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Effects of photoperiod on the testis fusion in the Asian comma butterfly, *Polygonia c-aureum* Linnaeus (Lepidoptera: Nymphalidae)

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ABSTRACT: The progress of testis fusion in the immature stages ranging from the 4th larval instar larvae to the pupae in *Polygonia c-aureum* was compared between two photoperiods (short-daylength and long-daylength). In this butterfly, imaginal diapause induction is controlled mainly by photoperiod and temperature during the immature stages. The study investigated the relationship between the imaginal diapause and testis fusion. The results showed that photoperiod did not exert significant effects on the process of testis fusion, indicating that testis fusion does not relate to the imaginal diapause. A pair of testes fused to a single testis during the prepupal stage and testis torsion occurred shortly after pupation. However, though in rare cases, a few male adults which had been reared in the laboratory and caught in the field had two testes, suggesting no occurrence of testis fusion during the prepupal stage.

KEY WORDS: Imaginal diapause, male, reproduction, testis fusion, torsion

INTRODUCTION

Numbers and morphology of testis in males considerably vary among insect species. In Lepidoptera, males have a pair of testes during the larval stage, and testes generally fuse to a single testis during the prepupal stage or the pupal stage as listed in Table 1.For example, in *Ostrinia nubilalis* (Parker and Thompson, 1926) and *Boarmia slenaria* (Scheepens and Wysoki, 1985), testis fusion occurs in prepupal stage, whereas in *Corcyra cephalonica* (Deb and Chakravorty, 1981) and *Papilio xuthus* (Numata and Hidaka, 1981), testis fusion occurs in pupal stage. However, in several moth species such as some Saturnids (Szöllösi, 1982) and *Bombyx mori* (Ômura, 1936), the testes do not fuse through their life span so that an adult has two testes.

P. c-aureum exhibits seasonal diphenism on their morphology, coloration of wings and reproductive manner, i.e. the summer form and autumn form. The summer form butterflies emerged in summer begin to reproduce shortly after emergence, while the autumn forms emerged in autumn induce an imaginal diapause and reproduce in spring followed by overwinter. Both the seasonal form and diapause induction are determined mainly by photoperiod and temperature during the immature stages: long daylength and/or high temperature favour the developing summer form, whereas short daylength and relatively lower temperature diapausing autumn

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form (Hidaka and Aida, 1963; Hidaka and Takahashi, 1967).

The relationship between diapause and testis fusion is less understood. In the case of pupal diapause, testis fusion in the diapausing pupae of *Papilio xuthus* is delayed as compared to the direct developing pupae (Numata and Hidaka, 1981). However, it is unknown whether or not imaginal diapause affects the timing of testis fusion. Pupal diapause is controlled by ecdysteroids, whereas imaginal diapause is controlled by juvenile hormones. As pupal periods of *Polygonia c-aureum* differ between short and long photoperiods (Hiroyoshi, 1992), it is possible that the process of testis fusion may differ between the prepupa or pupa destined to the developing adults and those destined to imaginal diapausing adults. In the present study, the process of testis fusion was examined in detail and compared between short and long photoperiodic conditions in imaginal diapausing species for the first time, and the existence of unfused testes both in the laboratory-reared and wild male adults of *P. c-aureum* was revealed in the butterfly.

MATERIALS AND METHODS

P. c-aureum larvae were collected at Tokyo Metropolis and Saitama Prefecture, Japan in 1989 and had been maintained as a laboratory stock colony under long daylength (15L9D) at 21±1°C in their life span. The feral male adults were collected at Saitama Prefecture in the various seasons of 1991 and 1992. To examine the relationships between testis fusion and diapause, immatures were reared under either short daylength (8L16D) or long daylength (15L9D) at 21±1°C. Adults were reared under the various combinations of photoperiods (short daylength, long daylength or constant darkness) and temperatures (5°C, 21°C or 25°C) differing in the period and timing of incubation. After dissection of adults used in various experiments, they were counted the testis number.

The number of testis was examined in the summer and autumn form adults reared under the laboratory and caught in the field. A pair of testes or a single testis was dissected out in a lepidopteran physiological saline (consisting of 8.6g NaCl, 0.33g $CaCl_2$ and 0.1g KCl and made up to 1 liter with distilled water) under a binocular stereomicroscope. The coloration of the lateral sides of which testes closely located each other was observed. More intense reddish area than its surrounding area on the lateral sides of testes were regarded as the part of testes contacted. The progress of testis fusion was divided into five grades by the following features due to the rate of the reddish area occupied on the lateral sides of testes: 1) nothing, 2) less than one third, 3) ranging from one third to less than half, 4) ranging from half to almost complete, 5) complete. The data on the degree of testis fusion were scored from 1 to 5 and analyzed by Mann Whitney's *U*-test to compare between short and long daylength.

In lepidopteran insects, it is known that after testis fusion the whole testis twists where this phenomenon is called as testis torsion. If the testis experienced the testis torsion, a single testis could not be separated into two testes with a pair of forceps. Therefore, separation of testis was attempted to determine if testis torsion occurred.

RESULTS

The progress of testis fusion was examined during the later larval and pupal stages. A series of the process of testis fusion was identified between short and long photoperiods (Table 2). There were no significant differences in testis fusion between two photoperiods at any stages and substages ($p>0.05$,by Mann Whitney's *U* test). The 4th instar larvae had a pair of testes that was closely located on the dorsal midline of the 8th abdominal segment. The rate of individuals having intense reddish areas with the shape of long circle on the central part of lateral side of testes increased with advancing the stage after the ecdysis to the fifth instar larvae. The intense reddish areas of each side of testis abruptly increased in size around at the wandering stage and then expanded to the whole lateral sides of both testes, contacting each other at the prepupal stage. Immediately after pupation, all pupae showed the complete fusion of the testes, indicating that testis fusion occurred during the prepupal stage.

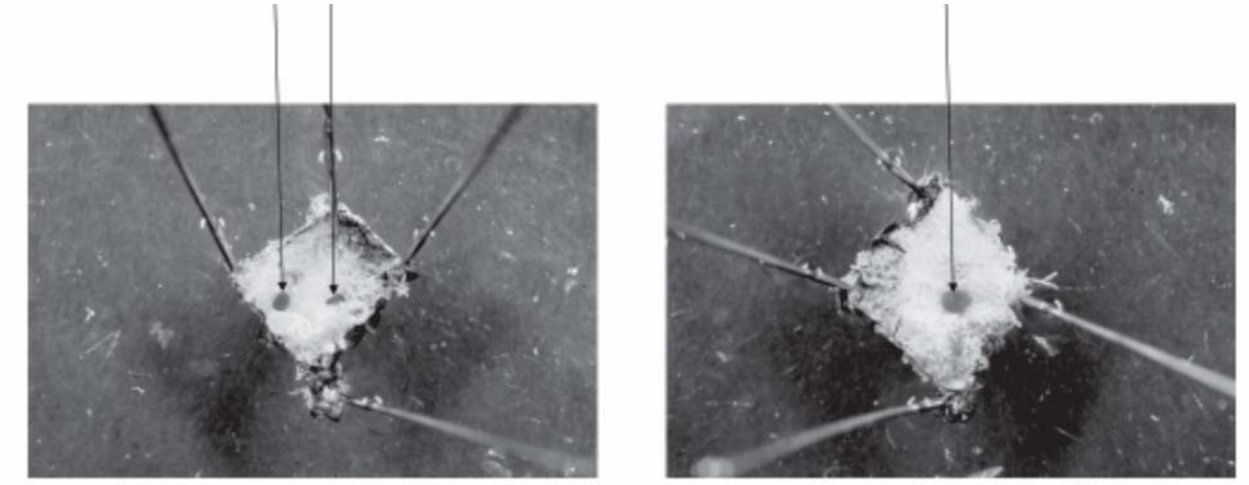

Fig. 1 Photographs of testis in *P. c-aureum* adult. Unfused testes in summer form collected from the field (left side) and fused testes in autumn form reared in the laboratory (right side). Arrows indicate the testis.

On the day of pupation, the testis was easily separated each other with an artificial manipulation, while on day 2 of pupae the testis was no longer separated. This reveals that testis torsion occurs between day 0 and day 2 after pupation.

In laboratory-reared insects, 5 out of 1390 adults (0.4%) examined had two testes. Also, 1 out of 143 wild adults (0.7%) showed two testes (Fig. 1). Since any larvae and pupae never had four testes, the existence of two testes seen in the adult implies that testis fusion did not occur in such individuals during the prepupal stage.

Most fused testes took the shape of sphere or like that, but some testes long and slender. On the other hand, the morphology of the testes that did not fuse differed among individuals and either right or left side of the testis: most testes took the shape of semi-sphere, but a few showed the shape of sphere as if it fused. All adults without testis fusion normally, at least seemingly, emerged and exhibited the normal development of the reproductive organs except for the testis fusion. One out of two adults without testis fusion examined showed the normal progress of spermiogenesis (data not shown): In the other individual, one testis had many two types of sperm, i.e. eupyrene and apyrene sperm, whereas the other one had a relatively less amount of apyrene sperm and few eupyrene sperm, indicating the abnormal spermatogenesis.

DISCUSSION

The present study demonstrated tha the paired testes of *P. c-aureum* fused into a single testis during the prepupal stage like other many lepidopteran species. However, the present study also showed that a few adults successively reared in the laboratory had a pair of testes that did not appear to fuse. It seems unlikely that the phenomenon that testes did not fuse may be caused by the abnormality of laboratory rearing conditions, because even an adult caught in the field had paired testes. Untestis fusion spreads over the butterfly species (Kato and Hiroyoshi, unpublished data) so that untestis fusion seen in *P. c-aureum* might have an evolutionary importance.

Testis fusion in *P. c-aureum* between short and long photoperiodic regimes occurs in the same way (Table 2). Thus, testis fusion has nothing to do with the seasonal form and diapause expressed in the adult stage, because the seasonal form and imaginal diapause are controlled by photoperiod and temperature. Butterflies with fused testis showed normal behavior including spermatogenesis and mating. This is the first report on the comparison of testis fusion between immatures destined for developing summer form and ones destined for diapausing autumn form adults in relation to imaginal diapause. Similarly, the phenomenon on

Table 1. Examples of testes fusion in various families of lepidopteran insects in the literature

Scientific name	No. of adult testis	Stage of testis fusion	Reference
Tineidae			
Corcyra cephalonica	1or2(rare)	pupa	Deb and Chakravorty (1981)
Gelechiidae			
Pectinophora gossypiella	1	?	LaChance et al. (1977)
Phthorimaea operculella	1	?	Brits (1978)
Hyponomeutoidea			
Acrolepiopsis assectella	1	?	Thibout (1979)
Xylorytinae			
Opisina arenosella	1	prepupa	Santhosh Babu and Prabhu (1989) Santhosh Babu (1995)
Tortricidae			
Choristoneura fumiferana	1	pupa	Outram (1970)
	1	prepupa	Retnakaran (1970)
Rhyacionia buoliana	1	prepupa?	Shen and Berryman (1967)
Gretchena bolliana	1	?	Tedders and Osburn (1970)
Laspeyresia caryana	1	?	Tedders and Calcote (1967)
L. pomonella	1	prepupa	Ferro and Akre (1975)
	1	prepupa	Giebultowicz and Brooks (1998)
Pyralidae			
Dioryctria abietella	1	?	Fatzinger (1970)
Ostrinia nubilalis	1	prepupa	Parker and Thompson (1926)
	1	prepupa	Jones et al. (1984)
	1	?	Chaudhury and Raun (1966)
Palpita unionalis	1	prepupa	Santorini and Vassilaina-Alexopoulou(1976)
Diatraea saccharalis	1	pupa?	Virkki (1963)
D. grandiosella	1	?	Davis (1968)
Ephestia kühnniella	1	prepupa	Nowock (1972)
	1	prepupa	Musgrave (1937)
Bombycidae			
*Bombyx mor*i	2	no fusion	Ômura (1936)
Saturniidae			
Saturniidae0SÿPÿ.	2	no fusion	Cook (1910)
Platysamia cynthia	2	no fusion	Szçllçsi (1982)
Sphingidae			
*Manduca sext*a	1	prepupa	Reinecke et al. (1983)
Agrius convolvuli	1	pupa	Kubo-Irie et al. (2011)

Scientific name	No. of adult testis	Stage of testis fusion	Reference
Geometridae			
*Boarmia selenari*a	1	prepupa	Scheepens and Wysoki (1985)
	1	prepupa	Scheepens and Wysoki (1986)
Lymantriidae			
Lymantria dispar	1	prepupa	Rule et al. (1965)
	1	prepupa	Salama (1976)
Arctiidae			
Hyphantria cunea	1	prepupa	Sugai and Teramine (1970)
Noctuidae			
Acronycta sp.	1	pupa	Cook (1910)
Heliothis virescens	1	prepupa	Vinson et al. (1969)
	1	prepupa	Chen and Graves (1970)
	1	prepupa	Chase and Gilliland (1972)
Heliothis zea	1	?	Callahan (1958)
	1	?	Callahan and Chapin (1960)
Helicoverpa assulta	1	prepupa	Hoon et al.(2001)
Mamestra brassicae	1	prepupa	Santa and Otuka (1955)
Trichoplusia ni	1	pupa	Holt and North (1970)a
	1	pupa	Holt and North (1970)b
Spodoptera litura	1	prepupa	Sridevi et al. (1989)
	1	?	Etman and Hooper (1979)
S. littoralis	1	?	Haines (1981)
	1	prepupa	Gelbiè and Metwally (1981)
Achaea janata	1	prepupa	Sukumr (1985)
Plathypena scabra	1	prepupa	Buntin and Pedigo (1983)
Hesperiidae			
Calpodes ethlius	1	prepupa?	Lai-Fook (1982)
Papilionidae			
Papilio xuthus	1	pupa	Numata and Hidaka (1981)
P. cresphontes	1	pupa	Cook (1910)
Pieridae			
Pieris brassicae	1	prepupa	Junnikkala (1985)
Nympahlidae			
Danaus plexxipus	1	?	Herman (1975)
D. chrisippus	1	?	Screen and Sharna (1995)

Table 2. Comparison of testes fusion between short daylength and long daylength during the larval prepupal and pupal stages in male *P. c-aureum*

Stage	No. of animals used	Grade of testis fusion (%) Short daylenght I	II	III	IV	V	No. of animals used	Grade of testis fusion (%) Long daylength I	II	III	IV	V	U1 Value	U2 Value	W Value	SD vs LD P Value
Larva																
4th-0		16	62.5	37.5	0	0	0	16	81.3	18.8	0	0	0	280	232	368	0.4841
4th-1		14	50	50	0	0	0	13	84.6	15.4	0	0	0	122.5	59.5	150.5	0.0614
4th-2		18	5.6	94.4	0	0	0	23	0	100	0	0	0	195.5	218.5	366.5	0.2583
Sleeping		23	0	23	0	0	0	17	0	100	0	0	0	195.5	195.5	348.5	1
5th-0		22	0	100	0	0	0	21	0	85.7	9.5	4.8	0	198	264	495	0.0694
5th-1		18	0	100	0	0	0	21	0	90.5	4.8	4.8	0	171	207	342	0.1847
5th-2		21	0	85.7	9.5	4.8	0	22	0	90.9	9.1	0	0	244	218	475	0.57
5th-3		25	0	84	16	0	4	19	0	78.9	15.8	5.3	0	223.5	251.5	441.5	0.6204
5th-4		12	0	66.7	25	8.3	0	21	0	61.9	19	19	0	116	136	194	0.6614
Wandering		22	0	22.7	27.3	45.5	4.5	17	0	29.4	17.6	52.9	0	193.5	180.5	333.5	0.8423
Prepupa		21	0	0	14.3	61.9	23.8	18	0	0	11.1	44.4	44.4	151	227	398	0.2329
Pupa																	
	0	17	0	0	0	0	100	17	0	0	0	0	100	144.5	144.5	297.5	1
	-2	13	0	0	0	0	100	10	0	0	0	0	100	65	65	120	1
	-4	15	0	0	0	0	100	12	0	0	0	0	100	90	90	168	1
	-6	14	0	0	0	0	100	10	0	0	0	0	100	70	70	125	1
4th instar		71	25.4	74.6	0	0	0	69	34.8	65.2	0	0	0	2976	3027	5442	0.9124
5th instar		120	0	72.5	12.5	10	0.8	121	0	74.4	12.4	13.2	0	7079.5	7440.5	14339.5	0.6574
prepupa		21	0	0	14.3	61.9	23.8	18	0	0	11.1	44.4	44.4	151	227	398	0.2329
pupa		59	0	0	0	0	100	49	0	0	0	0	100	1445.5	1445.5	2670.5	1

the testis, such as apyrene spermiogenesis (Hiroyoshi, 1999), testis shrinkage, disappearance of yellow membrane surrounding the testis (Hiroyoshi, 2000), and sperm movement (Hiroyoshi, 1997), did not differ between developing and diapausing individuals except for the quantitative differences: the testis of summer form grown under a long daylength is larger than that of autumn form grown under a short daylength (Hiroyoshi, 2000). These events on testis seem to have common endocrinological mechanisms, for example, the involvement of ecdysteroids, because the decrease of apyrene spermatogenesis, degradation of yellow membrane surrounding the testis, onset of testis shrinkage, and onset of apyrene sperm movement start with the same time, at the end of pupal stage.

Nowock (1972) demonstrates that the testis fusion was promoted by ecdysone in *Ephestia kuhniella*. In *P. c-aureum*, it does not seem likely that the occurrence of unfused testes does not appear to be provoked by the abnormality of synthesis and secretion of ecdysone in the prothoracic gland, because the individuals that did not fuse a pair of testes normally moulted, eclosed and developed the reproductive development except for the testis fusion. Probably, the occurrence of unfused testes may be induced by the abnormality of any step during the course of testis fusion. Alternatively, mutation on testis fusion might occur. Further study is needed to elucidate whether the ecdysteroid titer in hemolymph may affect the events around the testis or not.

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Insect diversity and extent of infestation of major rice pests in Burdwan district, West Bengal, India

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ABSTRACT: Insects collected from different rice fields of Burdwan District of West Bengal from February 2012 to November 2014 by light trapping, netting, sweeping or hand picking method recorded 32 species of arthropods under eight orders.The population of rice leaf folder, yellow stem borer, striped stem borer, army worm, hispa, brown plant hopper, green leaf hopper, gandhi bug and grasshoppers were found to be 7.95/hill and 7.86/hill; 2.36/hill and 1.62/hill; 0.19/hill and 0.27/hill; 0.98/hill and 0.73/hill; 0.87/hill and 1.04/hil; 4.89/hill and 3.47/hill; 4.24/hill and 3.76/hill; 2.15/hill and 2.68/hill; 4.17/hill and 3.82/hill in Galsi and Memari, respectively. Infestation of the crop and population of *C. medinalis* and *S. incertulas* in the rice fields at different locations of Galsi and Memari during dry and wet season in 2012, 2013 and 2014 were studied. Leaffolders were more prevalent in wet season than dry season. During the dry season of 2012, 2013 and 2014 the infestation of *S. incertulas* and the population of larvae in the rice fields were 90.24 - 90.47; 90.12 - 92.50; 89.56 - 91.98 percent and 7.00 - 7.33; 7.00; 6.33 - 7.00 per hill respectively. During the wet season of 2012, 2013 and 2014, the infestation and population of *S. incertulas* in the rice fields were 73.01 - 75.90; 68.44 - 70.1; 74.56 - 77.3 percent and 3.00 - 3.33; 2.67 - 3.67; 3.33 - 3.67 larvae per hill, respectively.

KEY WORDS: Insect, rice pest, rice leaf folder, yellow stem borer, infestation

INTRODUCTION

Reduction in the rice yield is dependent on many biotic and abiotic stresses such as, pests, diseases, soil fertility, rainfall, water logging and climatic conditions. Of the biotic stresses, insect pests are the major contributors in yield losses. Out of about 60% yield loss of rice due to pest and disease infestation, 35 - 50% is contributed by the insects (Teng *et al.,* 1993). Many species of arthropods inhabit rice fields. Some of them are harmful to the crops, but majority of them are not noxious to rice plant (Singh and Singh, 2014).

About 500 species of insects and spiders come into sight in a rice field in different seasons and only few of them are potential enemies of rice. Other arthropods are either beneficial being predators, parasites and parasitoids that control the insect pests or innocent visitors. The crop is infested by about 90 insects and a dozen of them viz. stem borers (SBs), gallmidge, plant hoppers, leaffolders (LFs),

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rice skipper, rice bug, grain weevil etc. are major pests (Teng *et al.,* 1993). In India, annually 41% economic loss has been estimated due to the infection of insect pest in crop plants.

In rice, the economic loss is measured at 26.3 metric tons with an estimated value of Rs. 9468 crores (Agarwal, 2011). Among five recorded species of LFs (*Cnaphalocrocis medinalis* Guenee, *Marasmia exigua* Butlar, *M. pentalis* Bradley, *M. ruralis* Walker and *Brachmia aurotrea* Mayrick), *C. medinalis* is the most serious and regular pest of rice in India (Teng *et al.,* 1993). Besides, out of six stem borers viz. *Scirpophaga incertulas* Walk. (yellow stem borer, YSB), *Scirpophaga innotata* Walk. (white stem borer, WSB), *Chilo suppresalis* Walk. (striped stem borer, SSB), *C. polychrysus* Meyr. (dark headed stem borer, DHSB), *C. auricilius* Dudgeon (stalked stem borer, DHSB) and *Sesamia inferens* Walk. (pink stem borer, PSB), YSB (dominant) and SSB are serious pests in India (Teng *et al.,* 1993). It is really important to study the ecology of different arthropods present in rice fields for controlling the insect pests and checking the yield loss. Several works have been done on the biology and ecology of the rice pests in Asian subcontinent (Pathak and Khan, 1994; Chaudhary *et al.,* 2002; Islam *et al.,* 2004; Arora and Dhaliwal, 1996) but no such information is available on the prevalence of rice pests in West Bengal. The present investigation was aimed to study the diversity of insects present in the rice fields and to observe the seasonal prevalence of the major pests of rice in Burdwan district, West Bengal, India.

MATERIALS AND METHODS

The rice field insect pests were collected from the paddy fields of different areas of Burdwan district of West Bengal from December 2012 to November 2014 to determine their prevalence in two rice growing seasons, i.e. wet and dry. The study was conducted in different spots extending six km away from each other and five fields at each spot for each season were selected as replicates.

Collection of Pests:

The insects were collected by adopting the methods of light trapping, netting, sweeping or hand picking depending upon the insect types. All suction and sweep net samplings were done between 8.00 and 11.00 a.m. and between 4 pm and 6 pm. The pests were collected on weekly basis from each field. Two types of sweeping nets were used. For the seedling stage, the diameter of the net was 16 cm and in both transplanting and flowering stages the diameter of the net was 23 cm. The length of the handles of both the nets was 60 cm and 95 cm, respectively. Five suitable quadrate (20 m × 20 m) plots were selected and marked at diagonal line by using bamboo sticks without disturbing the crop plant in situ. Mylar cages with potted plant, test tubes with seedlings and small boxes with seedlings were also used as collection cage (Kraker, 2000; Rani *et al.,* 2007). Alternatively, collected insects were transferred to rearing cages with clean potted plants. Collection cages were labeled with the respective collection dates, location names, and geographic positions.

The insects having economic importance were identified at the specific level by morphology (Bradly, 1981; Barrion *et al.,* 1991; Khan *et al.,* 1988; Dale, 1994; Maes, 1995); using keys (Barrion and Litsinger, 1994), photographs available (Pathak and Khan, 1994), and by taking the help of the subject experts. Other insects of less economic importance as rice pest were not identified as specific level.

Incidence of infestation:

Leaf folder:

The degree of infestation was calculated by counting the number of folded leaves per unit area per week. The number of leaves with more than 1/3 damaged leaf area (DL %) were recorded and were used for calculating degree of infestation following the given formula.

$$\text{DL (\%)} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves considered}} \times 100$$

Stem borer:

Sampling for stem borer damage was done in a 10-m^2 area at the center of each plot. The following formula was used for measuring the percentage of deadhearts:

$$\% \text{ deadhearts} = \frac{\text{deadhearts in infested hills}}{\text{Total no. of tillers observed in infested hills}} \times \frac{\text{No of infested hills}}{\text{Total hills observed}} \times 100$$

For determining the percentage of whiteheads the following formula was used.

$$\% \text{ whiteheads} = \frac{\text{No of whiteheads}}{\text{Total no. of pannicles observed}} \times \frac{\text{No of infested hills}}{\text{Total no of plants observed}} \times 100$$

RESULT AND DISCUSSION

During the study period 32 species of arthropods under eight orders were recorded (Table 1). Among them, leaf folders (*Cnaphalocrocis medinalis*), yellow stem borers (*Scirpophaga incertulas*), striped stem borer (*Chilo suppressalis*), army worm (*Mythimna* sp.), hispa (*Dicladispa armigera*), white leaf hoppers (*Cofana* sp.), green leaf hopper (*Niphotittix* sp), gandhi bug (*Leptocorisa* sp.) were the important pests. Prevalence of grasshoppers (*Oxya hyla, Atractomorpha lata, Acrida exaltata* and *Paratettix* sp.) was also observed. During the study it was observed that lepidopteran population was abundant in all the spots than the population of the other insect orders. Among the lepidopteran pests, *C. medinalis* and *S. incertulas* were present in almost all stages of rice plants and seasons.

Fig. 1 showed prevalence of different rice pests in the rice fields of the study area. The population of rice leaf folder, yellow stem borer, striped stem borer, army worm, hispa, white plant hopper, green leaf hopper, gandhi bug and grasshoppers was found to be 7.95/hill and 7.86/hill; 2.36/hill and 1.62/hill; 0.19/hill and 0.27/hill; 0.98/hill and 0.73/hill; 0.87/hill and 1.04/hill; 4.89/hill and 3.47/hill; 4.24/hill and 3.76/hill; 2.15/hill and 2.68/hill; 4.17/hill and 3.82/hill in Galsi and Memari, respectively. Among these insect species rice leaf folder, yellow stem borer and gandhi bug showed highest prevalence and crossed economic threshold level (ETL) viz, 1-2 damaged leaves/hill, 1 moth/ hill and 1 - 2 bugs/hill, respectively. The prevalence of striped stem borer,

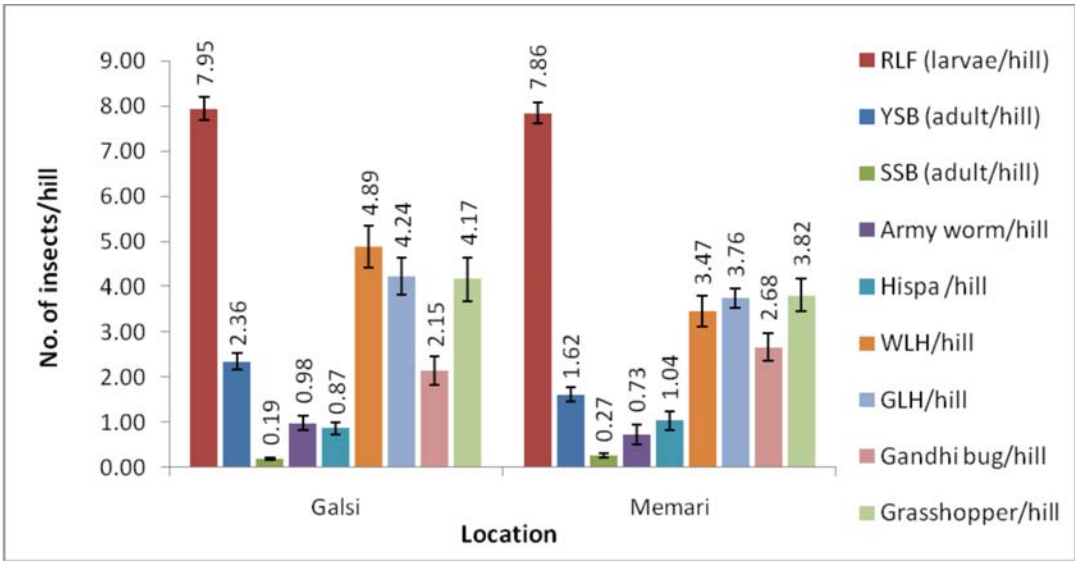

Fig 1. Insect pest prevalence in the rice field. RLF = leaf folder, YSB = yellow stem borer, SSB = striped stem borer, WLH = white leaf hopper, GLH = green leaf hopper.

Table 1. List of the arthropods recorded during the field study in the rice ecosystem

SL.No.	Common Name	Genus and Species	Order and Family
1.	Rice leaf folder	*Cnaphalocrocis medinalis* (Guenee, 1854)	Lepidoptera : Crambidae
2.	Yellow stem borer	*Scirpophaga incertulas* (Walker, 1863)	Lepidoptera : Crambidae
3.	Rice white stem borer	*Scirpophaga innotata* (Walker, 1863)	Lepidoptera : Crambidae
4.	Striped Stem Borer	*Chilo suppressalis* (Walker, 1863)	Lepidoptera : Crambidae
5.	Dark- headed striped borer	*Chilo polychrysus* (Meyrick, 1932)	Lepidoptera : Crambidae
6.	Rice case worm moth	*Nymphula depunctalis* (Guenee, 1854)	Lepidoptera : Crambidae
7.	Rice Leaf folder	*Brachmia arotraea* (Meyrick, 1911)	Lepidoptera : Gelechiidae
8.	Sugarcane Looper moth	*Mocis frugalis* (Fabricius,1775)	Lepidoptera : Erebidae
9.	Loreyi Leaf worm	*Mythimna loreyi* (Duponchel, 1827)	Lepidoptera : Noctuidae
10.	Common evening brown	*Melanitis leda ismene* (Linnaeus, 1758)	Lepidoptera : Nymphalidae
11.	Rice skipper	*Pelopidas mathias* (Fabricius, 1798)	Lepidoptera : Hesperiidae
12.	Rice hispa	*Dicladispa armigera* (Oliver, 1808)	Coleoptera : Coccinellidae
13.	Lady beetle	*Menochilus sexmaculatus* (Fabricius,1781)	Coleoptera : Coccinellidae
14.	Transverse ladybird	*Coccinella transversalis* (Fabricius, 1781)	Coleoptera : Coccinellidae
15.	Hyla rice grasshopper	*Oxya hyla intricata* (Stal, 1861)	Orthoptera : Acrididae
16.	Short horned grasshopper	*Acrida exaltata* (Walker, 1895)	Orthoptera : Acrididae
17.	Vegetable grasshopper	*Atractomorpha lata* (Saussure, 1862)	Orthoptera : Pyrgomorphidae
18.	Pygmy grasshoppers	*Paratettix sp.*	Orthoptera: Tetrigidae
19.	Silent leaf runner	*Metioche vittaticollis* (Stal, 1861)	Orthoptera : Gryllidae
20.	Marsh fly	*Sepedon* sp. (Latreille 1804)	Diptera : Sciomyzidae
21.	Gandhi bug	*Leptocorisa* sp.	Hemiptera: Alydidae
22.	White backed pl. hopper	*Sogatella furcifera* (Horvath, 1899)	Hemiptera : Delphacidae
23.	White rice leafhopper	*Cofana spectra* (Distant, 1908)	Hemiptera : Cicadellidae
24.	Green leaf hopper	*Niphotittix nigropictus* (Stal, 1870)	Hemiptera : Cicadellidae
25.	Stinkbug	*Cletus punctiger* (Dallas, 1852)	Hemiptera : Coreidae
26.	Pygmy wisp	*Agriocnemis pygmaea* (Rambur, 1842)	Odonata : Coenagrionidae
27.	Blue-tailed damselfly	*Ischnura elegans* (Vander Linden, 1820)	Odonata : Coenagrionidae
28.	Scarlet dragonfly	*Crocothemis erythraea* (Brulle, 1832)	Odonata : Libellulidae
29.	Yellow Ichneumon Wasp	*Xanthopimpla punctata* (Fabricius,1781)	Hymenoptera : Ichneumonidae
30.	Zipper spider	*Argiope catenulate* (Doleschall, 1859)	Arachnida : Araneidae
31.	Lynx spider	*Oxyopes javanus* (Thorell, 1887)	Arachnida : Oxyopidae
32.	Decorative silver orb spider	*Leucauge decorata* (Walckenaer, 1841)	Arachnida : Tetragnathidae

Table 2. Population of *C. medinalis* larvae and the extent of infestation in rice at different locations during dry and wet seasons

Survey period (season)	Location	Hill			Larvae[a]	
		Total (No./m^2)	Infested (No./m^2)	Infestation (%)	No./m^2	No./hill
Feb.-April 2012 (dry)	Galsi	50.33 ± 1.5	41.67 ± 0.9	82.86 ± 2.0	727.00 ± 47.0	13.33 ± 0.9
	Memari	49.00 ± 1.7	44.67 ± 0.9	91.3 ± 2.4	619.00 ± 42.3	11.33 ± 0.7
Sept.-Nov. 2012 (wet)	Galsi	48.67 ± 1.8	46.00 ± 1.7	94.51 ± 0.7	1296.67 ± 30.3	29.00 ± 1.2
	Memari	47.00 ± 1.7	27.67 ± 1.5	60.61 ± 0.1	1133.3 ± 110.9	26.00 ± 1.2
Feb.-April 2013 (dry)	Galsi	39.00 ± 1.2	31.33 ± 0.88	80.35 ± 0.5	480.67 ± 7.6	14.00 ± 0.6
	Memari	51.67 ± 0.9	44.33 ± 0.9	85.8 ± 0.6	691.33 ± 47.8	12.33 ± 0.9
Sept.-Nov. 2013 (wet)	Galsi	47.33 ± 1.2	29.00 ± 1.2	61.223 ± 1.0	940.00 ± 37.9	22.66 ± 1.5
	Memari	48.67 ± 0.9	45.00 ± 0.7	93.856 ± 1.1	1330.00 ± 66.6	29.00 ± 2.1
Feb.-April. 2014 (dry)	Galsi	46 ± 2.08	17.66 ± 0.7	38.53 ± 1.9	358.33 ± 24.6	7.67 ± 0.3
	Memari	45.33 ± 1.5	24.00. ± 1.7	52.91 ± 3.1	306.00 ± 22.7	7.00 ± 0.6
Sept.-Nov. 2014 (wet)	Galsi	43.33 ± 0.9	32.33 ± 1.5	74.54 ± 1.8	533.00 ± 46.0	13.67 ± 0.9
	Memari	47.67 ± 1.2	40.33 ± 1.5	84.57 ± 1.0	666.00 ± 30.6	15.00 ± 0.6

Table 3. Population of *S. incertulas* larvae and the extent of infestation in rice at different locations during dry and wet seasons

Survey period (season)	Location	Hill			White earhead	
		Total (No./m^2)	Infested (No./m^2)	Infestation (%)	No./m^2	No./hill
April-2012 (dry)	Galsi	49.00 ± 1.5	44.33 ± 1.5	90.47 ± 0.7	362.33 ± 33.6	7.33 ± 0.7
	Memari	48.00 ± 2.3	43.33 ± 2.4	90.24 ± 1.4	333.00 ± 4.9	7.00 ± 0.0
Oct.-2012 (wet)	Galsi	47.00 ± 1.5	34.33 ± 1.5	73.01 ± 0.9	170.33 ± 1.0	3.33 ± 0.3
	Memari	51.33 ± 1.8	39.00 ± 2.1	75.90 ± 1.9	154.67 ± 14.3	3.00 ± 0.0
April-2013 (dry)	Galsi	49.00 ± 1.0	45.33 ± 1.5	92.50 ± 1.8	333.67 ± 12.0	7.00 ± 0.0
	Memari	47.33 ± 0.9	42.67 ± 1.2	90.12 ± 1.5	323.67 ± 10.9	7.00 ± 0.6
Oct.-2013 (wet)	Galsi	48.00 ± 1.0	33.67 ± 1.5	70.1 ± 2.1	125.00 ± 16.5	2.67 ± 0.3
	Memari	50.67 ± 0.7	34.67 ± 1.5	68.44 ± 2.9	192.33 ± 11.5	3.67 ± 0.3
April-2014 (dry)	Galsi	51.00 ± 1.5	45.67 ± 1.5	89.56 ± 1.6	343.67 ± 17.1	7.00 ± 0.0
	Memari	49.67 ± 1.8	45.67 ± 1.5	91.98 ± 1.0	323.00 ± 27.1	6.33 ± 0.3
Oct.-2014 (wet)	Galsi	46.33 ± 3.0	36.00 ± 3.8	77.3 ± 3.3	154.00 ± 5.5	3.33 ± 0.3
	Memari	48.33 ± 0.9	36.00 ± 0.6	74.56 ± 2.3	169.67 ± 11.7	3.67 ± 3.7

army worm, white plant hopper, green leaf hopper were very low and below the ETL viz, 1 moth/hill, 1-2 larvae/hill, 15-20 insects/hill, 10-20 insects/hill, respectively in the rice fields of the study area. Infestation of the crop and population of *C. medinalis* and *S. incertulas* in the rice fields at different locations of Galsi and Memari during dry and wet season in 2012, 2013 and 2014 were studied. During the dry season the infestation of *C. medinalis* (number of larvae per hill) in the rice fields ranged from 82.86 - 91.30; 80.35 - 85.80; 38.53 - 52.91 percent and 13.33 - 11.33; 14 - 12.33; 7.67 - 7.00 respectively. During the wet season of 2012, 2013 and 2014, infestation of *C. medinalis*

(number of larvae per hill) in the ricefields was 94.51 - 60.61; 61.22 -93.86; 74.54 - 84.57 and 29.00 - 26.00; 22.66 - 29.00; 13.67 - 15.00, respectively (Table 2).

Infestation of the hills (94 and 93%, respectively) and population of LF larvae (29 and 26 larvae/hill) at Galsi and Memari respectively (Table 2). Leaf-folders were more prevalent in wet season than dry season. Crop infestation or pest prevalence varied significantly in different fields without having a common trend. The infestation of the hills varied from 38% to 94% and the population (larvae/hill) of LF larvae varied from 7-29.

During the dry season of 2012, 2013 and 2014, the infestation of *S. incertulas* and the population of larvae in the rice fields was 90.24 - 90.47; 90.12 - 92.50; 89.56 - 91.98 and 7.00 -7.33; 7.00; 6.33 - 7.00 respectively. During the wet season of 2012, 2013 and 2014, infestation of *S. incertulas* (the number of larvae per hill) in the rice fields were 73.01 -75.90; 68.44 - 70.1; 74.56 - 77.3 and 3.00 - 3.33; 2.67 - 3.67; 3.33 - 3.67 respectively (Table 3).

The rice crop was infested by different pests viz. leaffolder (LF), yellow stem borer (YSB), striped stem borer (SSB), army worm, rice hispa, white leaf hopper (WLH), green leaf hopper (GLH) and gandhi bug at different locations of Burdwan district of West Bengal during 2012 to 2014. Many species of arthropods inhabit rice fields but most of them are not truly noxious to the crops. For instance, some 500 species of insects and spiders may appear in a rice field in a particular season (Singh and Singh, 2014). Few of them seem to be casual visitors in search of food or hosts (parasitic wasps). The LF (*C. medinalis*) and YSB (*S. incertulas)* were the major and serious pests found to be infesting the rice plants cultivated in the study area. The rice leaf folder is a widely distributed migratory pest of rice in humid tropical and temperate regions of Asia, Oceania and Africa (Teng *et al.,* 1993; Nathan, 2011). There are more than 100 insect pests that inflict damage to rice-crop in India and among them, stem borers, gall midge, plant hoppers, leaf fodders, rice hispa, gundhi bug, case worm are the most important ones (Pathak and Khan, 1994). Chakraborty (2012) recorded guild composition of both pest and natural enemies in ricefields of West Bengal, and found four species of stem borers to be prevalent in the fields among which Yellow stem borer, *Scirpophaga incertulas*, Walker shared about 79.23% of the total borer population. The results of the field survey indicated that infestation of the crop would be different among the fields and seasons. As the crop infestation exceeded the economic threshold limit (ETL) (two fresh leaf damage/hill at flag leaf stage) and the action threshold level (ATL) (5-10% leaf damage) by the pest (Teng *et al.,* 1993), yield was reduced by about 80%. The observations supported the prediction that *C. medinalis* would be a major pest of rice with 60% or more loss in rice yields in India (Teng *et al.,* 1993).

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Biology of ginger rhizome fly, *Mimegralla* sp. nr *coeruleifrons* (Diptera: Micropezidae)

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ABSTRACT: A survey conducted in the ginger growing areas of Thrissur and Palakkad districts of Kerala, during 2013 and 20 14, revealed the presence of three species of flies infesting both healthy as well as diseased ginger rhizomes. The predominant, most injurious one was identified as *Mimegralla* sp. nr *coeruleifrons* (Macquart) (Diptera: Micropezidae). The biology of the same was studied in the laboratory on diseased ginger rhizomes. The mean incubation period was 3.75 days, while the mean duration of first, second and third larval instars was 2.25, 3.15 and 6.70 days respectively. The mean pupal period lasted for 8.80 days. The longevity of adult male and female flies was 43.90 and 51.00 days respectively, and the sex ratio was 1:1. The morphometric observations of each life stage are also described, with a note on the taxonomy of the fly.

KEYWORDS: rhizome maggot, *Mimegralla* sp., ginger rhizomes, biology

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is one of the earliest cultivated oriental spices grown throughout India. Nearly 46 species of insects are recorded to damage ginger in India (Devasahayam and Koya, 2005), among which rhizome maggots are considered to be the most important. Yield reduction of up to 31 per cent has been reported in ginger due to maggot infestation (Ghorpade *et al*., 1983), though it is often considered as a secondary pest, infesting diseased rhizomes (Devasahayam and Koya, 2005).

Several species of true flies *viz*., *Calobata indica* Robineau-Desvoidy (Maxwell - Lefroy and Howlett, 1909), *Mimegralla coeruleifrons* Macq. [Micropezidae] (Khaire *et al*., 1972), *Chalcidomyia atricornis* Malloch, *Formosina flavipes* Malloch [Chloropidae] (Malloch, 1927), *Celyphus* sp. [Celyphidae] (Nair, 1975), *Eumerus albifrons* Walker (Sathiamma, 1979) and *E. pulcherrimus* Brunetti [Syrphidae] (CPCRI, 1986) infest ginger**.** Among these the biology of *M. coerulifrons* have been studied by several workers (Ghorpade *et al*., 1988; Koya, 1989; Sontakke, 2000). However, there is some uncertainity regarding the correct identity of *Mimegralla* sp. on ginger which remains to be resolved.

The present study was carried out with the objective of studying the biology of major species of rhizome maggot collected during survey conducted in 2013-14 in ginger growing areas of Thrissur and Palakkad districts of Kerala.

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MATERIALS AND METHODS

A survey was conducted in the ginger growing areas of Thrissur and Palakkad districts of Kerala during 2013 - 2014 to document the rhizome flies infesting ginger. Healthy as well as diseased rhizomes infested with maggots were collected and brought to the laboratory, where they were reared to the adult stage. One thousand eight hundred and twenty three (1,823) maggots were collected from August to October, out of which 96 per cent belonged to one species which was identified as *Mimegralla* sp. nr *coeruleifrons* (Macquart) (Diptera : Micropezidae) by Dr K. Ghorpadé, one of the authors.

The life history of *Mimegralla* sp. nr *coeruleifrons,* was studied at the Dept. of Agricultural Entomology, College of Horticulture, Vellanikkara, Thrissur, Kerala. The study was conducted at a mean temperature of 28.7°C and mean relative humidity of 82 per cent. Rhizome maggots collected from ginger fields, along with the infested rhizome were placed in plastic containers covered with muslin cloth for emergence of adults. The newly emerged adults were collected and released into aluminium mesh cages of 75 × 30 × 30 cm size and provided with 10 per cent honey solution as food, as well as diseased ginger rhizome pieces in Petri dishes for oviposition. The eggs were collected at 24 h interval and were placed singly on a thin slice of ginger rhizome, each in a Petri dish lined with cotton. Twenty newly hatched maggots were reared individually on single pieces of ginger rhizome. The second instars were identified by the presence of a pair of red anal tubercles while third instar maggots were identified by the presence of black cephalic mouth hooks and a pair of anal tubercles. Pupae were placed in separate plastic containers until the adults emerged. Ten pairs of adult flies were released into aluminium cages @ one pair per cage for observing their adult longevity. The fecundity was recorded by releasing 10 pairs of adult flies into a single aluminium mesh cage and recording the total number of eggs laid. The results are presented in Table 1. Biometric observations of different life stages of *Mimegralla* sp. nr *coeruleifrons* were recorded using a Leica EZ4 HD stereo binocular microscope equipped with LAS image analysing software and are presented in Table 2.

RESULTS AND DISCUSSION

Egg was small, white and the chorion was sculptured with parallel longitudinal stripes. The eggs were pointed at the anterior end but rounded at the posterior end. Eggs recorded a mean length of 0.74±0.02 mm and mean width of 0.20±0.03 mm, which was in close conformity with the mean length and width of 0.77 mm and 0.17 mm respectively, reported in case of *M. coeruleifrons* (Koya, 1989). The incubation period varied from 3.31 to 4.19 days, with an average of 3.75 ± 0.44 days.

First instar larva

The maggot, on emergence, was tiny, apodous, translucent and colourless with a cylindrical body that lacked distinct segmentation. The body was narrow at the anterior end and widened towards the posterior end. The duration of the first instar ranged from 1.81 to 2.69 days, with an average of 2.25 ± 0.44 days. The larva measured 0.63 ± 0.05 mm in length and 0.16 ± 0.01 mm in width.

Second instar larva

The second instar larva had white, cylindrical, tapering body with twelve visible segments. A pair of reddish brown spiracles at the blunt end of last abdominal segment as well as two semicircular flaps or oral lobes anterior to the mouth orifice on the first body segment were characteristic of the instar. Spinulose areas, which helped in locomotion, occupied the anterior part on the ventral side of each abdominal segment. The duration of the second instar larvae ranged from 2.79 to 3.51 days, with an average of 3.15 ± 0.36 days. On an average, the second instar larva measured 4.20 ± 0.08 mm in length and 0.90 ± 0.08 mm in width at the broadest part.

Third instar larva

The fully grown third instar larva were creamy white and similar in appearance to the second instar

Table 1. Biology of ginger rhizome fly, *Mimegralla* sp. nr *coeruleifrons*

Sl. No.	Parameters	Duration * in days	Range (days) (Mean ± SD)
1	Incubation period	3.75 ± 0.44	3.31 – 4.19
2	First instar larva	2.25 ± 0.44	1.81 - 2.69
3	Second instar larva	3.15 ± 0.36	2.79 – 3.51
4	Third instar larva	6.70 ± 0.73	5.97 – 7.43
5	Pupa	8.80 ± 1.85	6.95 – 10.65
6	Adult male	43.90 ± 18.77	25.13 – 62.67
7	Adult female	51.00 ± 20.79	30.21 – 72.00
8	Fecundity (eggs)	55.40 ± 17.64	38.00 – 73.00

* Mean of 20 observations

Table 2. Measurement of different stages of *Mimegralla* sp. nr *coeruleifrons*

Sl. No.	Stage	Mean length* in mm (Mean ± SD)	Range (mm)	Mean width* in mm (Mean ± SD)	Range (mm)
1	Egg	0.74 ± 0.02	0.72 - 0.76	0.20 ± 0.03	0.017 - 0.23
2	First instar larva	0.63 ± 0.05	0.58 - 0.68	0.16 ± 0.01	0.15 - 0.17
3	Second instar larva	4.20 ± 0.08	4.12 – 4.28	0.90 ± 0.08	0.82 - 0.98
4	Third instar larva	8.11 ± 0.06	8.05 - 8.17	1.68 ± 0.04	1.64 - 1.72
5	Pupa	6.53 ± 0.62	5.91 - 7.15	1.65 ± 0.20	1.45 - 1.85
6	Adult female	13.56 ± 1.10	12.50 - 14.66	2.18 ± 0.77	1.41 - 3.00
7	Adult male	11.27 ± 1.40	9.87 - 12.67	1.30 ± 0.33	0.95 - 1.63

* Mean of 20 observations

maggot. However, the cephalic mouth hooks as well as the pair of spiracles on the last abdominal segment were thicker, darker and bigger. Spinulose areas on ventral surface of each abdominal segment were fleshy, blunt and directed backwards. A pair of dark brown to black, fan-shaped spiracles was present on the first thoracic segment. The duration of larval period ranged from 5.97 to 7.43 days on an average of 6.70 ± 0.73 days. The third instar larva measured 8.11 ± 0.06 mm in mean length and 1.68 ± 0.04 mm in mean width.

Pupa

The full-grown larvae pupated in the larval tunnels in ginger rhizomes. The puparium was dark brown and elongated, with posterior spiracles similar to those of larvae, though more sclerotized. The colour of puparia changed gradually from brown to black towards emergence time. The adult emerged by rupturing the puparium along a circular suture near the thoracic segments, detaching the anterior part while the posterior end of pupae usually remained loosely attached to its body. The pupal period ranged from 7.0 to 10.65 days with an average of 8.80 ± 1.85 days. The mean length and width of puparium was 6.53 ± 0.62 and 1.65 ± 0.20 mm respectively.

Adults

The adult flies were large and slender with elongate stilt like legs. The antenna was short with a sub-

basal arista. The abdomen, thorax and legs were brownish black. The tarsi of fore legs were white. The wings were transparent with well defined cross-bands. Males were smaller than females, and could be identified by the presence of conspicuous, prong like digitate claspers at the tip of abdomen. The last abdominal segments of female were modified into a short ovipositor. The males lived for an average of 43.90 ± 18.77 days and the females for an average of 51.00 ± 20.79 days. The adult male fly measured 11.27 ± 1.40 mm in mean length and 1.30 ± 0.33 mm in mean width. The adult female fly measured 13.56 ± 1.10 mm in mean length and 2.18 ± 0.77 mm in mean width.

Oviposition

The female flies became receptive to mating by the 10th day after emergence and oviposition occurred 2 to 3 days after mating. The females were normally observed to oviposit on diseased rhizomes. However, laying eggs on the tissue paper placed beneath the rhizome was also common. Eggs were laid singly and occasionally in batches of 4 to 7. The female flies recorded a pre oviposition period of 13 days and an average oviposition period of 3 days.

Fecundity

Mated female flies laid 38 to 73 eggs with an average of 55.40±17.64 eggs during the oviposition period which varied from 1 to 3 days.

Sex ratio

The sex ratio of female and male flies was 1:1.

The results of the present study on the duration of development as well as body measurements of different stages of the rhizome maggot, were broadly in agreement with previous reports on the biology of *M. coeruleifrons*.

For instance, the morphometric values recorded in case of egg, at a mean length of 0.74±0.02 mm and mean width of 0.20±0.03 mm, was in close conformity with the mean length and width of 0.77 mm and 0.17 mm respectively, reported by Koya (1989) as well as with the mean length and width of 0.81 mm and 0.22 mm respectively, reported by Ghorpade *et al.* (1988).

Similarly, the size of the first instar larva (0.63 ± 0.05 mm long and 0.16 ± 0.01 mm wide), were identical to the mean length of 0.63 mm and mean width of 0.15 mm, reported by Ghorpade *et al.* (1988). The morphometric observations of the second instar larva were also in conformity with the dimensions of 4.5 × 1.0 mm reported by the above authors.

The measurements of 8.11 ± 0.06 mm and 1.68 ± 0.04 mm for mean length and width in case of third instar larva were marginally lower than the mean length of 9.6 mm and mean width of 1.7 mm reported by Ghorpade *et al.* (1988) and mean length of 10 mm reported by Koya (1989) for *M. coeruleifrons*.

The morphometric measurements of pupa (mean length and width of 6.53 ± 0.62 and 1.65 ± 0.20 mm respectively) again were more or less similar to the dimensions of 8.0 × 1.7 mm reported by Ghorpade *et al.* (1988).

The morphometric data of the adult flies were also in agreement with the findings of Ghorpade *et al.* (1988) who reported that the length of females and males varied from 13 to 16 mm and 12 to 14 mm respectively.

It can be seen that the morphometric observations of the different stages were similar to those recorded in previous studies. However, there were variations in the duration of development of different stages. Thus, the mean incubation period of 3.75±0.44 days in the present study was greater than the 2.5 days reported by Sontakke (2000) while the mean duration of 2.25 days in case of the first instar larva was considerably shorter than the duration of 5 to 7 days recorded by Ghorpade *et al.* (1988). Similarly, the mean duration of 3.15 days for third instar larva is at variance with the findings of Ghorpade *et al.* (1988), who recorded mean duration of 2.0 days only for *M. coeruleifrons.* The same study had also observed the average duration of third instar larva to be 4.7 days, as against 6.70 days in the present study.

The pupal period ranged from 7.0 to 10.65 days with an average of 8.80 ± 1.85 days. This was in agreement with the findings of Koya (1989) who recorded a mean duration of 8 to 11 days.

The male and female flies had an average life span of 43.90 ± 18.77 and 51.00 ± 20.79 days respectively. These observations do not agree with findings of earlier studies. For instance, Ghorpade *et al.* (1988) had recorded the average longevity of male and female flies on ginger as 8.8 and 10.6 days respectively. Kotikal and Kulkarni (2000) also had reported the longevity of males and females as 10.50 ± 3.35 and 17.20 ± 2.66 days respectively. Sontakke (2000) reported average longevity of *M. coeruleifrons* adults as ranging from 13.8 to 20.4 days.

Considerable variation was also observed with respect to fecundity. Mean fecundity of 130 eggs, reported by Ghorpade *et al.* (1988) was higher than the mean value of 55.40±17.64 eggs that was recorded in the present study.

The findings of the study conformed to earlier reports both in terms of oviposition period as well as sex ratio. Both pre oviposition as well as oviposition period (13 and 3 respectively) recorded in the present study were identical to the values recorded by Ghorpade *et al.* (1988). Similarly the sex ratio of 1:1 was similar to earlier reports by Koya (1989) as well as by Ghorpade *et al.* (1988).

The variations in the duration of development could be due to variations in the ambient conditions under which the experiments were carried out, though the differences in terms of longevity and fecundity are too pronounced for such an explanation.The possibility of the rhizome larva under study being a new species near *Mimegrella coeruleifrons* also can not be ruled out. The genus *Mimegralla* Rondani of the family Micropezidae is currently under taxonomic revision (K. Ghorpadé, 2014: personal communication), requiring more detailed investigations of this poorly known genus and its species.

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Oviposition of *Helopeltis antonii* (Hemiptera: Miridae) on *Psidium guajava* fruits

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ABSTRACT: Detailed studies on the oviposition behaviour of *H. antonii* on different types of guava *Psidium guajava* fruit from April to December that corresponds from fruiting to harvesting period was carried out in 2015.A shift in the egg laying pattern in relation to availability of fruits of different types were recorded during the season. Maximum number of eggs /fruit was recorded on un matured scabby cracked fruits in the initial season of fruiting which shifted to ripe scabby fruits with the advancement of season. However data analysis on the egg laying for the entire season recorded significantly more number of eggs /fruit on un matured scabby cracked fruits. Co- relation between the availability of fruit type and number of eggs resulted in a positive linear curve with R^2 value = 0.97 indicating that un matured scabby and cracked fruits contain more eggs than other types of fruits screened.

Key words: *Helopeltis antonii*, egg laying, *Psidium guajava* fruits

INTRODUCTION

Guava, *Psidium guajava* L, (Family: Myrtaceae) a native of tropical America, introduced in 17th century is a major horticultural fruit of India (Menzel, 1985). *Helopeltis antonii Signoret* (Hemiptera: Miridae) commonly denoted as tea mosquito bug is an economically important pest causing significant marketable yield loss of guava. Besides guava, it is a major pest of cashew, cocoa and have an array of alternate hosts such as avocado, pomegranate, Singapore cherry, custard apple, grape wine, drumstick, silk cotton, spices (Devasahayam and Nair, 1986; Sunil Kumar, 2000), and many other forest trees such as neem (Miller, 1941; Stonedahl, 1991). Nymphs and adults sucks the sap from terminal shoots, young leaves and flower buds and young fruits (Balasubramanian and Kalyanasundaram, 1972). Sucking the sap from terminal shoots causes drying thereby affecting flowering and fruit setting. In the course of desaping, the insect injects saliva causing lesions leading to formation of scab appearance on fruits (Abraham and Nair, 1981; Geeta and Naik,2004). During field visits, *H.antonii* could be collected in large numbers from un-matured scabby cracked fruits. Inspection of un-matured fruits under a binocular microscope revealed presence eggs of tea mosquito bug. This study was carried out to determine the egg-laying behaviour of tea mosquito bug in relation to different types of guava fruits.

MATERIALS AND METHODS

The samples for the study were collected from a guava orchard at Indian Institute of Horticultural

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Research, Bangalore,(12°58'N; 77°35' E), India. The orchard consisted of fifty trees of cv. *Allahabad safeda* of 12 years old. This variety was observed to be susceptible to *H.antonii* based on the earlier field observations and hence selected for the study. In addition to the scabby on fruits infected by the feeding of *H.antonii*, scab of fruits is a inflicted disorder on guava that also was considered as one of parameters for the present study. Thus six type of fruits were selected for the study namely i. Un-matured healthy non- scabby, ii.Un-matured scabby iii. Un-matured scabby cracked, iv. Ripe scabby, v. Ripe non-scabby and vi. Ripe scabby fallen.

Twenty fruits of each type were collected randomly at fortnightly intervals and brought to laboratory for observation. The study was carried out from April to December months of the year 2015 that coincides with fruiting to harvesting of fruits.

The field collected fruits described above were individually examined under the binocular microscope and the number of eggs per fruit was recorded. These were totalled and average eggs/ fruit / fortnight was calculated. The data on number of eggs laid in different types of fruits /sample / fortnight was compiled to obtain the number of eggs/ fruit/month. For statistical analysis the original values were converted to square root values and subjected to ANNOVA for LSD. Co-relation and the R^2values between the type of fruits and number of egg laid were worked out.

RESULTS AND DISCUSSION

Egg laying in relation to different types of fruits across the months of April to December is given in Fig.2. Eggs were recorded in all types of fruits except in un-matured scabby and un-matured non-scabby (healthy). Egg laying on fruits started in the month of April and was recorded till December that coincided with harvest of the fruits. Egg laying was recorded in cracked fruits from fruiting to harvesting stage. In all other types of fruits egg laying was recorded from august onwards. About 4.4 eggs/fruit was recorded in April that increased to 7.4, 8, 11 and 15.4 eggs /fruit in June, July and August months respectively. Highest number of 17 eggs /fruit was recorded in the month of September which decline in the following months

In August and September months un-matured scabby cracked fruits recorded 15.4 to 17 eggs that were statistically significant to other types (Table-1). In October a shift in the egg laying from

Table 1. Egg laying pattern of *H.antonii* in different types of *Psidium guajava* fruits from April to December

S .No	Types of fruits	No. of eggs /fruit (months)					
		Aug.	Sept.	Oct	Nov	Dec.	Mean
1	un-matured scabby and cracked	15.4(4.0)[a]	17(4.2)[a]	7.8 (2.9)[b]	4.6 1.9) [c]	2.0(0.9)	8.3 (2.9)[a]
2	Ripe scabby	6.6(2.6) [c]	13.3(3.7) [b]	15.2(3.95) [a]	5.2(2.5) [b]	0 (0.7)	4.5(1.8)[c]
3	Ripe healthy	4.0(1.9)[d]	4.0(2.0)[c]	6.4(2.6)[c]	3.6(1.9)[d]	0 (0.7)	2.9(1.5)[d]
4	Fallen ripe scabby	9(3.0) [b]	13.2(3.7)[b]	14.6(3.9) [a]	8.4(2.6) [a]	0(0.7)	5.7(2.1)[b]
	CV	32.14	20.46	20.3	6.06	NS	39.8
	CD @0.05%	1.3	1.0	1.0	0.5	-	0.8

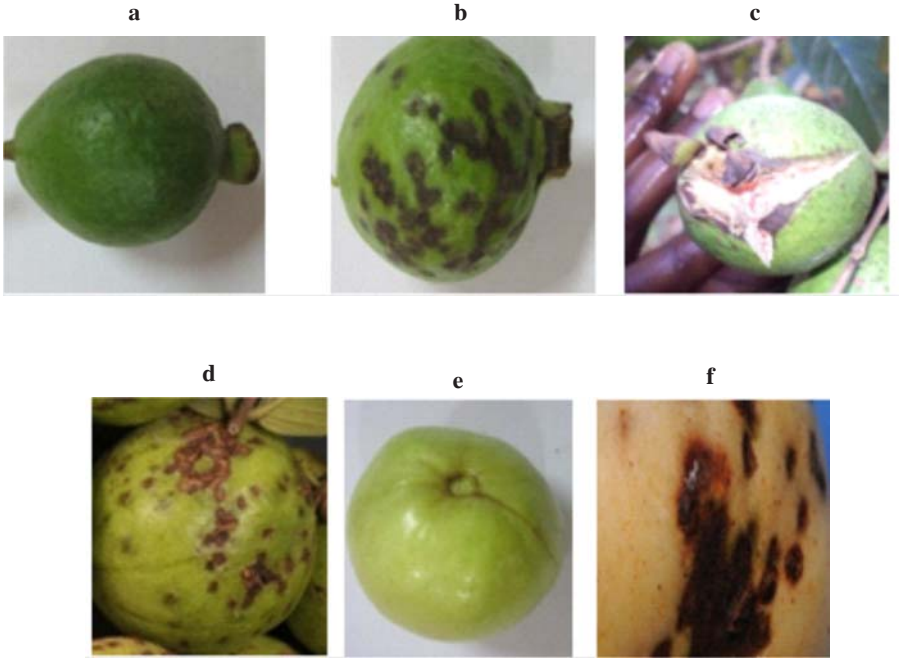

Fig. 1. Portrayal of the six types of fruits selected for the study

a) Un-matured non -scabby
b) Un-matured scabby
c) Un-matured scabby and cracked
d) Ripe scabby
e) Ripe healthy (non scabby)
f) Ripe scabby fallen

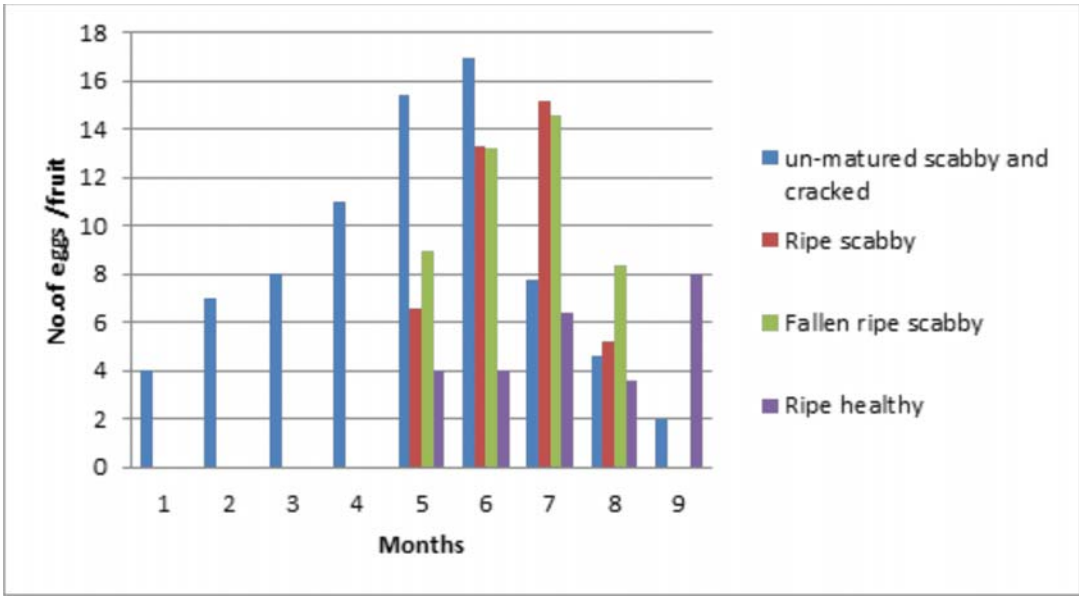

Fig. 2. Egg laying of *H.antonii* in different types of fruits from April to December

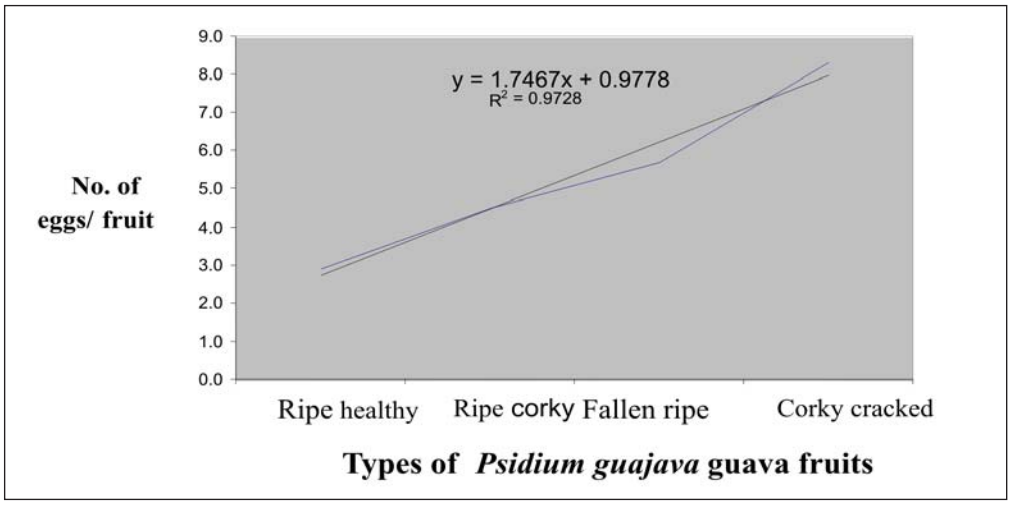

Fig. 3. Co-relation between fruit types of *Psidium guajava* and egg laying of *H. antonii*

a **b** **c**

Fig. 4. Eggs laid in diiferet portion of *Psidium guajava* fruit
a. in cracked portion; b. on fruit surface; c. on calyx

un-matured scabby cracked fruits to ripe scabby fruits was recorded. A mean value of 15.2 and14.6 eggs /fruit in ripe scabby on tree and fallen ripe scabby respectively. In December the egg laying in all types of fruits were reduced and were not significant statistically. Analysis of mean number of eggs for the entire season from April to December recorded a mean value of 8.3 eggs / un-matured scabby and cracked that was statistically significant to other types of fruits screened. Ripe healthy fruits were least preferred.

Co-relation analysis worked out between the dependent variable of fruit type and independent variable of .eggs/ fruit for the season resulted in a positive linear co-relation with an R^2 value of 0.97 indicating that un-matured scabby and cracked fruits are most preferred (Fig.1c)

Egg laying behaviour

Eggs were laid singly and in groups. Eggs were either inserted inside the soft portions of fruits or laid externally on fruit. On cracked fruits, eggs are laid inside the cracked portion in continuous linear manner (Fig.4).Eggs are inserted into the soft tissues and on the outer ridges of the cracked portion of fruits. However the number of eggs laid inside the cracked part was more than laid eggs on the ridges. In ripe fruits, eggs were laid singly or in

groups in the soft feeding scars, externally on fruits and even on the calyx portion (Fig -4b&c).A maximum number of 14eggs /cluster could be recorded. *H.antonii and* other *Helopeltis spp* are reported to insert their eggs singly or in a sequence into the soft tissues of plant parts such as tender shoots, mid ribs of apical leaves of its host plants (Bhat *etal.,* 2010; Ganga Visalakshy and Mani, 2010; Ritu Muhammad *etal* 1983,Sundaraju, 1996)This is the first report of recording eggs of *H. antonii* on external surface of fruits. Similarly oviposition of *H.antonii* on guava fruits is not yet reported.

Non chemical methods such as field sanitation and semio- chemicals are considered as effective components in IPM of insect pests. The present observations provide future researchable leads in the management of *H. antonii* on guava. Further research on the impact of field sanitation by removing scabby and cracked fruits is being initiated to develop effective IPM for *H. antonii* on guava.

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Efficacy of different IPM modules against major pests of cabbage

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ABSTRACT: Different IPM modules untreated control were evaluated against Diamond back moth, *Plutella xylostella*, cabbage butterfly, *Pieris canidia,* cutworm, *Agrotis ipsilon* and cabbage aphid, *Brevicoryne brassicae*. Among the modules, Module (M5) i.e. lamda-cyhalothrin @ 25g a.i. per ha contributed maximum effectiveness in reducing the population of various pests followed by Module (M1) consisting of 3 releases of *Trichogramma chilonis* @ 1 lakh/ha at 10 days interval + 3 releases of *T. pieridis* @ 1 lakh/ha at 10 days interval + one spray of Bt@ 2ml/lit at 15 days after release of *Trichogramma* + one spray of NSKE 5%. However, the highest population of coccinellids was achieved in the biopesticide treated plots compared to lamda-cyhalothrin treated plots. The highest marketable yield was recorded in Module (M5) (262.50 and 252.50 q/ha) with a cost benefit ratio of 2.28 and 2.62 which was followed by Module (M1) contributed the yield of 212.78 and 202.67 q/ha as against 114.89 and 96.11 q/ha in the untreated control plots with a cost benefit ratio of 1.79 and 2.03 during 2013-14 and 2014-15, respectively. Though the maximum return was obtained from Module (M5) followed by Module (M1), considering the coccinellids population, it may be concluded that instead of use of chemical alone farmers can adopt the IPM module M1 for effective reduction of pests on cabbage.

KEYWORDS: Cabbage pests, IPM module, economics

INTRODUCTION

Cabbage, *Brassica oleracea* var. *capitata* L. is one of the most popular winter vegetable grown throughout India. As a short duration crop, which is nutritionally superior and capable of producing high amount of food per unit area and time, cabbage has a great potential in modern agriculture. Cabbage demonstrate wide adaptability, and hence it is grown over varied agroclimatic conditions ranging from lighter sand to heavier clay soils having a pH ranging between 6 to 6.5.In the plains the crop is extensively grown during cool season as a winter crop, but in the hills, it is grown as spring and early summer crop.

Despite introduction of potential hybrids, the production of cabbage is low as compared to potential yields obtained up to 0.63 million metric tonnes, particularly in Assam. Out of the different reasons for poor productivity of cabbage in India, one of the major limiting factors is the damage caused by lepidopteran insect pests right from the vegetative stage to maturity stage. Among various pests diamondback moth, *Plutella xylostella* (L.), cabbage butterfly, *Pieris canidia* (L.), cutworm, *Agrotis ipsilon* (Hfn.) and cabbage aphid,

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Brevicoryne brassicae (L.) are of major importance.

Although conventional insecticides having novel target site of action have been used for many years to counter the problem of insect pests, but the pests become resistant to these conventional insecticides in recent years (Kabir *et al*., 1996). It is a known fact that often only 1% of the active ingredients of the insecticide reach the target pests, while 99% of these substances, some of which are highly toxic, trouble the environment (Hassan, 1992).

However, excessive use of chemical pesticides at frequent intervals is more complicated in case of cabbage which resulted in many ecological problems due to mortality of natural enemies, resurgence of minor pests, environmental pollution and residues in vegetables, destruction of native flora and fauna. Keeping in view the ill effects of pesticides, adoption of integrated strategies for ecofriendly management and incorporating selective, safer, modern pesticides and biopesticides seem to be the best alternative. Hence, the present research studies are conductedon the efficacy of different PM modules on major pests of cabbage at Jorhat (Assam).

MATERIALS AND METHODS

The experiment was conducted in the Experimental Farm, Department of Horticulture, Assam Agricultural University (AAU), Jorhat during *rabi* season of 2013-14 and 2014-15 with six modules and four replicationsby adopting randomized block design (RBD). The details of modules are as follows:

IPM Module 1

Three releases of *Trichogramma chilonis* @ 1 lakh/ha at 10 days interval+3 releases of *T. pieridis* @ 1 lakh/ha at 10 days interval + one spray of Bt@ 2ml/lit at 15 days after release of *Trichogramma* + one spray of NSKE 5%.

Egg parasitoids viz. *T. pieridis* and *T. chilonis* were first released at 30 DAT of the crop. First release was made by *T. pieridis* at 30 DAT, subsequently 2nd and 3rd releases were made by *T. pieridis* at 40 and 50 DAT maintaining an interval of 10 days when the crop was at vegetative stage against cabbage butterfly, *Pieris brassicae*. *T. chilonis* was released at 60, 70 and 80 DAT from starting of head formation at an interval of 10 days. Altogether there were six releases of Trichogrammatids against lepidopteran pests of cabbage.

Similarly, one NSKE was made at 15 DAT as the aphid was occurring early stage of the crop and there was a 15 days interval in between spraying of NSKE and released of parasitoids.

Bt was sprayed at 95 DAT against Diamond back moth because at latter stage of the crop infestation of Diamond back moth is very high.

IPM Module 2

Three releases of *T. chilonis* @ 1 lakh/ha at 10 days interval+3 releases of *T. pieridis* @ 1 lakh/ha at 10 days intervals + one spray of NSKE 5%.

First release was made by *T. brassicae* at 30 DAT, subsequently 2nd and 3rd releases were made by *T. brassicae* at 40 and 50 DAT maintaining an interval of 10 days when the crop was at vegetative stage against cabbage butterfly, *Pieris brassicae*. *T. chilonis* was released at 60, 70 and 80 DAT from starting of head formation at an interval of 10 days. Altogether there were 6 releases of Trichogrammatids against lepidopteran pests of cabbage.

Similarly, one NSKE was made at 15 DAT as the aphid was occurring early stage of the crop and there was a 15 days interval in between spraying of NSKE and released of parasitoids.

IPM Module 3

Three releases of *T. chilonis* @ 1 lakh/ha at 10 days interval + 3 release of *T. pieridis* @ 1 lakh/ha at 10days interval +one spray of Bt 2ml/lit at 15days after release of *Trichogramma*.

IPM Module 4

3 releases of *T. chilonis* @ 1 lakh/ha at 10 days interval + 3 releases of *T. pieridis* @ 1 lakh/ha at 10 days interval.

Table 1. Efficacy of different IPM modules on pest population of cabbage (2013-14 and 2014-15)

Module	DBM population per plant				Cabbage butterfly population per plant			
	Pre treatment count	15 DAT	30 DAT	45 DAT	Pre treatment count	15 DAT	30 DAT	45 DAT
M1	2.70	0.83	1.15	0.60	2.18	0.94	1.16	0.60
M2	2.86	1.80	2.30	1.70	2.27	1.90	2.12	1.63
M3	2.52	1.05	1.20	0.85	2.22	1.04	1.46	0.80
M4	2.72	1.90	2.34	1.70	2.20	1.95	2.10	1.70
M5	3.23	0.20	0.40	0.68	2.52	0.17	0.30	0.44
M6	3.69	4.26	5.43	5.80	2.18	3.72	4.17	4.50
S.Ed.(±)	0.57	0.30	0.46	0.30	0.64	0.20	0.43	0.45
CD (P=0.05)	NS	0.66	1.48	0.64	NS	0.46	0.92	0.96

Table 2. Efficacy of different IPM modules on pest population of cabbage (2013-14 and 2014-15)

Module	Cutworm population per plant				Aphid population per leaf			
	Pre treatment count	15 DAT	30 DAT	45 DAT	Pre treatment count	15 DAT	30 DAT	45 DAT
M1	0.90	0.31	0.47	0.63	6.65	3.55	3.13	4.45
M2	0.73	0.36	0.50	0.68	6.01	3.58	3.20	4.48
M3	0.95	0.82	0.80	1.12	6.40	5.60	4.93	6.01
M4	0.85	0.85	0.87	1.10	6.06	5.65	5.11	6.05
M5	0.90	0.10	0.12	0.22	6.42	1.67	1.07	2.00
M6	0.96	1.70	2.49	2.60	7.39	0.17	11.07	12.30
S.Ed.(±)	0.17	0.13	0.14	0.16	0.88	0.76	0.54	0.48
CD (P=0.05)	NS	0.29	0.32	0.35	NS	1.60	1.16	1.09

IPM Module 5

Chemical control (lambda - cyhalothrin) @ 25 g a.i/ha at appearance of pests. Total 3 sprays of lambda – cyhalothrin, from 30 DAT, 45 DAT and 60 DAT.

IPM Module 6

Untreated control

The twenty five days old cabbage variety Asha F1 seedlings of about 25 days were transplanted in the plot of 7.5 m^2 with a spacing of 60 cm × 30 cm during November for both the period. All together six modules including untreated control were applied in the experimental plot. The recommended agronomic practices were followed. All the treatments specially plant extracts *viz.,* Neem Seed Kernel Extract (NSKE 5%), Bt@2 ml/l, biocontrol agents *viz., Trichogramma chilonis*, *T. pieridis*@ 1 lakh/ha at 10 days were released during morning hours without contaminating the adjacent plots. Chemical and untreated check plots were kept in different places which was located at 50m away from IPM plots to avoid drifting of insecticides. Trichocards containing the appropriate number of eggs of biotic agents i.e. *T. pieridis* and *T. chilonis* @ 1 lakh/ha were glued to the disposal glass that containing honey and placed it over the stick. First spray and release of bioagents were started on 15

Table 3. Effect of different IPM modules on coccinellid predators population (2013-14 and 2014-15)

Modules	Pre treatment count	Post treatment count			% reduction (-) or increase (+)
		15 DAT	30 DAT	45 DAT	
M1	1.08	0.57	0.60	0.85	21.29(-)
M2	1.25	0.50	0.70	0.94	24.80(-)
M3	1.02	1.13	1.17	1.29	26.47(+)
M4	0.91	1.05	1.22	1.43	57.14(+)
M5	1.27	0.17	0.35	0.40	68.50(-)
M6	1.62	1.93	2	2.18	34.57(+)
S.Ed.(±)	0.30	0.14	0.18	0.13	
CD (P=0.05)	NS	0.29	0.38	0.28	

The symbol (-) implies reduction of pest population; The symbol (+) implies increase of pest population

Table 4. Economic viability of different IPM modules in cabbage (2013-14 and 2014-15)

Module	2013-14				2014-15			
	*Yield (q/ha)	Return (Rs./ha) Ratio	**Total cost (Rs./ha)	Cost Beneft	*Yield (q/ha)	Return (Rs./ha)	** Total cost (Rs./ha)	Cost Beneft Ratio
M1	212.78	4,25,560	6980	1:1.79	202.67	4,05,340	6980	1:2.03
M2	196.01	3,92,020	3430	1:1.68	156.66	3,13,320	3430	1:1.60
M3	205.28	4,10,560	5410	1:1.74	187.18	3,74,360	5410	1:1.89
M4	177.94	3,55,880	1860	1:1.53	133.55	2,67,100	1860	1:1.38
M5	262.50	5,25,000	452	1:2.28	252.50	5,05,000	452	1:2.62
M6 (control)	114.89	2,29,780	-	-	96.11	1,92,220		-

* Total of 6 harvest; ** Total cost of plant protection based on two rounds of treatments

For one round of treatment = cost of insecticide per hectare + cost of labour (2 labour per day @ Rs. 135 per labour

Market price of cabbage @ Rs. 2000 per quintal for both the seasons

Cost of NSKE = Rs.1300/spray; Cost of *B. thuringiensis* = Rs.3280/spray

Cost of *Trichogramma chilonis* = Rs. 525/3 releases; Cost of *T. pieridis* = Rs.525/3releases

Cost of lamda- cyhalothrin 5 EC = Rs. 91.00/100 ml

days after transplanting when the eggs of lepidopteran pests were seen in the field and subsequently, the treatments were imposed at 15 days interval. In chemical control plot, lamda-cyhalothrin @ 25 a.i./ha was sprayed and altogether three sprays were given at 15 days interval. Care was taken at the time of spraying of insecticide and biopesticide like NSKE, *B. thuringiensis* so as to give thorough coverage for better affectivity. No management practices were followed in case of control plot except water spray. Pest population were recorded before and after imposing of each treatment at 15 days interval. For pre treatment and post treatment count,ten plants were randomly selected from each plot to assess the number of lepidopteran pests as well as natural enemy complex. In case of counting of aphid (nymph and adult),observations were recorded on three leaves from top, middle and bottom.Yields of marketable heads per plot were also recorded at the time of harvesting from each plot and records of all pickings were pooled together to get the average yield.The

data generated were subjected to statistical analysis and the efficacy of different module were assessed.

RESULTS AND DISCUSSION

The results of present investigation indicated that all the modules exhibited overall significant effect in keeping down population of pests over untreated control. Among the six modules tested against the pests it was evident that the population of diamondback moth (0.20, 0.40, 0.68 per plant) as well as cabbage butterfly (0.17, 0.30 and 0.44 per plant) were significantly low in Module (M5) (lamda-cyhalothrin) followed by Module 1 registering 0.83, 1.15, 0.60 of DBM per plant and 0.94, 1.16, 0.60 of cabbage butterfly at 15, 30 and 45 days after treatment (DAT) during 2013-14 and 2014-15, respectively.

The reasons for the superior performance of Module (M5) might be due to quick knock down effect of lamda-cyhalothrin. Similar report of high order of performance of lamda-cyhalothrin against DBM was reported by Liu *et al.*(2003). The effectiveness of Module (M1) might be due to inclusion of all treatments *viz*., NSKE (Neem Seed Kernel Extract), Bt and egg parasitoids like *T. chilonis* and *T. pieridis*. The present findings on superiority of NSKE against DBM agreed with the earlier findings as reported by Schmutterer (1999), who reported the effectiveness of neem seeds/neem kernels against *P. xylostella* and showed a reduction in larval population of the pest with an average of 2.9 larvae/head.Besides these, the effectiveness of Bt included in Module (M1) was also supported by the findings of Oke *et al.* (2010) according to whom application of thuricide (*Bacillus thuringiensis)* resulted in lower percentage of head damage (9 to 10%) in comparison to non-treated plots that resulted in maximum mean percentage of head damage of 92%. The superiority of *T. chilonis* and *T. pieridis* which was also an important component of Module (M1) in reducing DBM population had also been reported by Miura (2003). According to him, *T. chilonis* was found to be effectively control DBM population showing a per cent parasitism of 80.

Similarly, it was also evident from the present investigation that Module (M5) was found to be significantly superior over rest of the modules in keeping down cutworm population with 0.10, 0.12 and 0.22 larvae per plant followed by Module (M1) registering 0.30, 0.47 and 0.63 larvae per plant at 15, 30 and 45 days after treatment (DAT) during 2013-14 and 2014-15, respectively.

Furthermore, it was also vivid from the results that Module (M5) also brought about a significant reduction on the incidence of aphid (1.67, 1.07 and 2.00 per leaf) over control followed by Module (M1) with a population of 3.55, 3.13 and 4.45 aphids per leaf for both the period.

The superiority of the Module (M5) might be due to inclusion of non-systemic insecticide lamda-cyhalothrin which exhibits adulticidal, ovicidal and particularly,larvicidal activity and disrupt the normal functioning of the nervous system of insect. Moreover, being a conventional insecticide, lamda-cyhalothrin has quick knock down effect and acts as both systemic and nerve poison. The present findings on superiority of NSKE against cutworm in Module (M1) also corroborate the findings of Viji and Bhagat (2001) who also reported that NSKE @ 20kg/ha provided good protection at earlier stages against the infestation of cutworm, whereas, at later stages, NSKE were less effective but registered higher yields when compared with untreated control. Furthermore, foliar application of neem-based insecticides have been reported to be the most effective in reducing the rates of honeydew excretion of aphid to 14-40 per cent compared to control (Shannag *et al.*, 2014). Besides these, the effectiveness of Bt included in Module (M1) might be due to presence of Btä-endotoxins which were found to exhibit low to moderate toxicity on aphid population in terms of mortality as well as growth rate.

Considering the other effects like mortality of coccinellids it has been further observed that the highest reduction in coccinellid predators was found in Module (M5, 68.50 per cent) as compared to Module (M1), Module (M2), Module (M3) and

Module (M4) respectively. In case of module (M1) and (M2) population of coccinellids were decreased in compare to (M3), (M4) and (M6) because in module (M1) and (M2) population of aphids were significantly less than the (M3), (M4) and (M6). As the was less availability of food, so the population of aphid predator coccinellids were also less.

Therefore, it may be concluded that instead of use of chemical alone farmers can adopt the IPM module (M1) consisting of 3 releases of *Trichogramma chilonis* @ 1 lakh/ha at 10 days interval + 3 releases of *T. pieridis* @ 1 lakh/ha at 10 days interval + one spray of Bt@ 2ml/lit at 15 days after release of *Trichogramma* + one spray of NSKE 5% for effective reduction of pests on cabbage.

The marketable yield revealed significant variations ranging from 262.50 to 114.89 q/ha (2013-14) and 252.50 to 96.11 q/ha (2014-15). The highest marketable yield was recorded in Module (M5) (262.50 q/ha) followed by Module (M1) and Module (M3). The gross return was more in Module (M5) followed by Module (M1) and Module (M3).

The economics of marketable yield over two years revealed that Module (M5) was the best effective module with highest BC ratio of 2.28 and 2.62 followed by Module (M1) with BC ratio of 1.79 and 2.03 during 2013-14 and 2014-15, respectively. The highest cost benefit ratio attributed by module (M5) might be due to its lower cost. Therefore, it can be suggested that instead of use of chemical alone farmers can adopt the IPM module (M1) consisting of 3 releases of *Trichogrammachilonis* @ 1 lakh/ha at 10 days interval+3 releases of *T. pieridis* @ 1 lakh/ha at 10 days interval + one spray of Bt @ 2 ml/lit at 15 days after release of *Trichogramma* + one spray of NSKE 5% for effective reduction of cabbage pests.

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Evaluation of different household practices to decontaminate organophosphate insecticide residues from *Amaranthus tricolor* L.

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ABSTRACT: *Amaranthus tricolor* L (Amaranth) is a major leafy vegetable extensively cultivated in Kerala. Efficiency of different decontaminating methods viz., washing, cooking, 2% common salt, 2 % vinegar, 1% turmeric, 2% tamarind and 1% veggie wash (produced by Kerala Agricultural university, Vellayani), in the removal of organophosphate insecticide residues from amaranth, sprayed with different organo phosphate insecticides *viz.,* chlorpyriphos 20% EC, dimethoate 30 EC, ethion 50% EC, malathion 50 % EC, profenofos 50% EC and quinalphos 25% EC, indicated that dipping in 1% veggie wash for 20 minutes followed by three further washings plus cooking was found to be most effective in removal of OP insecticide residues (83%), followed by 1 % veggie wash for 20 minutes, 1% veggie wash for 10 minutes plus cooking and 2% vinegar (78, 76 and 74% respectively).

KEY WORDS: Amaranth, pesticide, residues, decontamination.

INTRODUCTION

Amaranth is extensively cultivated as a green and leafy vegetable in many temperate and tropical regions. It has excellent nutritional value because of their high content of essential micronutrients such as â-carotene, iron, calcium, zinc, phosphorous, vitamin C and folic acid (Schonfeldt and Pretorius, 2011). In India, it is cultivated largely in the southern states. It is raised throughout the year in paddy lowlands, garden lands and homesteads. The crop cultivated throughout the year. Farmers use chemical pesticides of a wide range and often in excessive dosage and at close intervals. This tendency leads to high residues on products reaching the market. Nair *et al.,* (2013) reported that most of the agricultural commodities tested had multiple residues containing three to six pesticides. Department of Agriculture, Government of Kerala and Kerala Agricultural University through the Plan Scheme "Production and marketing of safe to eat (pesticide free) vegetables, fruits and food products for sale through government outlets" revealed that out of 34 red amaranthus samples analyzed during the period of January – December 2013, 14 samples were found with insecticide residues. In these detected insecticides, most of the residues belong to organophosphate group (PAMSTEV, 2014). However, owing to their widespread use together with their unique physical, chemical and biological properties, these insecticides have raised serious concern among the public regarding their adverse

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effects on human health and environment. So there is need to remove pesticide residues from commodity at consumer level. Standardization of simple and cost effective methods to remove residues from amaranth has been reported here.

MATERIALS AND METHODS

A preliminary survey was conducted to assess the pesticide residues in amaranth in Kalliyoor and Pappanchani of Thiruvananthapuram district during March 2014 – June 2014. Ten farmers each from two locations engaged in commercial cultivation of red amaranth were selected randomly for the survey. The red amaranth plants grown organically in grow bags in premises of PRRAL, Vellayani were used for the standardisation of household practice to decontaminate residues. An insecticide mixture emulsion (100 ppm) was prepared by using required quantities of each insecticide mixed in one litre water. The insecticides used were dimethoate 0.3 ml L^{-1} (ROGOR), malathion 0.2 ml L^{-1} (CELTHION), chlorpyriphos 0.5 ml L^{-1} (CLASSIC-20), quinalphos 0.3 ml L^{-1} (EKALUX), profenophos 0.2 ml L^{-1} (CURACRON) and ethion 0.2 ml L^{-1} (FOSMITE). The amaranth plants were sprayed with this insecticide mixture using a hand sprayer (l L). Sprayed plants were kept under covered conditions to protect from rain. Treated plants were harvested at one day after spraying. Individual treated plants were subjected to different decontamination practices and some plants were kept as un processed control for comparison. Preparation of working standards and analysis of each sample processed according to specific procedure for vegetables and samples were analysed under specific working parameters of Gas Chromatograph (Nair *et al.,* 2013). The residues in processed and control (unprocessed) samples were extracted in acetonitrile and clean-up was done with QuEchERS method. The different decontamination treatments used in this experiment are mentioned in Table 3.

RESULTS AND DISCUSSION

Out of 20 samples tested, 17 samples were contaminated with pesticide residues. As there were no MRLs notified by FSSAI for amaranth, EU-MRLs were taken for reference. Among twenty surveyed samples, 13 samples had residues of quinalphos (0.04-1.20 ppm) and 4 samples exceeded the EU-MRL (0.05 ppm). Chlorpyriphos was found in three samples and the levels detected in all the three were above EU-MRL level. Profenofos, bifenthrin, ethion and fenvalerate were found in one sample each as above EU-MRL. Among surveyed samples, lambda-cyhalothrin and cypermethrin were found in one sample each and they were below EU-MRL (Table 1).

The recovery and repeatability of these insecticides are presented in Table 2. The effect of different household decontamination practices in removal of OP pesticide residues from amaranth are summarized in Table 3. The treatments varied significantly on their effect to remove dimethoate residues. KAU veggie wash (0.19 ppm) was found to be superior over all the treatments. Common salt (0.34), tamarind (0.42) and vinegar (0.42) were found to be next best treatments, whereas, turmeric (0.55) and water (0.66) were found to be less effective.

In removal of malathion residues KAU veggie wash (0.05) was found as superior and this was on par with vinegar (0.07). These treatments were followed by common salt (0.09), water (0.11) and turmeric (0.11), these three treatments were statistically on par. In removal of malathion turmeric (0.12) found as inferior among all the treatments. Vinegar (0.07) was found to be superior among all treatments in removal of chlorpyriphos residues from amaranth. The next best treatments were veggie wash (0.80), common salt (0.81) and water (0.90). These were followed by tamarind (1.00) and turmeric (1.34). All these treatments were statistically differ with untreated check. In case of quinalphos highest reduction of residue removal was observed when subjected to KAU veggie wash (0.40). More or less similar amount of residues were removed hen subjected to common salt (0.44), tamarind (0.51) and vinegar (0.54). All the above treatments were statistically not different. Water (0.67) and turmeric (0.70) exhibited less removal;

Table 1. Extent of pesticide residues in farm-gate samples collected from selected farmers

Farmer	Pesticides detected	Amount of residues found (Conc. in ppm)	EU – MRL	Below / Above MRL
1	Chlorpyriphos	1.009	0.05	Above
	Quinalphos	1.05	0.05	Above
2	Quinalphos	0.04	0.05	Below
3	Chlorpyriphos	0.09	0.05	Above
	Quinalphos	0.04	0.05	Below
4	—			
5	—			
6	Quinalphos	0.08	0.05	Above
7	Profenophos	0.02	0.01	Above
8	Quinalphos	1.20	0.05	Above
	Fenvalerate	0.08	0.02	Above
9	——			
10	Lambda cyhalothrin	0.025	1.00	Below
11	Cypermethrin	0.19	0.70	Below
	Quinalphos	0.05	0.05	Below
12	Quinalphos	0.04	0.05	Below
13	Quinalphos	0.87	0.05	Above
14	Ethion	0.03	0.01	Above
15	Bifenthrin	0.09	0.05	Above
	Quinalphos	0.05	0.05	Below
16	Quinalphos	0.03	0.05	Below
17	Quinalphos	0.04	0.05	Below
18	Quinalphos	0.05	0.05	Below
19	Quinalphos	0.03	0.05	Below
20	Chlorpyriphos	1.00	0.05	Above

ppm - parts per million, EU- European Union, MRL- Maximum Residue Limit

however, these treatments were statistically on par with tamarind and vinegar.

Among all treatments, the superior treatment for removing profenophos residues was KAU veggie wash (0.66) and next best treatment was common salt (0.68) which was statistically on par with KAU veggie wash. These treatments were followed by vinegar (0.94), tamarind (1.06) and turmeric (1.19), these three treatments did not show any significant variation. However, water (1.38) was the least effective treatment. In removal of ethion residues KAU veggie wash (0.64) removed highest amount of residues. Even though it was highest in removal of ethion, it was statistically on par with tamarind (0.90) and common salt (0.98). These treatments

Table 2. Recovery and repeatability of organo phosphate insecticides in amaranth at different fortification levels

Sl. No	Insecticides	Level of fortification					
		LOQ (0.05 mg kg $^{-1}$)		5 x LOQ (0.25 mg kg $^{-1}$)		10 x LOQ (0.5 mg kg $^{-1}$)	
		Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)
1	Dimethoate	93.39 ± 6.19	6.63	95.72 ± 2.33	2.44	87.86 ± 15.28	17.39
2	Malathion	91.41 ± 8.83	9.66	95.24 ± 2.23	2.35	80.92 ± 8.72	10.78
3	Chlorpyriphos	92.07 ± 6.43	6.98	97.86 ± 1.52	1.55	88.60 ± 11.61	13.11
4	Quinalphos	86.65 ± 0.77	0.88	94.52 ± 2.41	2.55	87.88 ± 10.41	11.84
5	Profenophos	91.81 ± 4.59	5.00	95.66 ± 0.96	1.00	92.26 ± 9.54	10.34
6	Ethion	93.51 ± 4.43	4.74	95.31 ± 3.27	3.43	92.00 ± 6.95	7.56

Number of replications at each level (n) = 3; SD = Standard Deviation; RSD = Relative SD

were followed by vinegar (1.20) and turmeric (1.33). Whereas water treated samples contained 1.83 ppm residues.

Decontamination treatments including tamarind (2 %), vinegar (2 %), common salt (1 %) and KAU veggie wash (1%) and cooking process such as washing plus cooking and cooking after washing with KAU veggie wash (1%) showed significant effect in reducing organophosphate insecticide residues from amaranth when compared to dipping in tap water alone. The extent of removal of insecticide residues through dipping in water depend upon the solubility of the insecticides in water and the type of insecticide formulation. The ten insecticides analysed in this study were emulsifiable concentrates (EC) and water miscibility of these formulations were low. After one day of spraying when plants were subjected to dipping in water for 10 minutes followed by three normal washing, a wide range of pesticide residues were removed. When the amount of residues removed in washed samples were compared with those in un processed sample residues, maximum reduction was recorded in the case of malathion (80.56%). Among all the insecticides tested, lowest per cent removal was observed in dimethoate followed by ethion. In the case of dimethoate, systemic nature of the insecticide might be the reason for lower extent of removal. The effectiveness of washing on removal of residues depended upon the location of the pesticide present whereas the surface residues are responsive to washing, systemic residues present in tissue will be less amenable (Holland *et al.,* 1994).

Maximum removal of all pesticide residues was noticed in amaranth plants dipped in KAU veggie wash (1%) for 20 minutes plus washing and cooking and dipping in KAU veggie wash (1%) for 20 minutes followed by washing alone except in the case of chlorpyriphos. In the case of systemic insecticides, washing plus cooking could remove residues to a maximum extent of 86.27 per cent (Veggie wash + cooking) than other treatments. The extent of residue removal by this treatment was higher than dipping in water followed by cooking probably because of ionisation of residues in acidic solution. The pH of veggie wash (1%) was 3.16. These results agree with the observations of Vemuri *et al.* (2015) who reported synergic effect of treatment with acidic solution and cooking which together dislodged 99 to 100 per cent residues of dimethoate, methyl parathion, quinalphos, endosulphan and profenophos. Dipping amaranth plants in 1 per cent KAU veggie wash followed by

Table 3. Extent of removal of organo phosphate insecticides residues from amaranth

TREATMENTS	Mean per cent removal of insecticides (%)											
	Dimethoate		Malathion		Chlorpyriphos		Quinalphos		Profenophos		Ethion	
	Residues (ppm)	% removal	Residues (ppm)	% removal	Residues (ppm)	% removal	Residues (ppm)	% removal	Residues (ppm)	% removal	Residues (ppm)	% removal
T1- Water*	0.66^{e}	49.74^{d}	0.11^{d}	80.56^{c}	0.90^{c}	56.18^{d}	0.67^{b}	51.29^{c}	1.38^{d}	51.78^{d}	1.83^{c}	37.39^{d}
T2-2%Tamarind*	0.42^{c}	67.84^{c}	0.12^{d}	77.71^{d}	1.00	51.05^{e}	0.51^{b}	62.95^{b}	1.06^{c}	63.11^{c}	0.90^{a}	69.04^{b}
T3- 2% Common salt*	0.34^{b}	73.54^{b}	0.09^{c}	83.24^{c}	0.81^{c}	60.66^{c}	0.44^{a}	67.60^{b}	0.68^{b}	76.17^{b}	0.98^{a}	66.43^{b}
T4-1% Turmeric*	0.55^{d}	57.93^{d}	0.11^{d}	79.61^{c}	1.34^{d}	34.56^{f}	0.70^{b}	48.89	1.19^{c}	58.41^{c}	1.33^{b}	54.32^{c}
T5-2% Vinegar*	0.42^{c}	67.80^{c}	0.07^{b}	86.26^{b}	0.07^{a}	96.61^{a}	0.54^{b}	60.47^{c}	0.94^{c}	67.27^{c}	1.20^{b}	58.93^{c}
T6-1% KAU Veggie wash*	0.19^{a}	85.63^{a}	0.05^{b}	90.67^{b}	0.80^{c}	61.20^{c}	0.40^{a}	72.08^{b}	0.66^{b}	77.15b	0.64^{a}	77.93^{a}
T7-1% KAU Veggie wash* + cooking	0.18^{a}	86.27^{a}	0.02^{a}	96.47^{a}	0.27^{b}	86.45^{b}	0.24^{a}	81.36^{a}	0.38^{a}	86.60^{a}	0.63^{a}	78.59^{a}
T8- Washing* + cooking	0.30^{b}	76.94^{b}	0.08^{c}	84.86^{c}	0.80^{c}	61.15^{c}	0.39^{a}	71.62^{b}	0.69^{b}	76.00^{b}	1.10^{b}	62.30^{b}
Untreated	1.32	—	0.55	—	2.06	—	1.37	—	2.87	—	2.92	—
CD (0.05)	0.087	8.330	0.023	5.839	0.107	5.049	0.201	9.556	0.255	9.150	0.508	9.435
MRL (EU)	0.02		0.02		0.05		0.05		0.01		0.01	

* subjected to dipping in treatment solutions for 10 minutes followed by three normal washings

three washings with tap water also could remove residues up to the level of removal observed in dipping in KAU veggie wash (1%) plus cooking. The residue removal ranged from 61 to 90 per cent (Table 3). Whereas dipping in plain water alone removed residues only up to 56 per cent except in the case of malathion (80.56 %). This treatment had significant variation with dipping in water alone for all insecticides removal. The composition and pH may be the reason for the effectiveness (Mathew, personal communication, 2014). No such relevant studies were conducted earlier, but a study conducted by Rasheed (2013) pointed out a good adsorption efficiency (70 - 90 %) of lingo-cellulosic wastes of plant origin like coffee grounds, melon seeds and orange peels for o-nitrophenol and p-nitrotoluene. Thus, it could be inferred that, insecticide residues degraded at such a low pH and got adsorbed on to mucilage/lingo-cellulose fraction of veggie wash.

Up to 96.61 per cent of residues of chlorpyriphos were removed when amaranth plants were subjected to dipping in vinegar (2 %) for 10 minutes followed by three normal washing with tap water. Vinegar was found as the better option for chlorpyriphos sprayed amaranth plants as it removed up to 40 per cent more residues when compared to simple washing with tap water. Highest removal of organophosphate insecticides tested was in the case of chlorpyriphos (96.61%) whereas only 50 per cent of residue was removed by dipping in water. At the same time, no treatment other than vinegar (2%) could remove chlorpyriphos up to 90 per cent. The percentage of removal of the organophosphate group of insecticide was maximum in vinegar and this was attributed by polar nature of the insecticide belonging to this group. Varghese (2011) reported that the polar nature of insecticides is the deciding factor in removal by vinegar. These results agreed with those obtained by Nair (2013) who reported that dipping of curry leaf in 2 % vinegar for 15 minutes resulted in up to 93 per cent of organo phosphate residues and up to 66 per cent residue removal at one day after spraying.

The combination of washing with water (dipping of amaranth plants in water for 10 minutes) and cooking for 10 minutes (closed pan) had given satisfactory removal of residues of organophosphate insecticides. These results may be influenced by the physico-chemical properties of the pesticides when subjected to heat treatment. Abou-Arab (1999) found that home canning reduces organophosphates more than organo chlorine pesticide residue levels. The synergic effect of washing and cooking resulted in 39 to 100 per cent removal of pesticide residues from different food samples (Yang *et al.,* 2012). The loss of pesticide residue during heat processing may be due to evaporation, co-distillation., thermal degradation which vary with the chemical nature of the individual pesticide (Sharma *et al*., 2005 and Balinova *et al.,* 2006)

In the case of 2 % common salt treatment the results agree with those of Nair *et al.,* (2014) who reported that up to 68 per cent of organophosphate and 50 per cent of synthetic pyrethroid insecticide residues were dislodged in okra by subjecting to 2 per cent common salt for 15 minutes. The cause and effect of the reduction in 2 % NaCl washing solutions is still not known and needs further investigation. Dipping of amaranth plants in tamarind (2 %) solution for 10 minutes followed by three washings with plain water also removed impartially good amount of residues. Singh *et al*. (2007) reported that tamarind pulp had significant amount of organic acids, of which tartaric acid (98 %) is the major one having a pH of 2.7. Varghese and Mathew (2013) reported that 2 % tamarind solution was the best decontaminating solution in removing residues of spiromesifen (90.03 %) and propargite (96.69 %) from green chilli fruits. In the case of chlorpyriphos, turmeric (2 %) was inferior (34.56 %) over dipping in water (56.18 %) and superior over dipping in water (37.39 %) in the case of ethion (54.32 %). These results were not in agreement with the findings of Vijayasree *et al.,* (2012) and Nair (2013) who reported that turmeric solution (1%) was effective in removal of insecticide residues from curry leaves and okra respectively.

The efficiency of treatments differed with respect to different insecticidal chemistries and also with the properties of commodity tested. The effect of processing depends upon many factors such as water-octanol partition coefficients, water solubility, heat stability, vapour pressure etc. In all above treatments more removal noticed in organophosphate insecticide residues than in synthetic pyrethroid insecticides it may be because of higher solubility for organophosphate insecticides than synthetic pyrethroids and also because of polarity of compound (PPDB, 2015). Washing could remove more effectively in the case of surface residues. Washing is very effective in removal of residues located on surface of commodity. In the case of surface residues thermal treatment is also effective. This was supported by results of Dikshit (2001). From the above results it is clear that dipping in 1 per cent KAU veggie wash for 20 minutes followed by cooking and dipping in 1 % KAU veggie wash for 20 minutes followed by washing (without cooking) are recommendable treatments to remove significant amounts of pesticide residues from amaranth.

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Influence of meteorological factors on population build-up of spotted pod borer, M*aruca vitrata* Geyer in yam bean under agro-climatic zone I of North Bihar

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ABSTRACT: Population build-up studies of spotted pod borer, *Maruca vitrata* Geyer, on yam bean in relation to meteorological parameters *viz;* average ambient temperature, relative humidity and rainfall revealed that the pest was active between the second week of October to last week of December, while web formation abruptly stoped after third week of November. It attained and maintained its peak activity during November in both seasons recording a mean larval population ranging 9.51 to 17.51 and 11.31 to 19.31 per flower shoot while number of webs ranged from 1.59 to 3.00 and 1.73 to 3.68 webs per flower shoot during 2009-10 and 2010-11, respectively. Pest population build-up was favoured by a decline in average maximum and minimum temperature (from 30.15 to 26.55^{0}C and 16.25 to 12.10^{0}C, respectively) and in relative humidity at 7 am and 2 pm (96.30 to 94.70 per cent and 50.90 to 54.40 per cent respectively). No significant correlation existed between the larval and webs population with the factors, except the relative humidity at 2 pm which indicated negative but significant effect on larval and webs population.

KEY WORDS: *Maruca vitrata,* population build-up, temperature, humidity and rainfall

INTRODUCTION

Root and tuber crops are known to be the energy banks of nature serving either as primary or secondary staple food, meet the calorie needs of about one fifth of world's population. As such the tuber crops play a vital role in the food security, hunger reduction and poverty elimination. Amongst, yam bean (*Pachyrhizus erosus* L.) occupies an important place next to sweet potato and is being widely grown in uplands of Bihar, West Bengal (W.B), Uttar Pradesh, Odisha and Jharkhand. It is popularly known as Mishrikand, Kesaur in Bihar, Sankalu in W.B. and Odisha. Unlike other tuber crops it is leguminous and commercially propagated by seed. Yam bean crop grown for seed purpose, its flower buds, flowers and pods were reported to be infested by a lepidopteran pest identified as spotted pod borer, *Maruca Vitrata* Geyer., with the extent of pod damage due to its being as high as 40.0 per cent in Bihar (Singh *et al.,* 2006). Besides yam bean, it also occurs on many other economically important grain legumes. Among the constituents of pod borer community infesting early pigeonpea, the spotted pod borer, *Maruca testulalis* Geyer, predominantly throughout the crop season and poses serious threat in its cultivation in Bihar (Saxena, 1974; Sinha *et al*., 1979 and Akhauri *et al.,* 1994). No works seems to have been done to find out the relationship between larval population

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and number of webs on yam bean caused by *M. vitrata* and abiotic factors in any part of the country. This necessitated study on the influence of meteorological factors in population build-up of spotted pod borer, *M. vitrata* in yam bean grown under agro-climatic conditions prevailing in North Bihar.

MATERIALS AND METHODS

The yam bean, cv. R.M-1, was grown by following the normal agronomics practices under pesticide free conditions at the research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur (Bihar) in two consecutive crop season *i.e*., 2009-10 and 2010-11. Weekly observations with regards to larval population and number of webs of *M. vitrata* were recorded on randomly selected twenty five plants. The data so obtained were used to work out the mean number of pest larvae per flower shoot. Weekly metrological data on temperature (maximum and minimum) and average relative humidity (%) at 7am and 2pm were obtained from the locally stationed meteorological observatory for the period under study. The quantitative relationship between the weekly mean larval population per flower shoot and the weather parameters *viz;* mean maximum and minimum temperature (^{o}C) and average relative humidity (%) were worked out by using the method of correlation and regression analysis and were expressed in the form of mathematical equations. The quantitative influences of the two weather parameters on pest population prevailing during observation as well as one and two weeks prior to the corresponding period of observations were also worked out separately for the two crop seasons and finally on pooled basis.

RESULTS AND DISCUSSION

A comparative examination of the data presented in Table-1, revealed that larval population of *M. vitrata* remarkably fluctuated to changing abiotic factors. The mean larval population was found to increase progressively from 0.53 to maximum 22.00 larvae per flower shoot during the period between the 41st standard week to 47th standard week when the average maximum and minimum temperature decreased from 31.55^{0}C to 27.20^{0}C and from 21.85^{0}C to 1.05^{0}C, respectively, whereas average relative humidity at 7 am and 2 pm fluctuated between 94.20 to 95.45 and 60.50 to 44.75 per cent (Table-1). Its population started to decline gradually from 18.14 to 10.94 larvae per flower shoot from 48th standard week to 49th standard week and abruptly declined from 5.09 to 0.17 larvae per flower shoot in 50th and 52th standard week, respectively. It could also be noted that the mean number of webs per flower shoot in the beginning was low (0.37 webs/flower shoot) in 41st standard week which gradually increased and attained its peak (3.34 webs/flowers shoot) in 47th standard week.

The correlation coefficient (r) between the mean larval and webs population of *M. vitrata* per flower shoot on yam bean cv. R.M-1 and the environmental factors revealed that maximum temperature (r = -0.229), minimum temperature (r = -0.093) and rainfall (r = -0.309) showed negative but non-significantly influenced the mean number of larvae per flower shoot, while relative humidity at 2pm showed negative but significant effect with correlation coefficient value of -0.518 (Table-2). The mean number of webs per flower shoot showed positive but non-significant correlation with maximum and minimum temperature (r = 0.124 and 0.024, respectively) while, remaining abiotic factors *viz;* relative humidity at 7 am, 2 pm and rainfall showed negatively but non-significant effect on mean number of webs per flower shoot (r = -0.349, -0.402 and -0.215, respectively).

It may be further seen in Table-3 that the coefficient of determination (R^2) although varied from one year to another, its value on pooled basis gave an indication that the maximum and minimum temperature, relative humidity at 7 am, 2 pm and rainfall together contribute 51.70 and 52.00 per cent towards the changes in larval population and number of webs on flower shoot, respectively.

No work seems to have been done to find out the relationship among larval population, number of webs per flower shoot of yam bean caused by *M. vitrata* and abiotic factors in any part of the country.

Table-1. Population fluctuation of spotted pod borer, *Maruva vitrata* Geyer, in relation to seasonal changes during 2009-10 and 2010-11

Month	Standard week	Crop season	Mean no of larvae/flower shoot	Mean no. of webs/ flower	Weather factors				
					Average temperature (°C)		Average relative humidity (%)		Rainfall (mm)
					Maximum	Minimum	7AM	2PM	
September	38	A	0.00	0.00	30.50	25.00	94.70	79.50	4.4
		B	0.00	0.00	32.60	25.30	94.50	70.20	82.6
		C	0.00	0.00	31.55	25.15	94.60	74.85	43.50
	39	A	0.00	0.00	32.50	24.00	94.40	63.40	-
		B	0.00	0.00	33.70	25.50	90.70	65.40	-
		C	0.00	0.00	33.10	24.75	92.55	64.40	-
October	40	A	0.00	0.00	33.90	23.50	94.40	63.80	-
		B	0.00	0.00	32.20	25.00	92.10	76.70	-
		C	0.00	0.00	33.05	24.25	93.25	70.25	-
	41	A	0.39	0.33	31.50	22.20	95.00	65.50	-
		B	0.67	0.40	31.60	21.50	93.40	55.50	-
		C	0.53	0.37	31.55	21.85	94.20	60.50	-
	42	A	1.21	0.55	31.10	24.00	92.20	75.50	5.34
		B	1.40	0.57	32.60	18.50	94.10	46.20	-
		C	1.31	0.56	31.85	21.25	93.15	60.85	2.67
	43	A	5.80	1.09	31.20	20.30	97.20	55.70	-
		B	6.76	1.15	31.90	15.10	91.40	38.20	-
		C	6.28	1.12	31.55	17.70	94.30	46.95	-
November	44	A	9.51	1.59	29.30	16.50	90.70	55.40	-
		B	11.31	1.73	31.00	16.00	95.40	46.40	-
		C	10.41	1.66	30.15	16.25	96.30	50.90	-

Month	Standard week	Crop season	Mean no of larvae/flower shoot	Mean no. of webs/ flower	Weather factors				
					Average temperature (°C)		Average relative humidity (%)		Rainfall (mm)
					Maximum	Minimum	7AM	2PM	
	45	A	13.48	2.03	31.00	18.00	93.50	57.50	-
		B	15.67	2.13	30.90	15.80	93.10	42.20	-
		C	14.57	2.08	30.95	16.90	91.90	48.20	-
	46	A	16.68	2.68	30.00	17.70	95.40	48.10	-
		B	18.51	2.81	28.70	19.60	92.50	68.70	-
		C	17.59	2.75	29.35	18.65	93.00	63.10	-
	47	A	20.33	3.00	28.10	15.20	95.20	56.40	-
		B	23.67	3.68	26.30	10.90	95.50	41.40	-
		C	22.00	3.34	27.20	13.05	95.45	44.75	-
	48	A	17.51	-	26.40	13.20	98.00	52.80	-
		B	19.31	-	26.70	11.00	94.20	52.40	-
		C	18.41	-	26.55	12.10	94.70	54.40	-
December	49	A	11.57	-	26.50	11.60	99.40	61.70	-
		B	10.31	-	26.40	10.30	98.70	50.20	-
		C	10.94	-	26.45	10.95	98.35	51.50	-
	50	A	4.91	-	24.80	9.10	98.70	52.00	-
		B	5.27	-	24.80	10.10	98.20	56.00	-
		C	5.09	-	24.80	9.60	98.80	58.85	-
	51	A	2.30	-	23.90	6.80	98.20	51.70	-
		B	2.96	-	24.90	9.50	99.00	51.10	-
		C	2.63	-	24.40	8.15	98.85	51.55	-
	52	A	0.13	-	23.70	5.80	99.20	73.50	-
		B	0.20	-	22.30	6.20	98.80	48.80	-
		C	0.17	-	23.00	6.00	98.50	50.25	-

A= 2009-10, B= 2010-11 and C= Pooled mean of A and B

Table 2. Correlation co-efficient (r) between weather parameters (x) and damage pattern of spotted pod borer (*Maruca vitrata* G.) (Y) during 2009-10 and 2010-11

Meteorological parameters	Larval population (Y_1) (Mean No. larvae/flower shoot)			Number of webs (Y_2) (Mean No. of webs/flower shoot)		
	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
Maximum temperature (X_1)	-0.179	-0.300	-0.229	0.198	0.232	-0.0229
Minimum temperature (X_2)	-0.249	-0.365	-0.312	0.087	0.145	-0.312
Relative Humidity at 7AM (X_3)	-0.156	-0.025	-0.093	-0.381	-0.377	-0.093
Relative Humidity at 2AM (X_4)	-0.574*	-0.362	-0.518*	-0.385	-0.122	-0.518*
Rainfall (X_5)	-0.345	-0.295	-0.309	-0.172	-0.185	-0.309

* Significant at 5%, other are non-significant

Table 3. Co-efficient of determination (R) and multiple regression equations in relation to larvae and webs population of *Maruca vitrata* G. on yam bean cv. R.M-1 versus meteorological parameters at Dholi during 2009-10 and 2010-11

Year	R^2	Regression equation
2009-10	0.634	$Y_1 = 281.893 = 4.0393\ X_1 + 2.3079\ X_2 - 1.4082\ X_3 - 1.0378\ X_4 - 3.0111\ X_5$
2010-11	0.396	$Y_1 = 310.908 - 1.0422\ X_1 - 0.8899\ X_2 - 2.6969\ X_3 - 0.05716\ X_4 + 0.047796\ X_5$
Pooled	0.517	$Y_1 = 392.868 - 3.3281\ X_1 + 1.0522\ X_2 - 2.8283\ X_3 - 0.6533\ X_4 + 0.03053\ X_5$
(b) Meteorological parameters prevail during the period of web formation		
Year	R2	Regression equation
2009-10	0.569	$Y_2 = 24.42 - 0.1024\ X_1 + 0.14157\ X_2 - 0.1458\ X_3 - 0.1564\ X_4 + 0.2580\ X_5$
2010-11	0.212	$Y_2 = 16.89 - 0.02725\ X_1 + 0.010738\ X_2 - 0.1551\ X_3 - 0.1564\ X_4 + 0.2580\ X_5$
Pooled	0.520	$Y_2 = 46.24 - 0.609\ X_1 + 0.3772\ X_2 - 0.2696\ X_3 - 0.1468\ X_4 - 0.002406\ X_5$

However, the present result got a good support from the reports of several workers who determined the relationship between larval population and number of webs caused by *M. vitrata* vis-a-vis the physical factors like temperature, relative humidity and rainfall from India and abroad on various leguminous crops other than yam bean (Akhauri *et al.,* 1996; and Saxena *et al.,* 2007).

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Assessment of population and damage of pulse beetle, *Callosobruchus chinensis* L. on different pulse grains

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ABSTRACT: Population development and grain damage by C. *chinensis* was assessed on eight different host-grains *viz.,* greengram (*Vigna radiata* L.), blackgram (*Vigna mungo* L.), Bengalgram (*Cicer arietinum* L.), redgram (*Cajanus cajan* L.), cowpea (*Vigna sinensis* L.), soybean (*Glycine max* L.), pea (*Pisum sativum* L.) and pillipesara (*Phaseolus trilobus* L.) were estimated. Among all the host-grains, maximum oviposition was recorded in blackgram (7.75 eggs/ 5 g grain). Survival was highest in bengalgram (86.43) and mean developmental period was shortest in greengram (28.47 days) which were on par with that in pillipesara (28.77 days) whereas index of susceptibility was highest in greengram (6.09) and was followed by pillipesara (6.03). The damage in terms of percentage of grains damaged and weight loss of grains increased with increase in storage period. Among all the host-grains bengalgram recorded significantly maximum percentage of grain damage (90.65%) and weight loss of grains (58.55%).

KEYWORDS: *C. chinensis*, green gram, black gram, bengalgram, redgram, cowpea, soybean, pillipesara and pea

INTRODUCTION

Pulses are the "wonderful gift of nature" plays an important role both in Indian economy and diet. Pulses are important as they are rich source of protein, several amino acids, minerals and certain vitamins. India is the largest producer of pulses in the world, in 23.63 million hectares area; India produces 14.76 metric ton pulses (Anonymous, 2007-2008). One of the major constraints in production of pulses is the insect pests which inflict severe losses both in the field and storage. The world storage losses for all grains caused by insect pests of stored products have been estimated about 10% of the annual production which in quantitative terms is over 100 million tons (Anthony and Service, 1983).

According to Raina (1970) among five species of *Callosobruchus*, mainly three species of pulse beetle *viz*., *Callosobruchus chinensis* L., *C. analis* F. and *C. maculatus* F. (Bruchidae: Coleoptera) have been reported to cause damage in different kinds of pulses in India. Among these species, *C. chinensis* is considered to be the most destructive in India and causing severe damage to the extent of 93.33% in different pulse crops (Parsai *et al*., 1989). The first record of adults of the bruchid, *C. chinensis* was reported from stored grains of *Vicia faba* in India.

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MATERIAL AND METHODS

The studies on population development and damage of *C. chinensis* in different host-grains was carried out during the year 2013-2014 in the Department of Entomology, Agricultural College, Bapatla, Guntur district and Andhra Pradesh. The initial adult cultures of the test insect, *C. chinensis* was collected from the Post-harvest technology centre, Agricultural College, Bapatla and were maintained further in the laboratory on the greengram. One pair of freshly emerged adult beetles of similar age were introduced in one plastic jar (45x15 cm) with perforated lids containing 100 g of each host-grain and covered with muslin cloth. The beetles were removed after seven days and the jars containing the host- grains along with eggs were left for further development. The data on population development and damage of *C. chinensis* in different host-grains were analyzed by using one-way analysis of variance (ANOVA).

Assessment of Population Development

Ovipositional Preference: The eggs laid on different host- grains were counted and recorded at seven days after release of the adults by using magnifying lens.

Survival: The survival of the test insect was calculated by the formula suggested by Howe (1971),

$$\text{Survival} = \frac{\text{No. of adults emerged}}{\text{No. of eggs laid}} \times 100$$

Mean developmental period: Mean development period (MDP) is the time taken for 50 percentages of adults to emerge. The developmental period (time to adult emergence) was calculated based on the total number of bruchid that emerged on a given day. It was estimated using the following formulae (Howe, 1971).

$$\text{Mean developmental period} = \frac{d_1a_1 + d_2a_2 + d_3a_3 + \text{————} + d_na_n}{\text{Total number of adults emerged}}$$

Where,

d_1 = Day at which the adults started emerging (First day)

a_1 = Number of adults emerged on d_1^{th} day

Index of susceptibility: It was calculated by the formula given by Dobie (1974) as follows,

$$\text{Index of susceptibility (I)} = \text{Log}_e Y \times 100\ t$$

Where,

Y = Total number of emerged adults

t = Average developmental period of the progeny

Assessment of Damage

Percentage of grains damage: From each host-grain, a representative sample of five grams was taken; the damaged *i.e.* grains with characteristic holes and the total numbers of grains were counted and were subjected to the formula,

$$\text{Grains damage (\%)} = \frac{\text{No. of damaged grains}}{\text{Total no. of grains}} \times 100$$

Percentage weight loss of the grains: Weight loss assessment was conducted from five gram sample in each jar. The grains were separated into damaged and undamaged portions. The grains in each portion were then counted and weighed. This parameter was calculated by the formula given by Adams and Schulten (1978) as follows,

$$\text{Weight loss of grains (\%)} = \frac{(U\ Nd) - (D\ Nu)}{U\ (Nd + Nu)} \times 100$$

Where,

U = Weight of undamaged grains

Nu = Number of undamaged grains

D = Weight of damaged grains

Nd = Number of damaged grains

Moisture content (%): The moisture content in five gram sample of each host-grain was estimated using electronic moisture balance. (M/s Shimadzu Corporation, Analytical and measuring instruments division, Kyoto 604-8511, Japan).

RESULTS AND DISCUSSION

Population development of *C. chinensis* in Different Host- grains

The ovipositional preference of *C. chinensis* was maximum in blackgram (7.75) followed by cowpea (7.50), greengram (7.25), redgram (7.00), pillipesara (6.50) and pea (6.00). While the minimum (5.25) number of eggs laid on bengalgram and soybean which were on par with each other and significantly different from other host- grains. In the similar lines, Wijenayake and Karunarathe (1999) reported that the ovipositional preference of the *C. chinensis* varied with different pulses, except for chickpea, all the other pulses were utilized by the females for egg laying. The number of eggs laid per 40 seeds was observed highest in mungbean (35.1) followed by soybean (32.3) and white (25) and black (27.2) varieties of cowpea. The lowest numbers of eggs (6.9) were deposited on green pea. Oviposition was not observed on chickpea (Table 1).

The per cent survival of *C. chininesis* was significantly different on different host- grains on which it was grown (Table 1). The highest per cent survival was observed in bengalgram (86.43) which was significantly different from other treatments followed by pillipesara (84.78), redgram (83.65), greengram (83.51), blackgram (76.78) and pea (50.34). Redgram and greengram were on par with each other and lowest per cent survival was noticed in soybean (47.64).

The mean developmental period of *C. chinensis* was shortest in greengram (28.47 days) which were on par with pillipesara (28.77 days). The longest developmental period was on soybean (41.65 days) and followed by pea (38.72 days), blackgram (35.82 days), redgram (33.41 days), cowpea (31.26 days) and bengalgram (32.64 days) (Table 1).

Index of susceptibility of *C. chinensis* was highest in greengram (6.09) followed by pillipesara (6.03), cowpea (5.31) and bengalgram (5.07) and lowest in soybean (3.16) followed by pea (3.56), blackgram

Table 1. Population development of *Callosobruchus chinensis* in different host- grains

Treatment No.	Host-grains	Mean no. of eggs/5g *	Per cent survival of the insects**	Mean developmental period (days)	Index of susceptibility
1	Greengram	7.25(2.69)^{ab}	83.51(66.07)^{b}	28.47^{f}	6.11^{a}
2	Blackgram	7.75(2.78)^{a}	80.49(63.82)^{c}	35.82^{c}	4.78^{d}
3	Bengalgram	5.25(2.28)^{c}	86.43(68.40)^{a}	32.64^{d}	5.07^{bc}
4	Redgram	7.00(2.64)^{ab}	83.65(66.16)^{b}	33.41^{d}	4.93^{cd}
5	Cowpea	7.50(2.74)^{a}	76.78(61.19)^{d}	31.26^{e}	5.31^{b}
6	Soybean	5.25(2.29)^{c}	47.64(43.65)^{f}	41.65^{a}	3.16^{e}
7	Pea	6.00(2.45)^{bc}	50.34(45.48)^{e}	38.72^{b}	3.27^{e}
8	Pillipesara	6.50(2.54)^{abc}	84.78(67.04)^{ab}	28.55^{f}	6.03^{a}
SEm (±)		0.10	0.52	0.28	-
CD (P=0.05)		0.28	1.50	0.82	-

*Values in parentheses are square root transformed values
**Values in parentheses are angular transformed values

Table 2. Number of grains damaged (%) in different pulse grains by the infestation of *C. chinensis*

Treatment No.	Host-grains	Number of grains damaged (%) after the release of insects			
		30 DAR	60 DAR	90 DAR	120 DAR
1	Greengram	7.30(15.67)^{c}	22.09(28.03)^{c}	45.38(42.34)^{c}	81.82(64.78)^{b}
2	Blackgram	1.15(6.07)^{f}	4.83(12.68)^{e}	21.44(27.55)^{d}	60.50(51.06)^{d}
3	Bengalgram	12.57(20.77)^{a}	26.83(31.19)^{b}	65.17(53.85)^{a}	90.65(72.40)^{a}
4	Redgram	9.68(18.12)^{b}	15.51(23.19)^{d}	61.70(51.77)^{a}	78.49(62.38)^{c}
5	Cowpea	5.74(13.85)^{d}	40.80(39.70)^{a}	44.62(41.91)^{c}	82.63(65.78)^{b}
6	Soybean	0.00(0.00)^{g}	2.76(9.43)^{f}	14.63(22.48)^{e}	42.47(40.67)^{e}
7	Pea	5.77(13.90)^{d}	17.41(24.58)^{d}	24.39(29.59)^{d}	27.59(31.69)^{f}
8	Pillipesara	1.61(7.25)^{e}	2.60(9.13)^{f}	50.85(45.49)^{b}	77.91(62/02)^{c}
SEm (±)		0.35	0.78	0.91	0.81
CD (P=0.05)		1.02	2.28	2.65	2.37

DAR- Days After Release
Values in parentheses are angular transformed values
In each column values with similar alphabet do not vary significantly at P=0.0

Table 3. Weight loss of grains (%) in different pulse grains by the infestation of *C. chinensis*

Treatment No.	Host-grains	Weight loss of grains (%) after the release of insects			
		30 DAR	60 DAR	90 DAR	120 DAR
1	Greengram	2.94(9.86)^{a}	6.93(15.26)^{b}	28.54(32.29)^{b}	48.94(44.39)^{b}
2	Blackgram	0.21(2.63)^{d}	6.81(15.12)^{b}	13.96(21.93)^{d}	35.41(36.53)^{d}
3	Bengalgram	3.10(10.14)^{a}	4.89(12.78)^{c}	21.45(27.58)^{c}	58.55(49.92)^{a}
4	Redgram	0.50(4.05)^{c}	2.69(9.42)^{d}	22.84(28.55)^{c}	55.79(48.33)^{a}
5	Cowpea	0.56(4.30)^{c}	9.34(17.79)^{a}	33.21(35.19)^{a}	35.43(36.53)^{d}
6	Soybean	0.00(0.00)^{e}	1.24(6.40)^{f}	5.76(13.86)^{e}	18.19(25.21)^{f}
7	Pea	0.52(4.14)^{c}	2.16(8.40)^{e}	4.74(12.56)^{f}	21.22(27.41)^{e}
8	Pillipesara	1.09(5.99)^{b}	2.78(9.59)^{d}	29.94(33.17)^{b}	44.39(41.78)^{c}
SEm (±)		0.16	0.32	0.42	0.57
CD (P=0.05)		0.46	0.93	1.23	1.66

DAR- Days After Release
Values in parentheses are angular transformed values
In each column values with similar alphabet do not vary significantly at P=0.05

Table 4. Moisture content (%) in different pulse grains infested by *C. chinensis*

Treatment No.	Host-grains	Moisture content (%)				
		1DAR	30 DAR	60 DAR	90 DAR	120 DAR
1	Greengram	6.60(14.88)	8.37(16.82)^{a}	9.83(18.26)^{a}	11.61(19.90)^{b}	13.48(21.52)^{b}
2	Blackgram	6.28(14.49)	6.71(15.00)^{b}	7.97(16.38)^{bc}	10.03(18.46)^{d}	13.02(21.14)^{bc}
3	Bengalgram	6.88(15.19)	7.98(16.41)^{a}	9.97(18.39)^{a}	11.19(19.53)^{bc}	12.65(20.83)^{bc}
4	Redgram	6.43(14.67)	8.03(16.46)^{a}	9.78(18.22)^{a}	10.55(18.95)^{cd}	11.23(19.57)^{d}
5	Cowpea	6.78(15.07)	8.13(16.56)^{a}	8.81(17.26)^{b}	10.20(18.62)^{d}	12.10(20.35)^{cd}
6	Soybean	6.03(14.20)	6.13(14.33)^{c}	7.22(15.58)^{cd}	7.95(16.38)^{e}	9.10(17.56)^{e}
7	Pea	5.98(14.15)	5.98(14.15)^{c}	6.80(15.11)^{d}	7.56(15.96)^{e}	8.61(17.06)^{e}
8	Pillipesara	6.88(15.19)	8.23(16.67)^{a}	10.71(19.09)^{a}	13.43(21.49)^{a}	15.56(23.21)^{a}
SEm (±)		0.05	0.17	0.32	0.30	0.40
CD (P=0.05)		NS	0.49	0.93	0.86	1.17

DAR- Days After Release
Values in parentheses are angular transformed values
In each column values with similar alphabet do not vary significantly at P=0.05

(4.78), redgram (4.93). It revealed that greengram, pillipesara, cowpea and bengalgram were preferred host-grains for the development *C. chinensis* (Table 1).

Assessment of Damage

The damage caused by *C. chinensis* on different host-grains was observed in terms of percentage of grains damage and weight loss of grains was increased with increase in storage period of 120 days (Table 2). The highest percentage of grains damage was recorded in bengalgram (90.65) followed by cowpea (82.63) and greengram (81.82), whereas the least grain damage was observed in pea and soybean (27.59 and 42.47) at 120 DAR. The seed damage resulted by *C. chinensis* in different bengalgram varieties varied from 2.00 to 57.33%, being maximum in JG-12 variety (57.33%) and minimum in JG-74 variety (2.00%) (Choudhary and Pathak, 1989). The damage caused by *C. maculatus* was recorded 84% in bengalgram at six months after storage (Gupta *et al*., 1981).

The highest weight loss of grains was recorded in bengalgram (58.55) followed by redgram (55.79) and greeengram (44.39), whereas the least was recorded in soybean and pea (18.19 and 21.22) (Table 3). Thus both percentage of grains damage and weight loss of grains was highest in bengalgram at the end of the storage period. The present weight loss values were in conformity with the findings of Doharey *et al*. (1987), who reported that the significant increase in weight loss in greengram by *C. chinensis* was 0.62, 16.74 and 25.56 % at 30, 60 and 90 days after storage, respectively.

The damage caused by *C. chinensis* in terms of moisture content (%) in different host- grains was presented in the Table 4. As the storage period is increasing the moisture content was gradually and significantly increased in all the host-grains. The moisture content was maximum in pillipesara (15.56) followed by greengram (13.48), blackgram (13.02) and bengalgram (12.65). The increased moisture content in the stored grains is due to increased bruchid population, presence of their excreta and metabolic activity of the bruchid. Thus the increase

in moisture content in different host-grains were in conformity with the findings of Rawat and Srivastava (2011) who reported that the moisture content was maximum in greengram (8.27%) and followed by mothbean (8.2%) while minimum in cowpea (7.6%) after 40 days of storage period.

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Bio-ecology and seasonal incidence of thrips *Scirtothrips dorsalis* Hood in rose

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ABSTRACT: In rose. *Scirtothrips dorsalis* is the dominant insect species causing damage to tender shoots, leaves, buds, flowers and growing tips of rose plants in field and polyhouse. Rose thrips prevailed throughout the flowering period and attained peak during May. Thrips followed an annual pattern in distribution over time. Thrips numbers were more in polyhouse than in open field. Cumulative mean numbers of thrips was more in polyhouse than open fields. Temperature and sunshine hours were found to have positive effect on thrips density. Relative humidity, rainfall and wind velocity had negative effect. Temperature and relative humidity largely influenced seasonal incidence of thrips. In general, the biology was short in field compared to laboratory. Newly emerged adults were yellow with rectangular head. Eyes were very prominent and pink. Total fecundity ranged from 6 to 11 per female. Adult female longevity ranged from 4 to 8 days.

KEY WORDS: *Scirtothrips dorsalis*, rose, bio-ecology, seasonal incidence, field and polyhouse

INTRODUCTION

Rose is being attacked by many insect pests, among which the sucking pest, thrips, *Scirtothrips dorsalis* Hood is one of the serious pests. *Scirtothrips dorsalis* is a major pest of rose (Ananthakrishnan and Jagdish, 1968; Nair *et al*., 1991; Onkarappa and Mallik, 1998). The larvae and adults of *S. dorsalis* caused damage to all the stages of flower (Murugan, 2000). *S. dorsalis* alone can cause 28-95% damage with a population density of 11-33 thrips/flower (Gahukar, 2003). Ayyar *et al*. (1935) reported that thrips population was low in rainy season in Guntur (Andhra Pradesh) and Periyakulam (Tamil Nadu). Dev (1964) reported that *S. dorsalis* occurred almost throughout the year and attained peak during May. Raizada (1965) from Delhi reported thrips peak during spring and early summer. Borah (1987) reported *S. dorsalis* to be active throughout the year. Murugan and Jagadish (2004) reported that the incidence of *S. dorsalis* prevailed throughout the flowering period and attained peak (43.71 thrips per flower) on rose during second fortnight of April. Murugan and Jagadish (2004) also reported that incidence of *S. dorsalis* on rose was significantly positively correlated with maximum temperature and negatively correlated with mean relative humidity. The incidence was positively correlated with minimum temperature and negatively correlated with total rainfall though not significant.

Rao (1929) and Ayyar *et al.* (1935) reported that eggs were laid in the tissues of leaves and shoots.

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Female laid eggs singly in the tissues of buds and young leaves, usually near the mid-rib or in the veins, occasionally in older leaves. Patnaik *et al*. (1986) reported that 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 rose flower buds followed by tender leaves. Murugan (2000) reported that the female laid eggs singly in the tissues on the tender leaves, occasionally into the petals of the flower and older leaves.

Rao (1929), Ayyar *et al*. (1935) and Raizada (1965) reported that the incubation period varied from four to six days. Rao (1929) and Ayyar *et al*. (1935) reported that eggs were white and very minute. Murugan (2000) reported that the egg was kidney or oval shaped and glossy white and measured 0.23 to 0.26 mm in length and width ranged from 0.10 to 0.12 mm. Rao (1929) reported that there were two larval instars, duration of which varied from seven to eight days. Ayyar *et al*. (1935) and Patnaik *et al*. (1986) reported that larval period varied from five to six days. Dev (1964) reported that the newly hatched nymphs were almost white and the colour gradually changed to pale yellow. It was 0.29-0.32 mm long and 0.09-0.10 mm broad across the thorax and had a slender body. The antennae were seven segmented but the three distal segments were not distinct. Second stage nymph was orange yellow and was 0.48-0.59 mm long and 0.13-0.18 mm broad at the widest part of the abdomen. The antennal segments were distinct and were pale orange. The average total duration of the two nymphal instars was 6 days in March, 5.3-5.7 days in April, 5 days in May and 4.3 day in June. Murugan (2000) reported that total larval duration was 3.25 to 6.00 days with an average of 4.60 days. Rao (1929) reported that the pre-pupal period varied from 18 to 24 hours. Murugan (2000) reported that pre-pupal period varied from 0.75 to 1.50 days. The pre-pupa measured about 0.59 to 0.6 mm (length) and 0.21 to 0.2 mm (width). Murugan (2000) reported that pupa was dark yellow with pink eyes. The antennae were directed backwards over head and thorax. The pupa was 0.55 to 0.6 mm (length) and 0.21 to 0.25 mm (width). The pupal period ranged from 3.25 to 4.75 days. Ayyar *et al*. (1935) reported that pupation took place mainly in leaf axils, leaf curls, under the calyx of flower and fruits and in other tender parts of the plants. Murugan (2000) reported that the pupation occurred on the curled portion of the flower petals in laboratory condition. In field, it pupated on leaf litter and soil surface.

Dev (1964) reported that in female body length was 1.05 mm, breath was 0.19 mm; head was 0.06 mm long and 0.12 mm broad; antenna was 0.23 mm long; wing was 0.54 mm long. Body colour was orange yellow. Head was more or less rectangular. Eyes were prominent and deep pink. On the dorsal aspect of 2nd and 7th abdominal segments there were arc like pale brownish patches. Male body was 0.71mm long, 0.14 mm broad; head was 0.06 mm long, 0.11mm broad; antenna was 0.16 mm long; Wing was 3.38 mm long. Male was smaller than female and arc- like brown patches were absent on the abdominal tergites.

MATERIALS AND METHODS

The present study was carried out at Gandhi Krishi Vignana Kendra (GKVK), Lalbagh- a botanical garden, farmer field at Agar, Kanakapura Road and polyhouses at GKVK and Karthik Nursery, Ramohally, Bengaluru (12º 56' N and 77º35' E of 930m amsl) from 2008-2010. The seasonal incidence of *S. dorsalis* was studied in GKVK, Lalbagh and polyhouse at Ramohally. Field samples were collected at fortnightly intervals for two years, from January, 2008 to January, 2010. Ten plants were selected randomly on each sampling date. Observations on number of thrips were recorded from three fully matured flowers representing top, middle and bottom regions. The flowers were beaten on the black card board sheet individually and thrips numbers were counted. The average number of thrips per flower was worked out.

Thrips density was correlated with maximum, minimum and mean temperature, maximum, minimum and mean relative humidity, rainfall, sunshine hours and wind velocity. In case of polyhouse, the data on thrips density was correlated

with the maximum, minimum and mean temperature.

Bio-ecology

Studies on bio-ecology of *S. dorsalis* were made in laboratory during three seasons, summer (May, 2009), rainy (August, 2009) and winter (January, 2009). Tender leaves of rose plant were placed in test tubes (10 cmX2.5 cm) and exposed to oviposition by thrips and the eggs laid were identified by the oval shaped raised translucent surface. Leaves having eggs were kept in tubes. Wet cotton was placed at the bottom to maintain the moisture. The leaves were observed daily under stereo-binocular microscope for emergence of the young ones. Newly hatched larvae were released individually in test tube (10 cmX2.5 cm) on rose petals with the help of camel hair brush. The petals were changed once in two days. Daily observation was made on the stages. The data on durations of different stages viz., egg, Incubation period, first instar larva, second instar larva, pre-pupa, pupa and adult were recorded and range, mean and S.D was calculated. Ten experimental sets were made. Out of which, only five were taken for final result in which all the stages resulted with adult.

To study the longevity of adults and fecundity, freshly emerged female thrips were individually placed in tubes (10 cmX2.5 cm) containing tender leaves. New tender leaves were provided every day after removing the old leaves. The egg laying was noted by translucent raised surface on the leaves and such leaves were observed under stereo binocular microscope. Total such counts were made to know the fecundity of female. The leaves with eggs were kept separately in test tube and observed daily to know the incubation period. The females were individually observed to know the longevity. In *S. dorsalis*, males were rare and reproduction was mainly through thelotoky parthenogenesis.

Lactophenol clearing method (Carlson and Hibbs, 1962) was followed to count thrips eggs. Clearing solution was prepared using 85% lactic acid, phenol, distilled water and glycerin (1:1:1:2). This solution was boiled to the boiling point in a beaker. Rose leaves were immersed and boiled for three minutes in the clearing solution. After boiling, the leaves were immersed in cold lactophenol, so that the eggs were being cleared and later the eggs were counted.

To study the oviposition preference, an experiment was conducted during May, 2009 at laboratory with five replications. In a rearing cage, young leaves (5-20 days), matured leaves (>20-45days) and old leaves (>45days), petals and young buds (5 days old) were placed. In the centre, on a petri dish twenty newly emerged females were released and the materials were observed daily for oviposition. The materials were replaced on alternate days for ten days. The number of eggs laid on each part was separately counted under each replication and pooled and averaged.

In the field, ten samplings were conducted on different dates at weekly interval during May, 2009 to know the oviposition preference. In this, ten plants were sampled. In each plant, five random samples of young leaves, matured leaves, old leaves, petals, young buds were collected and they were observed under microscope for oviposition. The number of eggs laid on each part were separately counted on each observation date and pooled and averaged.

Study on morphological characters

To study different morphological characters and to measure the body dimensions, slides were prepared by adopting the method given by Mound and Pitkin (1972). The specimens were mounted on slide (75 mm long, 25 mm wide and 1.3 mm thick) on a drop of Canada balsam and covered with 13 mm cover slip gently to avoid the bubbles. The cover slip was gently tilted and pressed to spread the wings and arrange the specimen. The morphological characters viz., length and width of egg, first and second instar larva, pre-pupa, pupa, adult, antennae length and wing length of adult were recorded. Totally five experimental sets were made. The average was calculated for each stage. By using a calibrated ocular micrometer, the dimensions of the different stages of the thrips viz., egg, larval instars, pre-pupa, pupa and adults were measured.

Field biology of *S. dorsalis* was studied in rose field and polyhouse at GKVK during 2009. A newly emerged female larva was released on the young shoot and was covered with polythene bag (20X26cm) which was punched for aeration. Before releasing female, all the life stages of the thrips were removed from the young shoot. Twenty five experimental set up were made on bio-ecology of thrips to know fecundity, incubation period, duration of larval instars, pre-pupa and pupal stage and adult. Destructive sampling was followed. The data was pooled and averaged. Mean and S.D were calculated.

Correlation studies were made to find the relationship between the weather parameters and seasonal incidences of thrips, aphids and whitefly. Regression analysis was made to know the effect of abiotic factors on thrips density.

RESULTS

Peak populations of rose thrips (in numbers) were found during May in all the three locations in both the years (Table 1) at Lalbagh. For instance, during 2008-09, 61.8 thrips were recorded per flower during 3rd week of May. In May 1st week, 45.4 thrips were recorded during 2009-10. Similar peak numbers were observed between May1st and 3rd week at GKVK and polyhouse recording the highest thrips numbers viz., 57.8 and 65.4 during 2008-09 and 38.4 and 65.2 during 2009-10, respectively. Thrips density was minimum during 3rd week of November in all locations (8.7 at Lalbagh during 2008-09, 5.4 and 6.4 at GKVK during 2008-09 and 2009-10, respectively and 20.7 at polyhouse during 2008) and all the years except in polyhouse during 2009 where it was during November 1st week. In field as well as in polyhouse, thrips density peaked during May.

In polyhouse, where the environmental conditions are regulated, peak thrips numbers were found during May. The trend in the numbers of thrips was similar throughout the year both in field and polyhouse. These observations suggest that the rose thrips follow an annual pattern in distribution over time. However, when the cumulative mean was worked out and compared, rose thrips number was more in polyhouse (44.30 and 37.93 during 2008-09 and 2009-10 respectively) compared to open field in both the years. When the cumulative mean of Lalbagh (32.10 and 25.96 during 2008-09 and 2009-10 respectively) was compared to GKVK (26.31 and 19.96 during 2008-09 and 2009-10 respectively), it was noticed that the mean number of thrips were more in Lalbagh compared to GKVK.

Correlation coefficients indicated that there was significant positive correlation between maximum temperature (r = 0.722 and 0.802; 0.572 and 0.758; 0.515 and 0.784 for GKVK, Lalbagh and polyhouses during 2008-09 and 2009-10, respectively) and thrips density at all the three locations during both the years. With minimum temperature, there was positive correlation at three locations during both the years (r = 0.008 and 0.347 at GKVK, 0.137 and 0.241 at Lalbagh and 0.076 and 0.317 at polyhouse during 2008-09 and 2009-10, respectively) though they were not significant (Table-2).

Mean temperature was positively correlated with the thrips density in the three locations during both the years. When maximum relative humidity was correlated with thrips density during both years in fields, they were negatively correlated, r value being -0.334 and 0.-0.432 at GKVK, -0.501 and -0.412 at Lalbagh during 2008-09 and 2009-10, respectively. In Lalbagh during 2008, maximum relative humidity was positively and significantly correlated with thrips density (r = -0.501). Rainfall had negative correlation with thrips density at both the locations during both the years, but relation was not significant (r = -0.105 and -0.024 at GKVK, -0.021 and -0.199 at Lalbagh during 2008-09 and 2009-10, respectively). When thrips density was correlated with sunshine hours, they were positively correlated at both the locations during both years, even though the relation was not significant (r = 0.376 and 0.349 at GKVK, 0.232 and 0.360 at Lalbagh during 2008-09 and 2009-10, respectively). Wind velocity and thrips density had negative correlations at both the locations during both the years. In Lalbagh during 2009, they were

Table 1. Seasonal incidence of rose thrips, *Scirtothrips dorsalis* Hood 2008-10

Date/ Month	** Thrips numbers/ flower					
	Lalbagh		GKVK		Polyhouse	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Jan, 1st week	20.4	13.8	11.2	9.0	25.4	30.8
Jan,3rd week	21.0	12.2	19.0	11.2	25.8	32.2
Feb, 1st week	36.2	15.4	28.8	14.2	41.4	40.8
Feb, 3rd week	34.6	17.6	24.8	20.8	43.6	49.0
Mar , 1st week	42.8	38.4	33.6	31.2	54.6	53.4
Mar,3rd week	47.8	31.4	37.2	27.0	56.4	54.0
April, 1st week	39.4	41.2	35.2	39.6	64.0	58.4
April, 3rd week	51.2	39.8	41.0	37.3	57.2	63.2
May, 1st week	54.8	45.4	51.2	38.4	62.6	65.2
May, 3rd week	61.8	39.6	57.8	39.0	65.4	51.2
June, 1st week	30.8	33.2	27.8	29.0	55.2	39.6
June, 3rd week	28.8	*	24.8	27.0	48.6	38.6
July, 1st week	*	*	19.0	21.8	37.4	31.4
July, 3rd week	*	*	15.2	19.2	28.8	29.0
Aug., 1st week	10.8	12.8	10.8	12.8	27.6	25.4
Aug., 3rd week	15.2	18.8	7.6	9.0	37.2	22.4
Sep., 1st week	22.4	20.4	11.8	13.6	57.0	29.0
Sep., 3rd week	20.4	26.6	15.2	15.2	50.8	32.8
Oct., 1st week	42.6	21.9	19.6	14.8	54.4	29.6
Oct., 3rd week	27.8	28.6	20.8	18.8	64.8	33.3
Nov. 1st week	24.4	10.2	6.3	7.3	18.8	20.7
Nov. 3rd week	8.7	*	5.4	6.4	20.8	23.8
Dec. 1st week	*	*	11.4	5.7	36.0	25.6
Dec. 3rd week	*	*	9.6	10.8	29.4	30.8
Total	641.9	467.3	631.5	479.1	1063.2	910.2
Mean	32.10	25.96	26.31	19.96	44.30	37.93

* No flowers on the plant due to pruning. Hence no observation was made on thrips numbers.
** Average of ten plants. In each plant average no.of thrips per three flowers

significantly and negatively correlated (r = -0.168 and -0.259 at GKVK, -0.440 and -0.530 at Lalbagh, respectively).

Temperature and relative humidity largely influenced the seasonal incidence of rose thrips. Correlation values indicated statistically highly significant to significant relationship between temperature, relative humidity and thrips density.

Regression analysis revealed that seasonal incidence of rose thrips was influenced by weather parameters to an extent of 75.2 per cent and 72.2 per cent at GKVK, 55.2 per cent and 65.9 per cent at Lalbagh and 34.7 per cent and 42.3 per cent in polyhouse condition during 2008 and 2009, respectively (Table 3).

Bio-ecology

Egg

Eggs of rose thrips were bean shaped, tapering at end and white in colour. Incubation period ranged from 7 to 9 days in January, 2009 with mean ±S.D of 7.4±0.45, 5 to 6 days in May, 2009 with mean ±S.D of 5.4±0.55 and 6 to 8 days in August, 2009 with mean ±S.D of 7.0±0.71 under laboratory conditions (Table 4). In the field conditions, incubation period ranged from 5 to 7 days in January,

Table 2. Correlation between number of rose thrips, *Scirtothrips dorsalis* Hood and weather parameters, 2008-10

Weather Parameters	Correlation Values (r)					
	GKVK		Lalbagh		Polyhouse	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Maximum Temperature	.722*	.802*	.572**	.758*	.515*	.784*
Minimum Temperature	.008	.347	.137	.241	.076	.317
Mean Temperature	.264	.731*	.455*	.639*	.289	.702*
Maximum Relative Humidity	-.334	-.432*	-.501*	-.412*	-	-
Minimum Relative Humidity	-.345	-.586*	-.426*	-.397	-	-
Mean Relative Humidity	-.379	-.615*	-.488*	-.443*	-	-
Rainfall	-.105	-.024	-.021	.199	-	-
Sunshine hours	.376	.349	.232	.360	.474*	.311
Wind velocity	-.168	-.259	-.440*	-.530*		

*Significant at 5%

Table 3. Multiple Linear Regression Analysis for seasonal incidence of thrips, *Scirtothrips dorsalis* during 2008-10

Locations	Regression Equation	R2
GKVK-2008-09	Y= 40.782 -0.653 X1 +2.143 X2 -0.731 X3 -0.032 X4 +0.030 X5 -1.714 X6 -0.690 X7	0.752
GKVK-2009-10	Y= 11.901- 0.087 X1 +2.329 X2 -0.357 X3 -0.220 X4 +0.338 X5 -0.063 X6 -0.067 X7	0.722
Lalbagh-2008-09	Y= 92.759- 3.072 X1 +5.438 X2 -1.104 X3 -1.141 X4 +0.148 X5 -2.765 X6 -2.228 X7	0.552
Lalbagh-2009-10	Y= -44.008 -0.514 X1 +8.231 X2 -0.350 X3 -0.055 X4 +0.512 X5 -1.773 X6 -1.861 X7	0.659
Polyhouse, Ramohall Y-2008-09	Y= 37.230 – 2.784 X1 +4.389 X2 -0.703 X3 -0.015 X4 +0.015 X5 -1.172 X6 -0.0.446 X7	0.347
Polyhouse, Ramohall Y-2009-10	Y= 64.921+0.477 X1 +1.853 X2 -0.582 X3 -0.482 X4 +0.879 X5 -0.543 X6 -0.0.082 X7	0.423

Y - Number of thrips X1- Maximum Temperature X2 - Minimum Temperature X3 - Maximum Relative Humidity X4 Minimum Relative Humidity X5 – Rainfall X6 - Sunshine hours X7 - Wind velocity

2009 with mean ± S.D of 5.63±0.86, 4-6 days in May, with 2009 mean ±S.D of 5.25±0.66 and 6 to 7 days in August, 2009 with mean ±S.D of 6.25±0.43. In polyhouse, incubation period ranged from 5 to 7 days, 4 to 5 days and 5 to 6 days during January, May and August, 2009, respectively (Table 5). Egg measured 0.22 to 0.25 mm in length with mean ± S.D. of 0.24±0.01 and 0.09 to 0.11 mm in width with mean ±S.D of 0.10±0.01 (Table 6).

Larvae

There were two larval instars. Newly emerged first instar larva was white in colour, later turned to straw yellow colour. Antenna was seven segmented. Larvae had slender body. Eyes were small with pink colour. Abdomen was ten segmented, tapering posteriorly. Duration of the 1st instar larva ranged from 2 to 3 days in January, 2009 with mean ±S.D

of 2.8±0.45, 2 to 3 days in May, 2009 with mean ±S.D of 2.6±0.55 and 2 to 3 days in August, 2009 with mean ±S.D of 2.8±0.45 under laboratory conditions (Table 4). In the field, duration of the 1st instar larva ranged from 3 to 4 days in January, 2009 with mean ±S.D of 3.37 ±0.48, 2 to 3 days in May, 2009 with mean ±S.D of 2.5±0.55 and 2 to 3 days in August, 2009 with mean ±S.D of 2.5±0.5 (Table 5). In polyhouse, duration of 1st instar larva ranged from 3 to 4 days in January with mean ±S.D of 3.25 ±0.43, 2 to 3 days in May with mean ±S.D of 2.25±0.43 and 2 to 3 days in August with mean ±S.D of 2.25±0.43 (Table 5). First instar larvae measured 0.27 to 0.31 mm in length with mean ±S.D of 0.29±0.02 and 0.1 to 0.13 mm in width with mean ±S.D of 0.11±0.01 (Table 6).

Second instar was orange in colour. Antenna was pale orange with well distinct antennal segments with brown hairs. Duration of second instar larvae ranged from 3 to 4 days in January, 2009 with mean ±S.D of 3.4±0.55, 3 to 4 days in May, 2009 mean ±S.D of 3.2±0.55 and 3 to 4 days in August, 2009 mean ±S.D of 3.4±0.55 under laboratory conditions (Table 4). Second instar larvae measured 0.48-0.55 mm in length with mean ± S.D of 0.51±0.03 and 0.13-0.15 mm in width with mean ± S.D of 0.142 ± 0.008 (Table 6). In the field, duration of the 1st instar larva ranged from 3 to 4 days in January, 2009 with mean ± S.D of 3.37±0.48, 2 to 3 days in May and August with mean ±S.D of 2.5±0.5 (Table 5). In polyhouse, duration of the 1st instar larva ranged from 3 to 4 days in January, 2009 with mean ±S.D of 3.25 ±0.43, 2 to 3 days in May and August with mean ±S.D of 2.25±0.43 (Table 5). Total duration of 1st and 2nd larval instars ranged from 5 to 7 days (Table 4).

In the field, total duration of 1st and 2nd larval instars ranged from 6 to 8 days in January 2009, 5 to 7days in May 2009 and 5 to7 days in August 2009. In polyhouse, total duration of 1st and 2nd larval instars ranged from 6 to 9 days in January, 2009, 5 to 7days in May and August, 2009 (Table 5).

Prepupa and pupa

Both pre-pupa and pupa were non feeding stage of the thrips. Prepupa was yellow in colour with short wing pads reaching 3rd abdominal segment. Prepupal length varied from 0.57-0.59 mm with mean ±S.D of 0.58±0.008 and width ranged from

Table 4. Bio-ecology of *Scirtothrips dorsalis* Hood on rose under laboratory conditions, 2008

Life Stages	January, 2009		May, 2009		Aug, 2009	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Fecundity (Numbers/Female/day)	1-2	1.2±0.45	1-2	1.4±0.55	1-2	1.6 ±0.55
Incubation Period (Days)(IP) 7-8	7.4±0.45	5-6	5.4±0.55	6-8	7±0.71	
I Larval Instar(Days)(IL)	2-3	2.8±0.45	2-3	2.6±0.55	2-3	2.8±0.45
II Larval Instar(Days)(IIL)	3-4	3.4±0.55	3-4	3.2±0.55	3-4	3.4±0.55
Pre-pupa(Days)(Pp)	1-2	1.6±0.55	1-2	1.4±0.55	1-2	1.4±0.55
Pupa(Days)(P)	3-4	3.6±0.55	2-3	2.8±0.45	2-4	3.4±0.89
Adult Female Longevity (Days)	6-7	6.8± 0.45	4-6	5±0.71	6-8	6.8±0.84
Total developmental period (Days) (IP+IL+IIL+Pp+P)		23.41		17.8		18.2
Total Fecundity (Numbers/female)	7-11	9.6±0.54	6-10	7.4±0.63	6-11	7.8± 0.83

Table 5. Field Bio-ecology of *Scirtothrips dorsalis* Hood in rose, 2009

Life Stages	Field, 2009						Polyhouse, 2009					
	January		May		Aug		January		May		Aug	
	Range	Mean± SD	Range	Mean± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean± SD	Range	Mean ± SD
Fecundity (Numbers/Female/day)	2-4	2.87± 0.78	2-4	2.75± 0.66	2-4	2.5± 0.71	3-5	3±1	2-4	2.87± 0.78	2-4	2.62± 0.85
Incubation Period(IP) (Days)	5-7	5.63± 0.86	4-6	5.25± 0.66	6-7	6.25± 0.43	5-7	5.75± 0.66	4-5	4.6± 0.48	5-6	5.37± 0.48
I Larval Instar (IL) (Days)	3-4	3.37± 0.48	2-3	2.5± 0.5	2-3	2.5± 0.5	3-4	3.25± 0.43	2-3	2.25± 0.43	2-3	2.25± 0.43
II Larval Instar (IIL) (Days)	3-4	3.37± 0.48	3-4	3.25± 0.43	3-4	3.5± 0.5	3-5	4± 0.5	3-4	3.25± 0.43	3-4	3.13± 0.33
Pre-pupa(Pp) (Days)	1-2	1.12± 0.33	1-1	1±0	1-2	1.13± 0.33	1-2	1.5±0.5	1-2	1.12± 0.33	1-2	1.37± 0.48
Pupa(P) (Days)	3-4	3.87± 0.33	2-3	2.5±0.5	3-4	3.5±0.5	5-6	5.25± 0.43	2-3	2.38± 0.48	2-4	3±0.5
Adult Female Longevity(Days)	5-7	6.25± 0.66	4-5	4.6± 0.48	5-7	5.75± 0.83	6-7	6.37± 0.48	4-6	5± 0.50	5-7	6.13± 0.78
Total developmental period (Days) (IP+IL+IIL+Pp+P)		17.36		14.85		16.88		19.75		14.09		15.12

0.20-0.21 mm with mean ±S.D of 0.21±0.005 (Table 6). Duration of prepupal period in laboratory, field and polyhouse ranged from 1 to 2 days (Table 5).

Pupa was yellow in colour with pink eyes with antennae directed backwards over the head. Wing pads were reaching eighth abdominal segment. Pupal length varied from 0.55-0.56 mm and width from 0.20-0.23 mm (Table 6). Pupal period ranged from 3 to 4 days in January, 2009 with mean ±S.D of 3.6±0.55, 2 to 3 days in May, 2009 with mean ±S.D of 2.8±0.45 and 2 to 4 days in August, 2009 with mean ±S.D of 3.4±0.89 under laboratory (Table 4). In the field, pupal period ranged from 3 to 4 days in January with mean ±S.D of 3.87±0.33, 2 to 3 days in May with mean ±S.D of 2.5 ±0.5 and 3 to 4 days in August with mean ±S.D of 3.5±0.5 and in polyhouse it ranged from 5 to 6 days in January with mean ±S.D of 5.25±0.43, 2 to 3 days in May with mean ±S.D of 2.38± 0.48 and 2 to 4 days in August with mean ±S.D of 3 ±0.5 (Table 5). Total of pre-pupal and pupal period ranged from 3 to 6 days (Table 4).

Total developmental period from the time of hatching of egg till the adult emergence varied from 23.41 days in January and 17.8 days in May and 18.2 in August under laboratory condition (Table 4). Under field, total developmental period ranged from17.36 days in January, 14.85 days during May and 16. 88 days during August in field conditions and in polyhouse it was 19.75day, 14.09 days and 15.12 days during January, May and August, respectively (Table 5).

Adult

Under field conditions, reproduction was by thelytokous parthenogenesis. Males were very rare. Newly emerged adults were yellow in colour with head rectangular shape. Eyes were very prominent and pink in colour. Adult had three ocelli placed in triangle on the vertex. Antenna was 8 segmented and filiform.

Antenna measured 0.21 to 0.22 mm in length. Abdominal segments are provided with hairs and bristles. On the dorsal side of 2nd to 7th abdominal

Table 6. Morphometric parameters of *Scirtothrips dorsalis* life stages in laboratory (April-May, 2009)

Life Stages	Length(mm)		Width(mm)	
	Range	Mean ± SD	Range	Mean
Female				
Egg	0.22-0.25	0.24 ± 0.01	0.09-0.11	0.10±0.01
1st Instar larva	0.27-0.31	0.29±0.02	0.1-0.13	0.11±0.01
2nd Instar larva	0.48-0.55	0.51±0.03	0.13-0.15	0.14±0.008
Pre-pupa	0.57-0.59	0.58±0.008	0.20-0.21	0.21±0.005
Pupa	0.55-0.56	0.57±0.005	0.20-0.23	0.21±0.01
Adult body	0.9-1.02	0.97±0.06	0.18-0.19	0.19±0.004
Adult Head	0.04-0.05	0.05±0.004	0.10-0.12	0.11±0.007
Antennae	0.21-0.22	0.21±0.005		
Wing	0.52-0.53	0.52±0.005		
Male				
Adult body	0.5-0.6	0.58±0.044	0.12-0.14	0.13±0.008
Adult Head	0.04-0.05	0.05±0.005	0.1-0.1	0.1±0.00
Antennae	0.14-0.15	0.04±0.001		
Wing	3.34 -3.36	03.35±0.54		

segments arc like brownish patches are there. Adult female measured 0.9 to 1.02 mm in length and 0.18 to 0.19 mm in width. The length and width of head ranged from 0.04 to 0.05 mm and 0.10 to 0.12mm, respectively. Adult wing measured 0.52 to 0.53 mm in length (Table 6). Under laboratory, adult female longevity ranged from 6 to 7 days in January with mean ±S.D of 6.8±0.45, 4 to 6 days in May with mean ±S.D of 5 ± 0.71 and 6 to 8 days in August with mean ±S.D of 6.8±0.0.84 (Table 4).

Fecundity per female per day was tested in the laboratory, field and polyhouse conditions during 2009. Numbers ranged from 1 to 2 days in January, May and August with mean ±S.D of 1.2±0.45, 1.4 ± 0.55 and 1.6 ±0.55, respectively (Table 4). Under field, fecundity per female per day ranged from 2-4 days in January, May and August with mean ±S.D of 2.87 ± 0.78, 2.75±0.66 and 2.5±0.71, respectively. In polyhouse, fecundity per female ranged from 3 to 5 days in January with mean ±S.D of 3±1, 2 to 4 days in May and August with mean ±S.D of 2.87±0.78 and 2.6±0.85, respectively (Table 5).

Adult female longevity ranged from 5 to 7 days in January and August, 2009 with mean ±S.D of 6.25±0.66 and 5.75±0.0.83, 4 to 5 days in May with mean ±S.D of 4.6±0.48 days under field conditions. In polyhouse longevity ranged from 6 to 7 days in January with mean ±S.D of 6.37 ±0, 48, 4 to 6 days in May, 2009 with mean ±S.D of 5±0.5 and 5 to 7 days in August, 2009 with mean ±S.D of 6.13±0.0.78 (Table 6).

When total fecundity was studied under laboratory, the numbers ranged from 7-11 days in January with mean ±S.D of 9.6±0.54, 6-10 days in May, 2009 with mean ±S.D of 7.4±0.63 and 6-11 days in August, 2009 with mean ±S.D of 7.8±0.83 (Table 4).

Adult male was smaller than female measured 0.5 to 0.6 mm in length with mean ± S.D of 0.58± 0.04 and 0.12 to 0.14 mm in width with mean ± S.D of 0.13± 0.008. Head length was 0.04 to 0.05 mm with mean ± S.D of 0.05 ± 0.005 and width was 0.1mm. Antenna length was 0.14 to 0.15 mm with mean ± S.D of 0.04±0.001. Adult fore wing measured 3.34 to 3.36 mm in length with mean ±S.D. of 3.35 ± 0.54 (Table 6).

DISCUSSION

Seasonal incidence

Observations on seasonal incidence revealed that thrips occurred throughout the year, except during pruning time, when there were no flowers on plant. Thrips density started developing from December-January, reached peak in April-May, and then started declining during rainy period both in field and polyhouse. After rainy season, again thrips density started developing. It can be concluded that high temperature in April-May favoured the development and multiplication of the thrips. Rains would have washed the thrips to little extent during rainy season. Hence the density count was low during rainy season. These are in confirmatory with Ayyar *et al*. (1935) who reported that thrips population was low in rainy season. Dev (1964) reported that *S. dorsalis* occurred almost throughout the year, attained peak during May. Raizada (1965) reported thrips peak during spring and early summer. Murugan and Jagadish (2004) reported that severe infestation occurred from February-May.

The trend in the number of thrips was similar throughout the year both in open and polyhouse. These observations suggested that rose thrips follow an annual pattern in their distribution over time. However when the cumulative mean was worked out and compared, thrips number was more in polyhouse (43.43 and 37.93 during 2008-09 and 2009-10 respectively) (Table-1 and Figure-1) compared to open field both the years. For the thrips to be higher in number in polyhouse, may due to regulated temperature and humidity that favoured thrips density on rose plant. When the cumulative mean of Lalbagh (32.10 and 25.76 during 2008-09 and 2009-10, respectively) was compared to GKVK (22.71 and 19.98 during 2008-09 and 2009-10, respectively), it was noticed that cumulative mean was more in Lalbagh compared to GKVK. It may be due to the fact that in Lalbagh due to urbanization, the environmental conditions are changed and favoured thrips development compared to GKVK where it is undisturbed from urbanization.

Maximum, minimum and mean relative humidity, rainfall and wind velocity had negative correlations with thrips density. In Lalbagh during 2008, there was significant negative correlation with maximum relative humidity (r = -0.501). This is because of high rains which washed away the thrips. Thrips density was positively correlated with sunshine hours. They were positively correlated at all locations during both the years, even though correlation was not significant. These finding are confirmatory with Patnaik *et al*. (1986) who reported that rainfall and relative humidity were negatively correlated with thrips population but diurnal temperature variation was positively correlated. Murugan and Jagadish (2002) reported that incidence of *S. dorsalis* on rose was significantly and positively correlated with maximum and minimum temperature and negatively correlated with mean relative humidity and total rainfall. Hence, it can be concluded that both temperature and relative humidity largely influence seasonal incidence of rose thrips. Correlation values indicated statistical highly significant to significant relationship between temperature, relative humidity and thrips density.

Regression analysis revealed that seasonal incidence of rose thrips was influenced by weather parameters to 75.2 per cent and 72.2 per cent at GKVK, 52.2 per cent and 65.9 per cent at Lalbagh and 34.7 per cent and 42.3 per cent at polyhouse during 2008 and 2009, respectively. In polyhouse, regression analysis showed less influence of weather parameters (34 to 42%) compared to field (55 to 75%). This may be due to the fact that in polyhouse controlled environmental conditions would have influenced thrips density.

Rainfall, sunshine hours and wind velocity had no direct relationship with thrips incidence. Nevertheless, these factors may indirectly influence seasonal incidence of rose thrips. The correlation and regression analyses indicated that more than one parameter together influenced thrips incidence on rose. Rainfall, sunshine hours and wind velocity may not directly influence, but may have indirect impact via other weather parameters, crop phenology, natural enemies, biotic and abiotic components in rose cultivated ecosystem.

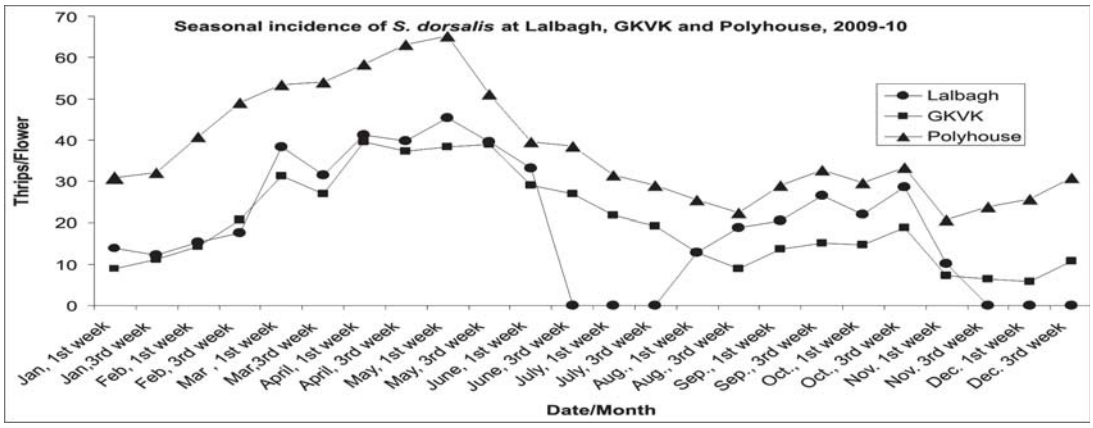

Figure 1. Seasonal incidence of *Scirtothrips dorsalis* at Lalbagh, GKVK and Polyhouse, 2009-10

Bio-ecology

In the field thrips laid eggs singly on young and matured leaves but in laboratory they preferred young leaves and buds. In laboratory, thrips got narrow choice unlike field that made them to prefer young buds. Hence it can be concluded that rose thrips preferred young and matured leaves for oviposition recording maximum egg numbers .Also, it was noticed that it laid more eggs on leaf veins and toward leaf margins. It was in confirmatory with the reports of Dev (1964), Raizada (1965), and Lewis (1973). Murugan (2000) reported that the female laid eggs singly in the tissues on the tender leaves, occasionally into the petals of the flower and older leaves. Number of eggs laid per female ranged from 6 to 11 in laboratory. Eggs of rose thrips were bean shaped, tapering at end and white in colour. Eggs measured 0.22 to0.25 mm length and 0.09 to 0.11 mm in width. Incubation period ranged from 7 to 8 days in January, 2009, 5 to 6days in May, 2009 and 6 to 8 days in August, 2009 in laboratory. In the field condition, incubation period ranged from 5 to 7 days in January, 4 to 6 days in May and 6 to 7 days in August. Dev (1964) reported that incubation period ranged from 7 to 8 days in March, 6 to 8 days in April and 6 to 7 days in May and June. Murugan (2000) reported that incubation period was 3.55 days.

Newly emerged first instar larva was white, later turned straw yellow. First instar larvae measured 0.27 to 0.31 mm in length and 0.1 to 0.13 mm in width. Antenna was seven segmented. Larvae had slender body. Eyes were small with pink colour. Abdomen was ten segmented, tapering posteriorly. Duration of the 1st instar larva ranged from 2 to 4 days. This is comparable with Dev (1964) and Patnaik *et al*. (1986). Murugan (2000) reported that total larval duration was 3.25 to 6.00 days with an average of 4.60 days. Second instar was orange in colour and measured 0.48-0.55 mm in length and 0.13-0.15 mm in breath with well distinct antennal segments with pale orange colour and with brown hairs. Duration of second instar larvae ranged from 3 to 4 days. Total duration of 1st and 2nd larval instars ranged from 5 to 8 days. This is comparable with Dev (1964) and Patnaik *et al*. (1986). Murugan (2000) reported that total larval duration was 3.25 to 6.00 days with an average of 4.60 days. Prepupa was yellow with short wing pads reaching 3rd abdominal segment. Prepupal length was 0.57-0.59 mm in length and 0.20-0.21 mm in width. Duration of prepupal period ranged from 1 to 2 days in laboratory, field and polyhouse.

Pupa was yellow with pink eyes with antennae directed backwards over the head. Wing pad was reaching eighth abdominal segment. Pupal length varied from 0.55-0.56 mm and width from 0.20-0.23 mm. Pupal period ranged from 5 to 6 days in January, 2 to 3 days in May and 2 to 4 days in August in laboratory. In the field conditions, pupal period ranged from 3 to 4 days in January, 2 to 3 days in May and 3 to 4 days in August, 2009. In polyhouse, pupal duration ranged from 5 to 6 days

in January 2 to 3 days in May and 2 to 4 days in August. Larvae preferred to pupate in leaf litter both in field and laboratory.

Total developmental period from the time of hatching of egg till the adult emergence varied from 18.2 to 23.41 days in laboratory, from 14.85 to 17.36 days in field. These findings are comparable with Ayyar *et al*. (1935), Dev (1964), Patnaik *et al.* (1986) and Murugan (2000). Newly emerged adults were yellow with rectangular shaped head. Eyes were very prominent and pink. Adult has three ocelli placed in triangle on the vertex. Antennae were filiform of type with 8 segments. Antennae measured 0.21 to 0.22 mm in length. On the dorsal side of 2nd to 7th abdominal segments arc like brownish patches were present. Adult of female measured 0.9 to 1.02 mm in length and 0.18 to 0.19 mm in width. The length and width of head was 0.04 to 0.05 mm and 0.10 to 0.12 mm, respectively. Adult wing measured 0.52 to 0.53 mm in length. Adult female longevity ranged from 4 to 8 days in laboratory, from 4 to 7 days in field and polyhouse. Fecundity per female per day ranged from 1to 2 in laboratory and 2 to 4 in field. Total fecundity in laboratory ranged from 6 to 11 per female.

It can be concluded that high temperature in April-May favoured the development and multiplication of the thrips. Rains would have washed the thrips to little extent during rainy season. Hence the density count was low during rainy season. These are in confirmatory with Ayyar *et al*. (1935) who reported that thrips population was low in rainy season. Murugan and Jagadish (2004) reported that severe infestation occurred from February-May. Rainfall, sunshine hours and wind velocity had no direct relationship with thrips incidence. Nevertheless, these factors may indirectly influence seasonal incidence of rose thrips. Correlation and regression analyses indicated that more than one parameters together might influence the incidence of thrips on rose.

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Biology of rice leaf mite, *Oligonychus oryzae* (Hirst) (Prostigmata: Tetranychidae)

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ABSTRACT: Biology of *Oligonychus oryzae* was studied under laboratory condition using rice leaf bits. The immature stages were followed by short quiescent stages namely, nymphochrysalis, deutochrysalis and teliochrysalis. Male (9.87) recorded shorter developmental period from egg to adult compared to female (10.47). Both sexual and parthenogenetic reproduction was recorded in *O. oryzae*. Progeny of mated female include male and female in the ratio 1: 3, while parthenogenetic female produced only male progeny. Pre-oviposition period of 0.89 and 1.02 days, oviposition period of 6.27 and 7.31 days and post oviposition period of 2.08 and 1.12 days were recorded, respectively for mated and unmated female. Mated and unmated female recorded fecundity of 21.27 and 17.18 eggs, respectively. Adult recorded longevity of 8.00 10.34 and 12.10 days,respectively for male, mated female and unmated female.

KEY WORDS : Biology, rice leaf mite, *Oligonychus oryzae*, reproductive biology

INTRODUCTION

Mites have emerged as serious pests of rice causing considerable damage, particularly in South India.The rice leaf mite,*Oligonychus oryzae* (Hirst) (Acari: Tetranychidae) and the sheath mite, *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae) are considered as major mite pests of rice (Laksmi *et al*., 2008). Among these, the rice leaf mite, *O. oryzae* is the predominant one.

It was first reported from South India by Cherian (1931). Later it was reported to damage rice from different regions of India. Large number of different stages of the mite colonise the undersurface of the leaves and desap causing white speckles on the upper surface which eventually turn yellow and dry up. When the mite population increases, they also colonise the upper surface of leaves and cause similar damage.A reduction of yield of upto 25 per cent has been estimated due to the severe infestation of this mite (Misra and Israel, 1968). Sporadic occurrence of leaf mite has been reported recently from rice growing areas of Palakkad, Kerala where intensive cultivation of rice is being practiced (Bhaskar and Thomas, 2011). Now the mite is emerging as a regular pest of rice during post monsoon season in the rice growing tracts of Palakkad district of Kerala (Annual Report, 2013). Hence, there is a need to develop a suitable management strategy against this pest which calls for a thorough understanding of the biology of the pest.

MATERIALS AND METHODS

Biology of rice leaf mite, *Oligonychus oryzae* was conducted in the Acarology laboratory, Department of Agricultural Entomology during July-August, 2014 at 27 $\pm$ 3^{0}C and 70.2 $\pm$ 7 per cent relative humidity, using the rice variety Jyothi. *Oligonychus oryzae* collected from infested rice fields of Nenmara, Palakkad district was mass multiplied in the laboratory on thirty days old rice seedlings raised

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in plastic pots after confirming the species identity(Gupta and Gupta, 1994)

The developmental periods of *O. oryzae* were studied using rice leaf bits. (Nayak *et al.*, 2008). Leaf bits of 4×1cm^2 area were cut from leaves of healthy plants maintained in pots in poly house and placed upside down on wet cotton pad in Petri plates of 150 mm diameter that were covered with lid after leaving a slight gap to prevent excessive moisture build up in Petri plate (Plate 1). In each Petriplate, five leaf bits were maintained. Sixty gravid females from the laboratory culture were transferred to individual leaf bit at the rate of two females per bit for oviposition. Six replications were maintained. After 48 hours, one day old eggs were retained for further observations and other eggs and gravid females were removed. Leaf bits were changed once in every five days.The morphology as well as development of immature stages of the mite was observed with the help of a stereo binocular microscope (Leica EZ4 HD with 8x - 35 x magnification) at 2 h interval until they reached maturity.

Newly emerged males and females were maintained on separate leaf bits to determine their longevity. Longevity of mated female was determined by placing a newly emerged female on a leaf bit onto which four males were released and males were removed 24 hours later. Ten replications each were maintained for males, mated females and unmated females to work out the longevity which was expressed as mean days $\pm$ Standard Deviation (SD).

To determine the duration of sexual development of mated female, one female teleiochrysalis was transferred to a leaf bit and four adult males were released onto the leaf bit and allowed to mate with the freshly emerged female. The males were removed 24 hours after the emergence of the female. The reproductive biology of unmated female was also studied by releasing only one teleiochrysalis on to leaf bit that moulted to female. Fifteen replications each were maintained for both mated and the unmated females. Observations on pre-oviposition, oviposition and post-oviposition periods were recorded. The numbers of eggs laid by the mated as well as the unmated females were recorded till death of the female by replacing the old leaf bits with fresh leaf bits at 24 h interval until the female stopped laying eggs.

Sex ratio and hatchability of eggs were studied following the method described by Gotch and Nagata (2001). The eggs laid by each mated as well as unmated female for the first five days were maintained and the viability was determined by counting the number of eggs that hatched out to larvae. The emerging mites were sexed out after reaching adulthood to determine the sex ratio. Ten replications each were maintained for both mated and unmated females.

RESULTS AND DISCUSSION

The life cycle of rice leaf mite consisted of five different stages such as egg, larva, protonymph, deutonymphand adult (Plate 2). In between the stages from larva to adult, short quiescent intervals called nymphochrysalis, deutochrysalis and teleiochrysalis were also observed.

Morphology and developmental duration of immature stages of *O. oryzae*

Eggs were laid singly or in small groups of 10-12 on the under surface of leaf bits by gravid females. The eggs were spherical in shape and transparent. They were like tiny drops of water when freshly laid. Two dark reddish coloured eye spots, which resembled the simple eye of larvae, were clearly visible on the eggs. But the eggs turned dull white in colour and gradually turned to brown prior to hatching. The mean incubation period was 3.80 days (Table 1).

Larva

The eggs hatched out to larvae with 3 pairs of legs. Newly hatched larva was white in colour.It was spherical and small in size and crawled around for sometime. The body colour changed to pale green upon feeding. The simple eyes on the dorsum of propodosoma were clearly distinguishable. The mean larval period recorded was 1.37 days for male and 1.40 days for female (Table 1).

Nymphochrysalis

Nymphochrysalis is the intermediate quiescent

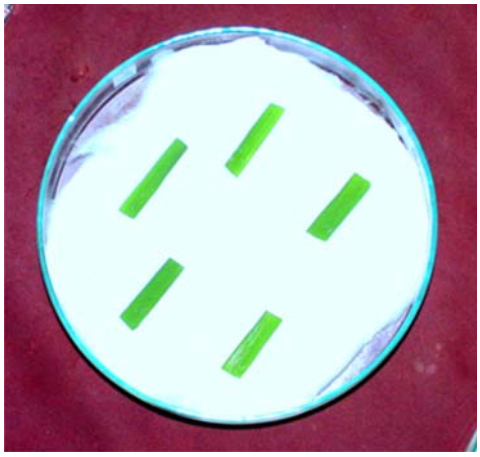

Plate 1. Leaf bits on wet cotton pad in petriplate to study the biology of *O. oryzae*

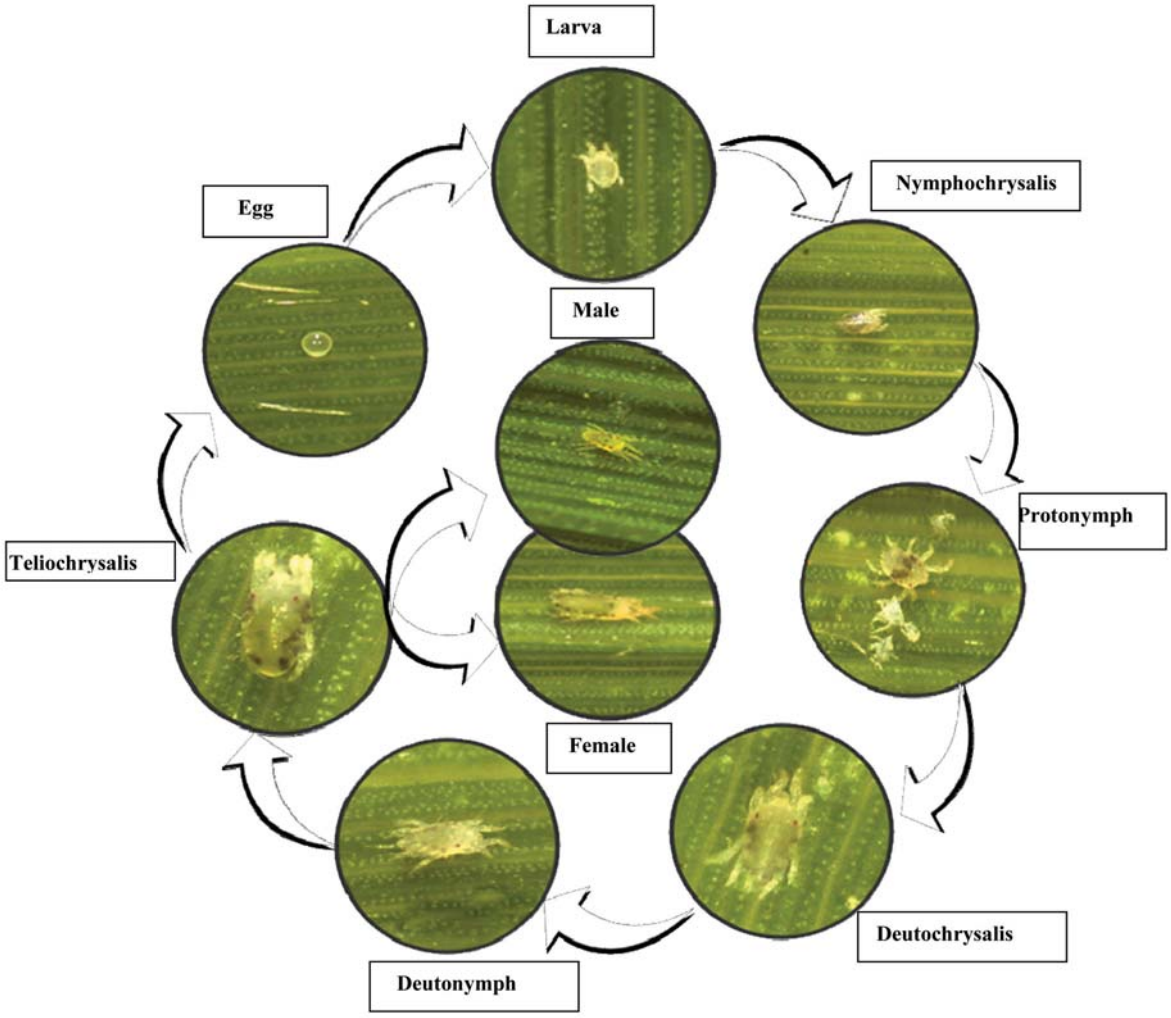

Plate 2. Life cycle of *Oligonychus oryzae*

Plate 3. Adult male of *O.oryzae*

Plate 4. Adult female of *O.oryzae*

stage between larva and protonymph. During this stage, larva stopped feeding, remained attached to leaf surface and entered into quiescence, with the anterior two pairs of legs kept forward and close towards the body and the posterior legs were extended backwards and held close to the sides of opisthosoma. This stage was immediately followed by moulting. Average duration of nymphochrysalis stage was 0.73 days for male and 1.03 days for female (Table 1)

Protonymph

Protonymph stage was the first nymphal stage that came out by splitting open the larval skin. Protonymph was oval shaped, deep amber coloured and larger in size compared to that of larva, with four pairs of legs. The mean protonymph period lasted for 0.91 days for male and 1.04 days for female (Table 1).

Deutochrysalis

Protonymph entered into deutochrysalis which was the second quiescent stage. It remained attached to the leaf surface and on an average, lasted for 0.69 days in the case of male and 1.12 days in the case of female (Table 1).

Deutonymph

Deutonymph was the second nymphal stage and emerged from deutochrysalis after moulting. They were actively moving and feeding. Deutonymph was greyish green in colour when emerged and became dark green later on. During the stage, sexes could be differentiated apparently by body size. Female deutonymph was larger and broader than their male counterpart while male deutonymph was elongate.

Table 1. Developmental duration of *Oligonychus oryzae* on rice

Stage	Developmental period (Mean days ± SD)*	
	Male	Female
Egg	3.80±0.70	3.80± 0.70
Larva	1.37± 0.68	1.40± 0.31
Nymphochrysalis	0.73± 0.40	1.03± 0.90
Protonymph	0.91± 0.35	1.04±0.40
Deutochrysalis	0.69± 0.30	1.12± 0.57
Deutonymph	0.98± 0.28	1.30± 0.37
Teleiochrysalis	1.15± 0.38	1.20± 0.47
Total	**9.87 ±0.72**	**10.47±0.51**

***mean of 50 observations*

Table 2. Adult longevity of *Oligonychus oryzae*

Sex		**Duration (Days ± SD)***
Male		8.00 ± 1.00
Female	Mated	10.34 ± 0.04
	Unmated	12.10 ±0.14

**Mean of ten observations*

The mean deutonymph period was 0.98 days for male and 1.30 days for female (Table1).

Teleiochrysalis

Teleiochrysalis was the third quiescent stage immediately after deutonymph. This period on an average lasted for 1.15 days for male and 1.20 days for female(Table 1)

Adult

Adult mite emerged after the final moult from teleiochrysalis. The mite exhibited sexual dimorphism in the adult stage. Male was smaller in sizewith light green hysterosoma and body tapering posteriorly to a blunt point(Plate 3). Female mite was white, larger and plumper with longer setae all over the body and legs, and turned dark green after mating (Plate 4). Both male and female possessed bright red eye spots on the dorso-lateral propodosoma.

Total developmental period

The total developmental period from egg to adult emergence recorded a mean of 9.87 days for male and 10.47 days for female (Table 1).

Adult longevity

Adult male recorded a mean longevity of 8.00 days while the corresponding figures for mated and unmated females were 10.34 and 12.10 days, respectively (Table 2).

The duration of development of various life stages of *O. oryzae* recorded in the present study was found to be shorter compared to that reported by Nayak *et al*. (2008) who reported development period of 10.58 + 1.50 days for male and 12.64 + 1.57 days for female in a laboratory study at Raichur during kharif season (June to November).

The results indicate that male *O. oryzae* completes development from egg to adult faster than female. This trend was also reported by Nayak *et al*. (2008) in *O. oryzae* where, males on an average took only 10.58 days in comparison to 12.64 days in females. Longer developmental duration in females was also reported in different species of tetranychid mites by several workers (Nazeh and Ashraf, 2012, Rajkumar, 2003). Similarly, the males of two spotted spider mite,*Tetranychus urticae* Koch recorded a shorter development period of 6.73 days compared to 7.52 days in females on okra (Krishna and Bhaskar, 2014).

Table 3. Pre-oviposition, oviposition and post-oviposition period of *Oligonychus oryzae*

Parameters		Duration (Mean ± SD)*
Mating period		1.00 ± 0.36 minutes
Pre-oviposition period	Mated female	0.89 ± 0.03 days
	Unmated female	1.02 ± 0.05 days
Oviposition period	Mated female	6.27 ± 0.06 days
	Unmated female	7.31 ± 0.26 days
Post-oviposition period	Mated female	2.08 ± 0.03 days
	Unmated female	2.12 ± 0.06 days

**Mean of ten observations*

Table 4. Fecundity, sex ratio and egg viability of *Oligonychus oryzae*

	Fecundity (No. of eggs)	Male: Female ratio	Egg viability (%)
Mated female	21.27 ±4.54*	1 : 3	89.67
Unmated female	17.18 ±3.54*	1 : 0	81.69

**Mean of ten observations*

Pre-oviposition, oviposition and post-oviposition period of females

The life span of adult female mites consisted of pre-oviposition period, oviposition period and post-oviposition period and the duration of life span was found to be longer in unmated females. The mean pre-oviposition period in mated and unmated females lasted for 0.89 and 1.02 days, respectively. Oviposition and post-oviposition periods lasted for 6.27 days and 2.08 days in mated females and 7.31 days and 2.12 days in unmated females, respectively (Table 3).

Fecundity, sex ratio and egg viability

Mated females on an average laid 21.27 eggs whereas unmated females laid only 17.18 eggs. Mated female produced a progeny consisting of both males and females in the ratio 1:3, whereas unmated females produced only males. The eggs of *O. oryzae* recorded a viability of 89.67 per cent

for mated females and 81.69 for unmated females (Table 4).

The shorter duration of unmated female in the present study is also in line with previous studies. For instance, the negative influence of mating on the life expectancy of females in tetranychid mites was reported earlier by several workers (Krishna and Bhaskar, 2014; Manujunatha and Puttuswamy 1989).

Laboratory studies carried out at Tamil Nadu Agricultural University on biology of *O. oryzae* at five different temperatures namely 20, 25, 28, 30 and 35°C revealed that the duration of development of various stages as well as total duration of *O. oryzae* decreased with increase in temperature (Radhakrishnan and Ramaraju, 2009). At 20°C, the mite took on an average, 16.10 days for development from egg to adult. The total development period was 13.65, 8.88, 8.35, 8.33 days at temperatures 25, 28, 30 and 35° C, respectively. The present study was carried out at a temperature of 27 + 3°C in the laboratory and hence the development duration (9.87 days for male and 10.47 days for female), which falls between 13.65 and 8.88 days corresponding to 25°C and 28°C respectively, is in agreement with earlier findings. Temperature was also found to have a profound impact on the duration of development stages of the red spider mite,*Oligonychus coffeae* Nietner on tea, as the mite completed its development in a shorter duration of 6.85 days at 32°C, while the same duration was prolonged to 14.47 days at 22.5°C (Mazid *et al*., 2013).

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Efficacy of insecticides against melon fruit fly *Bactrocera cucurbitae* (Coquillett) in bitter gourd

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ABSTRACT: Field experiments conducted to evaluate the efficacy of selected insecticides against melon fruit fly, *Bactrocera cucurbitae* in bitter gourd, revealed that Deltamethrin 2.8 EC + jaggery bait (0.0028 + 0.015 %) was the most effective treatment resulting in minimum fruit infestation (13.15%, 8.61%), as well as lowest number of maggots per fruit (12.58, 9.58). The next superior treatment was deltamethrin 2.8 EC (0.0028 %), azadirachtin 1 EC (0.005 %) and malathion 50 EC (0.1 %) which were on par in terms of reduction of fruit infestation. However, the number of maggots per infested fruits was significantly lower in deltamethrin and azadirachtin treatment as compared to malathion. However, spinosad 45 SC (0.014 %) and dichlorovos 76 SC (0.152 %) were found to be inferior with comparatively lesser reduction in fruit infestation as well as number of maggots per infested fruit as compared to the other treatments, except untreated control. The combination consisting of deltamethrin + jaggery bait (0.0028 + 0.015 %) spray was found to be the most superior.

KEYWORDS: *Bactrocera cucurbitae*, insecticides, jaggery bait, deltamethrin

INTRODUCTION

Fruit flies constitute an important group of pests infesting cucurbitaceous vegetables. Particularly bitter gourd (*Momordica charantia* L.), wherein the fruit fly damage is the major limiting factor in obtaining good quality fruits and high yield. The extent of loss caused by *B. cucurbitae* varies from 30 to 100 per cent depending on the cucurbit species and season (Dhillon *et al*., 2005). The history of fruit fly control with full cover sprays started with inorganic insecticides (eg, lead arsenate) in the early 1900s and spanned the century with a transition to synthetic insecticides such as chlorinated hydrocarbons, organophasphates and synthetic pyrethroids. The advantages of insecticidal cover sprays are that they are affordable, convenient and provide a high level of protection against fruit fly infestation with consistent results (Allwood, 1997). Keeping in view the damage inflicted by melon fly and also residual problems associated with the application of chemicals, there is a need to look at alternative strategies. Hence the present investigation explores emphasises the options for the management of melon fruit fly in bitter gourd with selected insecticides and minimise residual problems.

MATERIALS AND METHODS

Field experiments were conducted on bitter gourd during *kharif* season of 2014 at Division of Horticulture, Gandhi Krishi Vigyana Kendra, University of Agricultural Sciences (UAS),

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Bengaluru, which is located at 12° 58' N, 77° 35' E at an altitude of 930 m MSL. During *rabi* season of 2014-15, the field experiment with the same set of treatments was carried out at Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bengaluru located at 13° 13' N and 77° 48' E at an altitude of 890 m MSL. Sowing of bitter gourd variety 'Arka Harit' was done in plastic trays containing coconut husk and the seedlings were raised under greenhouse conditions. Transplanting of seedlings was done in the field during second week of August, 2014 during *kharif* at UAS, GKVK, Bengaluru and again during second week of November, 2014-15 during *rabi* season at Entomology Division, IIHR, Hessaraghatta, Bengaluru. The experiments was laid out in Randomised Complete Block Design with plot size of 3.5 m X 3 m. The distance between row to row and plant to plant was maintained at 1.0 m X 60 cm. The recommended dose of fertilizers was applied and hand weeding was done as and when required to keep the weeds under check. The crops were raised as per the recommended package of practices of UAS, GKVK, Bengaluru in both the locations during both *kharif* and *rabi* seasons. The treatments were same in both the experiments conducted during *kharif* and *rabi* season viz., T_1: spray of: deltamethrin + jaggery bait spray @ 0.0028 + 0.015 %, T_2: malathion @ 0.1 %, T_3: spinosad 0.014 %, T_4: dichlorovos 0.152%, T_5: azadirachtin @ 0.005 %, T_6: deltamethrin @ 0.0028 % and T_7: untreated control. Each treatment was replicated thrice. The first foliar spray of each treatment was done at the fruit setting stage of bitter gourd. A total of four such foliar sprays were made in case of each treatment at 10 days interval. At each fruit picking, the healthy and infested fruits were sorted out separately and the data was recorded from which the per cent fruit infestation was calculated. Cumulative per cent fruit infestation for each treatment during the entire cropping season was analysed. In addition, the data on the number of maggots per infested fruits in each treatment was also recorded by cutting open 5 fruits per plot (i.e., @ 15 fruits per treatment), the number of maggots were counted in order to know the treatment effect on the maggot population per fruit. The data were subjected to ANOVA to determine impact of treatments on per cent of fruit fly damage and fruit yield. The cumulative fruit yields that were obtained from both *kharif* and *rabi* seasons in respective location and were analysed statistically. Subsequently, the increase in yield over untreated control was also computed, by using the formula

$$\text{Percent increase over control} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in the untreated check}}{\text{Yield in the untreated check}} \times 100$$

The cost benefit ratio was calculated by using the formula:

$$\text{Benefit /Cost ratio} = \frac{\text{Gross returns (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

The results of the present investigation on the efficacy of selected insecticides against melon fruit fly in bitter gourd crop exhibited variable efficacy in reducing the fruit infestation as well as maggot density over untreated control during *kharif* and *rabi* seasons in UAS, GKVK and IIHR, Hessaraghatta, Bengaluru (Table 1). Among the treatments, spray of deltamethrin + jaggery bait, proved highly effective against melon fruit fly resulting in lower fruit infestation (13.15 %, 8.61 %) as well as number of maggots per infested fruit (12.58, 9.58) and fetched significant higher fruit yield (8240 kg/ha, 8170 kg/ha) as compared to the other treatments. These results are supported by the findings of Ranganath *et al*. (2015) who reported that the spray consisting of deltamethrin @ 1ml/l + jaggery bait @ 15g/l coupled with sanitation and cue lure traps recorded lower fruit damage. The bait spray (deltamethrin + jaggery) is applied to broad-leafed plants that serve as refugia for melon fruit fly adults (Ronald and Jayma, 2007). Bait encourages the adults (especially female) to feed on the spray residue and can provide good rates of kill. The next best treatment in the present study was deltamethrin (22.49 %, 15.62 %), azadirachtin (22.91 %, 16.00 %) and malathion (24.00 %, 18.70 %) which were on par in reducing fruit infestation but deltamethrin (19.17, 17.42) and azadirachtin (23.58, 22.75) recorded lesser number of maggots per fruit as compared to the malathion

Table 1. Effect of insecticides on infestation of *Bactrocera cucurbitae* in bitter gourd

Insecticides	Concentration (%)	Fruit infestation (%)		No. of maggot/fruit		Yield (kg/ha)	
		kharif	*rabi*	*kharif**	*rabi**	*kharif*	*rabi*
Deltamethrin 2.8 EC + jaggery Bait	0.0028 + 0.015	13.15 (21.25)[a]	8.61 (17.04)[a]	12.58[a]	9.58[a]	8240[a]	8170[a]
Malathion 50 EC	0.1	24.00 (29.24)[b]	18.70 (25.59)[bc]	29.25[cd]	26.58[cd]	7320[b]	7020[b]
Spinosad 45 SC	0.014	28.71 (32.19)[bc]	22.73 (28.45)[cd]	31.50[cde]	28.50[de]	6960[bc]	6890[b]
Dichlorovos 76 EC	0.152	31.11 (33.91)[c]	24.94 (29.92)[d]	36.33[e]	33.17[ef]	6550[c]	6550[b]
Azadirachtin 1 EC	0.005	22.91 (28.56)[b]	16.00 (23.58)[b]	23.58[bc]	22.75[bc]	7420[b]	7190[b]
Deltamethrin 2.8 EC	0.0028	22.49 (28.49)[b]	15.62 (23.29)[b]	19.17[b]	17.42[b]	7380[b]	7290[b]
Untreated control	-	40.63 (39.57)[d]	30.33 (33.42)[e]	47.25[f]	39.08[g]	4590[d]	4690[c]
CD (P = 0.05)		4.01	2.94	6.37	5.40	0.71	0.78

Note: Figures in the parentheses are transformed (arc-sine) values
*Values in the table are mean number of maggots (15 fruits per treatment) in respective treatments
Significant at 0.05 level

(29.25, 26.58). In Pakistan, Khan *et al*. (1992) observed that the application of deltamethrin 2.5 EC and malathion 57% EC at 10 days interval (4 sprays in total) significantly reduced infestation of *B. cucurbitae* on melon, as compared with untreated control. The results on the effectiveness of deltamethrin are in conformity with the findings of Doharey (1983) who also reported 100 per cent mortality of *B. cucurbitae* in the 96 h at 0.003 per cent concentration of deltamethrin. In bitter gourd, fruit damage by *B. cucurbitae* was effectively reduced upto 16 days after fruit and second spray of deltamethrin (15 g a.i/ha) as compared to malathion (500 g a.i/ha), (Ravindranath and Pillai, 1986). Ranganath *et al*. (1997) had reported the efficacy of neem based biopesticide against fruit flies in terms of reduction of fruit infestation and antioviposition effect. Sharma and Sinha (2009) also found "neem ban" to be most effective against *B. cucurbitae* in bitter gourd than endosulfan. Hassan (1998) tested neem seed kernel extract on persimmon for its efficacy against developing stages of the queensland fruit fly and found it to be most effective against 1st and 2nd instar larvae. The remaining treatments spinosad and dichlorovos also shown good effectiveness in reducing fruit infestation as well as number of maggots/fruit in both seasons compared to untreated control.

Cost - benefit analysis:

The cost benefit ratios were worked out in Arka Harit variety in *kharif* season of 2014. Accordingly it was maximum in deltamethrin + jaggery @ 0.0028 + 0.015 % (1 : 2.45) followed by deltamethrin alone @ 0.0028 % (1 : 2.26), malathion @ 0.1 % (1 : 2.29), dichlorvos @ 0.152 % (1 : 2.01), spinosad @ 0.014 % (1 : 1.98), azadirachtin @ 0.005 % (1 : 1.95) and least in untreated control (1 : 1.67). Similarly, in *rabi* season of 2014-15 the cost benefit

Table 2. Cost benefit ratio of different treatments evaluated against melon fruit fly in bitter gourd during *kharif* season, 2014 at GKVK, Bengaluru

Treatments	Concentration (%)	Marketable fruit yield (kg/ha	Yield increase over control (%)	Yield increase over control kg/ha	Value of additional yield (Rs/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)		Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	Cost benefit ratio
							Other expenditure	Chemical cost + labour charge			
Deltamethrin 2.8 EC + Jaggery	0.0028 + 0.015	8240	79.52	3650	91250	206000.00	74060.00	10000.00	84060.00	121940.00	1 : 2.45
Malathion 50 EC	0.1	7320	59.47	2730	68250	183000.00	74060.00	5600.00	79660.00	103340.00	1 : 2.23
Spinosad 45 SC	0.014	6960	51.63	2370	59250	174000.00	74060.00	13600.00	87660.00	86340.00	1 : 1.98
Dichlorvos 76 EC	0.152	6550	42.70	1960	49000	163750.00	74060.00	7200.00	81260.00	82490.00	1 : 2.01
Azadirachtin 1 EC	0.005	7420	61.65	2830	70750	185500.00	74060.00	21600.00	95260.00	90240.00	1 : 1.95
Deltamethrin 2.8 EC	0.0028	7380	60.78	2790	69750	184500.00	74060.00	7600.00	81660.00	102840.00	1 : 2.26
Untreated control	-	4590	-	-	-	114750.00	74060.00	-	74060.00	49690.00	1 : 1.55

*Bitter gourd fruits were sold at Rs.25 per Kg; Labour charges @ 200 Rs/day (two labour/ha were used for imposing treatments)

Table 3. Cost benefit ratio of different treatments evaluated against melon fruit fly in bitter gourd during rabi season, 2014 -15 at IIHR, Hesarghatta, Bengaluru

Treatments	Concentration (%)	Marketable fruit yield (kg/ha	Yield increase over control (%)	Yield increase over control kg/ha	Value of additional yield (Rs/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)		Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	Cost benefit ratio
							Other expenditure	Chemical cost + labour charge			
Deltamethrin 2.8 EC + Jaggery	0.0028 + 0.015	8170	74.20	3480	87000.00	204250.00	74060.00	10000.00	84060.00	120190.00	1 : 2.42
Malathion 50 EC	0.1	7020	49.68	2330	58250.00	175500.00	74060.00	5600.00	79660.00	95840.00	1 : 2.29
Spinosad 45 SC	0.014	6890	46.90	2200	55000.00	172250.00	74060.00	13600.00	87660.00	84590.00	1 : 1.96
Dichlorvos 76 EC	0.152	6550	39.65	1860	46500.00	163750.00	74060.00	7200.00	81260.00	82490.00	1 : 2.01
Azadirachtin 1 EC	0.005	7190	53.30	2500	62500.00	179750.00	74060.00	21600.00	95260.00	84490.00	1 : 1.90
Deltamethrin 2.8 EC	0.0028	7290	55.43	2600	65000.00	182250.00	74060.00	7600.00	81660.00	100590.00	1 : 2.23
Untreated control	-	4690	-	-	-	117250.00	74060.00	-	74060.00	-	1 : 1.58

*Bitter gourd fruits were sold at Rs.25 per Kg; Labour charges @ 200 Rs/day (two labour/ha were used for imposing treatments)

ratio was maximum in deltamethrin + jaggery @ 0.0028 + 0.015 % (1 : 2.42), followed by deltamethrin @ 0.0028 % (1 : 2.23), malathion @ 0.1 % (1 : 2.20), dichlorvos @ 0.152 % (1 : 2.01), spinosad @ 0.014 % (1 : 1.96), azadirachtin @ 0.005 % (1 : 1.90) and least was in untreated control (1 : 1.58) (Table 2 & 3). Cost benefit ratio forms the ultimate criterion for knowing the superiority of any treatment for crop protection. When jaggery (0.015 %) was used as attractant or bait and mixed with deltamethrin @ 0.0028 % and applied on bitter gourd crop, the cost benefit ratio was highest (1 : 2.45 and 1 : 2.42) in both *kharif* and *rabi* seasons, respectively. This was followed by deltamethrin @ 0.0028 % (1 : 2.26 and 1 : 2.23), malathion @ 0.1 % (1 : 2.29 and 1 : 2.20), dichlorvos @ 0.152 % (1 : 2.01 and 1 : 2.01), spinosad @ 0.014 % (1 : 1.98 and 1 : 1.96), azadirachtin @ 0.005 % (1 : 1.95 and 1 : 1.90) during *kharif* and *rabi* seasons, respectively.

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Biology and rate of food consumption of banana skipper *Erionota torus* Evans (Hesperiidae: Lepidoptera)

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ABSTRACT: Studies on life history of banana skipper, *Erionota torus* indicated female laid eggs in clusters on the under surface of the leaves of the banana plant. Incubation, total larval and pupal period ranged from 7 - 9 days, 26 - 33 days and 10 - 12 days, respectively. Fecundity of the female ranged from 18 -29 eggs. The amount of food consumed increased from II to V instars (10.28, 23.13, 25.01 and 41.56 % respectively). The weight gain in third instar was 33.51% of total larval weight. The values of growth rate (GR) decreased from II to V instar, the values varied between 0.03 and 0.16 g/day/g. Consumption index ranged between 0.64 and 2.15 g/day/g. The indices of food utilization efficiencies namely; AD values ranged from 80.89 to 97.86%, ECI 6.86 to 13.00 % and ECD 7.90 to 15.90 %.

KEY WORDS: Banana, *Erionota torus,* life history and food consumption rate

INTRODUCTION

The banana skipper or banana leaf-roller or red eye skipper, *Erionota torus* Evans, is a common banana pest in continental Southeast Asia, ranging from Sikkim to south China, Burma, Malaya and Vietnam (Corbet and Pendlebury, 1978; Inoue and Kawazoe, 1970: Okolle *et al*., 2006). In India, it appears that *Erionota torus* is the correct identity of the banana skipper which was earlier reported as *Erionota thrax*. It has been reported from Calcutta and Assam (Wynter Blyth, 1957); from Andaman and Nicobar Islands (Veenakumari and Mohanraj, 1991), Manipur (Prasad and Singh, 1987; Singh, 1997), Palani Hills (Ghorpade and Kunte, 2010), Chattisgarh and Madhya Pradesh (Tipple and Ghorpade, 2012), north districts of Kerala (Sivakumar *et al*., 2014), Coimbatore and Erode Districts of Tamil Nadu and Chamrajnagar District (Padmanaban, 2014), Bangalore (Kamala jayanthi *et al*., 2015) of Karnataka. The current outbreaks in South India (Karnataka, Kerala, Tamilnadu, Maharashtra, Andhra Pradesh) may be due to the absence of insecticidal applications coupled with low prevalence of natural enemies and possible climate shifts that would have helped the banana skipper populations to reach damaging thresholds (Raju *et al.,* 2015). The larva causes considerable damage to banana foliage by rolling the leaf while feeding on it (Chiang and Hwang, 1991). The larvae of these butterflies can cause mean defoliation of about 60 per cent, leading to yield loss of about 20 per cent (Okolle *et al*., 2010). During September 2014, there was an out break of *Erionota torus* in Coastal belts of Karnataka (Dakshina Kannada, Udupi and Uttar Kannada) and then spread to Malnad districts of Karnataka. This pest was so far not reported from this region either as a major

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or as a minor pest on banana in costal belt of Karnataka. Review of literature revealed scanty information on biology of *E. torus* on banana. Hence this study was undertaken.

MATERIALS AND METHODS

The study was conducted during July – October 2015 under laboratory conditions at Department of Agricultural Entomology, College of Agriculture, UAHS, Shivamogga (13° 58' N ; and 74° 84'E ; 613 MSL). During the study period, average temperature and relative humidity ranged from 24.8 to 27.3°C and 65 to 81 per cent, respectively.

Sufficient number of larvae and pupae was collected from unprotected banana field and brought to the laboratory. The larvae and pupae were kept in an insect rearing cage of size (30 X 30 X 45 cm) till adult emergence which served as a source of initiating the pure culture under laboratory condition. Ten pairs of newly emerged male and female adults were released in a green house condition (20 ft length X 25 feet width X 20 ft height) and inside that five banana plants (six months old, local banana variety - Ney Pooven (AB group)) were kept for egg laying. Banana inflorescence was kept nearer to banana plant which helped in getting nector for the adult male and female butterflies. Pure culture was started with eggs of the female on banana leaves collected from green house. The collected eggs were kept in a petriplate of having size of 5 cm diameter. The eggs were then examined at an interval of 6 hours for recording time to eclosion. After hatching, the first and second instar larvae were reared individually on fresh banana leaf which served as food and food was changed daily. The larvae were subsequently reared on a weighed quantity of fresh banana leaves supplied daily. Third, fourth and fifth instar larvae were reared in a plastic tub having size of 16 cm bottom diameter X 18.5 cm, top diameter X 22 cm height on rolled fresh banana leaf which served as food and changed daily. The larvae were examined daily for ecdysis. Head cap-sules were collected and kept in 70% ethanol. The length and width of the head capsules of different instars were measured using an ocular micrometer. Adult male and female longevity was recorded by releasing in a rearing cage (30 cm X 30 cm X 45 cm) and 10 per cent honey was provided and was replenished daily.

The morphological characters, body measurements, body weight of each instar and the faeces egested were taken daily. The prepupal period, pupal period, sexing of male and female and the time of adult emergence were also recorded. Daily observations were recorded on initial weight of the leaf, final weight of leaf, larval faeces, and larval weight. Regarding pre-oviposition, oviposition, post-oviposition periods and fecundity for females and adult male and female longevity were also recorded. Observations were made on the morphometry of all the stages *viz.,* egg, grub, pupa and adult by using occular micrometer. Larval performance in terms of food utilization indices were calculated as described by Waldbauer (1968) as:

$$\text{Food consumption index (C.I.)} = \frac{\text{Wt. of food consumed}}{\text{Wt. of instar x No. of feeding days}}$$

$$\text{Relative growth rate (G. R.)} = \frac{\text{Wt. gained by the instar}}{\text{Mean wt. of instar x No. of feeding days}}$$

$$\text{Approximate digestibility (A. D.)} = \frac{\text{Wt. of food ingested - Wt. of faeces}}{\text{Wt. of food ingested}} \times 100$$

$$\text{Efficiency of conversion of digested food (E. C. D.)} = \frac{\text{Wt. gained by the instar}}{\text{Wt. of food consumed - Wt. of faeces}} \times 100$$

$$\text{Efficiency of conversion of ingested food (E. C. I.)} = \frac{\text{Wt. gained by the instar}}{\text{Wt. of food ingested}} \times 100$$

RESULTS AND DISCUSSION

Egg: Gravid female laid eggs in clusters (n = 75) on the under surface of the leaves of the banana plant mostly nearer to the edge of the leaf (Fig. 1-3). Majority of females laid eggs in groups ranged from 11 to 30 (n = 50) but rarely eggs were found singly on upper surface of the leaf (1 to 2 per cent), midrib and sometimes when the infestation was high, adults also found to lay eggs on dried leaf also. Female preferred to lay eggs on top 4th to 6th leaves from

Fig 1. Freshly laid eggs

Fig 2. Eggs turned to pink colour

Fig 3. Eggs laid on midrip one day before hatching

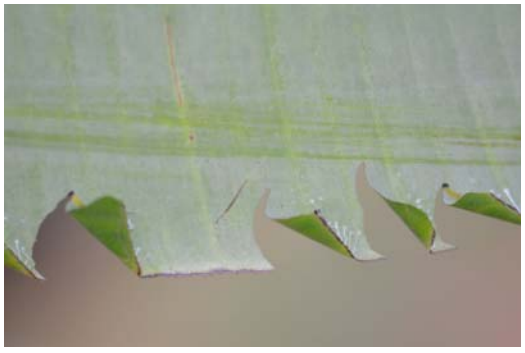

Fig 4. I Instar

Fig 5. III Instar

Fig 6. V Instar

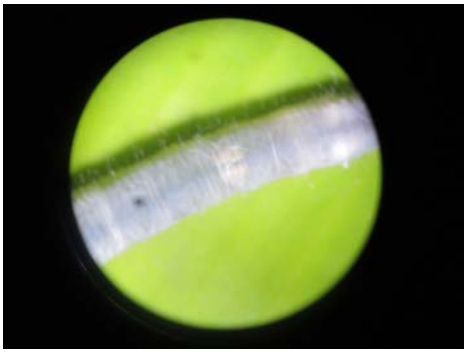

Fig 7. Gonads on VI abdominal segment

Fig 8. Pupa

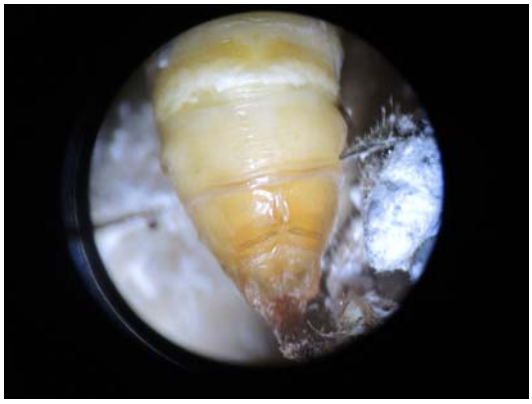

Fig 9. Female Pupa

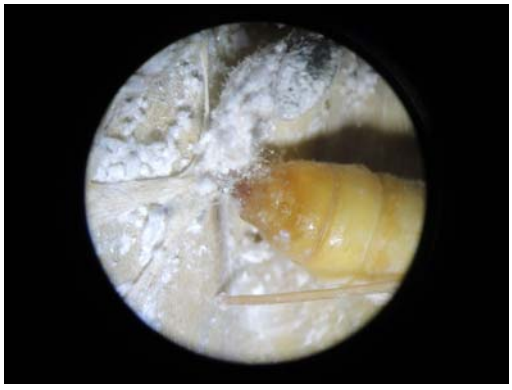

Fig 10. Male Pupa

Fig 11. Male

Fig 12. Female

Fig 13. Adult feeding on inflorescence

top. The eggs were dorsoventrally flattened, initially they were yellow in colour (Fig. 1) for one or two days turned to bright pinkish in colour (Fig. 2). Two days before hatching, the eggs turned to white with black head capsule of the developing larva become visible through the chorion (Fig. 3). Incubation period ranged from 7 - 9 days with a mean of 7.99 days (Table 1). There were 26-29 clearly expressed longitudinal ridges on chorion with a mean of 28.1 ridges. These measurements compare favorably with those of Hoffmann (1935), Waterhouse and Norris (1989) and Bascombe *et al*. (1999), Gunawardana *et al*. (2015) who studied the biology of *E. torus*. However, these results are in contrast with Igarashi and Fakuda (1997) who stated that normally eggs are singly laid on upper surface of the leaf. The average number of longitudinal ridges on chorion with a mean of 28.1 ridges on *E. torus.* However, there is no much variation with the diameter of the egg with respect to *E. torus* and *E. thrax*. But in *E. thrax* a maximum of 22 longitudinal ridges were found in *E. thrax* (Matthew, 2015).

Larval stages: Each larva passed through five distinct instars over a period of 26-33 days. First instar larva nibbled out large oval opening at dorsal part of the egg which first feed on chorion and started feeding from the edge of the leaf parallelly and close with silk through which it started folding the leaf (Fig. 4). First instar larva lasted for 3 - 4 days. Immediately after hatching, larval body was yellow in color later turned to whitish green with dark head. Second and third instars lasted for 2 - 4, 9 -11 days, respectively (Fig. 5). Fourth and fifth

Instars lasted for 5 - 6 and 7 - 8 days, respectively (Fig. 6) (Table 1). The head capsule length of the five instars was 1.29, 1.62, 2.30, 3.16 and 4.62 mm, respectively (Table 2). These findings are in line with Hoffmann (1935) reported on *E. torus*. Fully grown larval body was covered with white waxy matter. The waxy matter may be product from metabolism (Waterhouse *et al.*, 1998). Larva with six ocelli, five ocelli were present nearer to antenna in a semi circular fashion and one ocellus at base of the antenna. The male can be distinguished by the presence pale yellow coloured pair of gonads on dorsal side on sixth abdominal segment (Fig. 7). As the larva grows, it extended the cut and rolled more of leaf into the shelter and larval feaces were found inside the rolled leaf. Older larvae close their rolls or shelters more securely and produce enough waxy powder to be water-repellent. The total larval period of *E. torus* is not much varied from *E thrax* as reported by Mau *et al*. (1980) takes 25 - 30 days, and 20 - 29 days (Khoo *et al*., 1991).

Pupal stage: During the prepupal period of 3 - 4 days, the full-grown larva stopped feeding, turned pale yellow colour and covered with white waxy matter (Fig. 8). The proboscis extended almost up to the cremaster. Pupation took place in rolled leaf itself and packed on both sides. There was not much variation was observed in length of male and female pupa. The female pupal weight ranged 1.71-1.88 g with a mean of 1.80, whereas male pupal weight ranged from 1.41 to 1.74 with a mean of

Table 1. Duration of developmental stages of *Erionota torus* on banana leaves under laboratory condition (mean of 10 observations)

Sl. No.	Life stages		Range (days)	Mean (days)
1.	Incubation period		7 - 9	7.99 ± 0.88
2.	Larval period	I Instar	3 - 4	3.80 ± 0.42
		II Instar	2 - 4	3.20 ± 0.78
		III Instar	9 - 11	9.50 ± 0.70
		IV Instar	5 - 6	5.60 ± 0.51
		V Instar	7 - 8	7.50 ± 0.52
		Total	26 - 33	29.7 ± 0.61
3.	Pre- Pupal period		3 - 4	3.60 ± 0.69
4.	Pupal period		10 - 12	10.9 ± 0.73
5.	Pre oviposivision period		2 - 3	2.40 ± 0.51
6.	Oviposition period		1 - 2	1.40 ± 0.52
7.	Post oviposition period		6 - 7	6.30 ± 0.48
8.	Fecundity/female		18 - 29	27.20 ± 4.70
9.	Male adult longevity		7 - 9	7.90 ± 0.87
10.	Female adult longevity		9 - 12	10.20 ± 1.03
11.	Total life cycle	Male	53 - 67	60.09 ± 3.78
	(egg to adult)	Female	55 - 70	62.39 ± 3.94

Table 2. Length and breadth of adult *Erionota torus* reared on banana leaves under laboratory condition (Mean of five observations)

Details	Length (cm)		Breadth (cm)	
	Range	Mean ± SD	Range	Mean ± SD
Male	6.8 – 7.6	7.27 ± 0.23	2.6 – 3.00	2.76 ± 0.12
Female	6.8 – 7.8	7.35 ± 0.36	2.6 – 3.20	2.86 ± 0.18

Table 3. Measurement of head capsule length and width of different instars of *Erionota torus* (Mean of ten observations)

Stage of insect	Head capsule (mm)			
	Length	Mean ± SD	Width	Mean ± SD
I Instar	1.20 - 1.35	1.29 ± 0.05	1.00 - 1.20	1.10 ± 0.08
II Instar	1.58 - 1.68	1.62 ± 0.04	1.40 - 1.44	1.41 ± 0.02
III Instar	2.14 - 2.48	2.30 ± 0.14	1.84 - 2.40	2.04 ± 0.14
IV Instar	3.10 - 3.20	3.16 ± 0.05	2.25 - 2.82	2.48 ± 0.24
V Instar	4.52 - 4.75	4.62 ± 0.08	3.30 - 3.65	3.45 ± 0.17

1.48 g. The pupal stage lasted for 10-12 days (Table 1). The earlier workers reported the pupal period of *E. thrax* is about 10 days (Mau *et al*., 1980; Waterhouse and Norris, 1989) and 8 - 12 days (Khoo *et al*., 1991). The pupal period was in conformity with the findings of Soumya *et al*., (2013). The pupa was highly sensitive to slight touch (Corbert and Pendlebury, 1978). When it was about to emerge eyes turned complete red colour. Pupal sexing can be done by looking at the genital opening. In female, the genital pore or opening was found ventrally on 8th abdominal segment (Fig. 9). The opening starts with 8th abdominal segment and bisects its caudal margin and the opening extends posteriorly into the anteriar region of the 9th segment. In case of male, shorter genital opening with two distantly elevated tubercles were found ventrally on 9th abdominal segment (Fig. 10). In both the sexes, anal openings were found on 10th abdominal segment.

Adult: Freshly emerged adults were brownish with three yellowish spots on the forewing and hind wings which are of brownish in colour. Based on the abdominal tip males and females were identified (Figs. 11 and 12). There were three yellowish orange spots in the centre of the dorsal side of the forewing of which two or more or less equal in size which other is relatively small. More than 95 per cent of the adults emerged during afternoon hours (n = 50). In banana plantation, the adult butterflies were found actively flying during morning and evening hours and attracted to light and fly rapidly and erratically in evening and morning hours. Adults were also found to feed on nector from banana inflorescence (Fig. 13). Pre-oviposition, ovipositioion and post oviposition period ranged from 2 - 3, 1 - 2 and 6-7 days, respectively. In captivity, each female laid 18 to 29 eggs with an average of 27.20. The total life cycle of male and female ranged from 53 - 67 and 55 - 70 days, respectively (Table 1). Okolle *et al*., (2010) reported that *E. thrax* can lay eggs up to 60 and even more depending on the quality of the food. This variation in fecundity is due to species difference.

The female skipper survived for 10.20 days with a range of 9 - 12 days compared to male (7.9 days)

with a range of 7 - 9 days (Table 1). The average wingspan of female was 7.35 cm with a range of 6.8 to 7.8 cm and 2.86 cm breadth with a range of 2.60 to 3.20 cm. While in male, it was 7.27 cm with a range of 6.80 to 7.60 cm and 2.76 cm breadth with a range of 2.60 to 3.00 cm (Table 3). These results are in line with the findings of Waterhouse and Norris (1989).

Food consumption, growth and utilization: The data for the weight of food consumed and weight gained by the larvae are given in Table 4.The same data could not be collected for instar I due to its small size with consequent difficult in handling. The amount of food consumed increased from instar to instar, the proportion of total food consumed in instars from II to V being 10.28, 23.13, 25.01 and 41.56 %. Thus, there was greatest consumption in instar V. The weight gain corresponded to the food consumption trend of the respective instars. The weight gain in instar III was 33.51% of total larval weight. The values of growth rate (GR) decreased from instar II to to instar V, the values varied between 0.03 and 0.16 g/day/g. Consumption index (CI) values ranged between 0.64 and 2.15 g/day/g. The indices of food utilization efficiencies AD, ECI, and ECD. The range of AD values was 80.89 to 97.86%, that of ECI. 6.86 to 13.00 % and ECD. 7.90 to 15.90 % (Table 4). Adult feeding on the banana inflorescence may helps them to obtain proteins and carbon sources with such nutrient uptake helps in egg productivity. The larval food also appears to be highly nutritional as indicated by the observed values of assimilation efficiency (AD), the efficiency of conversion of ingested food (ECI), and the efficiency of conversion of digested food (ECD) into the body substance.

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Table 4. Mean Food consumption, growth and food utilization efficiencies of *Erionota torus* larva fed with banana leaves (N=10)

Instar	Wt. of food ingested (g)	Wt. of faeces (g)	Wt. gained by larva (g)	Mean wt of the larva during feeding	Number of feeding days	CI (g/day/g)	GR (g/day/g)	AD (%)	ECD (%)	ECI (%)
I*	-	-	-		-	-	-	-	-	-
II	4.22 ± 0.12	0.09 ± 0.01	0.33 ± 0.14	0.49	4.00	2.15	0.16	97.86	7.90	7.81
III	9.49 ± 0.55	1.71 ± 0.06	1.24 ± 0.43	1.21	11.00	0.71	0.09	81.98	15.90	13.00
IV	10.26 ± 0.26	1.96 ± 0.08	0.96 ± 0.41	1.63	6.00	1.04	0.09	80.89	11.50	9.35
V	17.05 ± 2.10	2.72 ± 0.45	1.17 ± 0.43	3.28	8.00	0.64	0.03	84.04	8.10	6.86

* : Indicates no data due to very small size of first instar.
CI = Consumption index: GR = Relative growth rate; AD = Approximate digestibility
ECD = Efficiency of conversion of digested food into body matter
ECI = Efficiency of conversion of ingested food into body matter

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Unusual sex ratio of *Vitessa suradeva* Moore (Pyralinae: Pyralidae: Lepidoptera) attracted to light traps

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ABSTRACT: The present communication is about the unusual sex ratio of *Vitessa suradeva* Moore attracted to light traps. Females are reported to be more attractive to light traps than their male counterpart. Only one male could be collected out of 25 samples over two years of collections in North East India.

KEYWORDS: Lepidoptera, Pyralidae, Pyralinae, *Vitessa suradeva* Moore.

Genus *Vitessa* was established by Moore in 1860 for its type species *Vitessa suradeva* Moore and presently is known by 28 species and 16 subspecies from the Globe with two species, *Vitessa suradeva* Moore and *Vitessa nicobarica* Hampson from India (Munroe and Shaffer, 1980). *Vitessa suradeva* Moore is further known by two subspecies, *Vitessa suradeva suradeva* Moore distributed from North and North East India to Myanmar, Thailand and Vietnam and *Vitessa suradeva rama* Moore distributed from South India, Nicobar to Sri Lanka. The former subspecies is larger than the latter one. Furthermore, both the subspecies can be separated on the basis of their slightly distinct male genitalia. The members of *Vitessa suradeva* Moore, 1860 have the wing markings atypical of Pyralinae but on the basis of external male and female genitalia the group conform to the characterization of subfamily Pyralinae.

The present communication is about the unusual sex ratio of *Vitessa suradeva* Moore attracted to light traps. Females are reported to be more attractive to light traps than their male counterpart. Only one male could be collected out of 25 samples over two years of collections in North East India. In addition to, the photograph of adult, external male and female genitalia of the species under reference is also given. Examples of the studied species were collected with the help of vertical sheet light traps fitted with mercury vapour lamp (160 W) during night time. The collection-cum-survey tours led to the collection of 25 examples of *Vitessa suradeva* Moore from different localities of North East India.

Vitessa suradeva Moore, 1860

Vitessa suradeva Moore, [1860] in Horsfield & Moore, Cat. Lep. Ins. Mus. Nat. East India House 2 : 299

Vitessa formosa Felder & Rogenhofer, 1875 Reise Fregatte Novara, Bd 2 (Abth. 2) (5): pl. 137

Description: Head and thorax golden yellow; 3rd joint of palpi and antennae black; abdomen banded with black and white. Forewings with the base golden yellow; two subbasal metallic black spots; two quadrate black antemedial patches; the medial area greyish white with an irregular medial band of dentate marks enclosing an oval white spot below the costa; outer area black, veins streaked with white. Hindwings white, the outer half bluish black. Male genitalia with uncus curved, base wide flattened, and laterally constricted; valvae with costa incurved for most of the length, apex truncate,

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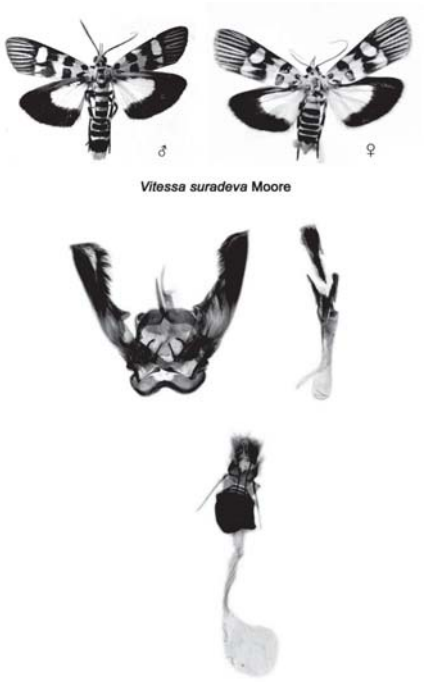
harpae present, saccus broad and notched. Aedeagus broadening towards tip, catena present; vesica with bunches of spines. Female genitalia with corpus bursae pear shaped, membranous; ductus bursae narrow and long; antrum sclerotized, pouch like.

Material examined: **Mizoram**: Mamit, 27. ix. 2013 -6♀; **Sikkim**: Dodak, 05. v. 2014 -1♀; **Meghalaya**: Shilong, 26. viii. 2014 -2♀; Mawsynram, 27. viii. 2014 -3♀, 28. viii. 2014 -4♀, Riat Khwan, 03.ix.2014 -3♀, Cherrapunjee, 04. ix. 2014 -2♀, 1♂, 05. ix.2014 -2♀; Umtasor, 15. ix. 2014 -1♀

Distribution: India: Sikkim, Assam, Hills of South India, Andamans (Hampson,1896), Peechi (Mathew and Menon,1984), Sylhet, Travancore, Anamalai hills (Cotes and Swinhoe, 1889); Sri Lanka; Bangladesh; Myanmar; Thailand; Vietnam (Munroe and Shaffer, 1980).

Host plant: *Dichapetalum gelonioides* (Dichapetalaceae) (Robinson *et al*., 2001)

Discussion: The present inferences are based on a sample of 25 specimens collected through different collection-cum-survey tours in the far flung localities of North East India. The collection-cum-survey tours were conducted in the pre monsoon and post monsoon seasons of year 2013 and 2014. During the collection surveys, *Vitessa suradeva* Moore was collected from the localities like Mamit (Mizoram); Dodak (Sikkim); Shilong, Mawsynram, Riat Khwan, Cherrapunjee, Umtasor (Meghalaya). The study revealed that out of the collected 25 specimens 24, are females and single specimen is of male. The present observation is in contrast to some earlier studies where the authors reported that males of some species are significantly more likely to be recorded at light traps than females (Garris and Synder 2010). But the case of *Vitessa suradeva* Moore is completely different where females outnumbered the males.



Vitessa suradeva Moore

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BOOK REVIEW

Integrated Pest Management in the Tropics

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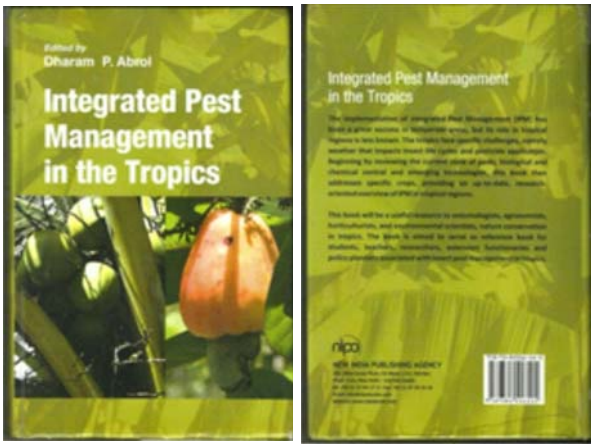

The increase in human population in the coming decades calls for the imperative need to produce more food. However this is beset with a host of problems including the ravages of both insect and non insect pests. Pests cannot be contained by any one method but require integrated pest management strategies. Ecofriendly and sustainable IPM technologies have to be developed, disseminated and implemented on a large scale especially in the tropics. The traditional indigenous technical knowledge on pest control has also to be validated and included in the strategies.

The present book "Integrated Pest Management in the Tropics" in two volumes edited by Dr. Dharam P. Abrol addresses the above issues in a comprehensive manner. It contains 26 diverse chapters written by authors with considerable expertise in their areas of interest. In chapter 1 of volume 1, the editor reviews the pest problems and losses caused by them in the tropics. The emerging pest problems in the tropics with important examples especially in fruit and field crops are explained in chapter 2. Chapter 3 deals with the methods in biological control of crop pests and the bio agents deployed. Biological control will be the cornerstone of IPM programmes in the years to come. The use of chemical pesticides for control of insect pests has been discussed in chapter 4. The authors have explained the use of chemicals for control of major insect pests, proper use of insecticides, insecticide resistance, resistance management, resurgence of pests *etc*. We cannot completely exclude chemicals from IPM as they might have to be applied in pest outbreak situations. The importance of cropping systems and crop diversity as a component of IPM is overviewed with examples in chapter 5. The impact of climate change on crop pests and disease scenario is discussed with examples in chapter 6 whereas in chapter 7, the future components of IPM involving biotechnology and other emerging technologies are briefly overviewed. Chapter 8 contains compilations of affordable technologies for IPM in selected tropical vegetables whereas IPM strategies developed in the tropics for cereals are dealt in chapter 9. The pest problems, various tools of IPM developed for legumes, roots and tubers, banana, citrus, sugarcane, cocoa, tea and coffee are comprehensively covered in chapters 10 to 15 by the respective authors. However IPM technologies in crops like mango have been omitted.

In volume 2, chapter 16 deals with the major pest problems of palms and the IPM measures undertaken in the palm growing countries. Cotton, a fibre crop grown in temperate as well as tropical regions is infested by a number of pest species. The pest problems, IPM technologies, their adoption and related issues like use of Bt cotton have been highlighted in chapter 17. The major pests and IPM methodologies in two important plantation crops *viz;* cashew and rubber have been in chapter18. The role of insect sex pheromones in IPM have been discussed with case studies in chapter 19. Chapter 20 also relates to the application of chemical ecology in IPM. The different types of semiochemicals, its source and function have been listed. Pheromones will have a major role in IPM of economically important crops in the future. More research and development has to be undertaken in this line. Plant chemicals mostly volatiles are important in insect behaviour and insect plant interactions and this aspect finds place in chapter 21. The problems of chemical pesticide abuse are dealt in chapter 22 and the need for alternative and sustainable ecological IPM is promoted by the authors. Chapter 23 exposes the reader to examples of cultural and physical methods in IPM in the tropics.

The role of taxonomy and systematics in providing an essential scientific fool proof basis for IPM especially biological control is stressed in chapter 24. The importance of accurate identification of insect pests and bio control agents in IPM is paramount. The collection of data, methods adopted and statistical analysis to obtain tangible results in IPM experiments are invaluable

and discussed in chapter 25. A brief analysis of the future of IPM in the tropics, the constraints and suggestions to alleviate them is the theme of the last chapter.

The book in two volumes with the foreword of Prof Marcos Kogan, Director Emeritus, Integrated Plant Protection Center, Oregon State University, USA, reiterates the need for IPM to be multidisciplinary, to integrate all tools and practices and to involve all concerned stakeholders. The authors have taken tremendous effort in compiling the information on pests, their management and presenting the same in a lucid manner. The references listed will be useful for deeper insight into the realm of IPM. This book will serve as an invaluable resource to students, researchers, scientists and extension specialists associated with entomology and IPM in agriculture and will be an asset to the Libraries of all the Universities.

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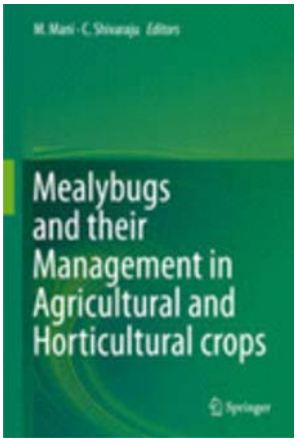
BOOK REVIEW

Mealybugs and their management in Agricultural and Horticultural Crops

Editors: **M. Mani and C. Shivaraju**

Publishers: **Springer**

Publication: **2016**



Mealybugs are common sap feeding pests that infest a wide range of agricultural and horticultural crops. Besides weakening the plants, the honey dew secreted by mealybugs allow the growth of sooty mould, giving the plants a blackened appearance. Severe infestations can reduce plant vigour and lead to stunted growth and premature leaf fall. In India, different species of mealy bugs (viz. *Planococcus citri, Planococcus lilacinus, Maconellicoccus hirsutus, Paracoccus marginatus, Phenacoccus solenopsis* etc.) have become major pests on various crops. Recently, invasive species like *Phenacoccus madeirensis* and *Pseudococcus jackbeardsleyi* have been recorded as serious pests on several host plants. The cassava mealy bug *Phenacoccus manihoti*, one of the most serious pests of cassava worldwide, has recently reached Asia, raising significant concern over its potential spread throughout the region and entering India. The area of infestation include undersurface of leaves, plant stems, entire fruits or fruit clusters, etc. The tendency of mealy bug nymphs and adults to live and multiply in semi-concealed parts of plants and their waxy coating make them "hard to kill" insects using chemical insecticides. Excessive use of insecticides for management of mealybug infestations on horticultural crops can lead to serious issues of pesticide residues, affecting the export market. At this juncture, this book on "Mealybugs and their management in Agricultural and Horticultural Crops" (Edited by M. Mani and C. Shivaraju) is an excellent attempt to compile all available information identification, biology, cytogenetics, population dynamics and management of mealybugs with an emphasis on the Indian perspective. The senior editor Dr. M. Mani has over three decades of experience in mealybug research, especially biological control and has contributed some of the significant initial chapters in the book. The contributing authors of the different chapters have succeeded in presenting information on the basic aspects and also on the seasonal occurrence and management of mealy bugs on different crops.

This book would be highly relevant as a reference book for students, researchers and extension workers and can be recommended as a useful addition in Libraries of all Agricultural Universities, Research Institutes and state Departments of Agriculture and Horticulture.

Dr Chandish R. Ballal

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I, Dr K. D. Prathapan, Secretary, Association for Advancement of Entomology, here by declare that the particulars given above are true to the best of my knowledge and belief.

Sd/-

Vellayani PO, Thiruvananthapuram 695522
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