers, though the correlations were not significant.

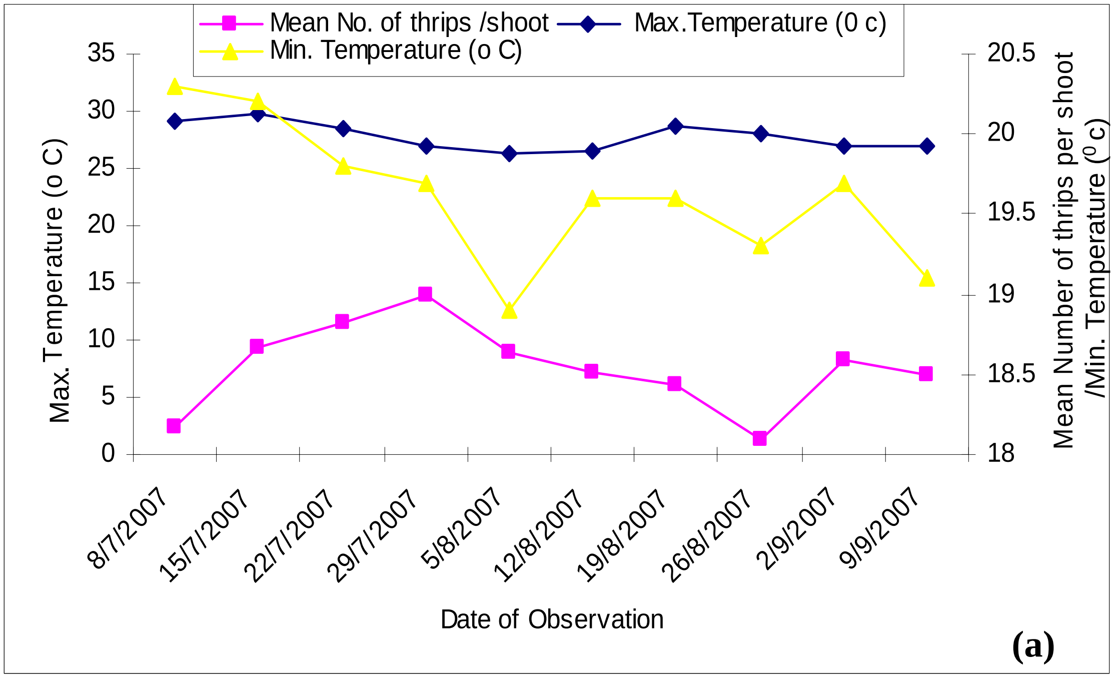
Fully matured leaves showed negatively significant correlation in both seasons with the thrips density (Table 10). This effect may be due to the non-preference of thrips to older leaves. Though, a few thrips prevailed even at the senescence stage, they were observed either at the apical tip of the shoots or within the bracts and bunches, thus clearly indicating their non-preference for matured leaves.

Pea and marble sized berries recorded a non-significant, negative correlation with the thrips density. However, the incidence was significantly negatively correlated with large sized fruits. This might be because with the advancement of crop growth the thrips density declined gradually as suitable niche (tender leaves mainly on which thrips bred and fed) was scarce. Further, large size fruits were not preferred for feeding. These observations are comparable with the reports of Kirk (1990) and Lewis (1997) and Harish (2002) that towards the end of season, populations decrease or sometimes crash rapidly to a lower level, mainly due to a decrease in preferred food.

5.2.2 Seasonal incidence of *S. dorsalis* on grapes

An understanding of the seasonal incidence of a pest is essential to plan its management. A perusal of the literature on the incidence of *S. dorsalis* revealed that it predominantly feeds on tender leaves and its seasonal incidence is influenced mainly by weather parameters. On chilli leaves, population was low during September to November and October to December in Guntur (Andhra Pradesh) and Periyakulam (Tamil Nadu), respectively (Ayyar *et al.*, 1935); on tea leaves during August to October at Toacklai (Assam) (Dev, 1964); on castor leaves during October to November at Delhi (Raizada, 1965) and on chilli leaves during September to December at Bhubaneswar (Orissa) (Patnaik *et al.*, 1985). In interior towns of Northern states (Delhi and Assam), severe winter also inhibited the resurgence of the population reduced by the monsoon (Raizada, 1965). On grapes, the population was peak during first week of November and third week of May (Harish, 2002).

In the present study, thrips occurred throughout the year in both the seasons (Kharif and summer) except during the late fruiting stage. In kharif, the crop was pruned during last week of June and in summer, pruning was done during first week of February. In both the seasons, the pest attack was observed immediately



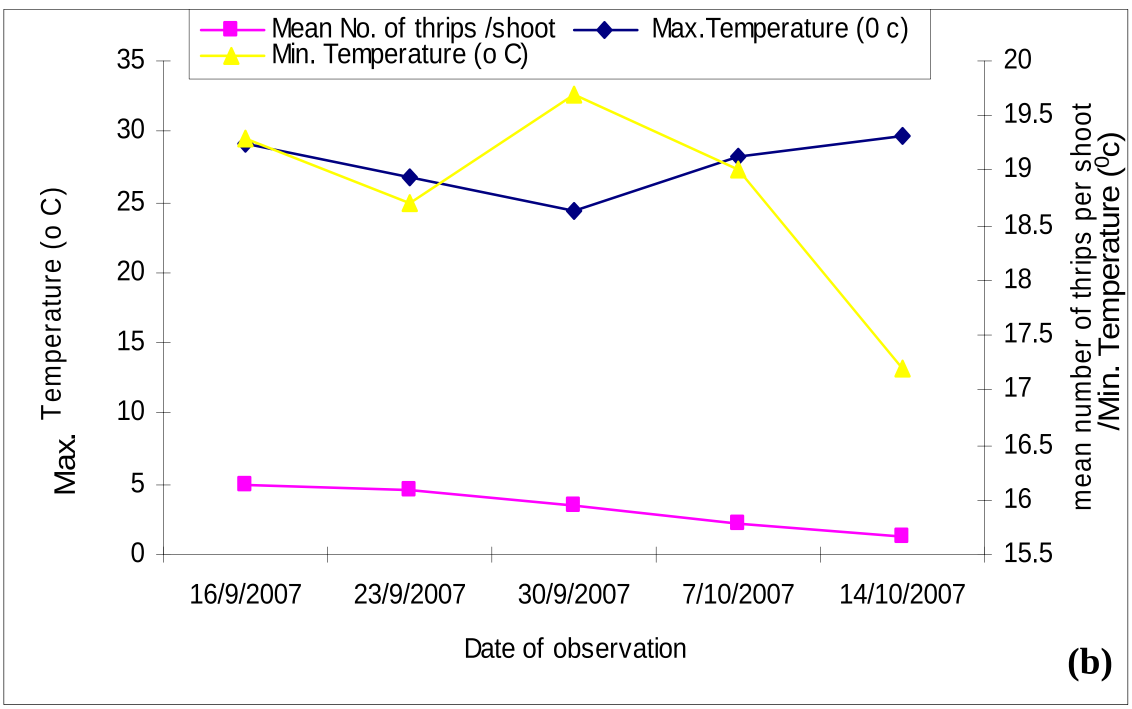


Fig 4A: Seasonal incidence of thrips and weather parameters during kharif, 2007 (a) before berry maturation and (b) after berry maturation

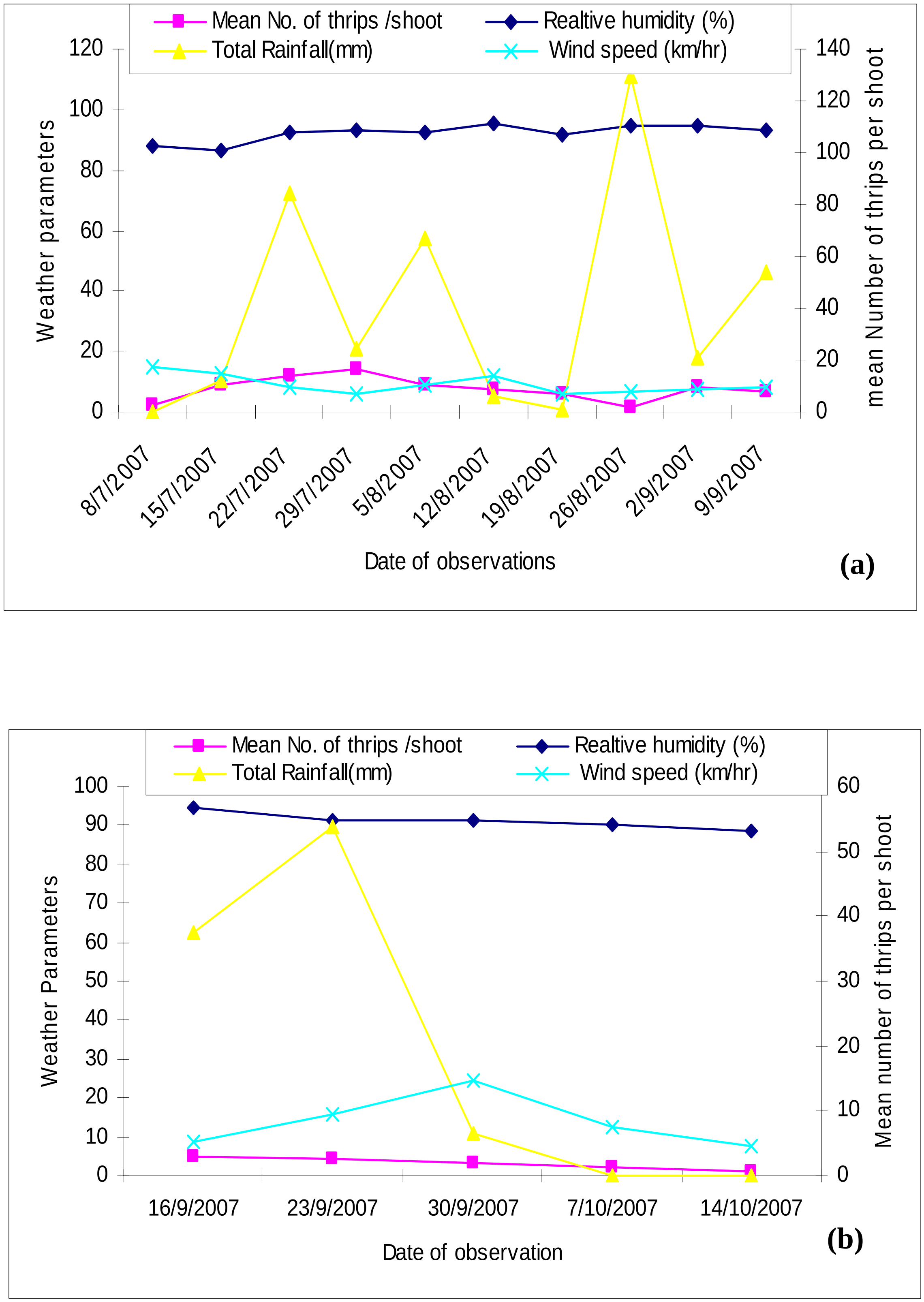


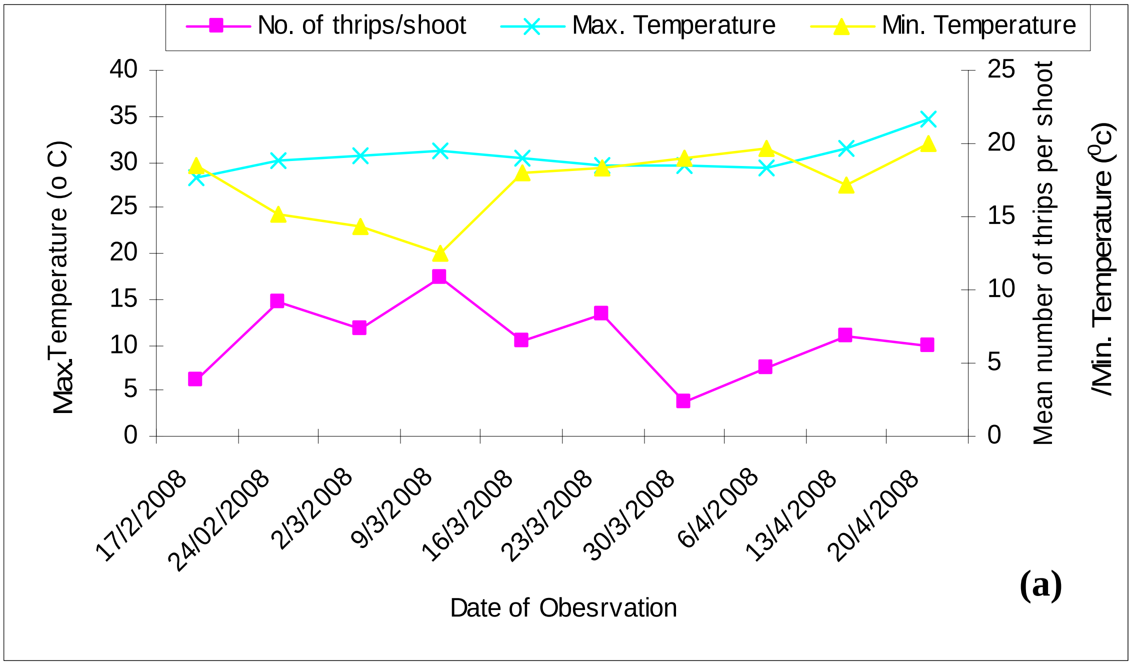
Fig 4B: Seasonal incidence of thrips and weather parameters during kharif, 2007 (a) before berry maturation and (b) after berry maturation

after the initiation of new flush and it continued throughout the crop growth. Thrips were found to be enclosed within the small tender leaves present at the top of the shoot and also hiding within the bracts. This favoured its protection and multiplication even during rainy season and hence the pest was found to occur throughout the year.

The pest attained its peak activity during the last week of July (13.93 mean thrips per shoot) and second week of March (17.43 mean thrips per shoot) in kharif and summer, respectively. Comparatively higher density of *S. dorsalis* was observed during summer in the present investigation, which is in close agreement with the findings of Lewis (1997) and Harish (2002), who observed peak activity of thrips during dry periods, mainly due to suitability of weather for population growth. Further, Wardle (1927), Urich (1928), Fennah (1965) and Evans (1967) also observed increase in thrips population during dry seasons (but not extreme drought). This agrees with the results of the present investigation although it is difficult to know whether the effect is nutritional or just the absence of mortality from rain. The increase in temperature during both seasons favoured the multiplication of the pest and this might be the reason for the peak occurrence of the pest. The present investigation is in close agreement with the findings of Kirk (1985b) and Harish (2002) that higher temperatures encourage crop growth and thus, physiological development of thrips, thus increasing the rate of population growth.

5.2.3 Correlation studies between weather parameters and incidence of *S. dorsalis*

The correlation coefficients were worked out to know the effect of weather parameters *(viz.,* maximum and minimum temperature, relative humidity, rainfall and wind speed) prevailing during the preceding week on the incidence of *S. dorsalis.*



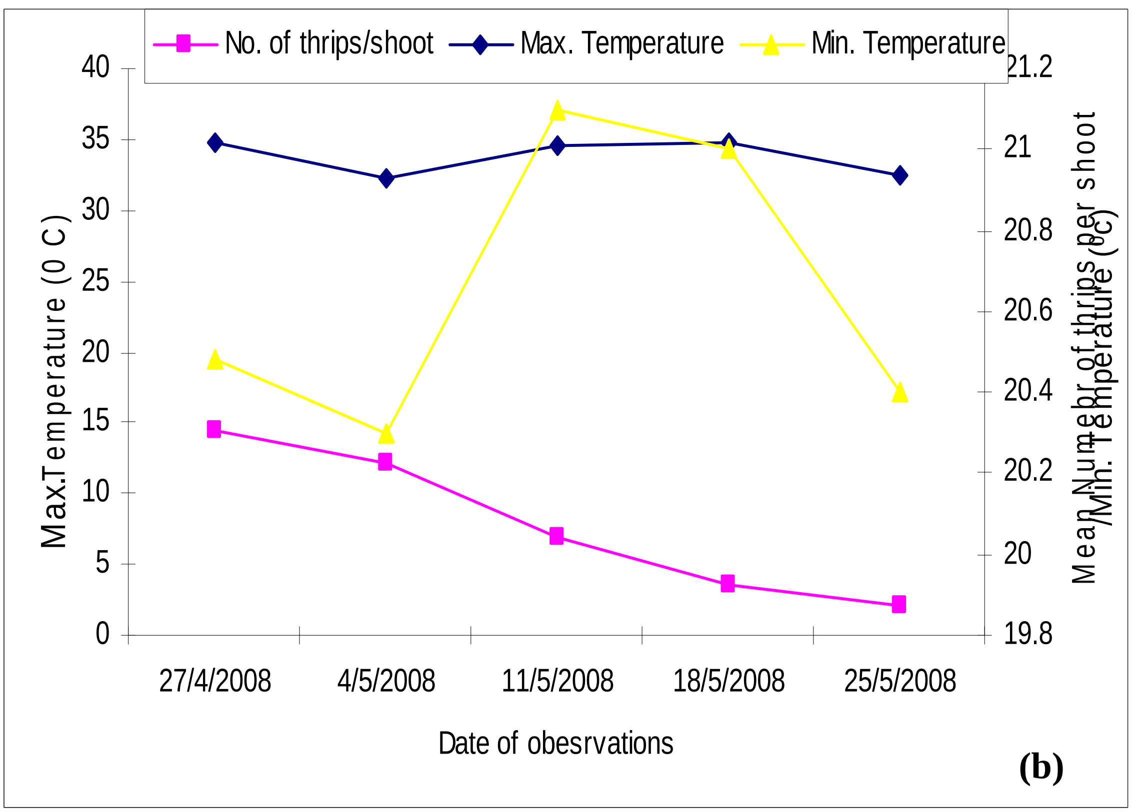
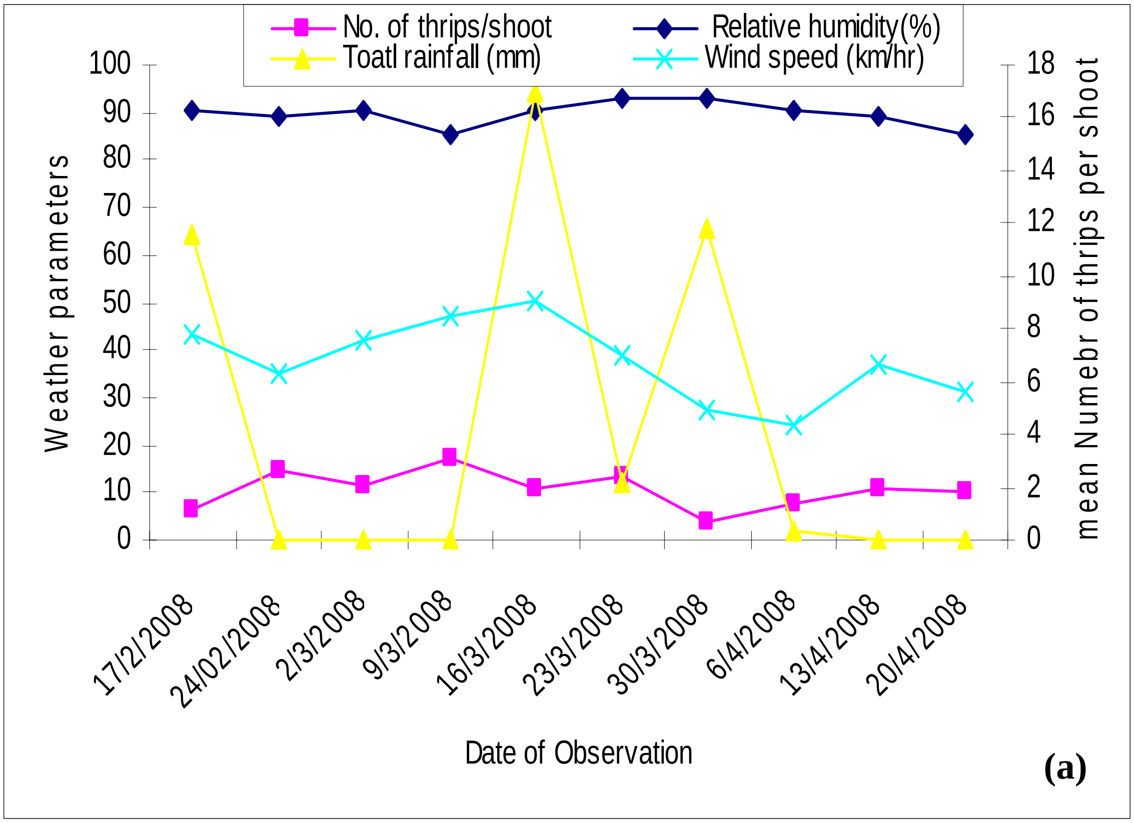


Fig 5A: Seasonal incidence of thrips and weather parameters during summer, 2008 (a) before berry maturation and (b) after berry maturation



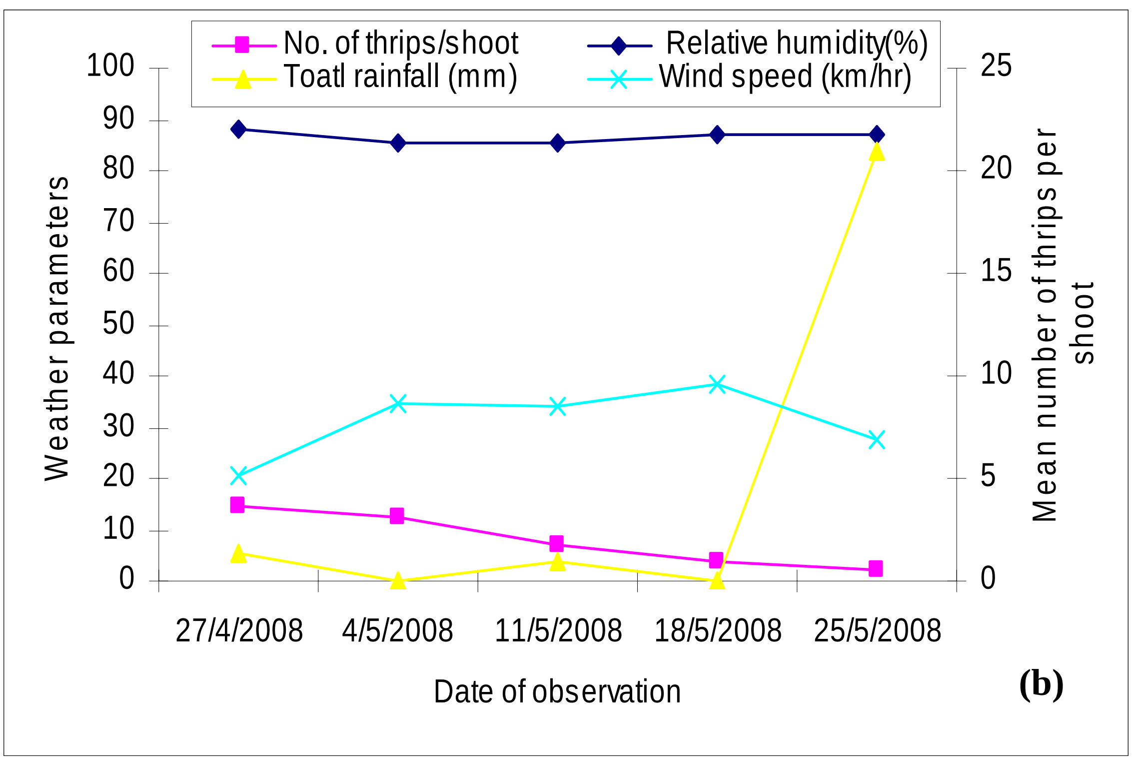


Fig 5B: Seasonal incidence of thrips and weather parameters during summer, 2008 (a) before berry maturation and (b) after berry maturation

The thrips density was significantly and positively correlated with the maximum temperature during both seasons (Fig 4A&B, Fig 5A&B). An increase in the temperature during both seasons favoured the development and multiplication of the pest and this might be the reason for the increased population of thrips with an increase in temperature. This is also corroborated by Ananthakrishnan and Jagadish (1968). Bagle (1993) observed the positive correlation of temperature with the population of thrips. This is in agreement with the results of present investigation. The incidence of *S. dorsalis* showed a positive trend with minimum temperature though the correlation was not significant. The present finding is in agreement with the reports of Kirk (1990), Lewis (1997) and Harish (2002) that thrips population decreases due to lower temperatures. Higher temperature regimes favoured *S. dorsalis*, and perhaps explain the longer life cycle duration under Delhi conditions (Raizada, 1965).

The relative humidity showed negatively significant correlation in both seasons with the population of thrips. This effect might be partly due to positive temperature effect and negative rainfall effect. Patnaik *et al.* (1986) and Harish (2002) reported negative correlation of *S. dorsalis* on chillies, groundnut and cotton in relation to relative humidity, which is in agreement with the present investigation.

Rainfall recorded a negative trend with the population of thrips during both the seasons. This might be because heavy rain can wash thrips off plants (and down the soil surface, causing sudden sharp declines in population density as also reported by Bailey (1933), Harris *et al.* (1936) and North and Shelton (1986a). However, the correlations were non-significant which may be due to occurrence of the thrips within the folds of tender leaves, which are yet to open at the tip of the shoot, and within the bracts. This, besides contributing to aggregation may have afforded protection from rains and hence the non significant correlation with rainfall. These observations are comparable with the findings of North and Shelton (1986b) that the habit of feeding on underside of leaves may lessen mortality from rain. Patnaik *et al.* (1986) reported non-significant negative correlation of *S. dorsalis* with rainfall, which is in agreement with the present investigation.

Wind speed recorded a non-significant negative correlation with the population of thrips. This again might be because of presence of thrips within the leaves and bracts.

After berry maturation, the thrips population declined and correlation coefficient showed a reverse trend for both maximum temperature and relative humidity. The former showed negative trend while the latter had positive trend. This is not a real reflection of the effect of weather parameters as during the fruiting stage the crop growth stages had a greater effect on thrips, being less preferred for thrips multiplication resulting in low thrips number and therefore not amenable to inferences from correlation coefficients with weather parameters.

5.3 Biology of S. *dorsalis*

5.3.1 Oviposition

In the present study, attempts to rear *S. dorsalis* on potted grape cuttings did not fully succeed, as they failed to complete the life cycle. Probably *S. dorsalis* breeds well on grapes in the open field. The missing link in grapes could not be identified, as this can be an ideal study for future. In the present attempt, thrips under caged conditions showed a tendency to escape, migrate downwards into the soil in the pot and die. Such escape tendencies and mortality have also been reported by Gilstrap and Oaten (1976) and Harish (2002). Hence, *S. dorsalis* was reared on French bean pods *(Phaseolus vulgaris* L.) in plastic jars. This is a popular approach for rearing *Frankliniella occidentalis* (Bailey and, Smith, 1956). However, this has been modified and used by several workers, using either bean sections (Sakimura, 1961; Lublinkhof and Foster, 1977; Lowry *et al.,* 1992) or complete beans (Ullman *et aI.,* 1992; Loomans *et al.,* 1995; Wijkamp *et al.,* 1995). This method was also used for rearing *F. schultzei,* (Loomans *et al.,* 1995; Steiner *et al.,* 1995), *F. intonsa* (Wijkamp *et al.,* 1995), *Thrips tabaci* (Loomans *et al.,* 1995) and *S. dorsalis* (Harish, 2002), though all their field hosts were different.

Scirtothrips dorsalis preferred tender bean pods to older pods for oviposition. Oviposition occurred on the lower (ventral) half of the pods. This character of oviposition by *S. dorsalis* on ventral half of the tender pods might be because the eggs are vulnerable to desiccation or changes in plant tissue and they cannot defend themselves against predators and parasitoids as also reported by Teulon *et al.* (1994). Further, this may also be due to the adult preference to feed on ventral surfaces. This behaviour is in agreement with the reports of Fennah (1963) who reported the distribution pattern formed by cacao thrips to be due to food quality and environmental factors when feeding on cashew leaf. Similarly, it may be to lessen the mortality from rain, predators, parasitoids etc. as reported by North and Shelton (1986b). The feeding sites also became ovipositional sites for thrips. This is in close agreement with the findings of Theunissen and Legutowska (1991) and Harish (2002) they found that adult thrips laying eggs where they fed. In the grape field too, the thrips were invariably found on the ventral surface of the leaves.

In this study, it was found that French bean pod is an ideal host for culturing *S. dorsalis.* This will be useful for mass rearing of *S. dorsalis* in other studies with reference to biological control, virus transmission etc. This is close agreement with the findings of Harish (2002).

5.3.2 Egg

The kidney shape and glossy white colour of the egg observed in this study were, similar to those reported by Dev (1964) on tea and Raizada (1965) on castor.

The oval shape of some eggs might be due to the absorption of water as stated by Hall (1930). He reported that the eggs of *Scirtothrips aurantii* laid on citrus fruits quickly lost their characteristic kidney shape and swelled into oval cylinders. The length and width range of the egg was almost same as reported by Dev (1964). The average incubation period of 3.73 days in the present study under Bangalore conditions overlaps with the range reported by Raizada (1965). The slightly longer period reported by Dev (1964), Patnaik *et al.* (1986) and Harish (2002) might, be due to the difference in host plants and/or other ecological factors.

5.3.3 Larvae

The colour, size and morphology of the larvae were similar to those described by Dev (1964). The total larval duration of 3.25 to 5.5 days with an average of 3.98 days observed in the present investigation were comparable with the reports of Ayyar *et al.* (1935), Dev (1964), Patnaik *et al.* (1986), Murugan (2000) and Harish (2002). Longer larval duration of seven to eight days recorded by Rao (1929) could be due to the difference in host plant and kind of material provided for the larval feeding and also due to the prevalent ambient conditions. This stage is crucial as they cause most of the damage on grapes.

5.3.4 Pupae

The pupation of *S. dorsalis* on the curled portion of bean stalk under laboratory conditions was probably due to forced rearing. The colouration, size and morphology of the pupal stages are similar to that described by Dev (1964). The pupal periods, which lasted from 4 to 6.25, days with an average of 4.86 days are in agreement with the reports of Ayyar *et al.* (1935), Raizada (1965), Murugan (2000) and Harish (2002). Pupae were not observed on the grapevine in the field. Presumably they fell into soil and pupated. However, soil raking as a treatment to dislodge or mechanically damage the pupae did not significantly reduce the thrips density.

5.3.5 Total developmental period

The total developmental period of *S. dorsalis* ranged from 10.5 to 17.25 with an average of 12.60 days. This agrees with the findings of Ayyar *et al.* (1935), Dev (1964), Patnaik *et al.* (1986), Murugan (2000) and Harish (2002) on chilli (10-15days), tea (13-17days), chilli (14-17days) rose (10-17 days) and beans (14.35 days) respectively. As the life cycle is completed in approximately a fortnight, several generations can be expected from flushing to berry development. Under Bangalore conditions, with warmer conditions prevalent through most part of the year thrips may occur throughout without an inactive period as also observed by Lewis (1997). This calls for vigil and appropriate frequency of management strategies.

5.3.6 Adult

The colouration and morphology of the adult was similar to that described by Dev (1964).However, the adults measured 0.91 mm in length and 0.19 mm in width, length being slightly shorter than that reported by Dev (1964). This difference may be due to the effect of host and change in the micro environment and method employed in rearing under laboratory condition. The adult reproduction appears primarily to be through thelytokous parthenogenesis as evidenced by the rarity of males, which is in close agreement with the reports of Morison (1957) for *Scirtothrips longipennis* and Raizada (1965) for *S. dorsalis.*

The duration of pre-oviposition, oviposition and post oviposition periods of *S. dorsalis* was 1.6, 1.93 and 1.60 days, respectively. These findings were in agreement with the report of Murugan (2000) and Harish (2002). In the present study the thrips laid one to four eggs per day and is in close agreement with the findings of Dev (1964), Murugan (2000) and Harish (2002). The longevity of thrips, which ranged from 3.25 to 6.75 days with an average of 4.88 days in the present study differs from the reports of 6-13 days at Delhi (Raizada, 1965) but agrees with the reports of an average of 3.67 days on chilli in Orissa coast (Patnaik *et* aI., 1986), three days on tea (Dev, 1964), 4.65 days on rose (Murugan, 2000) and 4.48 days on beans (Harish, 2002). This showed that the adult longevity varies with place and host plants.

5.4 Evaluation of new insecticide molecules including bio-pesticides against *S. dorsalis*

The trials at IIHR have shown that dimethoate and monocrotophos were not efficacious (Anon., 1999) on thrips. This might be due to the resistance,developed by thrips to these insecticides as also reported by Immaraju and Morse (1990) that a strain of *Scirtothrips citri* showed resistance to dimethoate. Further, the reason for resistance may be the profligate use of these compounds that encourage rapid development of resistance. This observation agrees with the reports of Sastrosiswgo (1991) that 16 sprays of quinalphos, acephate, formentanate and cypermethrin at 3 to 4 days interval are given to control *Thrips tabaci* and *T. palmi* on chilli and onion in Indonesia proving the ineffectiveness of pyrethroids, acephate and other organophosphates against thrips. Out of the 11 insecticides (including bio-pesticides) evaluated in the present study for the field control of *S. dorsalis,* fipronil 80 WG is new insecticide molecule which was used in this study is under testing, fipronil 80 WG (50 g.a.i. /ha), spinosad, fipronil 80 WG (40 g.a.i. /ha) and imidacloprid emerged as the most promising insecticides during summer 2008. The effectiveness of these insecticides excluding fipronil 80WG in the present study is in confirmation with the findings of a trial at IIHR (Anon., 1999). The effectiveness of spinosad and imidacloprid in the present study is confirmation with the findings of Seal *et al*. (2006).

Preliminary studies on number of insecticidal sprays to the grapevines in field showed that two sprays taken at an interval of 10 days provide a greater control of *S. dorsalis* than a single spray. Although, all the insecticides were

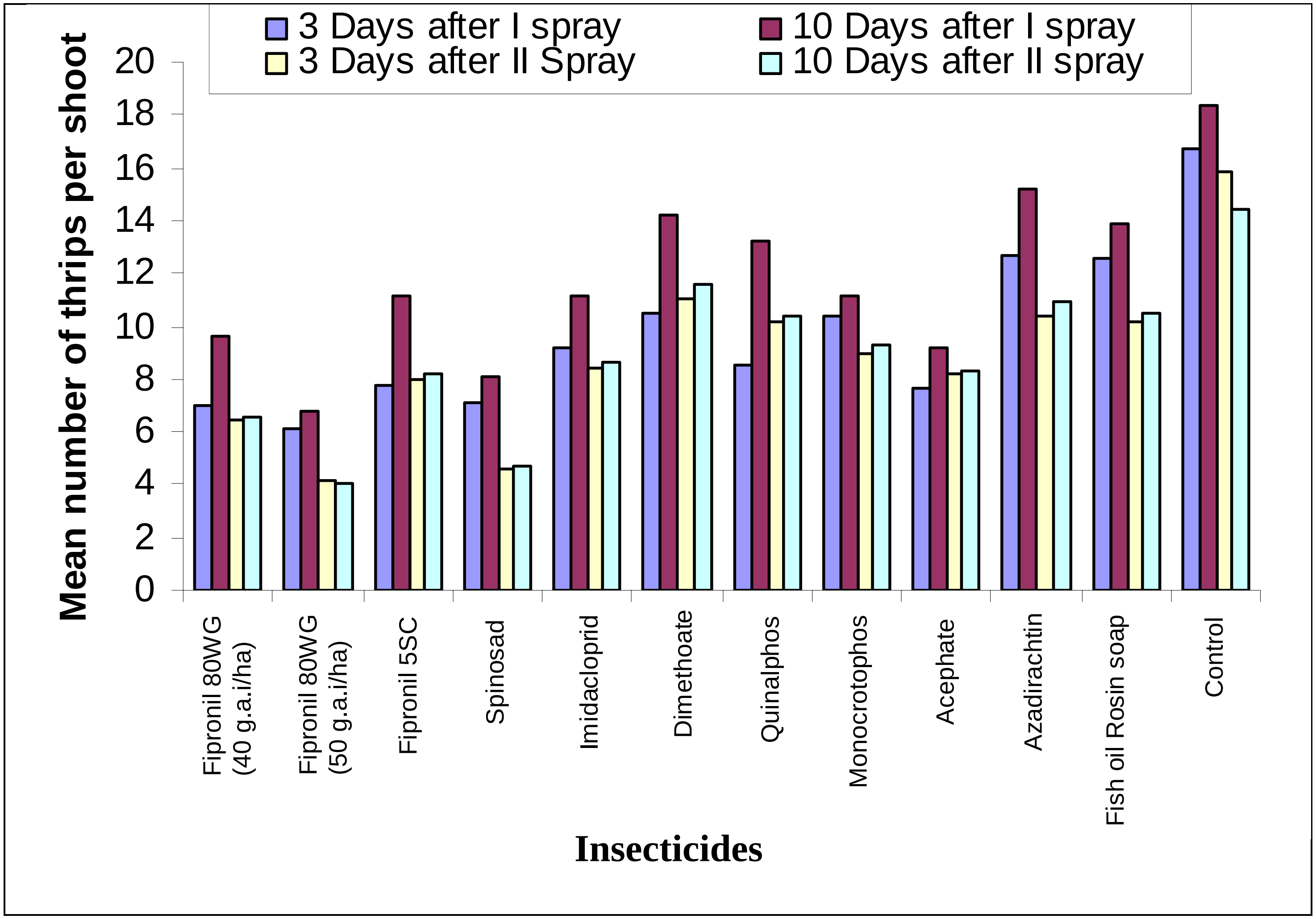


Fig. 6: Efficacy of new insecticide molecules including bio-pesticides on grape thrips, summer 2008

superior to control, it was the first spray, which initially reduced the population to a greater extent (Table 16, Fig: 6). The resulting lower densities of *S. dorsalis* were further reduced after the second spray.

Recovery of the populations after 10 days of first spray indicated that chemical control does not provide long lasting control of *S. dorsalis* and hence the second spray has to be taken shortly (within 10 days) after first spray. When the rate of recovery of *S. dorsalis* population is considered it can be seen that fipronil 80 WG (50 g.a.i. /ha), spinosad, fipronil 80 WG (40 g.a.i. /ha) and imidacloprid provide more effective control than other insecticides. Thus, when these four chemicals are used in the field for the control of *S. dorsalis,* subsequent second spray can be taken up 10 days after the first spray. In the present study none of the insecticidal treatments showed any type of phytotoxicity symptoms on grape vines at the dosages tried is confirmation with the findings of Balikai (2007).The highest yield was recorded in the plots treated with fipronil 80 WG (50 g.a.i. /ha) followed by spinosad, fipronil 80 WG (50 g.a.i. /ha) and imidacloprid.

Time of application of insecticides assumes greater importance in grapes to control *S. dorsalis.* First spray taken 25 days after pruning proved to be highly effective in bringing down the population to a greater extent. However, another back up spray is required (i.e. 35 days after pruning) to provide better control of *S. dorsalis.* The necessity of second spray is because, *S. dorsalis* reaches its peak level at 30-40 days after pruning with the availability of tender leaves and initiation of flowering.

The results of present study showed that grape fields need to be sprayed with insecticides at the early phase of the crop growth (25-30 days after pruning). Further, they need to spray grapevines with insecticides like fipronil 80 WG (50 g.a.i. /ha), spinosad, fipronil 80 WG (40 g.a.i. /ha) and imidacloprid twice after an interval of 10 days to keep the population at low levels.

Summary

VI. SUMMARY

The investigations on the thrips species complex, seasonal incidence in relation to weather parameters for two seasons, biology of *S. dorsalis* and chemical control of *S. dorsalis* were made (kharif and summer) in the field and laboratory during 2007-08.

During the survey, four species of thrips belonging to two different families were recorded. Of these, three are new records for India. This study has revealed two families *viz.,* Thripidae and Phlaeothripidae as having new records of species that are associated with *S. dorsalis.* This is a significant addition to the known species complex of thrips on grapes in Karnataka and India.

The larvae and adults of *S. dorsalis* caused damage to all stages of the crop. The insect pierced the leaves, petioles and berries and sucked the sap resulting in silvery white scorchy patches on the leaves and scars on berries. Under severe infestations, the leaves withered and ultimately fell down. Further, scarring and cracks on fruit surface was exhibited. The affected mature berries turn ugly and severely affected bunches are unfit for marketing.

The Different growth stages of the crop played a significant role in determining the level of thrips infestation. The density of *S. dorsalis* reached the peak level (13.93 during kharif) at 30-40 days after pruning, when the crop was in tender leaf stage and flowering initiated. Similarly, in summer, peak populations of *S. dorsalis* (17.43) coincided with tender leaf and flowering stage.

As far as the effect of crop growth stages on thrips density, tender leaves were found to have positive effect. Fully matured leaves, small, medium and large size fruits were found to have negative effect.

The incidence of S. *dorsalis* prevailed throughout the cropping period, except during the late fruiting stage. The pest number attained a peak during the last week of July (13.93 *S. dorsalis*/shoot*)* and second week of March (17.43 *S. dorsalis/*shoot*)* in kharif and summer season, respectively.

Regarding the effect of weather parameters on *S. dorsalis* infestation, temperature (both maximum and minimum) was found to have positive effect. Relative humidity, rainfall and wind speed were found to have negative effect

The female laid eggs singly in the tissues mostly on the tender pods, occasionally on older pods. The egg was kidney or oval shaped and glossy white in colour. On an average it took 12.60 ±1.51 days to complete the life cycle. On an average each stage *viz.,* egg, first, second instar larva, prepupa and pupa lasted for 3.73 ± 0.66 days, 1.15 ± 0.21 days, 2.83 ± 0.49 days, 1.03 ± 0.30 days and 3.83 ± 0.53 days, respectively. The oviposition started after a period of 1.6 ± 0.49 days and lasted for 1.93 ± 0.68 days. Female laid on an average 2.3 ± 0.94 eggs per day and lived for 4.88 ± 1.35 days.

The efficacy of new insecticide molecules including bio-pesticides *viz.,* fipronil 80 WG (40 g.a.i./ha), fipronil 80 WG (50 g.a.i./ha), fipronil 5SC, spinosad 2.5SC, imidacloprid 17.8 EC, dimethoate 30EC, quinolphos 25EC, monocrotophos 36SL, acephate 75SP, azadirachtin 1% and fish oil rosin soap were evaluated against *S. dorsalis* on grapes in the form of two foliar applications at 10 days interval. Of these fipronil 80 WG (50 g.a.i./ha) followed by spinosad, acephate and imidacloprid proved effective in the control of *S. dorsalis.* Whereas, fipronil 5SC, monocrotophos and quinolphos had moderate effect, dimethoate, fish oil rosin soap and azadirachtin were less effective in controlling *S. dorsalis.*

None of the insecticidal treatments showed any type of phytotoxicity symptoms on grape vines at the dosages tried. The highest yield was recorded in the plots treated with fipronil 80WG (50 g.a.i./ha) (31.25 ton/ha) followed by spinosad (29.08 ton/ha), imidacloprid (23.39 ton/ha) and acephate (26.14 ton/ha).

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