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POPULATION DYNAMICS AND ON-FARM FRUIT FLY INTEGRATED PEST MANAGEMENT IN MANGO ORCHARDS IN THE NATURAL AREA OF NIAYES IN SENEGAL

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ABSTRACT: The trend of the population of fruit flies follows the dynamic of the rains. This is more perceptible in *Bactrocera invadens* (Drew) than in *Ceratitis cosyra* (Walker). From 350 individuals captured per trap, *B. invadens* seemed to disrupt the presence of *C. cosyra* and the other related fruit fly species. Such behavior is probably due to an interspecific competition and could be the fact that *C. cosyra* dominated emergences from the incubated fruits of alternate host plants up to 87 % even though *B. invadens* was observed.

Integrated pest management (IPM) package was tested which included:

(1) male annihilation using wood blocks soaked in insecticide (malathion 50 EC) and lure (methyl eugenol and terpinyl acetate), (2) protein hydrolysate bait applications (Success Appat at 1 liter per ha) and (3) sanitation (weeding and destroying of the collected fallen fruits by the following practices: using black plastic bags, burying in holes, burning on the ground surface and incinerating with a barrel transformed into incinerator).

Aim was to control fruit flies in mango orchards. Results showed a control as an inferred improvement in fruit fly infestations in the treated plot up to 83% compared to the untreated. From all above particular method implemented to destroy collected fruits, a reinforced black plastic bag would be recommended for popular use.

When we compare methyl eugenol to the home-made baits of grinded or ground nutmeg and NET, a beauty cream, we found that methyl eugenol attracted significantly *B. invadens*. Methyl eugenol's half life is also significantly longer (5 weeks) than the grinded nutmeg (less than 1 week) ($P = 0.0109$; $t = 9.4935$; $df = 2$). No capture was recorded in the NET based trap. In case of lack of methyl eugenol, the grinded nutmeg might be recommended as an alternative product to renew every week.

Key Words: Fruit fly, IPM, alternate host plants, bait.

INTRODUCTION

Previously unknown as a pest in Senegal, the fruit flies in particular *Bactrocera invadens* (Drew) and *Ceratitis cosyra* (Walker), (Diptera, fam: Tephritidae), are seriously threatening the fruit production, particularly mangoes. Actually there is already a rearing record from Dakar dating back to 1912 for *C. cosyra*, a species widespread through western, Central, Eastern and Southern Africa (De Meyer personal communication). *B. invadens* was observed in Kenya for the first time by Lux and *al.* (2003). From Asia, it invaded very quickly the African continent, where the indigenous natural enemies present are inefficient for a consequent control. Thus, fruit flies constitute a serious threat because they are: - A plague due to their fast proliferation and the presence of important populations in all the main fruit growing areas - An agronomic problem by their polyphagy and quarantine insect pest status, among others -A socio-economic problem involving income and job, national and international market sharing losses, non profitable investments, etc. Losses are very important and are approximately 41,000 tones of mangoes and the national production is around 100,000 tones. The situation is further complicated by the fact that the fruit flies are regarded as quarantine pest in most of the countries of the world. The detection of only one larva in the countries of destination, will involve the destruction of the batch which will cost 30,000 Euros per container, supported by the exporter.

Within this scope, an IPM package is implemented in the Niayes, Senegal. It is aimed at studying the population dynamics of the fruit flies in relation to the rainfall, the effectiveness of an IPM package against the infestation of the fruit flies and to compare the conventional lure methyl eugenol, a *Bactrocera* attractant to the home-made baits of grinded nutmeg and NET (beauty cream). Wild fruits were also incubated for the identification of eventual alternative host

plants. It is expected for producers that after a short training by the National Plant Protection Service (NPPS) researchers, to carry out the routine operations themselves.

MATERIAL AND METHODS

Study site: The study was conducted from June 10 to October 1st in the rural community of Noto in the natural area of Niayes, the most important area of exportable horticultural products in Senegal (40 % of the mango orchards of Senegal and 60 % of exported mangos) For this study, three (3) orchards of late varieties, “Kent” and “Keit” are concerned. – (1) CADA limited Co., is a modern 70 ha of mango trees in which only one piece of 6 ha were used. This orchard is not supposed to receive any treatments. - (2) The orchard of Abdoulaye Diène, a small producer of the village of Noto; it is isolated and belongs to an environment which is not more than 15 ha of mango trees. The various treatments were carried out in this orchard. Both orchards (CADA and Ablaye’s) are 6 kms distant and located oppositely from the village of Noto. In the experiment, the orchard of Ablaye is called Noto. (3) In the last orchard (56 ha) selected in the village of Niague, the methyl eugenol were compare to the home-made baits of grinded nutmeg and NET.

Population dynamics of *B. invadens* and *C. cosyra*: (1) **Trapping *B. invadens* males by methyl eugenol (ME):** In one central hectare, 3 traps (“Tephri-trap”) are laid out. And at the bottom of each of the trap, a ME dispenser is deposited and a strip of insecticide dichlorvos (DDVP) suspended on the nacelle adhering under the lid of the trap. Traps are suspended in mango trees on a branch of the lower third of the foliage at the Northern side to avoid a long exposure to the sun rays. The openings are well hung in order to facilitate the access of flies into traps. The branch being used as support has been coated with solid

grease, on 10 cm length on both sides of the string which suspends the trap, in order to prevent any predatory activity of ants on trapped adults of flies (died at the bottom of the trap). The ME dispensers and strips of insecticide are renewed every month by recovering residues in plastic bags and left out the field. **(2) Trapping male *Ceratitis* by terpenyl acetate (TA):** The same as above protocol with ME, has been used. **(3) Trapping Tephritidae females and males by food Traps Torula:** In one central hectare, 10 traps have been laid out on line, at rate of 1 trap/10 trees (70 m distant) for the follow-up of female populations. Four (04) pellets of hydrolyzed protein “Torula” are plunged in each trap filled with water at the three lower quarters to avoid the dryness of the pellets. The installation scheme of traps is identical to those with paraperomone. The renewal of the water-soluble pellets of Torula was done every 10 days. The FT is neither selective for one sex nor specific to a species. The different captures of the traps are individually collected every 10 days in small plastic bags for TA and ME while for FT, they were collected in tubes using flexible grips. Collected samples were identified by mentioning the date and the trap identification number. Captures are then sorted out at the laboratory to be counted and specified.

Incubation of fruits of potential host plants:

Fruits of wild or cultivated plants are collected and incubated in small dishes filled with sandy soil obtained from dunes, humidified with water and then placed in wood cages (50x30x30cm). Daily observations are made to collect and identify the emerged adults.

Integrated pest management (IPM) package: (1) Male Annihilation Technique (MAT) using killer blocks that are wood blocks (5x5x1,25cm) soaked in insecticide (malathion 500 EC dose 4ml/block) and lures (methyl eugenol 1,25ml/blocks and terpinyl acetate 1,25ml/block). Twenty (20) blocks were used for one (1) ha. Blocks were nailed on the trees but not deeply. A container was also fixed under some blocks to visualize captures.

Every 30 days, the insecticide/lure mixture was applied with a brush on the exposed face of the block in the respect of the proportions of the above mixtures. **(2) Sanitation:** fallen fruits are supposed containing larvae and are consequently collected and destroyed by the following procedures: - **a)** putting fruits in black plastic bags (0,8X0.5 m) and leaving them under the sun light for 3 days - **b)** digging (1.5X1.5X1 m) and burying the fallen fruits in holes covered with minimum 30cm soil layer to avoid an emergence of adults - **c)** collecting fruits in heap and burning on the ground surface - **d)** weeding to eliminate eventual host plants - **e)** burning fruits in a transformed metal barrel (200 dm³) used as incinerator. **(3) Bait Application Technique (BAT):** these operations are carried out with “SUCCESS APPAT” at 0,24 g/l SC (new generation of pesticide has “spinosad”, organic origin as active ingredient prepared with protein bait to create a synergy). One liter (1) of the formulation is diluted in 5 l of water for one ha. This volume is applied to the part of the lower layer of the foliage (1 m² approximately) with rotation around the tree while penetrating a little bite inside the foliage and avoiding to treat fruits. Treatments are renewed every 10 days and in case of a rain of 10 mm or more. *B. dorsalis* another species, was shown to be susceptible to spinosad (Stark et. al. 2004).

The impact of the IPM package is evaluated by comparing the orchards in Noto and CADA following the approach of Stonehouse and Verghese (2005) referring to the improvement of infestation level between both orchards, where $I = U - T/U$ (I = improvement; U = untreated; T = treatment).

Comparison of effectiveness and duration of methyl eugenol, the nutmeg and the NET:

With the increasing threat of the fruit flies in particular the *B. invadens*, and the lack of paraperomones in the national market, various initiatives were undertaken by the producers among which the uses of the dermal cream “NET” and the nutmeg (*Myristica fragrans*; fam: Myristicaceae). The ME was used as reference to test the effectiveness

and the duration of both substances for comparison in a scoop of an IPM recommendation program for the extension agents. Three (3) traps are placed in the orchard of Niague following the principle above described to follow-up the importance of captures. The distance between traps was 50 m and each trap was allotted with a type of substance such as ME, NET, or crushed nutmeg; these three (3) substances attracting only *Bactrocera*. Traps are followed during 3 decades and at each decade, captures are reported. The half-life of substances are given according to the formula $LN(0,5)/\text{slope}$ (Stonehouse and Verghese, 2005) and the t test used for a significant difference to separate means.

RESULTS AND DISCUSSION

Population dynamics of *B. invadens* and *C. cosyra*. The curve (Figure 1) represents the overall individuals trapped with parapheromone and food baits in CADA and Noto (Ablaye Diène). The rainfall seems to have an influence on the population dynamics of *B. invadens*. At the beginning of rainy season, it was noted that the populations of the fruit flies have increased by the first rain (20 mm). Following the curve trend, it was noted that during the last fortnight of July the population has decreased. This drop was attenuated by the important rainfall recorded at the end of July making possible the curve to reach the first peak. Thus, the reduction of populations has evolved from the second decade of August to the first decade of September following the rains intensity and frequency. After the 25 mm of the second decade of September, a new increase in the captures was re observed (Figure 1). This figure shows the variation of *B. invadens* outbreak following the trend of the rains.

As for *C. cosyra*, a slight peak of the curve was perceptible during the second decade of July, followed by a decreasing trend in the first decade of August despite the intensity of the rain (Figure 3).

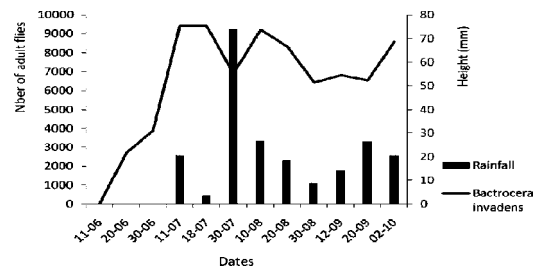


Figure 1: Population dynamics of *B. invadens* according to rainfall within the rural community of Noto (mango production season, 2007).

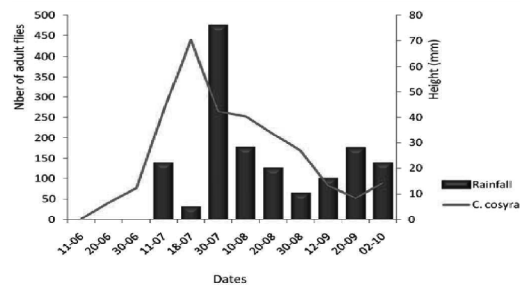


Figure 2: Population dynamics of *C. cosyra* according to rainfall within the rural community of Noto (mango production season, 2007).

The development of populations has been related to rainfall. Therefore, the number of individuals captured was higher from July 9 to August 20, the rainiest period (Figure 1 and 2) especially for *B. invadens*, the largely dominant species (Figure 3). The dependency on the rainfall conditions for *C. cosyra* was more obvious in the study carried out in 2004, period in which *B. invadens* was not yet invading. *C. cosyra* was found as the single fly pest recorded from the beginning to the end of the experiment. According to Vayssières (2004), the temperature and moisture have a direct effect on demography of the species but also an indirect effect by their incidence on the availability of plants hosts and the presence of natural enemies.

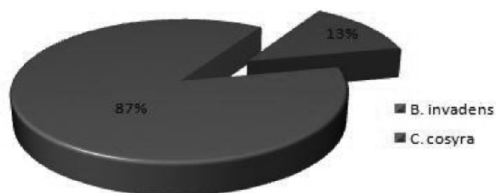


Figure 3 : Relative importance of the populations between *B. invadens* and *C. cosyra* in the rural community of Noto (mango production season, 2007).

Incubation of potential plant host fruits

Incubations of fruits of potential plant host fruits, as a source of infestation were made to observe emergences of flies. Results showed that most of emerged flies were *C. cosyra*. Thus, during the experiment, the low level of *C. cosyra* populations noted in both orchards and reported as the result of an interspecific competition might be confirmed by migrations of individuals towards other alternate host plants. Rearing results showed mango, loquat (*Eriobotrya japonica*), guava and grapefruit (*Citrus · paradisi*) to be the favored commercial host fruits for *B. invadens* (Mwatawala *et al.* (2006b). Such

behavior could explain the fact that *C. cosyra* dominated emergences from the incubated fruits of alternate host plants up to 87 % even though *B. invadens* was observed (7.4%) then followed by *Dacus longistylus*, with 5.5%. *Dacus longistylus* is a specialized species in *Calotropus procera* (White, 2006) Where polyphagous tephritid species have been introduced in areas already occupied by a polyphagous tephritid, interspecific competition has resulted in a decrease in number and niche shift of the pre-established species (Duyck *et al.* (2006). The genus *Capparid* seems to be a preferential alternate host for these flies, compared to Cucurbitaceae. Complementary study is necessary to conduct a more complete inventory of the various host plants and to confirm the prevalence of the genus *Ceratitid* (Table 1).

Integrated pest management (IPM) package

At the beginning of the experiment, exceptional captures of 48 individuals were achieved in Noto with the ME in the first decade of June while in CADA, there were 19 individuals. In Noto, from July to October 10, the

Table 1: Results of emergences from incubated fruits

Types of incubated fruits		
Scientific name	Number of incubated fruits	Number of Emerged flies
<i>Cucurbita pepo</i> var. <i>melopepo</i>	2	5 <i>B. invadens</i>
<i>Capparis corymbosa</i>	20	53 <i>C. cosyra</i> - 2 <i>B. invadens</i>
<i>Capparis decidua</i>	20	19 <i>C. cosyra</i> - 2 <i>B. invadens</i>
<i>Capparis tomentosa</i>	20	43 <i>C. cosyra</i> - 1 <i>B. invadens</i>
<i>Momordica balsamina</i>	10	3 <i>C. cosyra</i> - 6 <i>B. invadens</i>
<i>Cactus</i> sp.	8	5 <i>C. cosyra</i>
<i>Calotropis procera</i>	13	12 <i>Dacus longistylus</i>
<i>Psidium gayava</i>	10	4 <i>B. invadens</i>
<i>Citrullus lanatus</i>	1	1 <i>B. invadens</i>
<i>Cordyla pinata</i>	14	65 <i>C. cosyra</i>

following captures were much less important (Figures 4 and 5). This low level may be due to applied methods of control to drop the fruit fly infestations, compared to the untreated orchard in CADA. The total captures of *B. invadens* and *C. cosyra* from the different trapping methods was 83.180 individuals in CADA and 14.009 in Noto, illustrating an improvement achieved in controlling up to 83% of the flies in Noto. It was also concluded that the combination of home-made-bait BAT with soaked-wood-block MAT, used cooperatively at village level, and in particular when combined with cultural methods, may reduce fruit fly losses by 90% or more under most conditions (Verghese *et al.* 2005). Thus, this result might be improved if the IPM was implemented as an area-wide control approach. The various methods used for destruction of the collected fallen fruits were effective but they have some constraints. The burying of fruits was time consuming and labor intensive. Burning fruits on the ground surface required large quantities of dry wood in this semi arid area, which leads to exclude this practice. Incinerators had the advantage to last but required paper or brushwood of dry grass and fuel to consume. Black plastic bags seemed more practical but tear very easily. Therefore, they need to be reinforced to resist and to enable an economical use. Similar studies were conducted on fruit infestations by *B. zonata* and *B. dorsalis* in India. Patel *et al.* (2005) found reductions in fruit infestations, relative to a low base infestation rate of 1%, of 80% by soil raking, 90% by field sanitation (fruit collection), 100% by MAT, 60% by BAT, 50% by cover sprays and 100% by MAT and by cultural controls and others in combination. Protection by cover and BAT sprays was not significant. The relationship between the orchard infestation level and its impact on the fruit infestation can be valuable information and might be an easy way to determine the damage involved. It has curiously been found that the total individuals of *C. cosyra* captured were more important in Noto than in CADA, where the ecosystem was more favorable to its swarming, similarly as *B.*

invadens (Figure 4 and 5). Based on the average of 350 individuals captured per decade and per trap, the proliferation of *C. cosyra* seemed to be stopped by *B. invadens* through an interspecific competition. This particular situation has been illustrated by the populations' peaks in CADA recorded during the early 3rd decade of July and the mid-third decade of September in Noto and has confirmed the predominance of the newly introduced species, *B. invadens*. Apart *C. cosyra*, any other Ceratitidinae among those identified by Vayssieres (2004) has not been observed. According to Duyck *et al.* (2004), the data on tephritid invasions seem to support a hierarchical mode of competition; however, complete exclusion usually did not occur. Indeed, tephritid distribution and abundance are markedly structured by various abiotic (mostly climatic) and biotic (host plants) factors. No reciprocal invasions have been observed. Studies carried out in Kenya by Ekesi *et al.* (2006) mentioned that at most of the locations and especially at low elevations, *B. invadens* frequently shared the same fruit with the indigenous fruit fly species *C. cosyra* but often occurred at higher numbers than *C. cosyra*. The authors and Mwatawala *et al.* (2006a, b.) suggested that *B. invadens* is a predominantly lowland pest just like the Niayes area where the coastal sandy plain never reaches 50 m.



Figure 4 : Evolution of captures from ME and TA traps in CADA (2007)

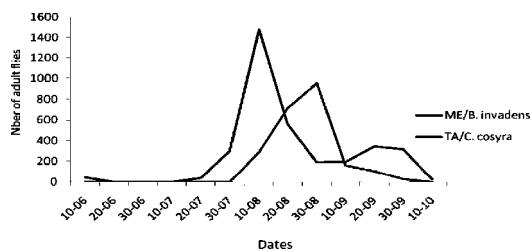


Figure 5: Evolution of captures from ME and TA traps in Noto (2007)

Comparison of the effectiveness and duration of methyl eugenol, nutmeg and NET

The ME presented a half life of 5 weeks (3,78 decades) compared to the grinded Nutmeg which is around one (1) week (0,66 decade). Because of the absence of captures, from the NET traps, its effectiveness and duration have not been included in the analysis. Decadal captures were 4639 made from ME and 56 from Nutmeg. Statistical analysis has shown a highly significant difference in effectiveness and duration of ME and Nutmeg ($P = 0.0109$; $t = 9.4935$; $df = 2$). The ME appeared as the more efficient substance in *B. invadens* males' annihilation technique. As well, the attractiveness of ME was longer than the Nutmeg's. However, in case of a lack of methyl eugenol, the grinded nutmeg might be recommended as an alternative product to be renewed every week. There were no captures recorded in the NET based trap (Table 2).

Conclusion and recommendations

B. invadens and *C. cosyra* populations followed the dynamics of the rains, since the number of the captures was more important during the rainiest period from July 9th to August 20th. This tendency is more perceptible on *B. invadens* than on *C. cosyra*. *B. invadens* seemed to displace *C. cosyra*. ME appeared as the best substance in the capture of the males of *B. invadens* compared with the NET, a beauty cream and the grinded Nutmeg. The nutmeg can be recommended as an alternative solution where there is a lack of ME or when the price makes it inaccessible for the small producers. In case that the nutmeg is used, it must be renewed every week. The IPM package results illustrate improvement achieved in controlling fruit flies infestation level to 83 % in Noto (treated plot) compared to CADA's orchard (untreated plot). Thus, if measures were taken on time in an area-wide approach, the level of control could be improved. Related to the processes used to destroy fallen fruits, the black plastic bag might gain to be popularized only after improvement of its resistance. Following the results obtained, this demonstration opens prospects and need to be pursued. The study of the relationships between the orchard infestation level and its impact on the fruit infestation need to be investigate to find an easy way for damage evaluation. This work allowed a beginning of the identification of some of the alternate hosts of *B. invadens* and *C. cosyra* but also to observe a specialized *Dacus*

Table 2: Results of three (3) decades trapping of *B. invadens* from ME, nutmeg and NET

Decadal period	Number of captures by types of substances		
	ME	NUTMEG	NET
1	1750	24	0
2	1677	29	0
3	1212	3	0
TOTAL	4639	56	

longistylus in *Calotropus procera*. It needs to be pursued with the estimates of the economic losses due to the fruit flies.

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GERMPLASM EVALUATION OF CHRYSANTHEMUM FOR RESISTANCE TO APHID, *Macrosiphoniella sanbornii* (Gillette)

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ABSTRACT: Forty eight germplasm/variety collections of chrysanthemum were evaluated for resistance to aphid, *Macrosiphoniella sanbornii* (Gillette) under polyhouse conditions during 2003-05 at Indian Institute of Horticultural Research, Bangalore. Genotype response was studied in terms of the number of aphids per terminal shoot and bud and the percent shoot infestation of aphids. Significant variations of aphid infestation were recorded among genotypes. Seven genotypes viz., 'Aparajitha', 'Asha', 'F-52', 'Heritage', 'PC-31', 'Punjab Anuradha' and 'Rangoli' were least susceptible (<5 aphids / shoot) to aphid. Among the rest, 12 collections were moderately susceptible, 21 were susceptible and 8 were highly susceptible (>25 aphids/shoot). A comparison of indigenous and exotic genotypes in their response to aphid indicated the superiority of former in being least susceptible to aphid.

Key words: Aphid, chrysanthemum, germplasm, *Macrosiphoniella sanbornii*, resistance

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflora* Tz.), also called 'Autumn Queen', is a leading commercial flower crop grown for cut flowers as well as pot plants. The area under its cultivation has also increased considerably in the recent past. Intensive cultivation involving large-scale use of synthetic fertilizers and pesticides, drastically changes the crop-pest equilibrium. Chrysanthemum is vulnerable to a number of insect pests and chrysanthemum aphid, *Macrosiphoniella sanbornii* (Gillette) (Homoptera: Aphididae), is one of the important pests (Sohi and Singh, 1995). Winged adults of *M. sanbornii* are 2-2.5 mm long, soft bodied and dark, shining mahogany brown. Wingless adults are 1-1.5 mm length. Nymphs have dull, brick red

bodies with relatively long legs and antenna. Both nymphs and adults suck sap from terminal buds, leaves, stem and flowers resulting in distorted growth. In severely infested plants the flower buds remain unopened or flowers fail to attain normal size. Besides, the honeydew excreted by aphids attracts sooty mold, which hampers the photosynthetic efficiency of leaves. Chrysanthemum aphid is also reported to act as a vector of tomato aspermy cucumo virus (TAV) and chrysanthemum B carlavirus (Jaskiewicz *et al.*, 2001). Insecticides are the widely used means of controlling insect pests on chrysanthemum and their large scale and indiscriminate use lead to development of pest resistance and resurgence, besides adding to environmental pollution as well as cost of production. Pest control measures on floricultural crops including chrysanthemums

should achieve near complete eradication because very low or zero damage is required for their commercial value (de Kogel *et al.*, 1998).

Keeping these in view, a sustainable and ecologically viable strategy is essential to combat insect pests and host plant resistance meets these requirements. Variation in host plant resistance of chrysanthemums has been reported for other arthropod pests, e.g., *Liriomyza sativae* Blanchard (Schuster and Harbaugh, 1979), *Liriomyza trifolii* (Burgess) (de Jong and Rademaker, 1991; Suenaga *et al.*, 1995), *Ostrinia nubilalis* (Hübner) (Schultz and Coffelt, 1989), *Spodoptera exigua* (Hübner) (Yoshida and Parrella, 1991), *Thrips palmi* Karny (Miyashita, 1990), *Frankliniella occidentalis* Pergande (de Jager *et al.*, 1995) two-spotted spidermite, *Tetranychus urticae* Koch. and bud borer, *Helicoverpa armigera* (Hb.) (Reddy *et al.*, 2004). Screening a large number of germplasm collections to identify the resistance sources is a prerequisite for the resistance breeding programme. This study was conducted to identify potential resistance sources against chrysanthemum aphid.

MATERIALS AND METHODS

Forty eight genotypes, including 22 exotic collections, of chrysanthemum were evaluated for resistance to aphid, *M. sanbornii* during 2003-05 at Indian Institute of Horticultural Research, Bangalore (12°58'N; 77°35'E). Seedlings of germplasm were raised during May-September in a naturally ventilated polyhouse in both the years of the study. The experiment was laid out in a completely randomized design with three replications. Fifteen plants in each collection were selected for observations and five plants constituted one replication. They were maintained free of any pesticide application and were evaluated based on natural aphid infestation. Observations on the number of aphids per shoot (10 cm length) were recorded three times at 15 days interval starting from the

bud initiation. The means of observations were tested for significance of differences at 5% level of probability by ANOVA after square root transformation. Based on the pooled means of two year data, germplasm collections were categorized into 5 groups *viz.*, immune (no aphids), least susceptible (<5 aphids/shoot), moderately susceptible (6-10 aphids/shoot), susceptible (11-25 aphids/shoot) and highly susceptible (>25 aphids/shoot) following a partially modified version of varietal classification suggested by Saikia and Dutta (1998) and Reddy *et al.*, (2004). A comparative assessment of indigenous and exotic genotypes, as per their response to aphid incidence, was also carried out.

RESULTS AND DISCUSSION

The extent of aphid infestation varied significantly among chrysanthemum genotypes in both the years (Table 1). The mean number of aphids per shoot and bud varied from 0.63 to 80.18 and 0.41 to 63.84 during 2002-03 and 2003-04, respectively. During 2002-03, 'Asha' was the least infested accession closely followed by 'Punjab Anuradha' (1.65), PC-31 (1.68), 'Rangoli' (2.24), 'Aparajitha' (2.34) and 'F-52' (3.37), which were on par with one another. Besides these, 'Flirt' (6.63), 'Fitoria' (7.02), 'Honey Comb' (7.65), 'Kundan' (7.46) and 'Kargil' (8.09) had less than 10 aphids/shoot. Among other accessions, 'Wall Street' (80.18), 'Yellow Star' (41.15), 'Hy-6' (35.72), 'F-25' (32.35), 'Saver Glow' (31.23) and 'Statesman' (30.63) had more than 25 aphids per shoot. In the following year, the trend was more or less on similar lines. 'PC-31' (0.41) had the least aphid infestation and was on par with 'Rangoli' (0.85) and 'Tata Century' (2.79). Closely following these were 'Punjab Anuradha' (3.38), 'Aparajitha' (4.69), 'Honey Comb' (4.47), and 'Gulmohar' (5.18). Accession 'Wall street' attracted the highest number of aphids (63.84), though comparatively lesser than the previous year followed by 'F-25' (41.52), 'Yellow Star' (39.65), 'Saver Glow' (40.57), 'Statesman' (36.00) and 'Hy-6' (30.84).

Table 1: Variable response of chrysanthemum germplasm to the aphid, *M. sanbornii*

S. No.	Collection/variety	Mean number of aphids/ shoot		
		2003-04	2004-05	Mean
1.	Annie	13.3 (3.65)	16.67 (4.08)	15.00 (3.87)
2.	Aparajitha	2.34 (1.53)	4.69 (2.16)	3.50 (1.87)
3.	Appu	17.00 (4.12)	16.35 (4.04)	16.67 (4.08)
4.	Apurva Singar	11.67 (3.41)	13.06 (3.60)	12.33 (3.51)
5.	Asha	0.63 (0.79)	2.34 (1.53)	1.50 (1.22)
6.	Bicolor Bonsai	20.38 (4.51)	12.63 (3.56)	16.50 (4.06)
7.	Chandi	7.34 (2.71)	9.74 (3.12)	8.50 (2.91)
8.	Chandrama	18.69 (4.32)	22.32 (4.72)	20.33 (4.51)
9.	F-25	32.35 (5.69)	41.52 (6.45)	36.93 (6.07)
10.	F-52	3.37 (1.83)	5.14 (2.38)	4.25 (2.06)
11.	Fitoria	7.02 (2.65)	11.32 (3.41)	9.17 (3.03)
12.	Flirt	6.63 (2.58)	10.35 (3.21)	8.49 (2.91)
13.	G-11	16.64 (4.08)	24.34 (4.93)	20.49 (4.52)
14.	Gitanjali	6.32 (2.52)	12.74 (3.51)	9.53 (3.08)
15.	Gulmohar	8.12 (2.84)	5.18 (2.38)	6.65 (2.58)
16.	Heritage	3.63 (1.91)	6.32 (2.45)	4.93 (2.22)
17.	Honey Comb	7.65 (2.77)	4.47 (2.16)	6.16 (2.48)
18.	Hy-6	35.72 (5.97)	30.84 (5.51)	33.28 (5.76)
19.	Jugali	28.42 (5.33)	34.65 (5.89)	31.50 (5.61)
20.	Jubilee	3.56 (1.88)	12.21 (3.51)	10.50 (3.24)
21.	Kargil	8.09 (2.83)	10.01 (3.21)	9.05 (3.00)
22.	Kundan	7.46 (2.73)	14.74 (3.83)	11.16 (3.34)
23.	Mini Orange	18.23 (4.26)	12.53 (3.56)	15.38 (3.92)
24.	Nain Tara	13.76 (3.71)	12.74 (3.51)	13.25 (3.64)
25.	PC-25	19.63 (4.43)	9.52 (3.05)	14.57 (3.81)

S. No.	Collection/variety	Mean number of aphids/ shoot		
		2003-04	2004-05	Mean
26.	PC-31	1.68 (1.29)	0.41 (0.81)	1.04 (1.02)
27.	Punjab Anuradha	1.65 (1.29)	3.38 (1.82)	2.50 (1.58)
28.	Ragini	22.74 (4.77)	16.42 (4.04)	19.58 (4.42)
29.	Rajah	9.54 (3.08)	13.76 (3.70)	11.65 (3.41)
30.	Rangoli	2.24 (1.49)	0.85 (0.92)	1.54 (1.24)
31.	Red stone	14.14 (3.76)	15.21 (3.87)	14.67 (3.83)
32.	Reagal Dvais	20.54 (4.53)	15.32 (3.92)	17.83 (4.22)
33.	Santa Diega	10.73 (3.27)	21.34 (4.62)	16.03 (4.03)
34.	Saver Glow	31.23 (5.58)	40.57 (5.54)	35.90 (5.99)
35.	Schizuka	18.54 (4.30)	14.21 (3.77)	16.37 (4.04)
36.	Shine Otome	9.32 (3.05)	11.37 (3.37)	10.35 (3.21)
37.	Statesman	30.63 (5.53)	36.00 (6.00)	33.31 (5.77)
38.	Sudha	11.48 (3.38)	13.56 (3.69)	12.52 (3.53)
39.	Swetha	16.24 (4.03)	21.24 (4.62)	18.74 (4.32)
40.	Taichung Queen	5.74 (2.39)	10.84 (3.26)	8.29 (2.88)
41.	Tata Century	8.16 (2.85)	2.79 (1.63)	5.48 (2.34)
42.	Tokyo	16.6 (4.08)	19.18 (4.36)	17.92 (4.23)
43.	Ushakiran	6.65 (2.58)	9.32 (3.11)	7.98 (2.82)
44.	Vasanthika	14.25 (3.77)	11.54 (3.37)	12.06 (3.47)
45.	Wall street	80.18 (8.95)	63.84 (7.98)	72.16 (8.49)
46.	White Bonsai	6.24 (2.50)	12.96 (3.60)	9.60 (3.09)
47.	Yellow Bonsai	9.76 (3.12)	14.14 (3.76)	11.95 (3.45)
48.	Yellow star	41.15 (6.41)	39.65 (6.30)	40.40 (6.35)
	CD (P=0.05)	0.73	0.98	0.84

Figures in parentheses are square root transformed values

Table 2. Classification of chrysanthemum genotypes according to their reaction to aphid, *M. sanbornii*

Susceptibility level	Genotypes	
	Indigenous	Exotic
Immune	Nil	Nil
Least Susceptible	‘Anuradha’, ‘Aparajitha’, ‘Asha’, ‘F-52’, ‘PC-31’, ‘Rangoli’	‘Heritage’
Moderately Susceptible	‘Chandi’, ‘Fitoria’, ‘Gitanjali’, ‘Gulmohar’, ‘Kargil’, ‘Sudha’, ‘Ushakiran’,	‘Flirt’, ‘Honey Comb’, ‘Taichung Queen’, ‘Tata Century’, ‘White Bonsai’
Susceptible	‘Appu’, ‘Chandrama’, ‘G-11’, ‘Kundan’, ‘Naintara’, ‘PC-25’, ‘Ragini’, ‘Rajah’, ‘Vasanthika’,	‘Annie’, ‘Bicolor Bonsai’, ‘Jubilee’, ‘Mini Orange’, ‘Red Stone’, ‘Reagal Davis’, ‘Santa Diega’, ‘Schizuka’, ‘Shine Otome’, ‘Swetha’, ‘Tokyo’, ‘Yellow Bonsai’
Highly Susceptible	‘F-25’, ‘Hy-6’, ‘Jugali’,	‘Saver Glow’, ‘Statesman’, ‘Wallstreet’, ‘Yellow Bonsai’, ‘Yellow Star’

Based on pooled means of two year data on aphid populations, genotypes were grouped into five susceptibility classes (Table 2). There was not a single genotype which was completely free from infestation and hence none was considered to be immune. Seven genotypes viz., ‘Aparajitha’, ‘Asha’, ‘F-52’, ‘Heritage’, ‘PC-31’, ‘Punjab Anuradha’, ‘Rangoli’ were found to be least susceptible. Moderately susceptible group consisted of 12 varietal collections, thus the least and moderately susceptible groups together accounting for about 42% of total genotypes evaluated. This shows the presence of a wide genetic base to be considered for aphid resistance in chrysanthemum. Among the rest, 21 genotypes were susceptible and only 8 were highly susceptible. Saikia and Dutta (1998) reported significant variations to aphid susceptibility in chrysanthemum varieties. They found ‘Yellow Button’ to be highly resistant (0.4 aphids/10 cm shoot) while ‘Snow Ball’, ‘Yellow Spider’ and ‘Raja’ to be highly susceptible (>31 aphids) and also recorded a negative correlation between the aphid susceptibility and the number

of stem trichomes. The role of stem trichomes in aphid resistance was also reported in tomato (Goffreda *et al.*, 1990) where the type IV trichomes and the amount and type of sugar esters were considered to be important features of the epidermis responsible for the aphid resistance. In case of thrips (*Frankliniella occidentalis*), 76% of varietal variability of chrysanthemum was attributed to the chemical composition of leaves (de Jager *et al.*, 1995a) and also presence of secondary metabolites was considered to be a strong factor of resistance than the absence of certain primary metabolites (de Jager *et al.*, 1996). Role of other morphological and biochemical factors in aphid resistance of chrysanthemum needs to be ascertained.

The distribution pattern of indigenous and exotic genotypes among different susceptibility groups reflected the relative superiority of indigenous collections over exotic ones in exhibiting resistance to the aphid. For example, out of 7 collections that were least susceptible, 6

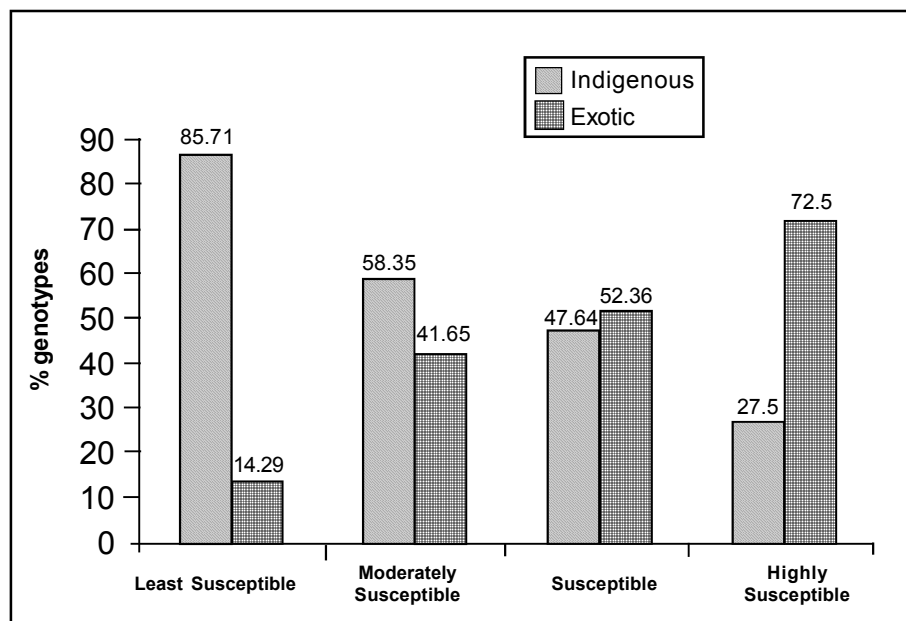


Fig. 1 : Comparative susceptibility of indigenous and exotic genotypes of chrysanthemum to *M. sanbornii*

were indigenous while only one was exotic. A comparative assessment of their response to aphid attack showed (Fig 1) that the susceptible and highly susceptible groups had higher percent of exotic genotypes (52.36 and 72.50% respectively) while indigenous germplasm dominated the least susceptible (85.71%) and moderately susceptible group (58.35%). This analysis underscores the importance of indigenous germplasm as source of resistance and hence more number of local collections deserves to be included in screening. The findings of the present study had established the existence of varietal variability and scope for resistance to aphid, *M. sanbornii* in chrysanthemum.

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SCREENING OF ACID LIME (*Citrus aurantifolia* Swingle) CLONAL SELECTIONS FOR RESISTANCE TO THRIPS, *Scirtothrips* sp. AND RUST MITE, *Phyllocoptruta oleivora* (Ashmead)

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ABSTRACT : Thirteen clonal selections of acid lime (*Citrus aurantifolia* Swingle) were screened for their relative susceptibility/resistance to citrus thrips, *Scirtothrips* sp. and rust mite, *Phyllocoptruta oleivora* (Ashmead) under field conditions at Citrus Research Station, Petlur, Nellore, Andhra Pradesh during 2006 - 07. A significant variation was observed among the genotypes in their response to the infestation of both the pests. Selections 21, 1 and Vikram were found to be resistant against thrips while Selections 1, 7, 25, and PKM 1 were least susceptible to mites. Our study revealed that 'Selection 1' showed combined resistance against thrips and mites. Highly susceptible group included Selection 11 against thrips and Selection 17 and 9 against mites. These are the preliminary findings based on which morphological and biochemical basis of resistance will be worked out.

Key Words: Acid lime, clonal selections, host plant resistance, *Phyllocoptruta oleivora*, *Scirtothrips*

INTRODUCTION

Acid lime (*Citrus aurantifolia* Swingle) is an important sub-tropical fruit crop of India and is the third most important fruit crop next to mandarins and sweet orange among all citrus species (Thirugnanavel *et al.*, 2007). Vitamin C rich acidic fruits of acid lime have numerous applications in food industry. Andhra Pradesh is the largest producer of acid lime and Anantpur, Chittoor, Nellore, Cuddapah, Nalgonda and Vijayanagaram are major lime growing districts of the state. Like other citrus species, acid lime is also vulnerable to attack by a number of insect

pests. Citrus trees are reported to be infested by nearly 250 insect species in India. Among these, thrips, *Scirtothrips* sp. (Thysanoptera: Thripidae) is considered to be of minor importance, but they have attained a status of major concern under specific agro-climatic conditions (Butani, 1979). Nymphs and adults of thrips lacerate the tissues and suck sap from flower buds, flowers and fruits. Thrips infestation leaves characteristic brown scars on fruits, which affects market value and results in revenue loss. Severe incidence of thrips also leads to dropping of flower buds and flowers. Rust mite, *Phyllocoptruta oleivora* (Ashmead) (Eriophyidae : Acarina) is another important pest

that causes severe damage to citrus fruits. Nymphs and adults of the mite congregate around the gland cells and suck sap there within resulting in bronzing of the rind and also hardening, which reduces its marketability. Further, the mite damaged fruits were found to have less fruit weight, fruit size, juice volume and titrable acidity, and more rind thickness, total soluble solids, sugars and ascorbic acid contents than the unaffected normal fruits (Kalaisekar *et al.*, 2003). Invariably both the thrips and mite infestations manifest low acceptability of the produce at market. Synthetic pesticides are the widely used control measures against thrips and mites, but the deleterious effects associated with their indiscriminate usage includes pest resurgence, insecticide resistance and residues apart from pollution and bio-instability. Hence, a viable alternative like host plant resistance, which can significantly bring down the insecticide requirement, forms an important component of Integrated Pest Management (IPM) package. Keeping this in view, field studies were carried out to evaluate the relative resistance level among 11 clonal selections and 2 cultivars of acid lime against thrips and mites, which forms a basis for integration of the same into IPM.

MATERIALS AND METHODS

The study was carried out at acid lime clonal block, Citrus Research Station, Petlur, Nellore Dt, Andhra Pradesh south of India during 2006-07. Observations on the extent of fruit damage due to thrips and mites were recorded on 8 year old trees at the time of harvest. Four trees were randomly selected and tagged for sampling in each selection/variety. Each tree constituted one replication. All the agronomic practices were carried out regularly and no insecticides spray was carried out during the study. The percent incidence of thrips and mites was calculated from the number of fruits infested out of total number of fruits harvested in respective varieties. The data were analyzed after suitable transformation and subjected to ANOVA to test the significance

Table 1: The percent infestation of thrips and mites in various acid lime selections

S.No.	Variety	% infestation on fruits	
		Thrips	Mites
1	'Selection 1'	3.15 (10.15)	2.16 (8.40)
2	'Selection 3'	30.43 (33.48)	12.25 (20.48)
3	'Selection 5'	13.41 (21.56)	15.20 (22.95)
4	'Selection 7'	15.28 (22.95)	3.15 (10.16)
5	'Selection 8'	16.16 (23.68)	17.55 (24.78)
6	'Selection 9'	45.24 (42.26)	35.70 (36.72)
7	'Selection 11'	67.86 (55.46)	21.70 (27.80)
8	'Selection 16'	19.12 (25.94)	25.75 (30.49)
9	'Selection 17'	26.14 (30.74)	46.10 (42.76)
10	'Selection 21'	2.80 (9.65)	7.50 (15.89)
11	'Selection 25'	13.14 (21.24)	2.10 (8.33)
12	'PKM 1'	15.89 (23.50)	1.55 (7.08)
13	'Vikram'	7.23 (15.58)	6.00 (14.18)
	CD (p=0.05)	3.67	2.85

Figures in parentheses are angular transformed values.

of differences. Clonal selections were classified as resistant (<10% fruit damage), moderately resistant (10.1-25%), susceptible (25.1-50%) and highly susceptible (>50%) based on the extent of damage in case of thrips (Reddy and Vasugi, 2004). Considering the high market sensitivity of mite affected fruits, a slightly lower rating scale

Table 2: Varietal response of acid lime against thrips and mites

S. No.	Resistance category	Thrips	Mites
1.	Resistant	‘Selection-21’ ‘Selection-1’ ‘Vikram’	‘PKM 1’ ‘Selection-1’ ‘Selection-7’ ‘Selection-25’
2.	Moderately Resistant	‘PKM 1’ ‘Selection -5’ ‘Selection-7’ ‘Selection-8’ ‘Selection-16’ ‘Selection-25’	‘Selection-3’ ‘Selection-21’ ‘Vikram’
3.	Susceptible	‘Selection-3’ ‘Selection-9’ ‘Selection-17’	‘Selection-5’ ‘Selection-8’ ‘Selection-11’ ‘Selection-16’
4.	Highly Susceptible	‘Selection-11’	‘Selection-9’ ‘Selection-17’

was adopted in case of mites with 0-5% as resistant, 5.1-15% as moderately resistant, 15.1-35% as susceptible and >35% as highly susceptible.

RESULTS AND DISCUSSION

The data indicated significant differences in fruit damage due to thrips among different varietal collections ranging from the lowest 2.8% in ‘Selection-21’ to the highest 67.86% in ‘Selection-11’ (Table 1). Similarly the lowest damage due to mites was in ‘PKM 1’ (1.55%) followed by ‘Selection 25’ (2.10%) and ‘Selection 1’ (2.16%), which were on par with each other and highest was in ‘Selection 17’ (46.10%) (Table 1). This reflects the existence of variations in the pest’s preference to different genotypes. Genotypes ‘Selection - 21’ and ‘Selection - 1’ were on par with each other in their least susceptibility to thrips. According to the varietal classification (Table 2), three selections viz., ‘Selection-21’ (2.80%), ‘Selection-1’ (3.15%), and ‘Vikram’ (7.23%) were resistant to thrips while ‘Selection-

11’ was highly susceptible. The moderately resistant group consisted of five selections (No. 2,7,8,16 and 25).

Cultivars ‘Vikram’ (6.00%) and ‘Selection 21’ (7.50%) showed moderate resistance to mite infestation and were on par with each other (Table 1). ‘Selection 5’ (15.20%) and ‘Selection 8’ (17.55%) were susceptible to mite infestation followed by selections 11 (21.70%) and 16 (25.75%). ‘Selection 17’ manifested highest percentage of mite infestation (Table 1). According to the varietal classification, four varieties viz., PKM 1, Selection 25, 7 and 1 were relatively resistant to mites while three cultivars, Vikram, Selection 21 and 3 were moderately resistant. Selections 5, 8, 11 and 16 were susceptible to mite infestation ranging from 15.20% to 25.75%. Highly susceptible group consisted of two clonal selections viz., Selection 9 and 17 (Table 2).

Based on these preliminary findings, ‘Selection 21’, ‘Selection1’ and ‘Vikram’ were identified as resistant genotypes to thrips and Selections 1, 7, 25 and ‘PKM 1’ against mites.

These genotypes can be considered as potential resistance sources in further acid lime improvement programmes to suit best in IPM strategies. Variations in thrips and mite infestation could be attributed to differences in ovipositional preferences and the suitability of fruit skin for the nymphal survival and development. The differences in quality among host plant genotypes have the potential to affect long-term herbivore dynamics and a number of factors can influence the overall quality of a plant as a host for insects and have been cited as possible causes of variation in herbivore population dynamics (Underwood and Rausher, 2000). The presence of aromatic amino acids in the flowers also plays a role in nutritional ecology (Brodbeck *et al.*, 2001). The plant traits that probably evolved for primary and defensive functions contribute to the ecological dynamics of herbivore populations (Agrawal, 2004). So, investigations on the morphological and biochemical basis of resistance in the above mentioned genotypes would be the future line of work.

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STUDIES ON DIFFERENTIAL SUSCEPTIBILITY OF SELECTED POLYEMBRYONIC VARIETIES OF MANGO TO ORIENTAL FRUIT FLY, *Bactrocera dorsalis* (Hendel)

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ABSTRACT: The Oriental fruit fly, *Bactrocera dorsalis* (Hendel) is one of the most important pests of mango, *Mangifera indica* L in India. The use of host-plant resistance to control this insect is an interesting and potentially useful technique, but in need of more research. The objective of the present study was to evaluate the ovipositional non-preference of *B.dorsalis* to selected polyembryonic varieties of mango viz., *EC 95862* and *Mylupilian* through choice/ no-choice bioassays. These polyembryonic genotypes were found less preferred over standard comparisons, showing ovipositional non-preference in both the assays. The practical utility of these results are discussed in detail.

Key Words: *Bactrocera dorsalis*, mango, Oriental fruit fly.

INTRODUCTION

Fruit flies (Diptera:Tephritidae) are considered as one of the most economically important groups of insect pests worldwide. Of all the species of frugivorous tephritids, the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) found exclusively in the Oriental region is a serious pest of a wide range of fruit crops in Taiwan, southern Japan, China and in the Indian subcontinent (Butani, 1979). In India, this species attacks mango and it causes serious loss ranging from 5-80% (Kapoor 1993, Verghese *et al.*, 2002). Given the tremendous economic importance of this species, most pre-harvest control programs for fruit flies have been directed towards the adults rather than the eggs or larvae through using methyl eugenol traps (Ishtiaq *et al.*, 1999), proteinaceous baits (Cornelius *et al.*, 1999 and 2000), insecticidal applications (Anjum *et al.*,

2000) and integrated methods (Verghese *et al.*, 2004). This is mainly because of the difficulty associated in targeting the egg and larval stages, where eggs are deposited beneath the fruit surface and larval development inside protective covering of the host fruit (Williamson, 1989). Under these, circumstances, by manipulating the plant's resistance features, these critical and injurious life stages may be targeted. Verghese (2001) stated that host plant resistance in fruits offers the maximum scope for economically viable IPM, as many fruit crops are grown on large scale, even tolerance mechanism can offset pest flare-ups. Therefore, it was clear that plant resistance could assist fruit fly control not only to limit the insecticide usage but also can be a viable component of IPM. Unfortunately, very few studies have been performed to inquire into fruit fly resistance. In his discussion of tephritid-host relations, Schoonhoven (1982) noted that 'in

contrast to insect control programs for other crops, very little attention has been given to the possibilities of breeding resistant varieties in perennial crops. However, in case of mango scattered accounts of innate host plant resistance to *B. dorsalis* do exist.

This study was prompted by field observations (Dr. Y.T.N. Reddy, Pers. Commun.) that some polyembryonic varieties of mango viz., *EC 95862*, *Mylopilian*, were relatively less susceptible to attack by *B. dorsalis*. Earlier studies also indicated that many varieties of mango (Eg. cv. *Langra* was found least susceptible to *B. dorsalis*) show varying degrees of resistance/ tolerance to fruit fly (Anon, 1985). Such varieties make an ideal source of resistance/ tolerance, as fruit fly is major limitation to export. Verghese (2001) reported *Cv. Banganapalli* as the most susceptible variety and the need for checking the progenies from *Banganapalli* parentage for fruit fly susceptibility before their release. Studies at Indian Institute of Horticulture Research on the mango hybrids showed that Hybrid 24-8 and *Arka Aruna* developed from susceptible parents have shown that these were highly susceptible and Hybrid 23-6 showed low susceptibility and deserves more attention in future for resistance breeding programs (Verghese, 2001). Therefore, all these studies clearly suggested that there is plenty of scope for the breeders to produce fruit fly resistant cultivars in mango, as this is best way to save the fruit, and it is completely hazard proof and a sure method (once achieved) to protect the fruits from the attack of fruit fly (Kapoor, 1993). This involves a lot of research with regard to the host-pest relationship, before resistance to this fruit fly should be taken into account in plant breeding efforts. So far very little work has been done on this aspect in India and there are no detail studies on its susceptibility/ resistance of different mango cultivars to fruit fly attack. Reported here are laboratory studies to determine susceptibility/ resistance status of selected polyembryonic cultivars of mango for *B. dorsalis*.

MATERIALS AND METHODS

The present study was done at Fruit Entomology Laboratory, Division of Entomology and Nematology, Indian Institute of Horticultural Research (IIHR), Bangalore (12°58'N; 77°35'E), India to confirm whether the varieties viz., *EC 95862* and *Mylopilian* are susceptible/ resistant to infestation by fruit fly.

Mango cultivars: In the absence of any known non-preferred mango cultivars, two polyembryonic cultivars were chosen for the experiment. The two varieties viz., *Mylopilian* (Accn. No.20069) and *EC 95862* (Accn. No. 19929) which are polyembryonic varieties (Dinesh and Vasugi, 2002) were used as test cultivars. The cultivars viz., *Alphonso* (known to be susceptible, Accn. No.345), *Totapuri* (known to be susceptible, Accn. No. 8753) and *Langra* (relatively less susceptible, Accn No. 441) (Dinesh and Vasugi, 2002), which are established commercial varieties, were used in experiments to provide standards for comparison. The details of these cultivars are presented in detail in Table 1. Fruits for this study were obtained from the fields of IIHR, Bangalore from unsprayed mango trees. Fruits that were in mature green stage of harvest maturity were used and the damaged fruits/fruits that had oviposition punctures were culled.

Insects: The Oriental fruit fly, *B. dorsalis* culture was established in the laboratory from the infested fruits collected from mango field at IIHR. The primary cultures were maintained in the laboratory at 28±1°C, as per procedure described by Jayanthi and Verghese (2002). Adults of both sexes were held 10-15 days post eclosion to assure sexual maturity and gravidity of females when used. From this culture, mature gravid females of 15-20 days old were selected for the experiments.

Choice/ No-choice bioassays: To assess relative ovipositional preference/ non-preference of *B. dorsalis* for selected polyembryonic

Table 1: Characteristics of different varieties

Variety	Fruit characters	Pulp characters
a) Polyembryonic		
➤ EC 95862	i) Fruit shape: Round ii) Colour of mature skin : Greenish yellow iii) Skin thickness : Medium thick iv) Skin texture : Smooth	i) Pulp texture : Soft ii) Adherence of skin to pulp : Present iii) Fibre in the pulp : Present iv) Quantity of fibre : Abundant v) TSS (°Brix) : 19.10
➤ Mylupilian	i) Fruit shape : Round ii) Colour of mature skin : Greenish yellow iii) Skin thickness : Thin iv) Skin texture : Smooth	i) Pulp texture : Juicy ii) Adherence of skin to pulp : Absent iii) Fibre in the pulp : Present iv) Quantity of fibre : Abundant v) TSS (°Brix) : 12.60
b) Monoembryonic		
➤ Langra (Resistant control)	i) Fruit shape : Elliptic ii) Colour of mature skin : Green iii) Skin thickness : Thick iv) Skin texture : Smooth	i) Pulp texture : Firm ii) Adherence of skin to pulp : Absent iii) Fibre in the pulp : Present iv) Quantity of fibre : Scarce v) TSS (°Brix) : 21.50
➤ Alphonso (Susceptible control)	i) Fruit shape : Round ii) Colour of mature skin : Greenish yellow iii) Skin thickness : Thin iv) Skin texture : Smooth	i) Pulp texture : Firm ii) Adherence of skin to pulp : Absent iii) Fibre in the pulp : Present iv) Quantity of fibre : Scarce v) TSS (°Brix) : 19.00
➤ Totapuri (Susceptible control)	i) Fruit shape : Oblong ii) Colour of mature skin : Greenish yellow iii) Skin thickness : Very thick iv) Skin texture : Smooth	i) Pulp texture : Firm ii) Adherence of skin to pulp : Present iii) Fibre in the pulp : Present iv) Quantity of fibre : Scarce v) TSS (°Brix) : 19.00

varieties viz., *EC 95862* and *Mylupilian*, we conducted series of 24 hr choice/no-choice laboratory bioassays in various combinations. These bioassays were conducted in an insect-proof nylon mesh cage with a wooden frame (1m x 1m x 1m) placed on a laboratory bench during June, 2003 – August, 2003. In the first choice-

bioassay, which was conducted in four different sets we compared *EC 95862*, *Mylupilian*, *Langra* and *Alphonso* varieties for ovipositional preference by *B. dorsalis*. In the second choice-bioassay, we allowed fruit flies to choose among *EC 95862*, *Mylupilian* and *Totapuri*. This assay was conducted in six different sets, in the first

five assays equal number of fruits (n=8) from all the three varieties were exposed to fruit flies. Whereas, in the sixth set, unequal number of fruits (arbitrarily chosen) were exposed to fruit flies considering the difference in the fruit size of *EC 95862* (n=24), *Mylopilian* (n=31) and *Totapuri* (n=15), so that flies had access to equal surface areas of fruits in all varieties. In the third choice bioassay, the polyembryonic varieties *viz.*, *EC 95862*, *Mylopilian* along with known resistant variety *Langra* were exposed to fruit flies in different combinations. Here, the fruits were exposed to fruit flies in peeled, semi peeled and unpeeled conditions to see comparative ovipositional preference of fruit flies. Finally, a no-choice bioassay was carried out for two polyembryonic varieties *viz.*, *EC 95862*, *Mylopilian* along with susceptible control, cv. *Totapuri*. Here, all the fruits of three varieties (n=20) were offered independently to confirm the fruit fly preference. The fruit position was randomized within the cage during experimentation. The fruits were exposed to sexually matured *B. dorsalis*. Two hundred pairs of fruit flies from the stock culture were sexed and released into a cage containing the fruits. The fruits were exposed to the females for 24 hrs. After 24 hrs, the fruits were removed from the cage and then each fruit was kept separately in plastic jars containing fine sand at the bottom (for maggots to pupate) covered with blotting paper (to absorb excess moisture) to allow maggots development. The preference/ non-preference for test cultivars was assessed by counting the number of maggots developed in test fruits exposed to fruit flies. The data was transformed in to $\sqrt{x+1}$ values and subjected to a one-way analysis of variance (ANOVA). Least significant differences (LSD) were used for the comparison of means (Little and Hills, 1978).

RESULTS AND DISCUSSION

Incorporation of resistance, although a long-term goal, would be a desirable method of control. Of three principal mechanisms of host plant

resistant *viz.*, non-preference, antibiosis and tolerance which are responsible for imparting resistance to insects, non-preference denotes a group of plant characters and insect responses that keep away the insect from using a particular plant or variety for oviposition, food, shelter or combinations of the three (Painter, 1951 and 1968). The importance of oviposition at favourable sites is particularly important for tephritids where eggs are deposited beneath the fruit surface and larval development inside protective covering of the host fruit (Williamson, 1989). Considering the limitations of chemical insecticidal sprays to protect fruits from *B. dorsalis* oviposition, a non-preferred cultivar for oviposition and larval establishment (antixenosis) is clearly an advantage in any breeding programme aimed at producing fruit fly resistant mango cultivars.

In the present study, the fruit fly *B. dorsalis* exhibited distinctly varying preference for oviposition in different test cultivars used. In the first choice bioassay (Table 2), considerable variation existed in the number of maggots/ fruit in all the four sets. In the first set, the resistant control *Langra* recorded zero number of maggots/fruit followed by *EC 95862* (1.88) and *Mylopilian* (2.50). However, all the three were found to be statistically on par with respect to low number of maggots/fruit and significantly ($P \leq 0.05$) superior to susceptible control *Alphonso* that recorded 20.38 maggots/ fruit. In the second set also, the same trend was exhibited, with *EC 95862* recording zero maggots followed by *Mylopilian* (0.88 maggots/ fruit) and *Langra* (2.00 maggots/fruit). Here also, *EC 95862*, *Mylopilian* and *Langra* were statistically on par and significantly ($P \leq 0.05$) superior to *Alphonso* (13.00 maggots/fruit) with respect to low maggot number/ fruit. In the third set, all the three varieties *viz.*, *EC 95862*, *Mylopilian* and *Langra* recorded zero number of maggots/ fruit and found significantly ($P \leq 0.05$) superior to *Alphonso* that recorded 5.33 maggots/ fruit. In the fourth set, *Mylopilian*, *EC 95862* and *Langra* recorded zero number of maggots/ fruit and found

Table 2: Combination of varieties exposed to *B. dorsalis* in choice bioassay [Cvs. *Langra* (resistant) and *Alphonso* (susceptible) as controls]

Choice bioassay	Set I		Set II		Set III		Set IV	
	No. of maggots /fruit	Per cent infestation	No. of maggots/ fruit	Per cent infestation	No. of maggots /fruit	Per cent infestation	No. of maggots/ fruit	Per cent infestation
a) <i>Mylupilian</i>	2.50 (1.56)	25.00	0.88 (1.39)	12.50	0.00 (1.00)	0.00	0.00 (1.00)	0.00
b) <i>EC 95862</i>	1.88 (1.38)	12.50	0.00 (1.23)	0.00	0.00 (1.00)	0.00	0.00 (1.00)	0.00
c) <i>Langra*</i>	0.00 (1.00)	0.00	2.00 (1.00)	12.50	0.00 (1.00)	0.00	0.00 (1.00)	0.00
d) <i>Alphonso</i>	20.38 (3.89)	60.25	13.00 (3.57)	100.00	5.33 (2.17)	50.00	54.00 (7.30)	100.00
CD (P=0.05)	1.58	0.90			0.84		0.88	

* Maggots in infested *Langra* fruits were dead
Figures in parentheses denotes $\sqrt{x+1}$ transformed values

significantly superior *Alphonso* that recorded 54.00 maggots/fruit respectively. The percent infestation calculated for all the sets also clearly showed that distinct variation present among varieties for level of infestation. The varieties viz., *Langra*, *EC95862* and *Mylupilian* were always less preferred with percent infestations, 0.00, 12.50, 25.00 (in I set); 12.50, 0.00, 12.50 (in II set); 0.00, 0.00, 0.00 (in III set) and 0.00, 0.00, 0.00 (in IV set) respectively over susceptible control *Alphonso* which recorded 60.25, 100.00, 50.00 and 100.00 per cent infestation in I, II, III, IV sets respectively.

In the second choice bioassay (Table 3), *EC 95862* and *Mylupilian* were exposed to fruit flies in combination with other susceptible control, *Totapuri* in six different sets. Here also, the number of maggots/ fruit was highly variable among the varieties, although consistent with the results of first choice bioassay. In the first set, non-preference for *Mylupilian* and *EC 95862* was very much evident which recorded 2.89 and 16.22 maggots/ fruit. Both the varieties were significantly ($P \leq 0.05$) superior to susceptible standard, *Totapuri* that recorded 55.11 maggots/

fruit. Similar trend was observed in II, III, IV and V sets also where significantly ($P \leq 0.05$) less number of maggots/ fruit were observed in *EC 95862* and *Mylupilian* compared to *Totapuri*. The percent infestation in all the three varieties across the different sets clearly indicated that *Mylupilian* and *EC 95862* were less preferred compared to *Totapuri* by *B.dorsalis* (Table 3). To further ascertain this, in the VI set unequal number of fruits (more number of *EC 95862/ Mylupilian* and less number of *Totapuri*) were exposed to fruit flies. Here also, the percent infestation was less in *EC 95862* and *Mylupilian*, which recorded 30.00 and 26.00 respectively when compared to *Totapuri* (93.33%).

Further, a third choice bioassay was conducted to ascertain the role of skin for different varieties viz., *EC 95862*, *Mylupilian* and *Langra* (observed as less preferred in previous bioassays), in the preference/ non-preference by fruit fly, *B. dorsalis* for oviposition (Table 4). This assay also clearly indicated the non-preference of *B. dorsalis* for oviposition in these varieties. In the first set, when peeled, semi peeled and unpeeled fruits of *EC 95862* and

**Table 3: Combination of varieties exposed to *B. dorsalis* in choice bioassay
(*Cv. Totapuri* as susceptible control)**

Choice bioassay	No. of maggots/ fruit					Per cent infestation
	Set I*	Set II*	Set III*	Set IV*	Set V*	Set VI**
a) Mylupilian	2.89 1.47 (11.11)	8.17 2.40 (50.00)	4.80 2.00 (40.00)	2.88 1.60 (25.00)	0.00 1.00 (0.00)	26.00
b) EC 95862	16.22 2.69 (22.22)	8.50 2.57 (66.60)	0.00 1.00 (0.00)	4.63 1.85 (25.00)	4.80 2.03 (40.00)	30.00
c) Totapuri	55.11 7.36 (100.00)	34.83 5.88 (100.00)	12.60 3.62 (100.00)	29.75 5.44 (100.00)	22.40 4.81 (100.00)	93.33
CD (P=0.05)	2.20	2.14	1.34	1.39	1.23	

Figures in parentheses denotes percent infestation; figures in bold denotes $\sqrt{x+1}$ transformed values

* n= 8 (equal number of fruits were exposed in all varieties)

**n=31 (*Mylupilian*); 24 (*EC 95862*); 15 (*Totapuri*)

Langra were exposed to fruit flies, irrespective of presence/ absence of skin all the fruits in *EC 95862* recorded zero infestation. Whereas, in *Langra*, the peeled (100.00%) and semi peeled (100.00%) fruits recorded maximum infestation compared to unpeeled mango fruits (66.67%). The numbers of maggots were also more (though statistically on par) in semi peeled fruits (54.00) followed by peeled (26.00) and unpeeled fruits (23.00). Interestingly, in infested *Langra* fruits, several maggots were found dead in II instar. In the second set, when peeled, semi peeled and unpeeled fruits of *EC 95862* and *Mylupilian* were compared, as in case of first set all the fruits of *EC 95862* recorded zero infestation irrespective of peeling/semi peeling/unpeeling. Where as, in case of *Mylupilian* semi peeled fruits recorded maximum infestation (75.00%) followed by peeled fruits (25.00%) compared to unpeeled fruits (0.00%). The numbers of maggots/ fruit were also significantly ($P \leq 0.05$) more in semi peeled fruits (6.50) followed by peeled fruits (1.75). Here also,

as observed in case of *Langra* in the first set, dead maggots of I and II instars were found in infested *Mylupilian* fruits. In the third set, when peeled/ semi peeled/ unpeeled fruits of *Mylupilian* and *Langra* were compared, unlike in the second set all the *Mylupilian* fruits recorded zero infestation irrespective of presence/ absence of skin. In case of *Langra*, maximum percent infestation was found in semi peeled fruits (100.00) followed by peeled (25.00) and unpeeled fruits (25.00). The numbers of maggots/ fruit were also significantly ($P \leq 0.05$) more in semi peeled fruits (35.50) compared to peeled (1.50) and unpeeled fruits (1.50).

Further, to confirm the ovipositional preference of *B. dorsalis*, a no-choice bioassay was carried out (Table 5). Here, unlike in the choice-bioassay (where fruit flies had choice to choose among the different fruits offered), the test fruits were offered individually and the fruit flies were compelled to oviposit on the fruits viz.,

Table 4: Different combinations of varieties exposed to *B. dorsalis* with/without skin peeling

Choice bio-assay	<i>EC 95862</i>		<i>Langra</i>		Remarks
Set I	No. of maggots/ fruit	Per cent infestation	No. of maggots/ fruit	Per cent infestation	
a) <i>EC 95862 x Langra</i>					
➤ Peeled	0.00 (1.00)	0.00	23.00 (4.49)	100.00	Maggots in cv. <i>Langra</i> fruits were died in II instar
➤ Semi peeled	0.00 (1.00)	0.00	54.00 (7.22)	100.00	
➤ Unpeeled	0.00 (1.00)	0.00	26.00 (4.55)	66.67	
CD (P=0.05)	3.22 (overall); 2.78 (interaction)				
Set II	<i>EC 95862</i>		<i>Mylopilian</i>		Remarks
	No. of maggots/ fruit	Per cent infestation	No. of maggots/ fruit	Per cent infestation	
b) <i>EC 95862 x Mylopilian</i>					
➤ Peeled	0.00 (1.00)	0.00	1.75 (1.46)	25.00	Maggots were found died in I and II instars in cv. <i>Mylopilian</i>
➤ Semi peeled	0.00 (1.00)	0.00	6.50 (2.55)	75.00	
➤ Unpeeled	0.00 (1.00)	0.00	0.00 (1.00)	0.00	
CD (P=0.05)	0.89 (overall); 0.63 (interaction)				
Set III	<i>Mylopilian</i>		<i>Langra</i>		Remarks
	No. of maggots/ fruit	Per cent infestation	No. of maggots/ fruit	Per cent infestation	
c) <i>Mylopilian x Langra</i>					
➤ Peeled	0.00 (1.00)	0.00	1.50 (25.00)	25.00	Maggots were found died in II instar in cv. <i>Langra</i> .
➤ Semi peeled	0.00 (1.00)	0.00	35.50 (100.00)	100.00	
➤ Unpeeled	0.00 (1.00)	0.00	1.50 (25.00)	25.00	
CD (P=0.05)	1.36 (overall); 0.96 (interaction)				

Figures in parentheses denotes $\sqrt{x+1}$ transformed values

Table 5: Varieties exposed to *B. dorsalis* under no-choice bioassay

Parameters observed	<i>EC 95862</i>	<i>Myilupilian</i>	<i>Totapuri</i>
i) Per cent infestation	50.00	20.00	85.00
ii) No. of maggots/ fruit	40.70	5.25	70.33
iii) No. of developmental stages found after holding period	Eggs, I, II, III instars & pupae	II & III instars	III instar
iv) No. of dead stages found			
➤ Eggs	0.90	–	–
➤ I Instar	0.10	–	–
➤ II Instar	2.80	–	–
➤ III Instar	33.20	3.00	–
➤ Pupae	0.2	–	–
v) No. of live stages found			
➤ II Instar	0.60	2.25	–
➤ III Instar	2.90	–	70.33

EC 95862, *Myilupilian* and *Totapuri* to determine the ovipositional preference. In this assay also, the fruit flies oviposited readily on *Totapuri* (85.00 per cent infestation was observed) over *EC 95862* and *Myilupilian* that recorded 50.00 and 20.00 percent infestations respectively. The number of maggots per fruit was also more in *Totapuri* (70.33) compared to *EC 95862* (40.70) and *Myilupilian* (5.25). Though, *EC 95862* recorded more infestation and more number of maggots per fruit compared to *Myilupilian*, maximum number of maggots were found dead (0.1, 2.8 and 33.2 in I, II and III instar respectively). Even unhatched eggs (0.9/fruit) were also found in the infested *EC 95862* fruits. The number of live maggots/ fruit was also less (0.6/2.9 of II and III instars respectively) in *EC 95862* compared to *Totapuri* where 69.80 maggots/ fruit were found to be live and only 0.53 maggots/ fruit being dead. Only 0.2 maggots/ fruit reached pupation in *EC 95862* compared to 100.00% in *Totapuri*. In case of *Myilupilian* also 3.00 maggots/ fruit were found dead and only 2.25 maggots/ fruit were found to be live.

In the absence of mango varieties with known resistance to fruit fly, *B. dorsalis*, the results in the present study clearly illustrated the differences in *B. dorsalis* response to polyembryonic varieties viz., *EC 95862*, *Myilupilian* compared to standard commercial varieties viz., *Alphonso*, *Totapuri* and *Langra*. In the first choice bioassay (Table 2) high rates of infestation and maximum number of maggots/fruit were observed in cv. *Alphonso* compared to polyembryonic varieties viz., *EC 95862*, *Myilupilian* and resistant control viz., *Langra*. The data in the second choice bioassay where the polyembryonic varieties were compared with another susceptible control viz., *Totapuri* also exhibited similar trend (Table 3). Thus these results supported the known (in field) low susceptibility of these cultivars and established significant differences in the preference of *B. dorsalis* for oviposition and larval establishment. The third choice bioassay which was carried out using peeled, semi peeled and unpeeled fruits confirmed the very wide variation in the per cent infestation and number of maggots/ fruit in all the three cultivars viz., *EC 95862*, *Myilupilian* and

Langra (Table 4). It is still unclear whether the non-preference of *B.dorsalis* in *EC 95862* and *Myilupilian* is because of rind as all fruits (peeled, semi peeled and unpeeled), recorded zero infestation. Nevertheless, this is indicative of lack of ovipositional stimuli and/or presence of certain ovipositional inhibitors in the fruits. However, in case of *Myilupilian* (when compared with *EC 95862*) unpeeled fruits were not at all preferred over peeled and semi peeled fruits indicating role of fruit rind in preference/ non-preference by *B. dorsalis*. Further, the maggots in infested *Myilupilian* fruits were found dead, showing the considerable adverse influence on developmental stages of insect. This indicates role of antibiosis where the resistant hosts that are nutritionally inferior to the insect species exhibit adverse effects on the developmental stages (Chelliah and Sambandam, 1974). Whereas, the role of rind for differences in percent infestation and maggot number is apparent in case of *Langra* (Table 4), where the percent infestation was found comparatively less in unpeeled fruits. Further, mortality of maggots in infested fruits indicates that antibiosis effect also involved for low infestation in this cultivar. The data in choice bioassays was further supported by no-choice bioassay where the polyembryonic varieties viz., *EC 95862* and *Myilupilian* recorded low fruit fly infestation and low maggot survival. The high mortality of immature stages, prolonged or arrested maggot growth and development observed in *EC 95862* and *Myilupilian* which were the familiar symptoms of nutritional deficiencies (House, 1963) strongly indicates the antibiosis effects are also contributing to the lower fruit fly infestation in these varieties.

The polyembryonic varieties viz., *EC 95862* and *Myilupilian* were less preferred by *B. dorsalis* in both choice and no-choice bioassays showing ovipositional non-preference resistance type in both the tests. Also, it was found that maggot survival was lowest in these varieties and the maggots eventually died within the pulp indicating influence of some mechanical and chemical barriers against *B. dorsalis*. On the

other hand, the varietal details presented in Table 1 showed presence of abundant fiber in the pulp of the polyembryonic varieties compared to other cultivars. These studies on the low susceptibility of these polyembryonic varieties to *B. dorsalis* throw light on the quantum of influence exerted individually by the fruit rind and the pulp. Therefore, the low susceptibility of these varieties may be due to combined influence of rind as well as pulp. Further, detailed studies to find out the role of biochemical components in the rind as well as fruit pulp should be envisaged to get deeper insights in to the mechanism of resistance involved in these varieties.

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BIOLOGICAL STUDIES ON THE SOUTHERN GREEN STINK BUG, *Nezara viridula* (L.) AND THE SMALLER STINK BUG, *Piezodorus rubrofasciatus* (F.) (PENTATOMIDAE: HEMIPTERA) INFESTING VEGETABLE COWPEA

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ABSTRACT : The life cycle and development of the southern green stink bug, *Nezara viridula* (L.) and the smaller stink bug, *Piezodorus rubrofasciatus* (F.) was studied on vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt at Vellayani, Thiruvananthapuram, Kerala. Both the pod bugs underwent five nymphal instars prior to adulthood. The developmental period of *N. viridula* from egg to adult extended for 22.59 ± 0.41 days. An adult female on an average laid 81.80 ± 17.76 eggs. Male and female adults lived for 32.00 ± 1.13 and 50.70 ± 1.60 days respectively. Nymphs of *N. viridula* emerging from the hexagonal egg mass were deep orange coloured. Later instars turned into shades of black, green with multicoloured spots. Adult *N. viridula* was green coloured with three white spots on the pronotum.

P. rubrofasciatus completed its developmental period from egg to adult in 20.19 ± 0.20 days. The mean fecundity was 52.00 ± 8.77 eggs. The longevity of male and female adults extended for 21.50 ± 2.74 and 29.80 ± 1.80 days, respectively.

P. rubrofasciatus laid hexagonal eggs in paired rows. Nymphs emerging were deep orange coloured with black head and thorax. The abdomen turned into metallic yellow shades in the later instars. Adult *P. rubrofasciatus* was pale green coloured with red or green band on the pronotum. This is the first report of biology of *P. rubrofasciatus* in vegetable cowpea.

Key words : *Nezara viridula*, *Piezodorus rubrofasciatus*.

INTRODUCTION

Vegetable cowpea has great demand in the domestic markets of Kerala as well as in the Gulf countries. Pod bugs are often the most troublesome pests infesting the crop. These bugs insert their stylets through the pod wall and desap the pods preferably from the seed region. As a result of which, light brown feeding

punctures occur on the pods. Tender pods are completely desapped. Partially desapped mature pods present shrinking, shrivelling and discolouration symptoms. Earlier, the alydid pod bug *Riptortus pedestris* (F.) was reported to cause severe feeding damage in cowpea (Visalakshi *et al.* 1976). Nair (1978) recorded *R. pedestris* as a major pest and *Nezara viridula*

(L.) as a minor pest of pulses in Kerala. However, recently a widespread occurrence of *N. viridula* was observed in the southern districts of Kerala. Also, a new pod bug, *Piezodorus rubrofasciatus* (F.) was associated with vegetable cowpea. Earlier the bug has been reported to infest lucerne (Joseph, 1953) and observed to be an emerging pest of soybean (Singh *et al.* 1989). In order to formulate effective management strategies against the pod bugs, attempts were made to study the development of *N. viridula* and *P. rubrofasciatus* in vegetable cowpea.

MATERIALS AND METHODS

Studies on the life cycle and development of *N. viridula* and *P. rubrofasciatus* was carried out under laboratory conditions at the College of Agriculture, Vellayani, Thiruvananthapuram during 2005 – 2006. Adult bugs were collected from vegetable cowpea fields. The bugs were confined in glass chimneys (15x10cm) with the tops secured with muslin cloth. Filter paper sheets were provided at the bottom of the chimneys to facilitate absorption of excretory materials. Fresh vegetable cowpea pods var. Sharika were supplied and the desapped ones were removed periodically. A cotton swab soaked in dilute honey solution was provided as a supplementary food source. Eggs laid were used for studying the biology of the bugs. Eggs of either bug species were individually removed and morphometric measurements (diameter and height) were recorded on five eggs of each of the bug species using a calibrated ocular micrometer mounted on stereo binocular microscope.

Eggs were observed daily for colour change and hatching. Incubation period of egg was worked out for 10 eggs of each bug species. Nymphs were segregated from second instar onwards in case of *N. viridula* whereas in *P. rubrofasciatus* individual confinement of nymphs was done soon after eclosion itself. Duration of each nymphal instar, colour change and morphological characters were noted for 10

nymphs of each of the bug species. Length and width of each nymphal instar were measured from five fully grown nymphs using a calibrated ocular micrometer mounted on a stereo binocular microscope. The total life cycle was computed from the day of egg laying till adult emergence. To study mating, oviposition behaviour and fecundity, a pair of freshly moulted male and female adults of the respective bug species was confined. Ten such replications were maintained for each species. The bug pairs were provided with fresh host pods and cotton swab soaked in dilute honey solution. Fecundity of the bugs was recorded by counting the number of eggs laid by an individual female of each of the bug species during the entire ovipositional period. Longevity was worked out from the date of adult emergence till the death of the insect.

RESULTS AND DISCUSSION

Multiple matings were noticed among the bug pairs in confinement. The bugs mated in an end to end position. Ovipositional period of *N. viridula* and *P. rubrofasciatus* lasted for 0.34 ± 0.06 and 9.90 ± 1.56 days respectively (Table 1 and Table 2).

Eclosion of eggs from a single egg mass occurred simultaneously in siblings of both the bug species studied. The number of nymphal instars, shape of the nymphs, segmentations of antennae and rostrum were similar for both the species of bugs. Five nymphal instars were observed prior to adulthood. The nymphs were slightly convex shaped. Rostrum was four segmented in nymphs and adults. Antennae were four segmented in nymphs and five segmented in adults. Wing buds became prominently visible in the fifth instar of both the bug species.

N. viridula

Egg

The egg mass was hexagon shaped. Eggs were barrel shaped and pale yellow when freshly laid. The diameter and height of the eggs were

0.73 mm and 1.05 mm respectively (Table 1). Eggs started assuming an orange hue after 1.40 days of oviposition. The incubation period was 4.50 days. The day before hatching the eggs turned deep orange coloured. Todd (1989) reported that eggs of *N. viridula* were pale yellow coloured, laid in polygonal clusters.

First instar nymph

The first instar nymphs hatched simultaneously from an egg mass and congregated over the egg shells for a day before they moved to feed on pods. Similar observations were made by Susanne and Sailer (1999) and Kumar and Ahmad (2003). Efforts made to

segregate the first instars led to cent per cent mortality. Desiccation, inability to utilize the pod with its fragile rostrum and meagre salivary secretion may be the attributing factors for the mortality of individually confined first instars. Lockwood and Story (1986) opined that aggregation of *N. viridula* nymphs could speed development and reduce mortality. Fully grown first instar nymph measured 1.66 ± 0.02 mm and 1.08 ± 0.02 mm in length and width respectively (Table 1). These nymphs were bright orange coloured with wavy red markings and glossy yellow legs. Eyes were brown coloured. The first instar nymphs could not right themselves on falling upside down. The duration of first instar lasted for 2.42 days (Table 1).

Table 1. Biology and morphometrics of *Nezara viridula* (L.) on vegetable cowpea var. Sharika

Stage	*Duration (days) (Mean \pm SD)	**Morphometrics (mm) (Mean \pm SD)	
		Diameter	Height
Egg	4.50 \pm 0.00	0.73 \pm 0.00	1.05 \pm 0.00
		Length	Width
First instar nymph	2.42	1.66 \pm 0.02	1.08 \pm 0.02
Second instar nymph	3.41 \pm 0.38	2.32 \pm 0.02	1.84 \pm 0.02
Third instar nymph	2.92 \pm 0.23	5.30 \pm 0.06	3.74 \pm 0.04
Fourth instar nymph	3.75 \pm 0.37	6.91 \pm 0.11	5.48 \pm 0.06
Fifth instar nymph	5.59 \pm 0.33	11.60 \pm 0.06	8.60 \pm 0.49
Total nymphal period	18.09 \pm 0.41		
Total life cycle	22.59 \pm 0.41		
Adult male	32.00 \pm 1.13	13.20 \pm 0.40	7.00 \pm 0.00
Adult female	50.70 \pm 1.60	13.60 \pm 0.49	7.00 \pm 0.00
Oviposition period	0.34 \pm 0.06		
Fecundity (Egg No.)	81.80 \pm 17.76		

* Mean of ten observations

** Mean of five observations

Second instar nymph

The second instar nymph was blackish brown measuring 2.32 ± 0.02 mm and 1.84 ± 0.02 mm length and width wise respectively. Eyes were blackish brown coloured. Each of the thoracic segments presented a pair of golden brown spots bordered black on either sides laterally. Second instar moulted to the third instar after 3.41 ± 0.38 days

Third instar nymph

Third instars were blackish brown coloured. The mean length and width were 5.30 ± 0.06 mm and 3.74 ± 0.04 mm respectively (Table 1). The paired rectangular spots of prothorax and mesothorax turned orange yellow and seemed more like lateral extensions from thorax. Those spots on the metathorax, observed in the previous instar were absent. The third instar duration extended for 2.92 ± 0.23 days (Table 1).

Fourth instar nymph

Fourth instar nymphs were blackish brown / green coloured measuring 6.91 ± 0.11 and 5.48 ± 0.06 mm, length and width wise respectively. The paired series of lateral rectangular spots on the thorax turned deep yellow coloured. The fourth instar duration was 3.75 ± 0.37 days (Table 1).

Fifth instar nymph

Fifth instars showed more perceptible increase in growth than any other instar measuring about 11.60 ± 0.06 mm and 8.60 ± 0.49 mm in length and width respectively (Table 1). The paired series of lateral rectangular spots on the thorax turned rufous. Fifth instars moulted to adults after 5.59 ± 0.33 days (Table 1).

Developmental period

In the present study conducted, the total nymphal period and total life cycle of *N. viridula* on vegetable cowpea extended for 18.09 ± 0.41 and 22.59 ± 0.41 days respectively. Mukhopadhyay and Roychoudhury (1987)

reported that *N. viridula* took an average of 44.40 days to complete its life cycle on *Vigna umbellata* (Thnb.). Der Chien *et al.* (1997) observed that *N. viridula* reared on *V. unguiculata* ssp. *sesquipedalis* took 5.40 and 34.90 days respectively to complete its egg and nymphal period.

Adult

The adult of *N. viridula* was a green coloured, pentatomid stink bug with three white spots lying horizontally on the pronotum. Adult female measured 13.60 ± 0.49 mm, 7.00 mm and adult male measured 13.20 ± 0.40 mm, 7.00 mm in length and width respectively. Longevity of male and female adults extended for 32.00 ± 1.13 and 50.70 ± 1.60 days respectively. An adult female laid an average of 81.80 ± 17.76 eggs. Bhalani and Bharodia (1988) observed a mean fecundity of 260 eggs when *N. viridula* fed upon pigeonpea pods. Der Chien *et al.* (1997) opined that adult *N. viridula* could live for 22.60 days and the fecundity was 215 eggs.

When the adult bugs of *N. viridula* were subjected to more than 12 hours of light exposure, the females failed to oviposit even after several matings and died shortly. However, egg laying occurred almost instantly on the same night when mated female adults were confined in darkness. This proves that light has an influential role with regard to mating and oviposition in *N. viridula*.

P. rubrofasciatus

The life stages of *P. rubrofasciatus* are presented in Fig.1.

Egg

Eggs were pale greyish, green coloured, barrel shaped with two dark green, horizontal bands encircling the sides. The top most portion was glistening, grey-green coloured and bordered by fragile white pedicellate structures. Eggs were laid in paired rows each with 6 – 23 eggs, glued to each other compactly. The incubation period was 4.58 days. The day before hatching, the eggs developed an orange brown

colouration. Singh *et al.* (1989) observed that in summer, the eggs hatched in two days.

Nymph

The head, thorax and legs of the nymphs were black coloured. Abdomen was deep orange in the first two instars. However, in the later instars, abdomen presented a metallic yellow colouration. Soon after the eclosion of the egg mass, siblings congregated over the chorion for a few hours before they moved to feed on pods. The average length and width of a fully grown first instar nymph was 0.86 ± 0.01 mm and 0.83 ± 0.01 mm respectively. First instar duration lasted for 2.88 days (Table 2). First instars of *P. rubrofasciatus* could survive on individual confinement and right themselves on falling

upside down unlike the first instars of *N. viridula*. Gregarious feeding was commonly observed. The mean length, width and duration of second to fifth instars are given in Table 2. Fourth instars closely resembled the third instars except for general size increase and lateral broadening of thorax. The fifth instars moulted to adults in 4.20 ± 0.13 days which was the longest duration observed than any other instar.

Developmental period

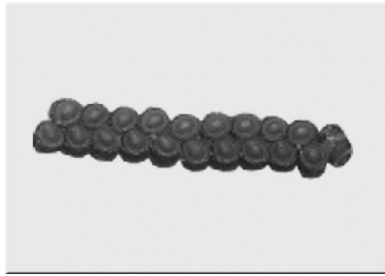
The results revealed that the total nymphal period and total life cycle of *P. rubrofasciatus* extended for 15.60 ± 0.20 and 20.19 ± 0.20 days respectively. In soybean, the bug took 15.70 days to complete its nymphal period (Singh *et al.* 1989).

Table 2. Biology and morphometrics of *Piezodorus rubrofasciatus* (Fab.) on vegetable cowpea var. Sharika

Stage	*Duration (Days) Mean \pm SD	**Morphometrics (mm) Mean \pm SD	
		Diameter	Height
Egg	4.58 ± 0.00	0.72 ± 0.00	0.86 ± 0.00
		Length	Width
First instar nymph	2.88 ± 0.00	0.86 ± 0.01	0.83 ± 0.01
Second instar nymph	3.20 ± 0.11	1.74 ± 0.02	1.59 ± 0.02
Third instar nymph	2.70 ± 0.09	3.27 ± 0.02	2.38 ± 0.02
Fourth instar nymph	2.63 ± 0.08	4.01 ± 0.10	2.94 ± 0.05
Fifth instar nymph	4.20 ± 0.13	7.62 ± 0.05	4.30 ± 0.03
Total nymphal period	15.60 ± 0.20		
Total life cycle	20.19 ± 0.20		
Adult male	21.50 ± 2.74	7.93 ± 0.05	4.62 ± 0.05
Adult female	29.80 ± 1.80	8.59 ± 0.04	5.07 ± 0.03
Oviposition period	9.90 ± 1.56		
Fecundity (Egg No.)	52.00 ± 8.77		

* - Mean of ten observations

** - Mean of five observations



Eggs



First instar nymph



Second instar nymph



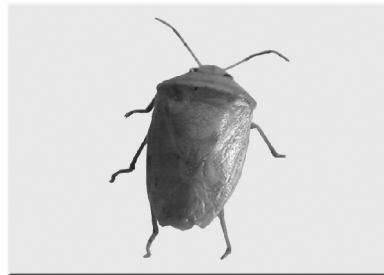
Third instar nymph



Fourth instar nymph



Fifth instar nymph



Adult

Figure 1 : Life stages of *Piezodorus rubrofasciatus*

Adult

The adult was a pale green, pentatomid stink bug with a red or green band on pronotum. Green band was characteristic of adult male. Eyes retained the brown colour. Antennae were five segmented, each coloured with varying shades of green. Adult female measured 8.59 ± 0.04 mm, 5.07 ± 0.03 mm and adult male measured 7.93 ± 0.05 mm, 4.62 ± 0.05 mm, length, width wise respectively. The longevity of adult male and female was 21.50 ± 2.74 and 29.80 ± 1.80 days respectively. An adult female on an average laid 52.00 ± 8.77 eggs.

In both the bug species, a rapid size increase was observed when the fourth instar moulted to the fifth instar (Table 1 and Table 2). This indicates the probability of increased feeding activity and damage to the pods by the fourth instar nymphs. The first instar of *N. viridula* is observed to be the most vulnerable stage in the life cycle of the bug being unable to resume its feeding positions on dislodgement from the plant. Therefore, wetting the crop canopy thoroughly during irrigation could wash off the first instars of *N. viridula*, thereby considerably reducing the pest population.

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SEASONAL INCIDENCE OF POD BUGS AND THEIR NATURAL ENEMIES IN VEGETABLE COWPEA ECOSYSTEMS OF KERALA

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ABSTRACT: Studies were undertaken at the College of Agriculture, Vellayani, Thiruvananthapuram, S. India during 2005-2006 to assess the seasonal incidence of pod sucking bugs infesting vegetable cowpea and their natural enemies. The nymphal and adult population of the pentatomid stink bug, *Nezara viridula* (L.) attained peak values during May 2006 and the first fortnight of April 2006, respectively. The nymphal population of the alydid pod bugs, *Riptortus pedestris* F. and *Riptortus ? linearis* (F.) was significantly higher during the first fortnight of May 2006 and the succeeding three fortnights. Adult population of *R. pedestris* and *R? linearis* peaked significantly during the first and second fortnights of June 2006 respectively, when compared to most other periods of the year. Minimum temperature was positively correlated with the population of nymphs of *Riptortus* spp., adult *R. pedestris* and adult *N. viridula*. Preying mantids and spiders were also documented in the cowpea ecosystem.

Key words : Cowpea, *Nezara viridula*, *Riptortus pedestris*, *Riptortus? linearis*

INTRODUCTION

Vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt is a proteinaceous vegetable crop, known for its succulent pods rich in essential vitamins, minerals and dietary fibre. Among the insect pests, pod sucking bugs are the most ingenious intruders during the post flowering phase of the crop. These bugs feed by desapping the juice from pods thereby affecting the quantity and quality of the produce. Temporal distribution of insect pests is often governed by complex interactions exerted by abiotic and biotic factors. Therefore, information pertaining to seasonal abundance of the pest would be beneficial while combating with them, to keep

their populations below damaging levels. Perusal of literature indicated deficit of data regarding population of pod bugs on a temporal scale. Hence, studies were taken up during 2005-2006, at the College of Agriculture, Vellayani, Thiruvananthapuram to derive information on the seasonal incidence of pod bugs infesting vegetable cowpea and their natural enemies.

MATERIALS AND METHODS

The seasonal occurrence of different species of pod bugs and their natural enemies in vegetable cowpea was studied by recording their population in the crop raised in the Instructional Farm, College of agriculture, Vellayani,

Thiruvananthapuram during August, 2005 to September, 2006. Seeds of vegetable cowpea var. Sharika were sown at a spacing of 45x15 cm in 40 sq m area, every month so as to ensure continuous supply of pods throughout the period of observation. The crop was maintained in the field as per recommended practices with the exception of pesticide application. (KAU. 2002)

Fortnightly observations were taken from five observational plants in the pod bearing stage. The pods, flowers, leaves and stem were closely examined for pod bug nymphs, adults and their natural enemies and the total number present in each plant was recorded. The meteorological parameters viz., maximum and minimum temperature, morning and evening relative humidity, rainfall and number of rainy days were recorded from the Department of Meteorology, College of Agriculture, Vellayani. The relationship between the population of different species of pod bugs and their natural enemies with weather parameters was worked out by correlation matrix.

RESULTS AND DISCUSSION

The population counts of the pod bugs, *Nezara* (L) *viridula*, *Riptortus pedestris* F. and *R? linearis* (F.) observed in vegetable cowpea from October 2005 to September 2006 are presented in Table 1.

N. viridula nymph

The nymphal stages of *N. viridula* were completely absent in the field during October 2005 and the population gradually started building up from the second fortnight of December 2005 onwards. The population showed definite hikes during the first fortnight of March 2006 (10.35 per plant) and the first fortnight of May 2006 (11.29 per plant). The population observed during this period, the second fortnights of May 2006, August 2006 and the first fortnight of September 2006 were significantly higher when compared with the population observed from October 2005 to December 2005.

N. viridula adult

Adults of *N. viridula* were observed from the first fortnight of November 2005 onwards. The population assumed peaks during the first fortnight of April 2006 (1.32 per plant) and the second fortnight of June 2006 (1.31 per plant) which were significantly higher than counts observed in October 2005, December 2005 and February 2005. Minimum temperature exerted significant positive effects on the adult population of

N. viridula during the fortnight of observation ($r = 0.5802$) as well as the succeeding fortnight of observation ($r = 0.5035$) (Table 3). Maximum temperature exhibited significant positive correlation with the population of the succeeding fortnight of observation ($r = 0.5205$) (Table 4).

Riptortus spp. nymph

During the first two fortnights of October 2005, the nymphal population of *Riptortus* spp. was almost constant (10.48 and 10.94 per plant respectively). The population followed a more or less constant pattern of rise and fall in the alternate fortnights attaining a maximum value by the first fortnight of May 2006 (36.07 per plant). This count was significantly higher than that observed in any other fortnight except the succeeding three fortnights which were on par. Minimum temperature showed a highly significant positive correlation with nymphal population of *Riptortus* spp. during the fortnight of observation ($r = 0.6653$) (Table 3) as well as the succeeding fortnight ($r = 0.6338$) (Table 4). The population was negatively influenced by morning relative humidity ($r = -0.4814$) (Table 3).

R. pedestris adult

The population of adult *R. pedestris* showed a gradual diminishing pattern from the first fortnight of October 2005 (4.14 per plant) to the second fortnight of November 2005 (2.70 per plant). The population followed a pattern of slight

rise and fall in the alternate fortnights. Maximum number of adults per plant (9.02 per plant) was observed in the first fortnight of June 2006 which was significantly higher than that observed during most other periods of the year.

Minimum temperature exhibited highly significant positive correlation on the adult population of *R. pedestris* during the fortnight of observation ($r = 0.5278$) (Table 3) and the succeeding fortnight of observation ($r = 0.6058$) (Table 4). Also, the evening relative humidity was significantly associated with the population of the current and succeeding fortnight ($r = 0.4404$ and 0.4421 respectively).

***R? linearis* adult**

The adult population of *R? linearis* was absent during the months of October 2005 and November 2005. A pattern of slight rise and fall in the alternate fortnights was observed from the first fortnight of December 2005 onwards. However, the population observed during the second fortnight of June 2006 (3.30 per plant) was significantly higher than in any other fortnight of observation.

Natural Enemies

The population of preying mantids and spiders observed during the different fortnights did not differ significantly (Table 2).

Preying mantids

The highest population of preying mantids (1.93 per plant) was noted during the second fortnight of December 2005. During the other periods of the year the mantid population ranged from 0.17 to 1.86 per plant. Morning relative humidity of the preceding fortnight showed significant negative correlation ($r = -0.4620$) with the population of the mantids.

Spiders

Population levels of spiders ranged from 0.31 to 1.54 per plant. Minimum temperature showed

highly significant association with the population of spiders during the fortnight of observation ($r = 0.6635$) (Table 3) and the succeeding fortnight of observation ($r = 0.6003$) (Table 4). Maximum temperature, too was positively correlated with the spider population of the succeeding fortnight ($r = 0.6873$) (Table 4).

The results of the present study revealed that minimum temperature of the previous fortnight as well as the current fortnight of observation exhibited significant positive correlation with the adult population of *N. viridula*, *R. pedestris* and the nymphal population of *Riptortus* spp. Also, the maximum temperature of the previous fortnight positively influenced the adult population of *N. viridula*. The findings are in confirmation with Sarma and Dutta (1996) who deduced a positive correlation between minimum temperature and population build up of *N. viridula* in green gram. Singh *et al.* (2002) reported that maximum and minimum temperature was positively correlated with population increase of *N. viridula* in cowpea. However, in black gram crop, Nayak *et al.* (2004) observed a negative correlation between peak numbers of *N. viridula* with minimum temperature and relative humidity. Also, they deduced that minimum temperature and relative humidity had a negative influence on activity of *Riptortus* spp.

Minimum temperature of the previous fortnight as well as the current fortnight of observation and maximum temperature of the previous fortnight exhibited highly significant positive association with the spider population. The results align with that of Hussein (1999) who stated that high temperature and dense vegetation cover positively influenced the peak activity and higher density of spiders.

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Table 1. Population of different species of pod bugs on vegetable cowpea from October 2005 to September 2006

Period	Pod bug (Mean number per plant)				
	<i>N. viridula</i> (Nymph)	<i>N. viridula</i> (Adult)	<i>Riptortus</i> spp. (Nymph)	<i>R. pedestris</i> (Adult)	<i>R? linearis</i> (Adult)
I FN October 2005	0.00 (1.00)	0.00 (1.00)	10.48 (3.39)	4.14 (2.27)	0.00 (1.00)
II FN October 2005	0.00 (1.00)	0.00 (1.00)	10.94 (3.46)	4.99 (2.45)	0.00 (1.00)
I FN November 2005	0.31 (1.15)	0.51 (1.23)	14.52 (3.94)	3.42 (2.10)	0.00 (1.00)
II FN November 2005	0.00 (1.00)	0.17 (1.08)	13.01 (3.74)	2.70 (1.92)	0.0 (1.00)
I FN December 2005	0.00 (1.00)	0.17 (1.08)	5.24 (2.50)	3.39 (2.10)	0.51 (1.23)
II FN December 2005	0.31 (1.15)	0.31 (1.15)	10.11 (3.33)	2.06 (1.75)	0.36 (1.17)
I FN January 2006	0.67 (1.29)	0.51 (1.23)	8.79 (3.13)	1.63 (1.62)	0.51 (1.23)
II FN January 2006	4.20 (2.28)	0.67 (1.29)	9.16 (3.19)	2.80 (1.95)	0.36 (1.17)
I FN February 2006	4.78 (2.40)	0.17 (1.08)	8.74 (3.12)	1.75 (1.66)	0.72 (1.31)
II FN February 2006	0.66 (1.29)	0.17 (1.08)	10.32 (3.37)	2.10 (1.76)	0.17 (1.08)
I FN March 2006	10.35 (3.37)	0.51 (1.23)	13.17 (3.76)	3.87 (2.21)	0.72 (1.31)
II FN March 2006	5.11 (2.47)	0.31 (1.15)	11.10 (3.48)	2.39 (1.84)	0.00 (1.00)
I FN April 2006	2.28 (1.81)	1.32 (1.52)	13.85 (3.85)	3.25 (2.06)	0.31 (1.15)
II FN April 2006	2.05 (1.75)	1.18 (1.48)	17.42 (4.29)	6.10 (2.66)	0.67 (1.29)
I FN May 2006	11.29 (3.51)	0.51 (1.23)	36.07 (6.09)	8.07 (3.01)	0.95 (1.39)
II FN May 2006	10.87 (3.45)	0.89 (1.38)	24.78 (5.08)	7.41 (2.90)	0.99 (1.41)
I FN June 2006	5.32 (2.51)	1.13 (1.46)	22.58 (4.86)	9.02 (3.17)	1.60 (1.61)
II FN June 2006	5.17 (2.48)	1.31 (1.52)	21.79 (4.77)	7.37 (2.89)	3.30 (2.07)
I FN July 2006	2.50 (1.87)	0.31 (1.15)	10.24 (3.35)	5.42 (2.53)	0.36 (1.17)
II FN July 2006	1.59 (1.61)	0.17 (1.08)	11.58 (3.55)	7.87 (2.98)	1.04 (1.43)
I FN August 2006	0.17 (1.08)	0.00 (1.00)	7.73 (2.95)	4.02 (2.24)	0.81 (1.35)
II FN August 2006	7.88 (2.98)	0.17 (1.08)	21.85 (4.78)	7.70 (2.95)	0.31 (1.15)
I FN September 2006	9.69 (3.27)	0.17 (1.08)	19.20 (4.49)	4.18 (2.28)	1.13 (1.46)
II FN September 2006	0.17 (1.08)	0.17 (1.08)	12.13 (3.62)	7.60 (2.93)	1.71 (1.65)
CD (0.05)	1.863	0.336	1.370	0.783	0.404

Figures in parentheses are $\sqrt{x+1}$ values
FN = Fortnight

Table 2. Population of natural enemies of pod bugs on vegetable cowpea from October 2005 to September 2006

Period	Predators (mean number per plant)	
	Preying mantids	Spiders
I FN October 2005	1.86 (1.69)	0.56 (1.25)
II FN October 2005	1.60 (1.61)	0.36 (1.17)
I FN November 2005	0.36 (1.17)	0.51 (1.23)
II FN November 2005	0.31 (1.15)	0.36 (1.17)
I FN December 2005	0.51 (1.23)	0.72 (1.31)
II FN December 2005	1.93 (1.71)	0.89 (1.38)
I FN January 2006	0.17 (1.08)	0.72 (1.31)
II FN January 2006	0.17 (1.08)	0.51 (1.23)
I FN February 2006	0.51 (1.23)	0.36 (1.17)
II FN February 2006	0.36 (1.17)	0.72 (1.31)
I FN March 2006	0.51 (1.23)	0.89 (1.38)
II FN March 2006	0.17 (1.08)	0.72 (1.31)
I FN April 2006	1.13 (1.46)	1.23 (1.49)
II FN April 2006	0.51 (1.23)	1.48 (1.58)
I FN May 2006	0.95 (1.39)	1.13 (1.46)
II FN May 2006	0.89 (1.38)	1.54 (1.59)
I FN June 2006	0.56 (1.25)	0.72 (1.31)
II FN June 2006	0.56 (1.25)	1.23 (1.49)
I FN July 2006	0.51 (1.23)	0.51 (1.23)
II FN July 2006	0.36 (1.17)	0.56 (1.25)
I FN August 2006	0.17 (1.08)	0.36 (1.17)
II FN August 2006	0.56 (1.25)	0.67 (1.29)
I FN September 2006	0.17 (1.08)	0.31 (1.15)
II FN September 2006	1.22 (1.49)	0.56 (1.25)
CD (0.05)	--	--

Figures in parentheses are $\sqrt{x+1}$ values
 FN = Fortnight

Table 3. Correlation coefficient of weather parameters with the population of pod bugs and their natural enemies of the current fortnight of observation

Pod bug/Natural enemy	Maximum Temperature	Minimum temperature	Morning relative humidity	Evening relative humidity	Rainfall	Rainy days
<i>N. viridula</i> (nymph)	0.0423	0.1589	-0.1184	0.0937	-0.2660	-0.085
<i>N. viridula</i> (adult)	0.1970	0.5802**	-0.0586	-0.1028	-0.1367	-0.0865
<i>Riptortus</i> spp. (nymph)	0.1598	0.6653**	-0.4814*	0.1768	-0.0321	-0.0016
<i>R. pedestris</i> (adult)	-0.2090	0.5278**	-0.3817	0.4404*	0.1907	0.2474
<i>R? linearis</i> (adult)	-0.3573	0.3161	-0.2563	0.2578	0.2828	0.2686
Preying mantids	0.1480	-0.0226	-0.2592	-0.1172	0.1336	0.0300
Spiders	0.3923	0.6635**	-0.0826	-0.2315	-0.1407	-0.0799

* - Significant at 5 per cent level

** - Significant at 1 per cent level

Table 4. Correlation coefficient of weather parameters with the population of pod bugs and their natural enemies of the succeeding fortnight of observation

Pod bug/Natural enemy	Maximum Temperature	Minimum temperature	Morning relative humidity	Evening relative humidity	Rainfall	Rainy days
<i>N. viridula</i> (nymph)	0.1579	0.1250	0.1162	-0.1453	-0.2920	-0.1442
<i>N. viridula</i> (adult)	0.5205**	0.5035*	0.2540	-0.1778	-0.2247	-0.1684
<i>Riptortus</i> spp. (nymph)	0.3383	0.6338**	-0.0510	0.1474	-0.1224	0.0569
<i>R. pedestris</i> (adult)	-0.0433	0.6058**	-0.2385	0.4421*	0.2357	0.3197
<i>R? linearis</i> (adult)	-0.0661	0.2338	0.0241	0.3474	-0.0808	0.0349
Preying mantids	0.1883	0.0922	-0.4620*	-0.1527	0.1114	-0.0261
Spiders	0.6873**	0.6003**	0.0946	-0.2650	-0.2632	-0.3269

* - Significant at 5 per cent level

** - Significant at 1 per cent level

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ROLE OF *Aphis gossypii* Glover (APHIDIDAE: HOMOPTERA) ON TEMPORAL AND SPATIAL SPREAD OF *Papaya Ringspot Virus-W* ON PUMPKIN (*Cucurbita moschata* L.)

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ABSTRACT : *Papaya ringspot virus-W* (PRSV-W), previously referred to as *Watermelon mosaic virus-1* (WMV-1) is one of the most important plant viruses that infect cucurbits in India. More than twenty species of aphids, are reported as vectors of PRSV-W. Field studies were conducted in pumpkin field from August to September 2005 and 2006 to document the vectors involved in the spread of PRSV-W, relationship between vector number and incidence, spatial and temporal distribution of virus, and extent of yield loss. *Aphis gossypii* Glover, was observed to be the predominant species in yellow funnel traps. The infection time in relation to plant growth play an important role in deciding the fruit weight and is directly proportional to yield loss.

INTRODUCTION

Aphids cause yield loss through direct feeding damage and as vectors of a number of viral diseases on many crops. Aphids in a non-persistent mode transmit most of the viral diseases. *Aphis gossypii* Glover, *A. craccivora* Koch, *Myzus persicae* (Sulzer), spirey aphid, *A. spiraecola* Patch are some of the major aphid vectors of viruses in the Indian subcontinent. In cucurbits, the major viral diseases are *Cucumber mosaic virus* (CMV), *Papaya ringspot virus-W* [(PRSV-W) previously referred as *Watermelon mosaic virus-1* (WMV - 1)], *Watermelon mosaic virus-2* (WMV - 2) and *Zucchini yellow mosaic virus* (ZYMV) (Lovisolo, 1980). All these viruses severely limit the production of cucurbits (Lovisolo, 1980; von Wechmer *et al.*, 1995). Among these, PRSV-W is a member of the family

Potyviridae and is the type species of the genus *Potyvirus*. This virus inflicts major damage on a number of cucurbitaceous vegetables reducing both quality and yield (Guner *et al.*, 2002). Recently, this virus has been reported on bottle gourd (Mantri *et al.*, 2005).

Among cucurbits, pumpkin (*Cucurbita moschata* L.) is an important vegetable cultivated in India. In recent years, PRSV-W has been one of the major constraints in the successful cultivation of pumpkin in south India. More than twenty species of aphids are reported as vectors of this virus (Zitter *et al.*, 1996). Aphids are an important factor in the spread of viruses both within and between fields. In many cases, it has been noted that initially infected plants act as source-plants for rapid disease spread within the field (Jeger, 2004). In the epidemiology of plant

viruses, delaying virus infection is critical as earlier (and therefore the longer) that the virus is present; the greater is the damage to the crop (Thresh, 1974). In India, the vector species involved in the epidemiology, dynamics of PRSV-W as influenced by the dynamics of aphid population and extent of yield loss due to virus infection need further investigation. Hence, field studies were conducted to document aphid vectors involved in the spread of PRSV-W, identify the relation between vector number and virus infection, spatial and temporal spread of virus and extent of yield loss due to PRSV-W infection in pumpkin.

MATERIALS AND METHODS

Pumpkin field establishment

Pumpkin var. *Arka Suryamukhi* seeds were sown during August 2005 at the Indian Institute of Horticultural Research (IIHR), Bangalore (12° 58' N; 77° 35' E). Crop was raised with a spacing of 300 cm between rows and 60 cm between plants. The total crop area was 0.5 ha (4,200 plants). Plants were raised following standard agronomic practices without applying insecticides. Similarly, during 2006, pumpkin var. *Arka chandan* was raised on pendal at same spacing. Total crop area was 0.2 ha (1,800 plants).

Monitoring of aphids

Aphids abundance in pumpkin field was assessed using five plastic, yellow funnel water traps (30 cm diameter placed at canopy height) and by sampling 20 randomly selected pumpkin plants. Four traps were placed, each at a distance of 10 m around the corner and one at the center. Water was filled to the brim and a drop of soap solution was added. Trapped aphids were collected every 24 h. Samples were filtered and aphids were identified to the species level (Martin, 1983) and numbers of each species was recorded.

PRSV-W disease assessment

The progress of PRSV-W following first infection was assessed at weekly interval based on symptoms. The first symptom of PRSV-W was noticed on new leaves as mosaic but with the passage of time affected portion were distorted. Blisters were noticed on leaves and apical leaves were malformed. Such infected plants (fresh infection as and when noticed) were tagged during regular weekly observation.

Correlation between aphids and PRSV-W disease

Data were subjected to correlation analysis to determine the extent and nature of association between number of aphids and fresh percent PRSV-W infection. Mean numbers of aphids trapped in yellow funnel traps per week were correlated with percent freshly infected plants of the corresponding week and succeeding 1-5 weeks.

Disease progression

The spatial pattern of PRSV-W disease progress was assessed through aggregation indices using Lloyd's index of patchiness and mean crowding. In the first trial, the cropped area (0.5 ha) was divided into 5m² quadrates, each consisting of 3 rows of 20 plants each with a total of 60 plants /quadrate. The mean (m) and variance (v) of number of virus diseased plants per quadrate were calculated for each assessment time. With these statistics, variance-to-mean ratio ($VTM=v/m$); Lloyd's mean crowding ($m^*=m+[VTM-1]$); and Lloyd's patchiness (m^*/m) indices of aggregation were calculated.

Effect of time of infection on pumpkin yield and seed parameters

Fruits from the tagged and infected plants were harvested individually. Fruit weight (g) and diameter (cm) were recorded *in situ* by selecting 25 fruits randomly for each date of infection. Fruits were preserved for one month at ambient

temperature, later cut and observations on seeds number and weight were recorded. Number of seeds in each fruit was counted. Seeds from infected plants were mixed and weights of 100 seeds were recorded for 10 replications. Data from infected fruits were compared with healthy plants using *t* - test.

RESULTS AND DISCUSSION

Aphid species trapped in yellow funnel traps

Six species of aphids were recorded in the yellow funnel water traps during the cropping period. The melon aphid, *A. gossypii*, cowpea aphid, *A. craccivora*, green peach aphid, *Myzus persicae*, spirey aphid, *A. spiraecola*, cabbage aphid, *Brevicoryne brassicae* (Linnaeus), and mustard aphid, *Lipaphis erysimi* (Kalt.) were observed in traps. Among these, the first four species are reported vectors of PRSV-W (Zitter *et al.*, 1996).

During the study period, no species of aphid was observed significantly colonizing pumpkin plants. In the first trial, *A. gossypii* was the only species consistently trapped (78.28 % of total aphids). Numerically less number of *A. craccivora*, *M. persicae* and *A. spiraecola* were trapped (Table 1). Catches of these three species were not consistent and probably not influencing

large scale PRSV-W spread. Hence only the number of most consistently trapped species *viz.*, *A. gossypii* was correlated with number of freshly PRSV-W infected plants.

PRSV-W incidence was correlated with current, first, second, third, fourth and fifth previous week *A. gossypii* trap catches. Earliest PRSV-W infection was recorded during the 6th week in both the trials. In the I trial, total numbers of freshly infected plants with PRSV-W symptoms at 6, 7, 8, 9, 10, 11, 12 and 13 weeks after sowing were 2, 15, 24, 37, 74, 219, 38 and 30 or 0.04, 0.31, 0.57, 0.88, 1.76, 5.21, 0.90 and 0.71 per cent infection, respectively. The final overall PRSV-W infection incidence was 10.34%. Significant correlation was observed between percent freshly infected plants and the fourth previous weeks mean *A. gossypii* trap catches ($r=0.76$) (Table 2). Similarly, in the II trial, a significant correlation was recorded between the fourth previous week mean trap catches ($r=0.74$) (Table 2). Further, a total of 161 *A. gossypii* (74.19% of total aphids) were caught on traps. Numerically less number of *A. craccivora* (7.37% of total aphids); *M. persicae* (8.76% of total aphids) and *A. spiraecola* (2.76% of total aphids) were trapped. Highly significant correlation between trap catches four weeks prior to noticing PRSV-W infection may be due to time lag required to express clear PRSV-W symptom under field condition or delayed expression of

Table 1. Number of aphids trapped and their species composition (%) in pumpkin field during August to September 2005 and 2006.

Aphid species	2005		2006	
	# Trapped	%	# Trapped	%
<i>Aphis gossypii</i>	156	74.28	161	74.19
<i>Aphis craccivora</i>	15	7.14	16	7.37
<i>Aphis spiraecola</i>	11	5.23	6	2.76
<i>Brevicoryne brassicae</i>	11	5.23	7	3.23
<i>Lipaphis erysimi</i>	9	4.28	8	3.69
<i>Myzus persicae</i>	8	3.80	19	8.76

Table 2. Correlation between # *Aphis gossypii* per trap per week and % fresh PRSV-W infection on pumpkin during 2005 and 2006

PRSV infection	r value	
	2005	2006
Same week	0.12	0.002
First succeeding week	0.09	-0.025
Second succeeding week	0.16	0.17
Third succeeding week	0.34	0.31
Fourth succeeding week	0.76*	0.74*
Fifth succeeding week	0.40	0.43

* Significant at $p=0.05$

symptoms. This also indicated that, PRSV infection followed *A. gossypii* trap catch data signifying the role of *A. gossypii* in PRSV-W epidemics.

PRSV - W disease progression

The progress of disease over time represented by spatial statistics is given in table 3. No plant with characteristic symptom was observed till the 5th week after sowing. Only two diseased plants were identified on the 45th day after sowing and they were randomly located. Seven days later (7 weeks after sowing), 13 quadrates had diseased plants. Some newly infected plants were near the previously infected quadrates, but others infected plants were well separated. This indicates the significance of both primary and secondary PRSV-W infection by aphid vectors. All aggregation indices indicated randomness in disease spread both for the 6th and

7th week. At 8th and 9th weeks after sowing, mean crowding and patchiness were not significant. Till this time, randomness was observed in the spread of disease. During 10th week, >50% of the quadrates had one or more diseased plants. At this date, both mean crowding and patchiness were significant indicating clustering of diseased plants. This may be due to acquisition and subsequent transmission of virus by transient *A. gossypii* from infected plants to nearby plants. Similarly, aggregation indices were significant during 11th week. However, mean crowding and patchiness indicated randomness during 12th and 13th week. This may be attributed to saturation with multiple inoculation of virus by aphid vectors and new infection sites becoming scarce. This may also be due to less efficiency of aphid vectors in recovering the virus from older, infected plants or less susceptibility of older plants to virus infection. Age of the leaves from

Table 3. Spatial statistics of PRSV-W disease spread in pumpkin during 2005

Statistic	Weeks after sowing							
	6	7	8	9	10	11	12	13
m	0.02	0.17	0.40	0.52	1.05	3.12	0.54	0.38
v	0.02	0.14	0.38	0.51	1.53	6.46	0.51	0.38
VMR	0.98	0.84	0.97	0.97	1.45*	2.06*	0.94	0.9
m*/m	0.01	0.01	0.37	0.50	1.50*	4.19*	0.48	0.38
Mean crowding	0.49	0.07	0.92	0.94	1.42*	1.34*	0.89	0.99

which aphids acquire a virus has been shown to affect the efficiency of aphid transmission (Foxe and Rochow, 1975). The observation on disease progression was stopped from this week with the onset of senescence.

Effect of time of infection on pumpkin yield and other components

The period from the time of PRSV-W infection to fruit maturity and harvest significantly influenced the yield. There was significant increase in fruit diameter and yield when the infection was delayed even by a week. Plants infected at 42-49 DAS after sowing, yielded 64% less than healthy plants. Further, a stepwise decrease in yield reduction was observed as infection was delayed. In the I trial, PRSV-W infection at 7, 8, 9, 10, 11, 12 and 13 week after sowing decreased fruit weight by 39.04, 33.75, 18.11, 15.73, 10.58, 5.99 and 0.93%, respectively

(Table 4) compared to mean fruit weight in healthy plants. Correspondingly, the fruit diameter was reduced by 32.49, 18.82, 15.93, 13.23, 5.72, 4.98, 3.49 and 0.16%. In the II trial, for 8, 9, 10, 11, 12 and 13 week PRSV-W infection, there was a decline in fruit weight by 97.10, 85.13, 79.73, 72.78, 66.86, 39% respectively when compared to healthy plants. Similarly, the diameter of fruit reduced by 74.61, 53.76, 43.12, 34.81, 33.12, and 20.24% respectively. These results show that PRSV-W has the potential to cause substantial yield loss in pumpkin. Number of seed was reduced by 39.36% in infected fruits. Furthermore, test weight (100 seed weight) was reduced by 22.87%. Seed weight is a reflection of seed quality that manifests as germination percentage, longevity and seedling vigour. Although effect of week-wise PRSV-W infection on these parameters was not calculated, results indicate that PRSV-W infection has potential impact not only on pumpkin yield but also seed quality.

Table 4. Effect of time of PRSV-W infection on pumpkin fruit weight and diameter (at harvest) during 2005

Infection (Weeks after sowing)	N	Fruit weight (g)			Fruit diameter (cm)		
		Mean	% Reduction over healthy	t-test	Mean	% reduction over healthy	t-test (compared to healthy)
6	6	318.33	64.92	*(t=2.01)	28.43	32.49	*
7	14	553.21	39.04	*	34.19	18.82	*
8	25	601.02	33.75	*	35.41	15.93	*
9	25	743.20	18.11	*	36.54	13.23	*
10	25	764.80	15.73	*	39.71	5.72	*
11	25	811.52	10.58	*	40.02	4.98	*
12	25	853.20	5.99	*	40.65	3.49	*
13	25	893.04	0.93	*	42.05	0.16	*
Healthy	25	907.52	-		42.12		

N = number of fruits observed

Table 5. Effect of time of PRSV-W infection on fruit weight and diameter (at harvest) during 2006

Infection (Weeks after sowing)	N	Fruit weight (g)			Fruit diameter (cm)		
		Mean	% Reduction over healthy	t-test (compared with healthy)	Mean	% reduction over healthy	t-test (compared to healthy)
8	6	32.25	97.10	*	11.50	74.61	*
9	18	165.55	85.13	*	20.94	53.76	*
10	25	87.47	79.73	*	25.76	43.12	*
11	25	300.80	72.98	*	29.52	34.81	*
12	25	368.89	66.86	*	30.29	33.12	*
13	25	678.95	39.00	*	36.12	20.24	*
Healthy	25	1113.06	-	-	45.29	-	

N = number of fruits observed

Table 6. Effect of PRSV-W infection on number of seeds and seed weight

2005				
Parameter	I week infected	Healthy	t - test	% Reduction over control
Number of seeds in fruits	106.26	175.26	*	39.36
Test weight	7.52	9.75	*	22.87

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SCREENING OF CHILLI GERMPLASM FOR RESISTANCE TO *Helicoverpa armigera* (Hübner) IN CHILLI

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ABSTRACT : Thirty three genotypes were screened under field conditions for the fruit borer, *Helicoverpa armigera* (Hübner) damage for two seasons. The mean of two season for percent fruit borer damage ranged from 3.25 in SL-37 to 70.19 in PAU-101.

As per the scattered diagram, the seven selected genotypes of chilli and capsicum were SL-37, Arka Lohith, Purired, Devarhippargi, TC-1, Button and H.C.-28 and were grouped as resistant. The six genotypes, Hybrid Agni, CA-960, LCA-312, California Wonder, North-Hira and PAU-101 which recorded more than 48.7 percent fruit borer damage were grouped as highly susceptible. The remaining 20 genotypes were rated as susceptible.

Key words : Chilli, *Helicoverpa armigera*.

INTRODUCTION

In India over 80 percent of the production of chilli comes from four states viz. Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. Dharwad district of Karnataka has the distinction of being the district with highest area (1.14 lakh ha) and production (0.55 lakh t) of chilli in India. Reddy and Puttaswamy (1983, 1984) encountered 51 and 39 species of pests damaging transplanted and nursery crops, respectively, in northern parts of Karnataka. Among these, thrips, aphids, mites and whiteflies have been identified as major pests. In Lepidoptera, *Helicoverpa armigera* Hb. And *Spodoptera litura* F. were the major fruit bores of chilli. Studies have been conducted on the varietal susceptibility to *H. armigera* in cotton (Burt, 1916), pigeonpea (Kushwaha et al. 1985) and tomato (Mishra & Mishra 1993). Trials have also been conducted on damage due to *S. litura* in chilli (Rao et. al. 1984). The present study was

conducted on varietal response to the fruit borer *H. armigera* in chilli and capsicum.

MATERIALS AND METHODS

Reaction of chilli genotypes for the damage by *H. armigera* was assessed. The chilli germplasm was planted in two rows and each genotype was replicated three times at MRS, Dharwad and KRCCH, Arabhavi campus. In another screening trial, the prereleased and released varieties of chilli and capsicum were planted in Entomology block, in plot size of 45 m x 16 m and planted at a spacing of 90 cm x 90 cm in black cotton soil. Each entry was planted in a single row with 15 plants. The planting was taken up in the month of July, 1997. All the package of practices recommended for the crop was followed, except the plant protection measures for fruit borer control. At the time of planting, drenching with chlorpyrifos (2 ml/litre) was done to protect the crop from cut worm.

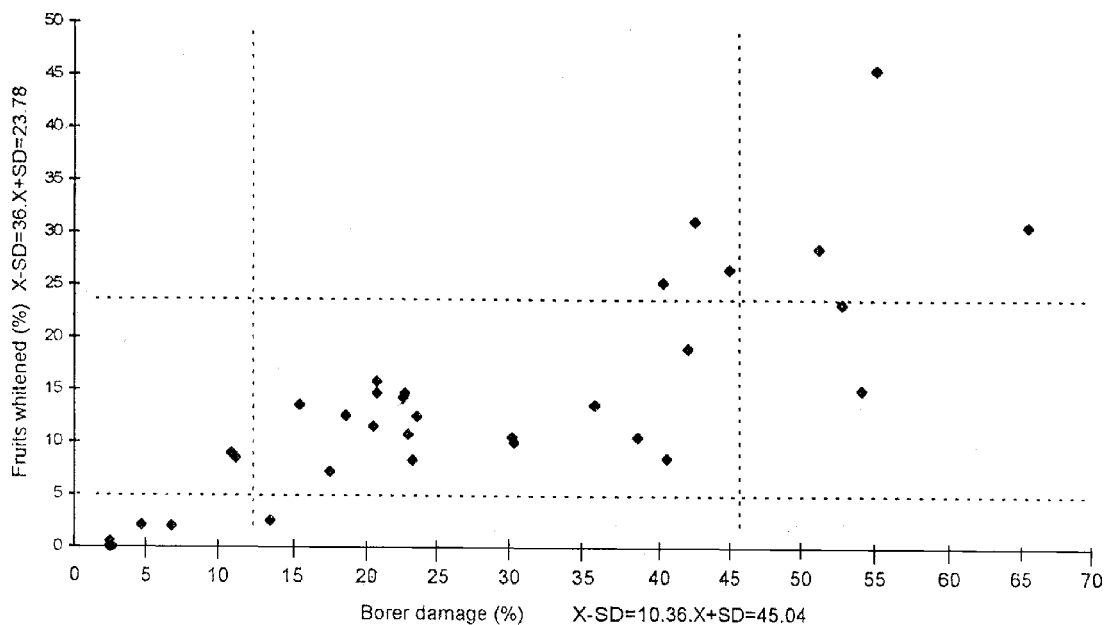


Fig. 1 : Distribution of elite chilli genotypes based on borer damage and whitened fruits (1996)

Phosphamidon and kelthane were sprayed four times at 20 days interval upto flowering of the crop for the control of thrips and mites. Fruits were harvested three times and at each harvest, the number of damaged and healthy fruits, and damaged fruits turning to white were recorded in each variety / genotype.

At the time of maturity, per cent fruit borer damage was recorded. For screening various chilli genotypes, the methodology employed for brinjal fruit borer was adopted (Anon., 1996). Accordingly the genotypes were classified into the following scales: Genotypes showing upto 5 percent damage 0-5 percent, were considered as free / resistant, 6-10 percent was least susceptible, 10-20 percent less susceptible, 20-40 percent susceptible and above 40 percent highly susceptible.

RESULTS

Thirty three promising selected genotypes were screened under field conditions for the borer damage for two season in 1996 and 1997.

During 1996 (Table 1), the average per cent fruit borer damage ranged from 2.44 in SL-37 genotype to 65.54 in PAU-101. Highly promising genotypes which fell under first category were SL-37, Arka Lohith (chilli cultivar), purired and devarhippargi TC-1 was least susceptible. Less susceptible genotypes were Button, H.C.-28, Hissar Shakti, GPC-69, CO-1 and Pant-C1.

The susceptible genotypes were Sankeswar, Hybrid-Arch-236, Indira, Byadagi Kaddi Yellow, Hybrid-HOE-818, Hisar Vijay, RHRC-50-1, Sel-2, Phule-C-5, Solar Hybrid and Chincholi. Above 40 per cent were Nath Hira, K.T.-1, Byadagi Dabbi, LCA-315, Hybrid Agni, GPC-80, C.A.-960, LCA-312, California Wonder and PAU-101.

As per scattered diagram (Fig.1), the five selected genotypes during 1996, SL-37, Arka Lohith, Puri red, Devarhippargi and TC-1 were grouped as resistant. The 23 genotypes, Button, HC-28, Hissar Shakti, GPC-69, Co-1, Pant C1, Sankeshwar, Hybrid Arch-236, Indira, Byadagi Kaddi, Yellow, Hybrid-HOE-818, Hissar Vijay, RHRC-50-1, Sel-2, Phule-C5, Solan hybrid,

Table 1 : Screening of selected germplasm of chilli and capsicum for fruit borer (*kharif, 1996*).

Borer damage	Category	Genotypes	Borer damage (%)	Fruits whitened (%)	Wt. of healthy fruits (g)	Wt. of damaged fruits (g)
I. 0-5%	Free/ Resistant	1. SL-37	2.44	0.00	93.33	2.50
		2. Arka lohith	2.49	0.52	410.50	2.00
		3. Purired	2.65	0.00	390.00	6.00
		4. Devar hippargi	4.71	2.10	126.00	8.00
II. 5.0 - 10%	Least susceptible	1. T.C. - 1	6.78	2.00	256.00	12.00
III. 10.0 -20%	Less susceptible	1. Button	10.90	8.94	122.00	20.00
		2. H.C.-28	11.20	8.50	126.00	22.00
		3. Hissar shakti	13.52	2.50	250.00	26.00
		4. GPC-69	15.50	13.52	150.00	30.00
		5. Co-1	17.54	7.20	70.60	22.66
		6. Pant-C1	18.60	12.50	220.00	30.00
IV. 20.0 -40%	Susceptible	1. Sankeswar	20.50	11.50	86.00	24.10
		2. Hybrid-Arch 236	20.75	14.69	120.00	20.00
		3. Indira	20.75	15.80	320.00	20.60
		4. Byadagi kaddi	22.56	14.25	142.00	18.00
		5. Yellow	22.70	14.70	250.00	44.00
		6. Hybrid-HOE-818	22.90	10.75	150.80	20.00
		7. Hisar vijay	23.21	8.29	280.00	40.00
		8. RHRC-50-1	23.52	12.45	240.00	30.50
		9. Sel-2	30.20	10.52	300.00	45.00
		10. Phule-C-5	30.33	10.00	300.00	50.00
		11. Solan hybrid	38.50	10.50	150.00	70.00
		12. Chincholi	35.72	13.56	160.00	60.00
V. >40%	Highly susceptible	1. Nath Hira	40.25	25.30	217.00	80.00
		2. K.T.-1	40.50	8.52	200.00	52.00
		3. Byadagi dabbi	42.00	19.00	305.50	80.00
		4. LCA-315	45.00	23.50	266.50	65.00
		5. Hybrid Agni	51.25	28.52	250.00	80.50
		6. GPC-80	52.52	31.33	280.00	90.00
		7. C.A.-960	52.80	23.20	280.00	65.00
		8. LCA-312	54.12	15.00	226.00	85.00
		9. California wonder	55.20	45.50	218.00	78.00
		10. PAU-101	65.54	30.61	210.00	58.00

For borer damage (%)

Mean = 27.70

Standard deviation (std) = 17.34

Mean-Standard deviation = 27.70-17.34 = 10.3 (No. 5 genotypes)

Mean+standard deviation = 27.70+17.34 = 45.04 (No. 6)

Mean-std to Mean + std = 10.36 to 45.04 (No. 22)

For Whitened fruits (%)

Mean = 13.49

Standard deviation = 10.29

Mean-Standard deviation = 13.49-10.20 = 3.20 (No. 6)

Mean+standard deviation = 13.49+10.29 = 24.78 (No.4)

Mean-std to Mean + std = 3.20 to 24.78 (No. 23)

Table 2 : Screening of selected germplasm, cultivars of chilli and capsicum (kharif, 1997).

Borer damage	Category	Entries Name	Borer damage (%)	Fruits whitened (%)	Wt. of healthy fruits (g)	Wt. of damaged fruits (g)
I. 0-5%	Free/ Resistant	1. SL-37	4.07	0.00	83.33	4.24
		2. Purired	4.83	0.00	100.00	2.12
II. 5.0 10%	Least susceptible	1. Arka lohith	6.58	0.98	400.00	5.83
		2. Devar hippargi	7.84	2.30	116.00	8.48
III. 10.0 20%	Less susceptible	1. Button	13.00	11.90	216.66	15.90
		2. H.C. 28	13.30	10.39	116.66	16.43
		3. TC-1	17.25	2.11	216.66	27.56
		4. Co-1	17.74	8.06	66.66	11.66
		5. GPC-69	18.68	14.95	116.66	20.35
		6. Hissar shakti	19.26	2.50	200.00	9.37
IV. 20.00	Susceptible	1. Pant-C1	20.72	15.10	200.00	28.09
		2. Sankeswar	22.81	12.93	66.66	15.90
		3. Hybrid-Arch. 236	24.10	18.02	100.00	28.62
		4. Yellow	25.01	17.76	216.66	34.45
		5. Hisar vijay	25.11	10.72	233.33	39.72
		6. Solan hybrid (Capsicum)	25.80	12.50	117.83	37.70
		7. Hybrid-HOE-818	25.92	16.15	133.33	18.02
		8. Byadagi kaddi	27.62	17.64	140.00	20.00
		9. RHRC-50-1	28.34	16.79	200.00	33.39
		10. Phule-C-5	36.03	17.13	316.66	53.53
		11. Sel-2 (capsicum)	37.03	8.23	260.66	47.13
V. >40%	Highly	1. K.T.-1 (capsicum)	41.17	12.50	125.00	32.99
		2. Chincholi	44.42	15.42	66.66	28.62
		3. LCA-315	49.83	27.81	166.66	22.26
		4. Byadagi dabbi	52.01	22.92	233.33	39.22
		5. Hybrid Agni	56.24	31.79	216.66	27.68
		6. Nath Hira (capsicum)	57.14	28.27	117.83	37.70
		7. C.A.-960	54.48	27.81	200.00	57.77
		8. GPC-80	59.08	34.66	200.00	34.45
		9. LCA-312	59.23	16.03	116.66	30.74
		10. California wonder (Capsicum)	60.00	50.00	105.25	42.42
		11. Indira (Capsicum)	62.80	25.00	227.00	23.56
		12. PAU-101	74.84	58.16	100.00	37.63

For borer damage (%)

Mean = 33.22

Standard deviation (std) = 19.55

Mean-standard deviation = 33.22-19.55 = 13.67 (No. 6 genotypes)

Mean+standard deviation = 3.22+19.55 = 52.77 (No. 8)

Mean-std. to Mean + std = 13.67-52.77 = (No. 19)

For Whitened fruits (%)

Mean = 17.16

Standard deviation = 13.02

Mean-Standard deviation = 17.16-13.02 = 4.14 (No. 6)

Mean+standard deviation = 17.16+13.02 = 30.18 (No.4)

Mean-std to Mean+std = 4.14-30.18 (No. 23)

Table 3 : Two years mean (1996-97) of selected genotype evaluation for *H. armigera* damage in chilli and capsicum

Borer damage (category)	Genotypes	1996	1997	Mean (borer damage (%))	Mean (whitened fruits %)
I. 0-5% (Free/Resistant)	1. SL-37	2.44	4.07	3.25	0.00
	2. Arka lohith	2.49	4.83	3.66	0.75
	3. Puri red	2.65	6.58	4.61	0.00
II. 5.0-10% (Least susceptible)	1. Devar hippargi	4.71	7.84	6.27	2.20
	2. Button	10.90	13.00	11.95	2.05
III. 10.0-20% Less susceptible	1. TC-1	6.78	17.25	12.01	10.42
	2. HC-28	11.20	13.30	12.25	10.70
	3. Hissar shakti	13.52	19.26	16.39	2.50
	4. GPC-69	16.50	18.68	17.59	14.18
	5. Co-1	17.54	17.74	17.64	7.63
	6. Pant-C ₁	18.60	20.72	19.66	13.80
IV. 20.0-40% (Susceptible)	1. Sankeswar	20.50	22.81	21.65	12.21
	2. Hybrid-Arch-236	20.75	24.10	22.42	16.65
	3. Yellow	22.70	25.01	23.85	16.23
	4. Hissar Vijay	23.21	25.11	24.16	9.50
	5. Hybrid-HOE-818	22.90	25.92	24.41	13.45
	6. Byadagi kaddi	22.56	27.62	25.09	15.94
	7. RHRC-50-1	23.52	28.34	25.93	14.62
	8. Solan hybrid	35.50	25.80	30.65	11.50
	9. Phule C-5	30.33	36.03	33.18	13.56
	10. Sel-2	30.20	37.03	33.61	9.37
V. >40% (Highly susceptible)	1. Chincholi	35.72	44.42	40.07	14.44
	2. KT-1	40.50	41.17	40.83	10.51
	3. Indira	20.75	62.50	41.62	20.40
	4. GPC-80	52.52	34.66	43.59	32.88
	5. Byadagi Dabbi	42.00	52.01	47.00	20.96
	6. LCA-315	45.00	49.83	47.41	25.65
	7. Nath Hira	40.25	57.14	48.69	30.15
	8. Hybrid agni	51.25	56.24	53.74	25.75
	9. CA-960	52.80	59.08	55.94	15.51
	10. LCA-312	54.12	59.23	56.67	47.75
	11. California wonder	55.20	60.00	57.60	26.78
	12. PAU-101	65.54	74.84	70.19	44.61

For borer damage (%)

Mean = 30.11

Standard deviation (std) = 17.65

Mean-Standard deviation = 30.11-17.85 = 12.46 (No. 7 genotypes)

Mean+Standard deviation = 30.11+17.65 = 47.76 (No. 20)

Mean-std to Mean + std = 12.46 to 47.76 (No. 8)

For whitened fruits (%)

Mean = 15.90

Standard deviation = 11.34

Mean-Standard deviation = 15.90-11.34 = 4.56 (No. 8)

Mean+Standard deviation = 15.90+11.34 = 27.24 (No. 15)

Mean-std to Mean + std = 4.56 to 27.24 (No. 12)

Chincholi, Nath-Hira, K.T-1, Byadagi Dabbi and LCA-315, as susceptible.

The six selected genotypes of chilli and capsicum, Hybrid Agni, GPC-80, CA-960, LCA-312, California wonder and PAU-101 which recorded more than 45.33 per cent fruit borer damage, were grouped as highly susceptible.

The average per cent fruit borer damage ranged from 4.07 in SL-37 to 74.84 in PAU-101, during 1997 (Table 2). The genotypes which recorded 0.0-5.0 per cent were SL-37 and Purired. 5.1 to 10.0 per cent were Arka Lohith and Devarhipparagi. In the 10.1 to 20 per cent category they were Button. H.C-28, T.C-1, Co-1, G.P.C-69 and Hissar Shakti. In the 20.1 to 40 per cent category, the entries were pant-C1 Sankeshwar, Hybrid Arch-236, Yellow, Hissar Vijay, Solan hybrid (capsicum), Hybrid-HOE-818, Byadagi Kaddi, RHRC-50-1, Phule-C5 and Sel-2 (capsicum).

Genotypes which recorded above 40 per cent damage were K.T-1 (capsicum), Chincholi, LCA-

315, Byadagi Dobbi, Hybrid Agni, Nath Hira (capsicum) C.A. 960, GPC-80, LCA-312, California Wonder (capsicum), Indira (capsicum) and PAU-101.

As per scattered diagram (Fig.1), the selected genotypes (six) of chilli and capsicum during 1997, SL-37, Purired, Arka Lohith, Devarhipparagi, Button and HC-28, were grouped as resistant and the 19 genotypes TC-1, Co-1, GPC-69, Hissar Shakti, Pant-C1, Sankeswar, Hybrid Arch-236, Yellow, Hissar Vijay, Solan Hybrid, Hybrid-HOE-818, Byadagi kaddi, RHRC-50-1, Phule-C5, Sel-2, KT-1 and Chincholi, LCA-315 and Byadagi Dabbi as susceptible.

The eight selected genotypes of chilli and capsicum, Hybrid Agni, Nath-Hira, CA-960, GPC-80, LCA-312, California wonder, Indira and PAU-101 which recorded more than 52.15 per cent fruit borer damage were grouped as highly susceptible.

The mean of 1996 and 1997 for per cent fruit borer damage ranged from 3.25 in SL-37 a selected genotype to 70.19 in PAU : 101 (Table 3).

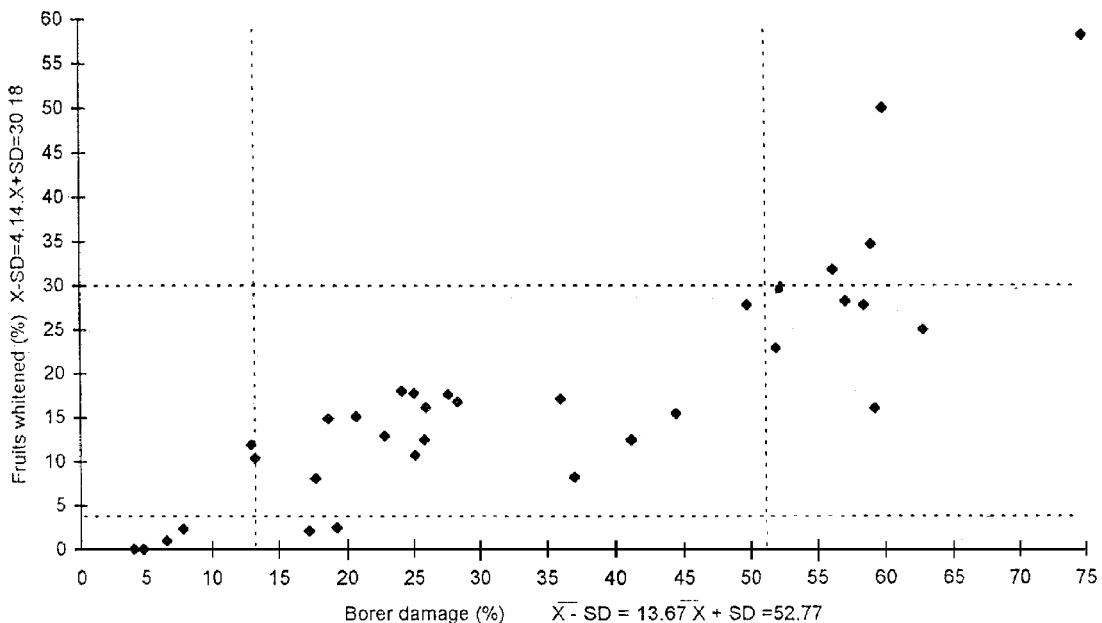


Fig. 2 : Distribution of elite chilli genotypes based on borer damage and whitened fruits (1997)

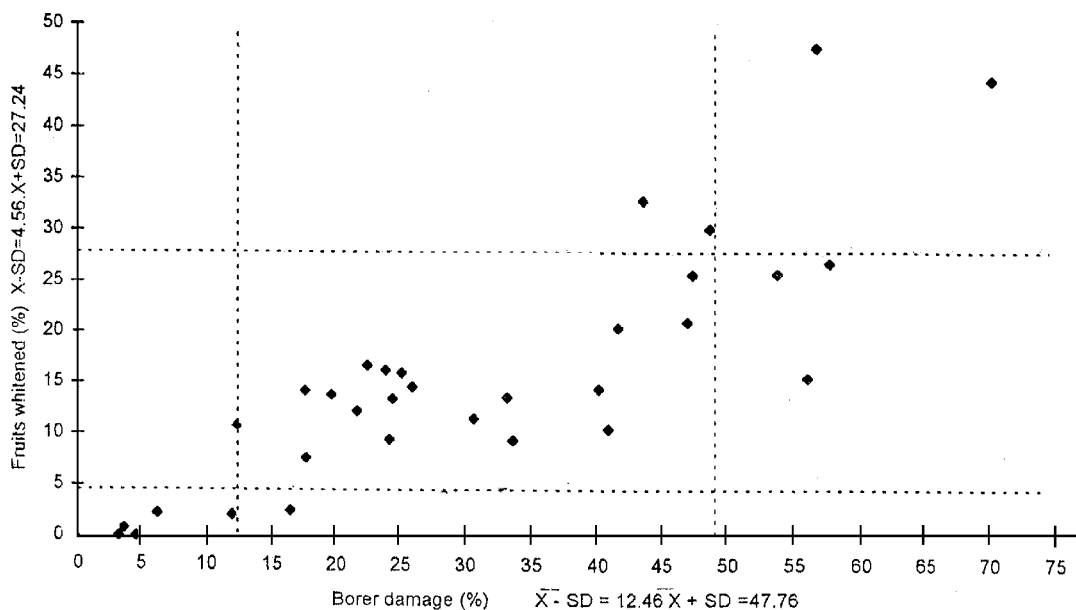


Fig. 3 : Distribution of elite chilli genotypes based on borer damage and whitened fruits (1996-97)

The resistant genotypes which fell under first group were SL-37, Arka lohit and Purired. Devarhippargi and T.C.-1 were least susceptible. Less susceptible genotypes were Button, H.C.-28, Hissar Shakti, GPC-69, CO-1 and Pant-C1. The susceptible genotypes were Sankeswar, Hybrid Arch-236, Yellow. Hisar Vijay, Hybrid-HOE-818, Byadagi kaddi, RHRC-50-1, Solan hybrid, Phule-C-5, Sel-2. Highly susceptible were Chincholi, K.T.-1, Indira, GPC-80, Byadagi Dabbi, LCA-315, Hybrid Agni, C.A.-360, L.C.A.-312, California Wonder Nath Hira and PAU-101.

As per scattered diagram (Fig.3) for the mean of 1996 and 1997, the seven selected genotypes of chilli and capsicum, SL-37, Arka Lohith, Purired, Devarhippargi, TC-1, Button and H.C.-28 were grouped as resistant. The 20 genotypes viz., Hissar Shakti, GPC-69, Co-1, Pant-C1, Sankeswar, Hybrid Arch-236, Yellow, Hissar Vijay, Hybrid-HOE-818, Byadagi kaddi, RHRC-50-1, Solan hybrid, Phule-C-5, Sel-2, Chincholi, KT-1, Indira, GPC-80, Byadagi Dabbi and LCA-315, were susceptible. The six genotypes, Hybrid Agni, CA-960, LCA-312,

California wonder, Nath-Hira and PAU-101 which recorded more than 48.77 per cent fruit borer damage were grouped as highly susceptible.

DISCUSSION

33 genotypes of chilli and capsicum were screened against *H. armigera* during *kharif* seasons of 1996 and 1997, and recorded the percent fruit borer damage and whitening of the fruits. The fruit borer damage ranged from 3.25 percent (SL-37) to 70.19 percent (PAU-101). Whereas whitening of fruits varied from 0.00 (SL-37 and Purired) to the maximum of 47.75 percent (California Wonder). Based on mean of 1996 and 1997, the free resistant group of genotypes were three namely SL-37, Arka Lohith and Purired. Least susceptible were Devar hippargi and TC-1. These genotype viz., SL-37, Arka Lohith, Purified, Devar Hipargi, TC-1, Button and HC-28 (based on first category and mean-standard deviation) cultivar may be tested under artificial condition for the resistance to *H. armigera*. These genotypes may be further used as donor parents

in resistance breeding programme. Rao *et al.* (1984) screened eight released varieties of chilli against fruit borer *S. litura*. There was significant difference in the fruit borer damage between protected (14.12% to 52.66%) to unprotected (47.90% to 65.40%). However, four varieties, viz. X203, X180, CA 1068 and X197 exhibited comparatively less borer damage.

Screening of selected promising cultivars and genotypes over two seasons revealed that SL-37, Arka Lohit, Puri Red, Devarhippargi, TC-1, Button and HC-28 were promising. These may be considered for further breeding.

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CROP LOSS ASSESSMENT DUE TO *Helicoverpa armigera* (Hübner) IN CHILLI

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ABSTRACT : Chilli yield loss assessment due to the fruit borer *Helicoverpa armigera* (Hubner) on plants in green house and field conditions. Under green house condition in potted plants, the observed percentage fruit damage was zero, 13.46, 21.30, 31.18, 40.00, 46.65 and 49.30 with 0,1,2,3,4,5 and 6 larvae per plant respectively. Yield reduction due to individual larva was 2.5 q/ha. Further, it was evident that 2,3,4,5 and 6 larvae resulted in yield reductions of 4.26, 6.23, 7.77, 9.07 and 9.99 q/ha. In field experiment, it was revealed that the fruit damages were zero, 11.68, 18.84, 25.00, 31.25, 40.27 and 50.00 at 0,1,2,3,4,5 and 6 larval load per plant respectively. The yield reduction for 1,2,3,4,5 & 6 larvae per plant was zero, 2.49, 3.61, 4.72, 6.94, 8.05 and 11.11 q/ha respectively.

Based on regression equation, for every increase in larval number per plant the increase in damage to fruits was 7.87%, while yield decreased by 171 q/ha. The regression equation based on the cost of plant protection measures against the pest and market price of the produce projected that the economic threshold of *H. armigera* in chilli was 1.46 larvae / plant.

Key words : Chilli, *Helicoverpa armigera*.

INTRODUCTION

India being the largest chilli producer, has vast potentiality to increase the production in order to promote export, besides meeting its domestic requirements. A number of limiting factors could be attributed to low productivity. Mayeux and Wene (1950) reported the occurrence of *Helicoverpa armigera* (Hubner) on chilli for the first time causing considerable damage and loss. Damage caused by this pest has been studied by Katagihallimath (1963) who has reported 6 larvae of *H. armigera* per plant and 77 percent fruit damage on chilli from Kolar district during April to June. The chilli pod borer accounted for 61.2 percent in the absence of

chemical sprays and insecticidal treatments reduced the damage from 2.1 to 32 per cent (Rao and Ahmed, 1985). The present study was conducted to estimate the crop loss caused by the fruit borer *H. armigera* in chilli, in Dharwad district of Northern Karnataka.

MATERIALS AND METHODS

a. Crop loss estimation due to *H. armigera* in chilli fruits

Yield loss assessment due to the borer was made artificial infestation of *H. armigera* of plants in green house. There were seven treatments replicated thrice. Release of 0,1,2,3,4,5,6 larvae /

plant formed seven treatments. Work was done in MRS, UAS, Dharwad.

Recommended dose of fertilizer was added to the pots before planting of chilli seedlings. Byadagi chilli seedlings were planted in 21 pots. After planting, three sprays of plant protection chemicals were given (Kelthane + Carbendazim + Phosphamidon) at 20 days intervals to control early sucking pests and foliar diseases. When the plants were peak flowering (60 days after planting) they were examined for the eggs, larvae and adults of *H. armigera* and were removed from the plants. The third instar larvae of *H. armigera* reared and maintained in the laboratory were released on the potted plants as per the treatments. The potted plants were covered with nylon cloth nets; Observations were made upto pupation of the larvae. After pupation, cloth nets were removed and data on the number of healthy fruits, fruits damaged per plant are recorded.

In the field study, variety Byadagi was raised on a 1000 sq.m area following the recommended package of practice. At the reproductive stage six plants selected at random from each treatment were disinfested manually.

Each treated plant, after releasing the known number of larvae was covered with nylon net of size of 2m x 2m x 2m to make it insect proof. After releasing the larvae observations were made on the number of healthy fruits and number of damaged fruits and yield.

b. Economic Injury Level (EIL)

Based on the level of infestation, yield per plant, cost of insecticide used and the average market price of chilli fruits per quintal, the economic injury level was computed according to Stone and Pedigo (1972) and modified by Ogunlana and Pedigo (1974).

The correlation co-efficient 'r' between population level (x) and reduction in fruit weight per plant (y) regression co-efficient and were calculated by following formula.

$$R = \frac{N \sum xy - \sum x \sum y}{\sqrt{N \sum x^2 - (\sum x)^2 N \sum y^2 - (\sum y)^2}}$$

Where 'N' is the total number of observations : 'x' is the population levels of the larvae per plant and 'y' is the reduction in fruit weight per plant.

The economic injury level was computed as

$$EIL = \frac{\text{Gain threshold}}{\text{Yield reduction per larvae}}$$

$$\text{Gain threshold} = \frac{\text{Cost of pest control (Rs. / ha)}}{\text{Market price of pods (Rs./ha)}}$$

For calculating the cost of pest control, the chemical cost (carbaryl) Btk (Dipel) Achook (Neem based pesticide) and application cost including labour were considered. The cost of carbaryl was Rs. 600/- per ha (Rs. 300/Kg), B.t.k. was Rs. 800/- per ha (Rs. 800/litre) and Achook was Rs. 700/- per ha (Rs. 280/litre) and labour charges for applications of pesticide was calculated at the rate of Rs. 400 per hectare. The market price of chilli fruits was taken at Rs. 1000.00 per quintal for green chilli.

RESULTS

Based on the regression equation ($y = 3.87 + 8.33X$), it could be inferred that the individual larvae was responsible for 12.20 percent fruit damage. Further, it was estimated that two, three, four, five and six larvae were responsible for 20.52, 28.85, 37.18, 45.50 and 58.83 percent damage respectively. The observed per cent unit fruit damage was zero, 13.46, 21.30, 31.18, 40.00, 46.65 and 49.3 with 0,1,2,4,5 and 6 larvae per plant respectively in plotted experiment (Table 1).

Yield reduction due to individual larva was 2.59 q/ha. Further, it was evident that 2,3,4,5 and 6 larvae resulted in yield reduction of 4.26, 6.23, 7.77, 9.07 and 9.99 q/ha. Whereas, based on regression equation ($Y = 0.70 + 1.64x$), yield

Table 1 : Chilli fruits damaged by different larval population of *H. armigera* in potted plants

No. of caterpillar / plant	No. of fruits / plant	No. of fruits damaged	Percentage fruits bored	Correlation coefficient	Regression equation
0	37.00	0.00 ^o	0.00	r = 0.99	Y = 3.87 + 8.33x
1	34.67	4.67f	13.46		
2	36.00	7.67e	21.30		
3.	36.33	11.33d	31.18		
4.	35.00	14.00c	40.00		
5.	35.00	16.33b	46.65		
6.	36.00	18.00a	49.39		

*Significant at 5 percent level.

Valued followed by the same letter are not significantly different by DMRT at 0.05 level.

Table 2 : Yield reduction due to attack of different larval population of chilli, *H. armigera* in potted plants

No. of caterpillar / plant	Yield in Q / ha	Yield reduction Q / ha	Correlation coefficient	Regression equation
0	22.83 ^c	0.00	r = 0.99	Y = 0.70 + 1.64x
1	20.24 ^c	2.59		
2	18.57 ^{bc}	4.26		
3.	16.60 ^{+b}	6.23		
4.	15.06 ^{ab}	7.77		
5.	13.76 ^{ab}	9.07		
6.	12.84 ^a	9.99		

*Significant at 5 percent level.

Values followed by the same letter are not significantly different by DMRT at 0.05 level.

reduction due to an individual larva was 2.34 q/ha and two, three, four, five and six larvae caused an yield loss of 3.98, 5.62, 7.28, 8.89 and 10.53 q/ha respectively, in the potted experiment (Table 2).

Chilli fruit damage by *H. armigera* in field experiment revealed that individual larva was responsible for 9.60 per cent fruit damage based on regression equation ($y = 1.76 + 7.84x$). It was estimated that for 2,3,4, 5 and 6 larvae the respective damages were 17.44, 25.28, 33.12, 40.96 and 48.80 percentage whereas, the observed fruit

damages in the field experiments were zero, 11.69, 18.84, 25.00, 31.25, 40.27 and 50.00 per cent at 0,1,2,3,4,5 and 6 larval load per plant respectively (Table 3).

Based on regression equation ($y = 0.07 + 1.71x$) and in comparison to healthy plant, it was found that an individual larva can cause an yield loss of 1.78 q/ha. The yield loss was zero, 2.49, 3.61, 4.72, 6.94, 8.05 and 11.11 q/ha for zero, one, two, three, four, five and six larvae, respectively (Table 4).

$$\text{Gain threshold (GT)} = \frac{\text{Cost of pest control}}{\text{Market price of yield / q}}$$

$$= \frac{2500/-}{1000} = 2.5$$

$$\text{Economic injury level (EIL)} = \frac{\text{Gain Threshold}}{\text{Yield reduction / larvae}}$$

$$= \frac{2.5}{1.71} = 1.46 \text{ larva}$$

From the results, it is evident that as the number of larvae increased from one to six there was increasing in the level of fruit damage ranging from 11.68 to 50.00 per cent. Further, it resulted, in the reduction of yield from 2.49 q/ha to 11.11 q/ha in the experiment.

Based on the regression equation, for every increase in a larval number per plant, the increase in damage to fruits was 7.87%, while yield decreased by 1.71 q/ha. The regression equation based on the cost of plant protection measures against the pest and market price of the produce

Table 3 : Chilli fruits damaged by different larval population of *H. armigera*

No. of caterpillar / plant	No. of fruits / plant	No. of fruits damaged	Percentage fruits bored	Correlation coefficient	Regression equation
0	40.50	0.00 ^o	0.00	R=0.99	Y=1.76+7.84x
1	38.50	4.50 ^f	11.68		
2	34.50	6.50 ^e	18.84		
3	34.00	8.50 ^d	25.00		
4	40.00	12.50 ^c	31.25		
5	36.00	14.50 ^b	40.27		
6	40.00	20.00 ^a	50.00		

*Significant at 5 percent level.

Values followed by the same letter are not significantly different by DMRT at 0.05 level.

Table 4 : Yield reduction due to attack of different larval population of chilli, *H. armigera* (field)

No. of caterpillar / plant	Yield in Q / ha	Yield reduction Q / ha	Correlation coefficient	Regression equation
0	24.99 ^d	-	r = 0.98	Y = 0.07 + 1.71x
1	22.50 ^e	2.49		
2	21.38	3.61		
3	20.27 ^{bc}	4.72		
4	18.05 ^{bc}	6.94		
5	16.94 ^b	8.05		
6	13.88 ^a	11.11		

* Significant at 5 percent level.

Values followed by the same letter are not significantly different by DMRT at 0.05 level.

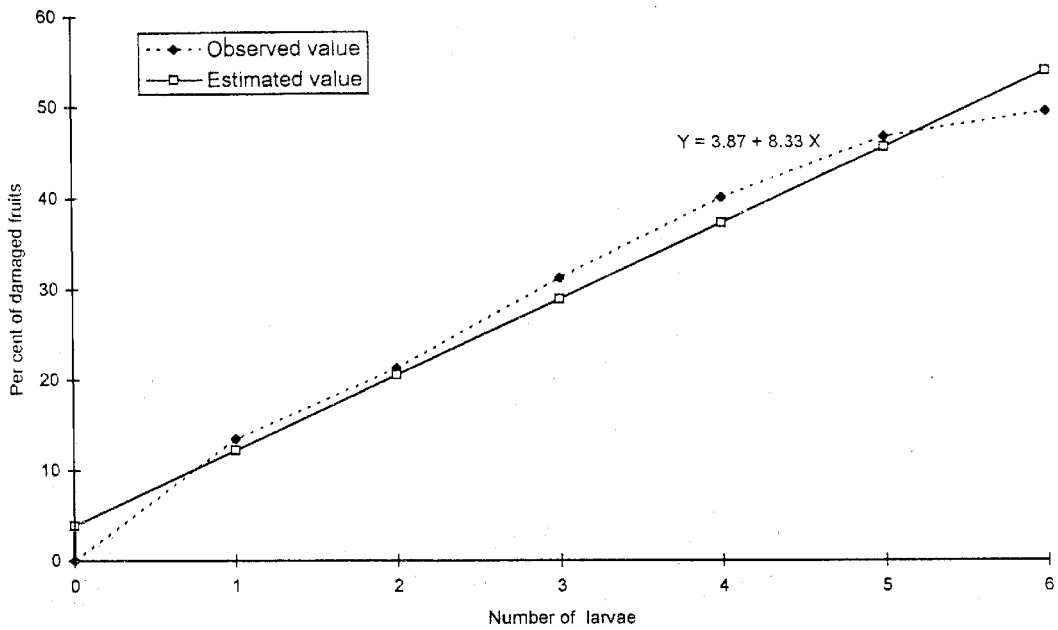


Fig. 1 : Per cent of fruit damage in chilli due to fruit borer *H. armigera* under green house conditions

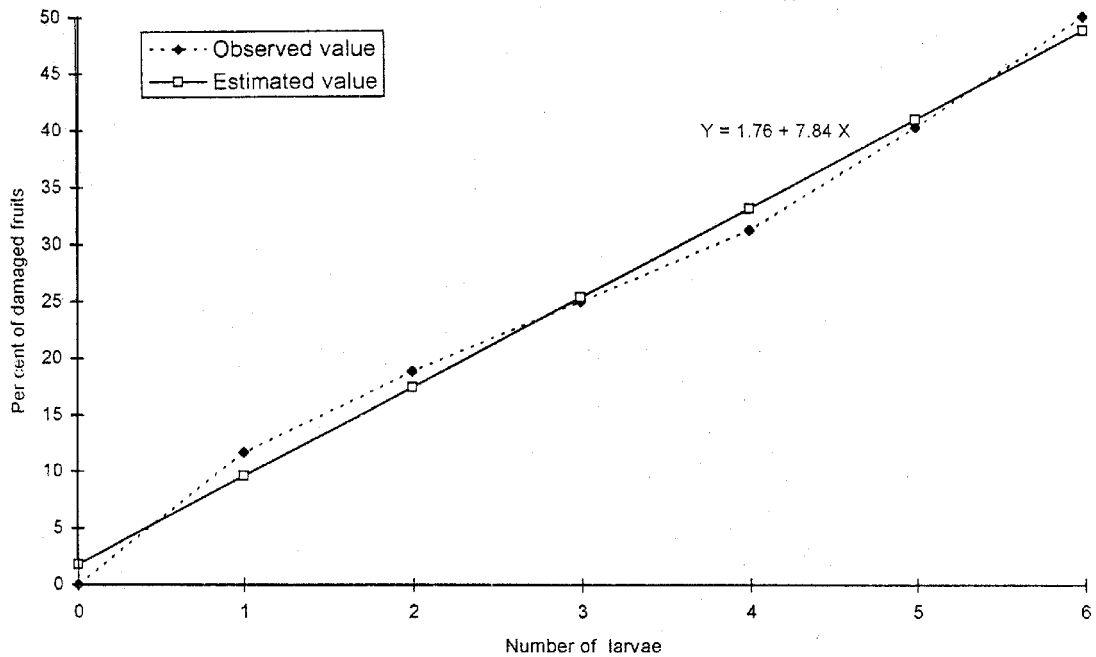


Fig. 2 : Per cent of fruit damage in chilli due to fruit borer, *H. armigera* under field conditions

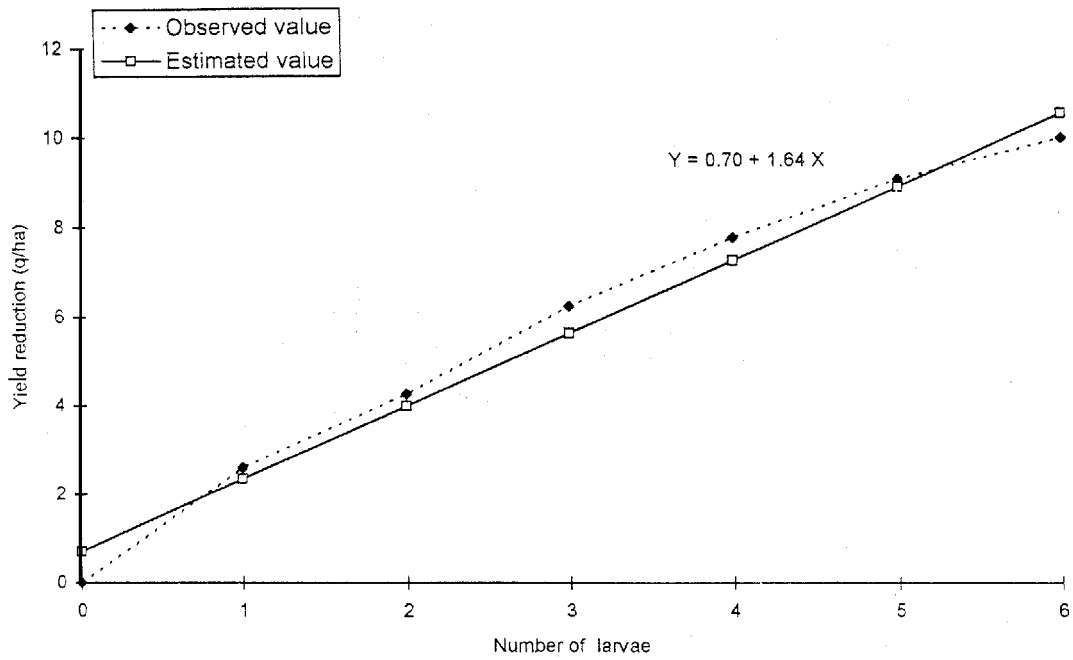


Fig. 3 : Reduction of the yield in chilli due to fruit borer, *H. armigera* under green house conditions

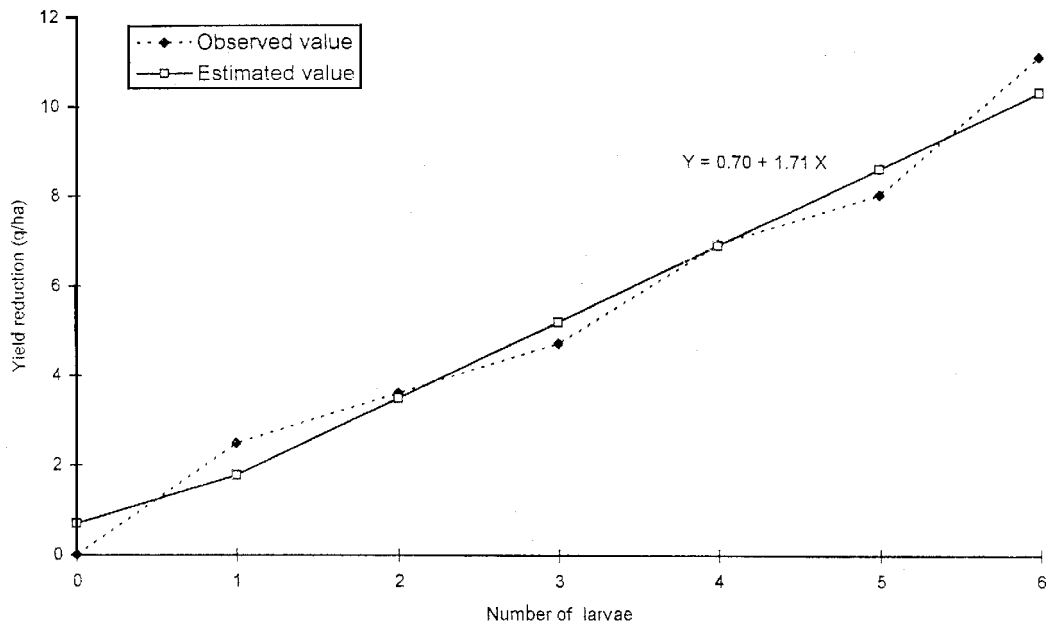


Fig. 4 : Reduction of the yield in chilli due to fruit borer, *H. armigera* under field conditions

projected that the economic threshold of *H. armigera* in chilli to be 1.46 larvae / plant.

DISCUSSION

Crop loss estimation on chilli due to *H. armigera* was conducted in potted plants and in field condition. In case of pot experiment, one larva per plant caused 17.70 percent while six larvae caused 43.70 percent fruit damage (Fig. 1).

Crop loss estimation in chilli due to *H. armigera* in the field condition showed that one larva was responsible to cause the fruit damage upto 11.23 percent.

Yield loss was estimated in chilli due to fruit borer damage to the chilli. Individual caterpillar caused damage that resulted in the yield loss upto 2.52 q/ha. Further, it was estimated that two, three, four, five and six larvae per cent were responsible to cause in yield loss upto 4.26, 6.29, 7.78, 9.08 and 9.99 q/ha respectively on potted plants (Fig.3).

Under field condition yield loss due to single caterpillar was upto 2.49 q/ha. Further, it was estimated that there was linear increase in yield loss which was due to six larvae plant (Fig.4).

Such studies are lacking on chilli to compare present findings. But studies on chilli reported by Katagihallimath (1963) revealed six larvae percent can cause upto 77 percent fruit damage and under no plant protection. Rao and Ahmed (1985) reported 61.2 percent damage of chilli pod. However, results of present investigation were compared with results obtained on other crops. Reddy (1973) estimated that the crop loss in pigeonpea due to *H. armigera* based on cage studies by releasing two, four and six larvae per cent resulted in yield production upto 12.17, 18.08 and 21.71 q/ha, respectively. Whereas Ashok Kumar (1976) estimated yield losses in cotton by releasing *H. armigera* larvae at one, two, four and

six per cent in caged condition which accounted for yield reduction of 2.55, 4.93, 9.03 and 13.13 q/ha. Margal (1990) estimated the crop loss due to *H. armigera* in sunflower where 8.91, 13.05, 19.01, 23.17, 28.37, 35.82 and 40.51 percent loss was recorded corresponding to larval densities of 1,2,4,6,8,12 and 16 respectively and the economic injury level was one larva / plant or 4 larvae / 5 plant. These comparisons further proved that loss due to *H. armigera* was comparatively more on pigeonpea, cotton and sunflower than on chilli.

In the present investigation it was also revealed that 3 larvae for 2 plants was critical for taking control measures on chilli crop. But other workers have reported varying larval populations of *H. armigera* on different crops. Reddy (1973) reported on pigeonpea based on market value of pigeonpea per quintal and including cost of plant protection measures, one larvae per 5 plants of pigeonpea as economic injury level. Whereas Butter *et. al* (1994) reported that action threshold as 2 to 3 larvae of *H. armigera* per plant or 5 per cent infestation of shed or infected fruiting bodies of cotton as effective for initiation of insecticidal control. Wightman *et.al.* (1995) reported based on seed yield of chickpea in cage studies that one larva of *H. armigera* (fourth instar and above) constitute the critical density on chickpea.

Estimation of crop loss on chilli due to fruit borer *H. armigera* was studied both in the laboratory and in the field. Based on the regression equation, and cost of plant protection and market price of produce, the economic threshold for *H. armigera* in chilli was 1.46 larva per plant.

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EVALUATION OF INTERCROPPING SYSTEM BASED MODULES FOR THE MANAGEMENT OF MAJOR INSECT PESTS OF BRINJAL

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ABSTRACT : An IPM based module consisting of brinjal (PKM 1) + cluster bean (4:1) + six releases of *Trichogramma chilonis* @ 2.5 cc/acre on 15, 22, 29, 36 43 and 50 days after transplanting (DAT) + two releases of *Chrysoperla* eggs @ (20,000 eggs/acre) on 60 and 70 DAT + yellow sticky trap @ 25/acre + *Lencinodes orbonalis* pheromone trap @ 5 /acre (Intercropping system based module I) was found to be the best in managing major pests of brinjal.

Key words : Brinjal pests.

INTRODUCTION

Brinjal is highly cosmopolitan and popular vegetable grown as poor man's crop in India. In vegetables, consumption of chemical pesticides for the management of major insect pests in brinjal eco-system has been increasing which leave residues on the economic parts more than tolerable level. Intercropping affects the pests by changing micro-climate through change in crop canopies (Srinivasa Rao *et al.*, 2003). Field efficacy of *Trichogramma chilonis* Ishii in brinjal eco-system for the management of shoot and fruit borer, *Leucinodes orbonalis* Guen. has been well demonstrated at different doses (Hanapur and Nandihalli, 2003). Similarly, *Chrysoperla carnea* (Green) is considered as an important predator in different crop eco-system (Balakrishnan *et al.*, 2004 a, b). Two companion crops, cluster bean and onion, selected as remunerative intercrops for brinjal in an earlier field experiment during July - December 2006 were evaluated under field condition against the incidence of major insect pests and their natural enemies by integrating

with release of laboratory reared natural enemies and erection of yellow sticky trap and pheromone trap, in order to evaluate the intercropping system based modules for the management of major insect pests of brinjal.

MATERIALS AND METHODS

A field experiment was conducted during March - July 2007 in an area of 0.10 acre at Mini Orchard, Agricultural College and Research Institute, Madurai, S. India. The remunerative intercropping systems (brinjal + cluster bean, brinjal + onion) were laid under field condition separately in which release of lab reared natural enemies, erection of yellow sticky trap and pheromone trap were made, as detailed below:

T₁ Brinjal (PKM 1) + cluster bean (4:1) + six releases of *T. chilonis* @ 2.5 cc/acre on 15, 22, 29, 36 43 and 50 days after transplanting (DAT) + two releases of *Chrysoperla* eggs @ (20,000 eggs/acre) on 60 and 70 DAT + yellow sticky trap @ 25 /acre + *L. orbonalis* pheromone trap @ 5 /acre (Intercropping system based module I)

- T₂ Brinjal (PKM 1) + onion (4:1) + six releases of *T. chilonis* @ 2.5 cc/acre on 15, 22, 29, 36 43 and 50 DAT + two releases of *Chrysoperla* eggs @ 20,000 eggs/acre on 60 and 70 DAT + yellow sticky trap @ 25 / acre + *L. orbonalis* pheromone trap @ 5 / acre (Intercropping system based module II)
- T₃ Brinjal (PKM 1) + clusterbean (4:1)
- T₄ Brinjal (PKM 1) + onion (4:1)
- T₅ Brinjal sole crop

Each treatment was replicated five times and the experiment was conducted when the weather condition was 28 ± 1°C and 58 ± 2 per cent RH.

Observation on the population/ per cent infestation of insect pests of brinjal and their natural enemies were made at weekly intervals starting from transplanting to harvest. Yield on brinjal pure crop and intercrop was recorded separately and the C:B ratio was calculated. Data on population and per cent damage by insect pests of brinjal were statistically analysed after subjecting them into square root and angular transformations (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Intercropping system based module I and II recorded low mean shoot damage of 9.7 and 10.0

Table 1. Shoot and fruit damage caused by *L. orbonalis* in intercropping system based modules and brinjal pure crop

Treatment	Shoot damage (%)	Infestation by <i>L. orbonalis</i> (%)		Mean no. of moths/ trap
		Fruit damage**		
		Number basis	Weight basis	
Brinjal + cluster bean (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	9.7 (18.15) ^a	14.6 (22.46) ^a	14.5 (22.38) ^a	9.40
Brinjal + onion (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	10.0 (18.44) ^a	15.4 (23.11) ^a	15.0 (22.79) ^a	8.53
Brinjal + cluster bean (4:1)	11.7 (19.78) ^b	17.4 (24.35) ^b	17.9 (25.03) ^b	-
Brinjal + onion (4:1)	12.5 (20.71) ^b	19.1 (25.91) ^b	18.2 (25.22) ^b	-
Brinjal (sole crop)	34.8 (36.15) ^c	45.7 (42.53) ^c	36.5 (37.17) ^c	-
Mean	15.7 (22.64)	22.36 (27.67)	20.42 (26.52)	8.97
SEd	0.09	1.06	0.29	-
CD (0.05%)	(0.05%)	0.28	2.95	-

* Mean of 20 observations; ** Mean of 11 harvests

Figures in parentheses are arcsine transformed values

In a column, means followed by the same letter(s) are not significantly different by DMRT (P=0.05)

SEd: Standard Error Deviation.

per cent, respectively while it was 34.8 per cent in brinjal as sole crop. The lowest mean fruit damage of 14.6 (number basis) and 14.5 (weight basis) per cent was recorded in module I, followed by module II (15.4 and 15.0 %) while it was 45.7 and 36.5 per cent in brinjal as sole crop (Table 1). Cluster bean was reported to be the best companion crop in cotton to reduce the incidence of pests with increased population of natural enemies (Balasubramanian, *et al.*, 1998). Onion used in the present study was also reported as good intercrop to reduce the pest population in cotton (Smith and Vanden Bosch, 1970) and chilli (Aswantharayanareddy *et al.*, 2006).

Erection of sex pheromone trap @ 5 /ha in intercropping system based modules is one of the reasons to reduce the incidence of shoot and fruit borer which indirectly helped in the present study to attract a part of the males of shoot and fruit borer (9.4 moths/trap) and disrupted the oviposition, as suggested by Reddy and Rosaiah (1987). It is evident that using sex pheromone trap as one of the components in TNAU IPM module was reported to reduce the pests population in rainfed cotton (Balakrishnan *et al.*, 2005).

Release of *T. chilonis* at weekly interval (15, 22, 29, 36 43 and 50 DAT) @ 2.5 cc/acre/release was highly helpful to reduce the egg load by *L.*

Table 2. Population of *H. vigintioctopunctata* and *Mylokerus subfasciatus* in intercropping system based modules and brinjal pure crop

Treatment	<i>H. vigintioctopunctata</i> (No./ three leaves)*	<i>Mylokerus subfasciatus</i> (No./ three leaves)*
Brinjal + cluster bean (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal + onion (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal + cluster bean (4:1)	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal + onion (4:1)	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal (sole crop)	6.7 (2.51) ^b	1.9 (1.3) ^b
Mean	1.26 (1.07)	0.34 (0.83)
SEd	0.01	0.02
CD (0.05%)	0.04	0.07

* Mean of 20 observations

Figures in parentheses are square root transformed values

In a column, means followed by the same letter(s) are not significantly different by DMRT (P=0.05)

orbonalis during various stages of crop growth. Eggs of shoot and fruit borer were susceptible to *T. chilonis*, as they are laid singly without hairy covering unlike in *Spodoptera litura* F. reported by Murali Baskaran *et al.* (2000). Field efficacy of *T. chilonis* on eggs of *L. orbonalis* has been well demonstrated by Raja *et al.* (1998), David Abilash (2000) and Sangappa (1999).

Total absence of the incidence of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius) and ash weevil, *Myloccerus*

subfasciatus Guerin in intercropping based modules (Table 2) of the present study was due to the disruption of physical and chemical stimuli by the introduction of either cluster bean or onion as intercrop in brinjal.

Two releases of *C. carnea*, in the present study, could be useful to look after the population of shoot and fruit borer (eggs, neonate larvae), left unmanaged by *T. chilonis* and pheromone traps. In addition, the reduction in population of sucking pests, *Coccidohystrix insolitus* Green,

Table 3. Population of sucking pests in intercropping system based modules and brinjal pure crop

Treatment	<i>C. insolitus</i> (No./ three leaves)*	<i>A. gossypii</i> (No./ three leaves)*	Mean no. of <i>A. gossypii</i> / trap	<i>A. devastans</i> (No./ three leaves)*	<i>B. tabaci</i> (No./ three leaves)*
Brinjal + cluster bean (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	3.5 (1.87) ^a	21.8 (4.67) ^a	4.56	0.00 (0.71) ^a	0.00 (0.71) ^a
Brinjal + onion (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	3.9 (1.97) ^a	22.0 (4.68) ^a	5.13	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal + cluster bean (4:1)	4.3 (2.06) ^b	25.4 (5.04) ^b	-	0.00 (0.71) ^a	0.00 (0.71) ^a
Brinjal + onion (4:1)	4.9 (2.21) ^b	27.2 (5.21) ^b	-	0.0 (0.71) ^a	0.0 (0.71) ^a
Brinjal (sole crop)	10.2 (3.19) ^c	57.2 (7.56) ^c	-	8.0 (2.83) ^b	5.9 (2.42) ^b
Mean	5.36 (2.26)	30.72 (5.43)	4.84	2.0 (1.13)	1.58 (1.05)
SEd	0.11	0.18		0.02	0.01
CD (0.05%)	0.29	0.51		0.06	0.04

*Mean of 20 observations

Figures in parentheses are square root transformed values

In a column, means followed by the same letter(s) are not significantly different by DMRT (P=0.05)

Aphis gossypii Glover, *Amrasca devastans* Dist. and *Bemisia tabaci* Gennadius in modules I and II might be due to the release of *C. carnea* (60 and 70 DAT) at ten days interval, recording 3.5, 21.8, 0.0 and 0.0 no./three leaves and 3.9, 22.0, 0.0 and 0.0 no./three leaves, respectively, while it was 10.2, 57.2, 8.0 and 5.9 no./three leaves in brinjal as sole crop (Table 3). The field efficacy of *C. carnea* in reducing the population of sucking pests has been well demonstrated in several crops including cotton (Balakrishnan *et al.*, 2005) and groundnut (Murali Baskaran *et al.*, 2000). Erection of yellow sticky trap @ 25 /acre to attract the sucking pests in intercropping system based modules I and II (4.56 to 5.13 no. of *A. gossypii* / trap) might be one of the reasons to reduce the population of sucking pests.

The highest mean population of coccinellids (6.2 and 5.4 no./plant), syrphids (2.8 and 2.2 no./plant) and spiders (1.8 and 1.6 no./plant) was recorded in the intercropping system based module I and II, respectively (Table 4). A large build up of natural enemies, *Chrysoperla* sp. and predatory spiders in IPM fields was reported by Tanwar *et al.* (2005) where neem, *Trichogramma* and pheromone traps were used.

The module I recorded the highest brinjal yield of 16.32 t/ha, followed by module II (14.6 t/ha) while it was 13.18, 12.53 and 8.33 t/ha in brinjal + clusterbean, brinjal + onion and brinjal as a sole crop, respectively. The cost benefit ratio was high in both intercropping system based modules I and II (1:3.22 and 1:3.18) while it was

Table 4. Population of predators in intercropping system based modules and brinjal pure crop

Treatment	Coccinellids (No./ Plant)*	Syrphids (No./ Plant)*	Spiders (No./ Plant)*
Brinjal + cluster bean (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	6.2 (2.49) ^a	2.8 (1.67) ^a	1.8 (1.33) ^a
Brinjal + onion (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	5.4 (2.38) ^b	2.2 (1.49) ^b	1.6 (1.26) ^b
Brinjal + cluster bean (4:1)	4.6 (2.15) ^c	2.0 (1.42) ^b	1.4 (1.18) ^c
Brinjal + onion (4:1)	4.4 (2.10) ^c	1.8 (1.34) ^c	1.3 (1.14) ^c
Brinjal (sole crop)	1.0 (0.99) ^d	1.1 (1.05) ^d	1.0 (0.99) ^d
Mean	4.32 (2.01)	1.98 (1.39)	1.42 (1.18)
SEd	0.04	0.03	0.02
CD (0.05%)	0.11	0.07	1.05

*Mean of 20 observations

Figures in parentheses are square root transformed values

In a column, means followed by the same letter(s) are not significantly different by DMRT (P=0.05)

1: 1.66 in brinjal as pure crop (Table 5). The highest cost benefit ratio is realized whenever intercropping system is used as one of the components in IPM, as reported in cotton + onion

(Smith and Vanden Bosch, 1970), cotton + cluster bean (Balasubramanian *et al.*, 1998), brinjal + coriander (David Abilash, 2000), chilli + onion (Aswantharayanareddy *et al.*, 2006) *etc.*

Table 5. Yield and cost benefit ratio in intercropping system based modules and brinjal pure crop

Treatment	Estimated healthy brinjal fruit yield (t/ha)	Yield of intercrops (kg/ha)	Income from brinjal (Rs.)	Income from intercrops (Rs.)	Cost of cultivation on (Rs./ ha)	CB ratio
Brinjal + cluster bean (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	16.32 ^a	980	130560	4900	42046	1: 3.22
Brinjal + onion (4:1) + six releases of <i>Trichogramma chilonis</i> + two releases of <i>Chrysoperla carnea</i> + pheromone trap @ 5 no./acre + yellow sticky trap @ 25 no./acre	14.61 ^b	1300	116880	15600	41646	1: 3.18
Brinjal + cluster bean (4:1)	13.18 ^c	920	105440	4600	40460	1: 2.72
Brinjal + onion (4:1)	12.53 ^d	1180	92240	14160	40060	1: 2.66
Brinjal (sole crop)	8.33 ^e	0.00	66640	0.00	40000	1: 1.66
Mean	13.19					
SEd	0.03					
CD (0.05%)	0.07					

Cost of cultivation: Rs. 40,000/- + seed cost of intercrops, Brinjal - Rs.8/ Kg; Clusterbean - Rs.5/ Kg; Onion - Rs.12/ Kg, *Trichogramma chilonis* @ 2.5cc/ ac/ one release – Rs. 45.00, *Chrysoperla* eggs @ 20,000/ ac/ one release – Rs. 100.00, *Leucinodes orbonalis* pheromone trap – Rs. 30/ trap, Yellow sticky trap Rs. 5/ trap

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RELATIONSHIP BETWEEN THE LEVELS OF INFESTATION OF *Xylosandrus crassiusculus* Motschulsky (COLEOPTERA: SCOLYTIDAE) AND GROWTH PARAMETERS OF GRAPE

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ABSTRACT: The present field studies were carried out on untreated grape orchard cv. Bangalore Blue at Nagadasanahalli, Bangalore (North) (12° 58'N; 77° 35'E), Karnataka, India to know the relationship between the infestation level of scolytid, *Xylosandrus crassiusculus* Motschulsky and growth parameters of grape vine. Similar studies were also carried out on treated grape orchard at Indian Institute of Horticultural Research, Bangalore. The number of scolytid damaged holes on the main trunk was significantly and negatively correlated with total number of bud sprouts. This implied that as the infestation levels of scolytids increased on the vine trunk, the number of sprouts produced by the vines after pruning reduced. Similarly, as the number of sprouts decreased with the severity of the shot hole borer infestation, the number of bunches per vine also decreased. However, within a bunch, the number of berries, which directly contributed to the weight of the bunch, was not affected. But overall productivity was affected. From the study carried out at the Indian Institute of Horticultural Research vineyard, where control measures were taken immediately after noticing the shot hole borer attack on the trunks by regular and close monitoring of pest attack, the growth and development of the vines and yield (number of bunches) were not affected.

Key Words: Grape, *Xylosandrus crassiusculus*

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the most important commercial fruit crops of sub-tropical regions. It was introduced to India from Iran and Afghanistan in 1300 AD (Bose *et al.*, 1999). In India, grape is commercially grown in an area of about 0.43 lakh hectares with an annual production of 10.83 lakh tonnes (Anonymous, 2000). Grape cultivation in India acquires great significance due to its high productivity (21.08

tonnes/ha), profitability and export potential. In India, the main grape growing states in India are Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh (Anonymous, 2000).

The commonly grown grape varieties in Karnataka are Thompson seedless, Anab-e-shahi, Dilkush, Bangalore Blue and Gulabi. Of these, Bangalore Blue is the most popular cultivar of southern districts of Karnataka in South India. It is believed to be a natural hybrid of *Vitis vinifera*

L. and *V. labrusca* L. Bangalore Blue is a moderate yielder and the vines are medium in vigor. Bunches are small to medium in size and compact. The berries are medium sized, bluish black or dark purple in colour, seeded and spherical in shape. Pulp is green and juicy. The juice is purple in colour; foxy flavored having total soluble solids of about 16–18° Brix and about 0.8–1.0% acidity (Winkler *et al.*, 1974). The cultivar Bangalore Blue is preferred more for juice and wine making than for table purpose. It is quite hardy, compared to Thompson seedless, Dilkush and Anab-e-shahi. Its popularity may be due to the twice-bearing character in a year and low production cost compared to other varieties. Extensive and intensive cultivation of grapes tend to attract a number of insect pests to the vineyard. Bourmier (1977) listed 132 insect pests attacking grapes in the world. In India, as many as 94 species of insects and mites have been reported attacking grapes (Tandon and Verghese, 1994).

Some of the common major pests reported so far are flea beetle (*Scelodonta strigicollis* (Motschulsky)), shot hole borer (*Xylosandrus crassiusculus* (Motschulsky)), mealy bug (*Maconellicoccus hirsutus* Green), thrips (*Rhipiphorothrips cruentatus* Hood and *Scirtothrips dorsalis* Hood) and stem girdler, *Sthenias gristator* (Fabricius). The shot hole borer *X. crassiusculus* (Coleoptera: Scolytidae) is a serious pest particularly on Bangalore Blue, which is grown mainly in and around Bangalore and Kolar districts. It was first spotted as *Xylosandrus semiopacus* (Eichhoff) and was considered to be a serious pest on grapes in Karnataka, in mid-seventies (Veeresh *et al.*, 1976). They found the beetle tunneling into the main trunks. Each trunk had several tunnels and each tunnel was a nest in which broods were raised. It mainly attacks the main trunks, starting from the base of the plant. Eventually the nest building activity on the main trunk damages the vine. The beetle belongs to the group of insects popularly known as “Ambrosia beetles” as it cultivates an ambrosia fungus (*Ambrosiella* spp.) in the

excavated tunneled nests on which the grubs feed.

Initially the beetles bore and make pin-holes into the main trunk of the vine to a depth of 2-3 cm and later they bored randomly in all directions (Veeresh *et al.* 1976). In these bored holes, the beetles cultivated Ambrosia fungus and laid eggs. The grubs on hatching fed on fungal spores and completed their life cycle. From the bored holes, gum like substance started oozing. In severe cases the vine started wilting and drying. The trunk dried and starts cracking and ultimately it breaks.

The foremost symptom of the pest attack is the appearance of pin- holes on the main trunks. Initial attacks on the trunks do not show any symptoms since the insects are so tiny and their entry holes on trunk of the host are inconspicuous. But as the damage progresses, “tooth pick” like cylinders of saw dust are pushed out of the holes, thus entry holes of the insect into the trunk become evident. As infestation progresses, gummy exudate can be seen along the main trunk. Severely affected vines show yellowing of leaves and wilting. Gradually the plants begin to dry and in a span of 15-20 months, the affected vine dies (Verghese and Tandon, 1995). So present study was carried out to know the impact of the beetle attack on plant growth parameters and yield.

MATERIALS AND METHODS

Field studies were carried out on untreated grape orchard at Nagadasanahalli, Bangalore (North) (12° 58'N; 77° 35'E) South India to study the relationship between the level of scolytid infestation and growth parameters of grape vine. The studies were carried out on twenty one-year-old grape vines cv. Bangalore Blue. The vines were pruned during 30th and 31st January 2003, one and half month after harvest. Sprouting started 14 days after pruning. Fourteen shot hole borer infested vines were selected randomly and marked. Total number of holes (both active and

dead holes) present on each trunk was recorded separately. Similarly, 10 healthy (uninfested) vines from the same orchard were selected at random and marked to treat as control.

In another trial, growth parameters of vines where shot hole borer infestation was nipped at first sight (treated) were also taken at the Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bangalore. The vines were pruned on 01/04/2003. Five shot hole borer infested vines which were promptly treated with dichlorvos @ 3 ml/l and covered by plastic cover and marked. Five healthy vines were randomly selected to treat as control and marked. Later, the data were subjected to correlation analysis to know the relationship between the level of infestation and growth parameters.

In both trials, on those marked vines, further observations were taken up on total number of sprouts per vine and recorded separately. Later, five sprouts were randomly selected from these and tagged. On these sprouts, the parameters like length of the canes (cm) and number of leaves were recorded at fortnightly interval up to three months after sprouting. Later from the selected vines, total number of bunches per vine were recorded. Next, ten bunches were randomly selected and tagged, and the number of berries were recorded separately and average weight of the ten tagged bunches of each vine was recorded separately during harvest.

Later, the data from untreated (Nagadasanahalli) and treated (IIHR) were subjected to correlation analysis to know the relationship between the level of infestation and growth parameters.

RESULTS AND DISCUSSION

Relationship between the level of infestation of *X. crassiusculus* and growth parameters of grape cv. Bangalore Blue

The data on total number of bored holes by *X. crassiusculus* on grape vines in untreated

(Nagadasanahalli) and treated (IIHR) were subjected to correlation analyses with growth parameters to find out the relationship of infestation with the parameters. The parameters were total number of sprouts of each vine, mean length and number of leaves on canes, total number of bunches per vine, mean number of berries per bunch and mean bunch weight.

Correlation of *X. crassiusculus* holes with total number of sprouts of vines

Correlation analyses on the total number of holes of *X. crassiusculus* of a vine with total number of sprouts revealed in untreated vines a significant negative correlation ($r = -0.91$) at $p = 0.01$. Whereas in treated vines it was non-significant ($r = 0.62$) (Table 1).

It is well known that infestation by an insect, which bores the stem, affects growth and yield. Shot hole borers are no exception to this. In order to find out the extent to which the infestation affects the vine, correlation coefficients were worked out between the level of infestation (total number of shot hole borer holes) of a vine and growth parameters like number of sprouts per vine, length of canes, number of leaves, number of bunches per vine, number of berries per bunch and weight of each bunch. It was found that the infestation negatively affected the sprouting of buds (Table 1), implying that as the infestation levels of shot hole borer increased on the vine, the number of sprouts produced by the vines (post pruning) reduced.

Reduction in sprouts reduces productivity as number of canes per unit area is also reduced. Further it was observed that in severely shot hole borer affected vines, the bud sprouting was delayed by 2-3 days post pruning. It was also observed that in infested vines the shock of pruning was more, unlike the healthy vines. Thus invariably, infested vines showed partial wilting and drying of some of the canes after pruning. This may occur due to large canker formations at the beetle-attacked sites on the main trunk of

Table 1 : Correlation coefficient (r) between total number of holes of *X. crassiusculus* and growth parameters

Parameters	'r' Values			
	Number of sprouts per vine	Number of bunches per vine	Mean number of berries per bunch	Mean weight of bunch
Untreated	-0.91**	-0.92**	-0.39 ^{NS}	-0.39 ^{NS}
Treated	0.62 ^{NS}	0.26 ^{NS}	0.33 ^{NS}	0.30 ^{NS}

** Significant at 1 per cent

NS = Non significant

the vine resulting in girdling like situation. The holes on the main trunk hinder the conduction of water and nutrients from roots to growing tip. These observations are supported by the reports of Browne (1961) and Schedl (1962) who found that attacks by *X. crassiusculus* on lower stems of large drake elm saplings resulted in cankers at the site of attacks resulting in gradual death of the saplings.

The total number of shot hole borer holes showed significant negative correlation with the number of bunches per vine, clearly showing how productivity was lowered. However, it was non-significant with mean number of berries and mean bunch weight (Table 1), implying that the bunches that formed, even if less in numbers had the same number of berries and berry weight. However, this does not compensate for productivity. This was as expected, as the number of sprouts decreased with the increase in the severity of shot hole borer infestation. So the number of bunches per vine also decreased. However within a bunch, the number of berries, which directly contributes to the weight of the bunch was not affected. This might be due to, lateral branches of the vine itself produced less number of sprouts in severely infested vines and whatever the nutrients and water that was absorbed by roots may have been diverted directly to available productive canes where photosynthesis occurs and the few reproductives (bunch) develop into sinks. But as

number of bunches decrease, the yield also gets reduced, causing loss to farmers.

Correlation of total number of *X. crassiusculus* holes with number of bunches per vine, mean number of berries per bunch and mean weight of bunches

The data on total number of holes by *X. crassiusculus* was subjected to correlation analyses with number of bunches, mean number of berries of bunches and mean weight of bunches in untreated and treated vines. The results revealed that in untreated vines total number of holes of *X. crassiusculus* showed highly significant negative correlation with total number of bunches ($r = -0.92$) at $p = 0.01$. The correlation of total number of holes with mean number of berries and mean bunch weight were non-significant with $r = -0.39$ and $r = -0.39$, respectively. In treated vines, total number of holes showed a non-significant correlation with number of bunches ($r = 0.26$), mean number of berries of bunches ($r = 0.33$) and mean bunch weight ($r = 0.30$) (Table 1).

Correlation of *X. crassiusculus* holes with length of canes

The total number of shot hole borer holes in untreated grape vines showed significant negative correlation with length of canes with a correlation co-efficient (r) values of -0.79, -0.73, -0.80, -0.84, -0.84 and -0.83 at 15, 30, 45, 60, 75 and 90 days after buds sprouting, respectively at $p =$

0.05. Whereas in treated vines, the total number of shot hole borer holes showed non-significant correlation ($r = -0.35$) with length of canes at 15 days after buds sprouting and significantly negative correlation coefficient (r) values of $-0.66, -0.73, -0.78, -0.74$ and -0.77 at 30, 45, 60, 75 and 90 days after buds sprouting, respectively at $p = 0.05$ (Table 2).

Table 2. Correlation coefficient (r) between total number of holes of *X. crassiusculus* and mean length of canes at different days after sprouting

Days after sprouting	'r' values	
	Untreated	Treated
15	-0.79*	-0.35 ^{NS}
30	-0.73*	-0.66*
45	-0.80*	-0.73*
60	-0.84*	-0.78*
75	-0.84*	-0.74*
90	-0.83*	-0.77*

* Significant at 5 per cent

NS- Non-significant

The length of the canes that sprouted, showed significant negative correlation with total number of shot hole borer holes at 15, 30, 45, 60, 75, and 90 days after bud sprouting (Table 2). This may be due to the stress caused by beetle's attack on the main trunk of the vines, affecting the flow of water and nutrients to leaves, which in turn affect the production and flow of photosynthates to the roots. Further, this may also affect the growth and development of roots by which active absorption of water and nutrients takes place from the soil.

Apart from these, gummy exudates from the bored holes (a plant defensive chemicals against shot hole borer beetles) divert a lot of photosynthates which otherwise would have been utilized for growth. This will contribute to the reduction of normal healthy growth of the vine. These observations are comparable with the reports of Veeresh *et al.* (1976) and Verghese and

Tandon (1995) that severely affected vines, show wilting, yellowing and slow death of vines.

Correlation of *X. crassiusculus* holes with mean number of leaves of canes

The total number of holes of *X. crassiusculus* in untreated vines showed significant negative correlation with mean number of leaves of canes at 15, 75 and 90 days after buds sprouting with 'r' values $-0.58, -0.63$ and -0.64 , respectively at $p = 0.05$. However, at 30, 45 and 60 days after bud sprouting the correlation was found to be non significant with 'r' values of $-0.46, -0.48$ and -0.50 , respectively. In treated vines, the total number of shot hole borer holes showed non-significant correlation with mean number of leaves at 15, 60, 75 and 90 days after buds sprouting (Table 3). It was found that there was significant negative correlation with values of -0.79 and -0.83 ($p = 0.05$) at 30 and 45 days after buds sprouting.

The total number of shot hole borer holes showed significant negative correlation with mean number of leaves of canes at 15, 75 and 90 days after bud sprouting and non significant negative correlation at 30, 45 and 90 days after bud sprouting (Table 3). As discussed above, the shot hole borer tunnels (through xylem and phloem vessels) affecting the movement of photosynthates to the roots, which in turn affects the effective root development. These tend to get reflect in reduced number of leaves on the secondary and tertiary braches. It is a natural corollary that poorly developed canes due to poor root system result in less number of leaves. At 75 and 90 days after buds sprouting, the growth of the canes completely ceased in shot hole borer-affected vines, with the older leaves showing yellowing and premature drop. These observations are in agreement with Deshpande *et al.* (1981) in case of coconut palms, infested with *X. crassiusculus* the palms had less number of fronds (9.50) than the normal palms (19.0) and all the fronds were drying, with the crown region only remaining greenish.

At 30, 45 and 60 days after bud sprouting, the total number of shot hole borer holes showed non-significant negative correlation with mean number of leaves. This may be due to, active growth period of the canes after 30, 45 and 60 days after bud sprouting, which produce large number of small sized leaves in shot hole borer infested vines.

Table 3. Correlation coefficient (r) between total number of holes of *X. crassiusculus* and mean number of leaves

Days after sprouting	'r' values	
	Untreated	Treated
15	-0.58*	-0.26 ^{NS}
30	-0.46	-0.79*
45	-0.48	-0.83*
60	-0.50	-0.62 ^{NS}
75	-0.63*	-0.28 ^{NS}
90	-0.64*	-0.07 ^{NS}

* Significant at 5 per cent

NS = Non Significant

Field studies at the farm (treated) of the Indian Institute of Horticultural Research

This study was similar to the above study, except that the parameters were observed on vines, which were promptly treated at the initial attack of the shot hole borer. It was essentially conducted to know whether the growth parameters were affected or not if shot hole borer infestation is nipped at first sight. At the Institute vineyard, regular supervised scouting is done every week to examine the overall health of a vine. As a sequel to this, when shot hole borer attack was first noticed, the vines were treated and damage controlled. Growth parameters of such vines were monitored.

It was found that the shot hole borer infestation was not correlated with total number of sprouts, number of bunches, mean number of

berries per bunch and mean bunch weight (Table 1), It clearly revealed that there was no damage or loss to the vines because of shot hole borer infestation if the vines are promptly treated at early infestation. Therefore, farmers should regularly monitor for the pest attack by closely observing the vine trunks at regular intervals (preferably weekly).

The shot hole borer infestation showed significant negative correlation with length of canes at 30, 45, 60, 75 and 90 days after bud sprouting except at 15 days after pruning (Table 2). This might be due to the fact that even light early infestation may affect the growth of cane. Perusal of literature showed that information of growth being affected due to early infestation is lacking. This study needs to be more inclusively carried out, especially if threshold levels have to be worked out. Sufficient to point out here that in *X. crassiusculus*, the threshold level is quite low, may be 1-3 holes per vine.

The shot hole borer infestation was showed non-significant correlation with mean number of leaves at 15, 60, 75 and 90 days after bud sprouting. Whereas infestation was significantly and negatively correlated at 30 and 45 days after bud sprouting (Table 3). This may be due to the fact that 30 and 45 days may be sensitive periods in the growth cycle, post pruning. However, between 60-90 days, the plant growth was stable and seemed to have countered the early shock due to infestation. Physiologically any damage to the trunk prompts gummosis and the vines tend to divert energy towards this, which may be at the cost of number of leaves. Two things seem to emerge here: One, even early minor damage can cause a reduction in leaves; and two, in case of minor early damage, if controlled, the plant responds by reversing the loss and will have normal number of leaves. This effect may be due to the canker formation at the site of shot hole borer infestation as discussed above and affect the cane growth, which in turn affects the mean number of leaves. However, if control measures are taken immediately after the shot hole borer

attack is found on the trunks by regular and close monitoring, the pest attack will not affect the growth and development of the vines and yield.

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Proceedings of the Group Meeting National Scenario on Management of Sucking Pests IIHR, Bangalore on 7th March, 2008

Organized by

Association of Advancement of Pest Management in Horticultural Ecosystems (AAPMHE),
Society for Promotion of Horticulture (SPH) and
Indian Institute of Horticultural Research (IIHR), Bangalore, India
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A group meeting on *National Scenario on Management of Sucking Pests* was organized at the Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangalore 560089 on the 7th March, 2008. Dr. N. K. Krishna Kumar, Head, Division of Entomology & Nematology, welcomed the participants, introduced the theme and the importance of the group meeting. The following points emerged in the plenary session.

1. Systematics: A strong base is needed in identification of aphids, whiteflies, leafhoppers and planthoppers, thrips, mealybugs and mites. This is also important considering globalization and increased import/exports in floriculture.
2. Field guide: There is an urgent need for identification of sucking pests at field level and some field guides need to be developed.
3. Use of insecticides: The house strongly recommended against mixing of insecticides to manage the problem of sucking pests.

Rather, application of neem alternatively was suggested. Ketoenols, nicotinamides, pyrazoles are promising groups for sucking pests and must be explored.

4. Organic management of sucking pests is needed especially for export oriented crops.
5. Host plant resistance plays a major role for managing sucking pests e.g., whitefly. This is a based on which IPM can be developed. Much effort is needed in this direction.
6. Compatibility charts especially for new molecules to be supplied by the respective companies that they promote.
7. Fundamental knowledge on digestive system of sucking pests is lacking. We have to develop a student community and give research oriented problem on these aspects. There is a need for human resource development in this aspect and encourage young researchers to take up this field of enquiry for their research.

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The following scientists participated :

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|----|-----------------------|--------------------------------|
| 1. | Dr. C. A. Viraktamath | UAS, Bangalore |
| 2. | Dr. B. Mallik | UAS, Bangalore |
| 3. | Dr. B. V. Patil | UAS, Dharwad |
| 4. | Dr. K. S. Mohan | Monsanto, Bangalore |
| 5. | Dr. T. Ambika | Monsanto, Bangalore |
| 6. | Dr. S. Suresh | TNAU, Coimbatore |
| 7. | Dr. R. Sundararaj | Wood Science & Tech. Bangalore |

8.	Dr. S. Joshi	PDBC, Bangalore
9.	Dr. N. Narayanan	Multiplex, Bangalore
10.	Dr. H.M Venkatesh	Dupont, Bangalore
11.	Mr. Ranganatha M. C.	Syngenta, Bangalore
12.	Dr. S. S. Ravi Kumar	Bayer, Bangalore
13.	Dr. S. G. Eswara Reddy	Indofil, Bangalore
14.	Dr. D. K Nagaraju	Mahyco, Bangalore
15.	Miss. B. R. Jayanthi Mala	Mahyco, Bangalore
16.	Dr. R. Palaniappan	IIHR (Soil Science)
17.	Dr. G. S. Prakash	IIHR (Fruit Crops)
18.	Dr. M. Prabhakar	IIHR (Vegetable Crops)
19.	Dr. M. Krishna Reddy	IIHR (Plant Pathology)
20.	Dr. K. Madhavi Reddy	IIHR (Vegetable Crops)
21.	Dr. A. Krishnamoorthy	IIHR (Entomology)
22.	Dr. P. N. Krishna Moorthy	IIHR (Entomology)
23.	Dr. Abraham Verghese	IIHR (Entomology)
24.	Dr. B. Jhansi Rani	IIHR (Entomology)
25.	Dr. K. S. Krishna Prasad	IIHR (Nematology)
26.	Dr. Ganga Vishalakshi	IIHR (Entomology)
27.	Dr. R. Asokan	IIHR (Entomology)
28.	Dr. H. R. Ranganath	IIHR (Entomology)
29.	Dr. V. Shridhar	IIHR (Entomology)
30.	Dr. K. Gopalakrishna Pillai	IIHR (Entomology)
31.	Dr. P. D. Kamala Jayanthi	IIHR (Entomology)
32.	Dr. P. V. Rami Reddy	IIHR (Entomology)
33.	Dr. Achala Paripoorna	IIHR (Entomology)
34.	Dr. N. K. Krishna Kumar	IIHR (Entomology)

In his opening remarks Dr. N. K. Krishna Kumar drew the attention to the IPM and IRM considering the fact that sucking pests such as mirids, mealy bugs, red spider mites, etc are becoming a serious problem on a number of crops. He dealt with the scenario in cotton (especially Bt cotton) in Punjab, Haryana, Gujarat, Maharashtra and Karnataka where the success of Bt technology is put to test by sucking pests. He drew the attention of the participants to the mealybug infestation and how Bt technology has to reorient IPM in the light of this new menace. He focused on the observations made by certain international groups that the transgenic technology over years may not deliver the economic advantage. The resurgence of unexpected mirid not only in India but also in

countries such as China and Australia points to certain similarities cutting across geographical boundaries and is not a mere local phenomenon. The decrease in the efficacy of molecules such as imidacloprid on leafhoppers over time indicated our lack of scientific comprehension on events at cellular level in sucking pests, he added. The importance of an in-depth understanding/need to study the physiology of digestion, absorption, assimilation and excretion in different families of Hemiptera taking into consideration the role played by symbionts in the development of insecticide resistance, biotypes and ability to infest new host plants that were traditionally not infested (mites on tomato, grapes etc.) is needed. He concluded that a holistic interaction is needed to address the gaps in our knowledge.

Dr. C. A. Viraktamath gave a brief presentation on systematics, problems in the identification of hemipterans, morphology, diversity, importance of ant association and damage. He was of the opinion that usually damage by sucking pests is underestimated in contrast to damage by Lepidoptera and Coleoptera, which is usually over estimated. He said that more than 80,000 species are reported in the world, of which around 6500 species occur in India. Contrary to earlier classification (Hemiptera-Homoptera, Heteroptera) in the recent classification, Hemiptera is divided in to

Suborder : Sternorrhyncha – Aphids, psyllids, whiteflies, scales & mealy bugs

Suborder : Heteroptera – Pentatomorpha, Cimicomorpha *etc.*

Suborder : Auchenorrhyncha - Leafhoppers, Treehoppers, Froghoppers, Planthoppers, Fulgorids *etc.*

Most Sternorrhyncha are associated with ants which provide shelter against natural enemies in return for honey dew. Hemiptera can be carnivorous or phytophagous. On plants their main damage is by sucking, affecting plant vigor. Some leafhoppers, mirids, psyllids inject toxin. Oviposition injury is also observed from hoppers. Aphids, leafhoppers, planthoppers, psyllids, mealy bugs, whiteflies, thrips *etc.* transmit some of the most economically important plant viruses and phytoplasma. While most leafhoppers feed on phloem (*Orosius*, *Hishimonus*, *Amrasca*) some feed on the xylem tissue and are characterized by a swollen face or frons. Some leafhoppers, tingids, mirids and lygaeids feed only on mesophyll tissue. Certain mirids in addition to injecting toxins predispose plants to fungal infection.

Morphological and structural similarities and size render identification of Hemipteran bugs an extremely difficult task. Normally species can be separated using distinct features of male

genitalia. However, many species need special collection technique and preparation of specimen for correct identification. In some cases use of molecular technique is inevitable. Revision of many families of Indian insects is pending making species identification a difficult task; often there is sexual dimorphism within a species leading to misidentification. While many hemipterans have a highly modified midgut, Auchenorrhyncha and Sternorrhyncha have a filter chamber (that removes excess water from its body) and excrete honey dew. The digestive system among Hemiptera is extremely diverse and complicated.

The biology of many Hemipteran is very similar in which they undergo incomplete metamorphosis with 3 stages., egg, nymph and adult. There are typically 4 molts. However, whiteflies and male coccids undergo complete metamorphosis.

Communication in Hemiptera is through sound and pheromones, whereas in Auchenorrhyncha, surface vibrations are also utilized. Aphids and coccids predominantly use pheromones.

A number of *Nephotettix* species are green and have dorsal black spots and can easily be confused. Further distinct biotypes (*populations of a species with novel physiological trait to adapt to a particular host*) occur among aphids, whiteflies, leafhoppers, planthoppers. At least 3 biotypes in *Nilaparvata lugens* and *Nephotettix virescens* and 5 biotypes in *Rhopalosiphum maidis* occur. These can be differentiated using molecular markers in addition to differential hosts which are traditionally used.

In whiteflies distinct B biotype of *Bemisia tabaci* is reported from Karnataka and only use of advanced molecular methods showed that this biotype is close to Sahel group. Origin of B-biotype is presumed to be Mediterranean / North African region, accordingly. Such information is valuable for success of biocontrol. Species of *Eretmocerus mundus* (Spain), *E. hayati*

(Pakistan), *E. emiratus*, *Eretmocerus* sp. (Ethiopia) field released in California have established and are promising in control of the B biotype. *Eretmocerus* from Spain, Pakistan and Middle East were most efficient parasitoids.

While some sucking pests facilitate entry of facultative pathogens, some are transmitted mechanically. Majority of species have intimate relation with pathogens. Tissue on which they feed limits their ability to acquire and transmit pathogens.

Certain Pyrrhocorids and a few Lygaeids transmit yeast fungus, e.g., Cotton stainers, certain cercopids and cicadellines transmit xylem restricted bacteria. Dr. C.A. Viraktamath made a special mention of the glassy winged sharpshooter transmitting xylem restricted bacteria, *Xylella fastidiosa* a major disease of grapes in the USA. Among leafhopper vectors, *Nephotettix virescens*, *N. nigropictus*, *Recilia dorsalis*, *Orosius albicinctus* and *Hishimonus phycitis* were some of the most important vectors. He emphasized different sucking insects infesting rice and damage caused especially by *Leptocorisa acuta*. He also listed mirids associated with cotton, those associated with pulses, ground nut, and vegetables. He highlighted mango leafhoppers with special reference to damage caused by *Amrasca splendens* (Ghuri), and said the tip burning symptoms on leaves was due to oviposition injury and not feeding injury.

Dr. C.A. Viraktamath discussed about increased infestation of mango mealy bugs in recent years due to indiscriminate use of chemicals that may only increase the problem. He briefly touched upon mirid pests on sorghum, and informed that the damage by *Ochrophara montana* on bamboo often resulted in breaking entire branch or plant. He concluded that we have a long way to go in identification, understanding anatomical and physiological interactions, vector pathogen interactions etc.

This was followed by a lively discussion on a number of aspects.

Dr. Abraham Verghese : B type of *B. tabaci* was not present in India earlier and first report was from Kolar on tomato, what would have been the route of entry?

Dr. C. A. Viraktamath : Chances of it being introduced to India along with imported plant materials is very high.

Dr. Venkatesh : Boxes heavily infested with whitefly in private nursery and they are imported plants have been observed.

Dr. N. K. Krishna Kumar : Is it possible to segregate families of Hemiptera based on honeydew excretion? Is ant association species specific or season specific?

Dr. C.A. Viraktamath : a) Heteroptera do not excrete honey dew but all members of Auchenorrhyncha and Sternorrhyncha excrete honey dew. But the nature of sugar excreted and the fungal growth on them need further investigation. All the time ants are present because of honey dew; however it appears more regional and seasonal.

Dr. A. Krishnamoorthy : Species of ant-sucking pests associations vary with geographical location and host (e.g., mealybug). Same species of ants are associated with different species of sucking pests at different geographical regions. Not all ant species are detrimental to natural enemies.

Dr. C.A. Viraktamath : Efficient management of ants would lead to better management of sucking pests; as the attending ants ward off parasitoids and predators and aid in dispersal by carrying the adults/nymphs of sucking pests. Severe outbreak of scale/mealybug was observed on areca in *S. canara* and the use of neem oil could give excellent control.

Dr. K. S. Mohan : Digestion and assimilation physiology is not well understood to take biotechnical investigations for management of sucking pests. Insect physiologists are not many to take up such studies.

Dr. C. A. Viraktamath : Yes, I agree.

Dr. Krishna Reddy : a) Does *Hishimonus* mostly transmits diseases of annual crops and *Orosius* mainly perennials? b) Whether areca spindle bug is xylem or phloem feeder.-

Dr. C. A. Viraktamath : a) There are mixed records. It is not so distinct. b) Not sure

Dr. B. V. Patil, Director of Instruction (Agri), College of Agriculture, Raichur made a brief presentation on *National Scenario on Emerging Sucking Pests of Cotton*.

To begin with he highlighted the incidence of mirid bug, *Creontiades biseratense* (Distant) that was reported earlier as a minor pest on cotton and now has attained major pest status. In central India, Nagpur, *Campylomma livida* Reuter is the predominant species and most often feeds on squares causing extensive square shedding. In Australia a different species *Creontiades dilutus* is known to infest cotton. Mirid bug eggs generally take 5-7 days to hatch and pass through 5 distinct nymphal instars in 12-18 days. Adult longevity of male and female was 10-14 days and 15-25 days, respectively.

In Bt cotton in north Karnataka, the incidence of mirid bug has not been noticed for the first 50 days after sowing. Population increased from the first week of November to first week of December and started declining from December first week onwards. Population increased again from January third week till February second week and later showed a declining trend. Both adults and nymphs fed on tender squares & bolls that led to squares becoming black and anthers discolored. The boll opening was incomplete. The feeding punctures of mirid bugs could be easily observed as black spots on bolls and at the base of squares.

Affected squares & bolls were shed prematurely due to influence of toxins injected while feeding. This pest is also recorded on pigeon pea, sunflower, safflower, maize, bajra, castor, dhaincha etc. Application of Acephate @ 750 g ai/ ha is being recommended for its control.

Dr. Patil emphasized the importance of red cotton bug and dusky cotton bug that affect lint quality. Among other sucking insects dusky cotton bug flares up in the absence of pesticide spray on Bt cotton. Though there was no yield reduction, loss of quality (strength of fibre) was observed. Mealy bug problem on cotton he said is restricted to certain pockets of north Karnataka and not widespread as generally believed. The infestation of mealy bugs was noticed only on Bt cotton during October- November in 2007. Infested plants were totally covered with mealy bugs and subsequently succumbed to its infestation. However, the species found affecting Bt cotton was not identified though at least 3 species are reported. It was surprising to note that *desi cotton* (neither on *Herbarium* nor on *arborium*) grown in the same area was totally devoid of this problem possibly due to presence of glandular trichomes.

Dr. Narayanan : Whether mirid bug damage is feeding damage or oviposition punctures? Why discoloration near damage area?

Dr. B. V. Patil : Punctures followed by injection of toxins cause discoloration.

Dr. K. S. Mohan : Lesser known insects became problem on Bt cotton mainly because no pesticides are used. But in spite of no spraying, *desi cotton* was free of all these pests is an interesting observation.

Dr. B. V. Patil : The mirid bug avoids light (photo-negative). The *desi cotton* squares are open and this may be the reason for non-preference of *desi cotton* and such traits need to be exploited.

Dr. N. K. Krishna Kumar : Can you say Bt cotton is no more economic or marginally economic?

Dr. K. S. Mohan : *Bt* is for irrigated areas and not for rainfed. In spite of the cost of seed *Bt* cotton is still economical in irrigated areas and for non-irrigated areas non-*Bt* varieties may be the answer.

Dr. N. K. Krishna Kumar : What is your opinion of using transgenic *Bt* on monophagous pests such as brinjal fruit borer? How will the pest react to selection pressure?

Dr. B. V. Patil : So far the *Bt* cotton is also effective on pink boll worm which is nearly a monophagous pest. Each pest reacts to selection pressure in an innate mode and there may not always be similarities.

Dr. Abraham Verghese : *Phenococcus* may be a phenomenon of temporal or cyclic occurrence.

Dr. B. V. Patil : The problem is in genotype. *Bt* is incorporated in kokar genotype which is highly susceptible to the mealybug.

Dr. Mohan : Kokar parentage which is highly susceptible is in Indian genotypes. But after 6-7 backcrosses with desirable parent the trait is diluted.

Dr. Narayanan : Role of kokar parentage should be further investigated.

Dr. A. Krishnamoorthy : Absence of natural enemies may be reason for outbreak of mealy bugs.

Dr. K. C. Mohan presented *Biotechnological approaches for management of sucking pests* whiteflies, jassids, thrips, which continue to be a challenge in cotton cultivation. He said that this has to do with sucking pests' physiology, particularly of hemipterans which are still a black box because physiology of sucking pests is poorly understood compared to lepidopterans and coleopterans.

Some thoughts for management discussed were

- New molecules are not easy to discover for sucking pest control.

- Host-plant factors particularly resistance to mealybugs and mirids in native cotton that Dr. Patil mentioned may be useful. A comprehensive understanding of the role of secondary metabolites on sucking pests is lacking.
- Resistance to sucking pests is usually polygenic phenomenon, so use of markers will be helpful.
- Transgenesis: a) no progress regarding lectins b) near knock-down effect of *Bt* on lepidopteran but not in case of lectins c) novel *Bt* strains needed d) digestive physiology/ assimilation in hemipterans is real need of the day e) RNAi technology-prerequisite is genomics of sucking insects.

Dr. Mohan presented some challenges:

- Wide array of regulatory driven studies drive up cost and time to reach market of transgenics.
- No screens for hemipterans (good screens like *Lygus* in USA).

Dr. Sukhada Mohan Das: Mealybug infestation in *Bt* Cotton is it because of kokar genes?

Dr. K. S. Mohan : The kokar genes have been flushed out during the six backcrosses with the desirable parent; further the present *Bt* genes that have been introduced have Indian blood. Hence, mealybug infestation in cotton does not appear to be because of kokar genes.

Dr. Sukhada Mohan Das : Since there is increased infestation of sucking pest in hybrid cotton, do you think there is a need for pesticide application?

Dr. K. S. Mohan : The infestation of sucking pest appears mainly due to withdrawal of pesticides in *Bt* cotton and one or two sprays may be required for the management of sucking pests and many are still susceptible to the commonly used pesticides.

Dr. Sukhada Mohan Das : Since there is a synthesis of additional Bt protein in Bt cotton, do they need additional nutrition.

Dr. Mohan : Normal fertilizer dose given for hybrid cotton is adequate.

Dr. Sukhada Mohan Das : Is RNAi technology shown to be useful for management of pests? Are there any clear products?

Dr. Mohan: A concept paper in *Nature Biotechnology* has been published for the management of corn pests and also a paper in China saying that detoxification of gossypol leads to susceptibility in bollworm.

Dr. Ambika presented briefly *How to integrate the knowledge of Bioinformatics to biology and to other applied tools to help IPM*

a) To manage pests & diseases by looking for plant genes e.g., *desi* cotton; setting up libraries, screening and gene expression

b) Exploiting the genes for sucking pests e.g., No Bt proteins for sucking pests because there are no receptors in sucking pests for *Bt*. There is need to search for unique genes particular to sucking pests as it may be there elsewhere.

There are no case studies in science of bioinformatics on IPM so far, she added.

Dr. N. K. Krishna Kumar : Can bioinformatics be used to elucidate the role of primary, secondary and tertiary structures of proteins.

Dr. Ambika : Yes

Dr. R. Palaniappan, dwelt on the *Role of plant nutrition on the incidence of sucking pests*. He highlighted that while a great deal of attention has been focused on insecticides and insecticide resistance, Bt and plant genotype, one of the main reasons for the increasing insect pest infestation is because of imbalanced plant nutrition. Generally increased use of fertilizers and pesticides have accentuated and exacerbated pest problems. Monocultures in conjunction with imbalanced nutrition of major nutrients (N:

P: K) led to higher losses due to pests especially sucking pests such as aphids, thrips, mites and mirids.

Dr. Palaniappan attributed that the reason for sucking pests not being a menace on organically raised crops is probably because organic farming releases plant nutrients in a balanced way for a sustainable period. High soil organic matter enhances the level of soil macro and micro-biota which in turn contributes for better plant health. This has implications for management of sucking pests as nutritionally they need to concentrate more of proteins and less of sugar. Thus, a rapid surge in N status in the plant due to application of nitrogenous synthetic fertilizers could only result in increased infestation of sucking pests.

The major nutrients like N impart succulence, micronutrients like boron imparts insect tolerance and beneficial elements such as silicon contribute to resistance. Giving examples, he said that when KNO_3 is applied in polyhouse, soil turns more alkaline leading to more mite infestation. Aphids incidence is more when K:N ratio is low, whereas loopers show no reaction. Mirids usually increase with high amino acid content. If N is less *Leptopterna dolabrata* (Miridae) moves out of host to an alternate host. Particularly when N is given in ammonical form plants are unable to utilize and the pests will be more. Zinc deficiency leads to flea beetle damage in grapes and thin berries also attract more thrips damage. In banana, Ca deficiency is usually accompanied by thrips damage. Thrips, *Frankliniella occidentalis* population usually increases with more N and females will also be more.

Dr. Palaniappan stated that the uptake of many of the nutrients such as N, K, Ca etc., is not mutually exclusive of other essential macro or micronutrients. Soil fertility management has to take into account the relation between N:K, Ca: N, Ca:B and N:Si as these are the elements (Nitrogen, Potassium, Calcium, Boron and Silicon) which are involved in cell wall formation, carbohydrate metabolism, regulation of sugar movement, cell wall thickness and mechanical

barrier. Considering that the piercing and sucking insects need to puncture cell wall to gain access to the cell contents, this assumes greater significance. Further, physiology of digestion and assimilation in sucking insects is specialized with reference to carbohydrate and protein metabolism and any change induced in protein/carbohydrate metabolism in the plant will influence feeding and digestion in sucking pests.

Further, Dr. Palaniappan explained the futility of dealing with soil fertility without understanding water management. He said infact they are the two sides of the same coin. Water management decides the availability and uptake of nutrients in a passive way for potassium. He emphasized that in addition, the form in which N is made available too plays a significant role in N release and in turn leaf-nutrient status of many other nutrients. Application of more nitrate nitrogen fertilizers in polyhouse and fertigation systems with lopsided K application leads to excessive accumulation of NO_3^- . Increased N:K ratios, reducing K leads to K deficiency and predisposes to infestation of thrips on grapes, onion and capsicum. Changing the supply of N:K ratio from: 0.5 to 1:1 and 1.5 resulted in reduced glucose accumulation of dry matter in the above said crops paving the way for lesser incidence of thrips. In crops such as soybean and cotton, detection of more NO_3^- - N and soluble nitrogen was associated with aphids and mirids attack with an 'r' value of 0.75 to 0.82 respectively. In tomato, female thrips were found to cause more damage with increased N status in the leaves. In papaya, less of Ca, K and B led to more infestation of mites as well as powdery mildew. This is expected as Calcium is the structural component of cell wall; K is responsible for stem rigidity and water balance and B for cell wall formation by way of improving the calcium uptake and movement in the system.

Soil health includes physical, chemical and biological properties; it affects the water holding capacity which in turn has an impact on uptake of nutrients from fertilizers. Acid soils where calcium status was poor, a higher incidence of thrips is reported on grapes and mites infestation

on pomegranate. When oil cakes were applied as a source of N and K in a regulated manner during summer, nutrient imbalance was minimum in comparison to application of high nutrient content fertilizers. Similarly, form, dose and source of fertilizers influenced mites and thrips incidence significantly in polyhouse rose cultivation. Soil surface encrustation and bending of neck in onion, in Bangalore soils was observed conducive for increased infestation of thrips.

Dr. Palaniappan also highlighted the pH of the water used is critical in the efficacy of insecticide and fungicides. While a pH of 6.5 (acidic) was ideal, a higher pH in the alkaline range reduces the efficacy.

Dr. Venkatesh : What is the quantum of damage/change in pest infestation level due to imbalanced plant nutrition on the incidence of insects and pests?

Dr. Palaniappan : The damage may range from 20–25 per cent in general, while that of sucking insects 60 – 65 per cent.

Dr. Narayanan : How to calculate soil quality index?

Dr. Palaniappan : NBSS & LUP of ICAR do the land use classification based on physical, chemical and biological properties of soil and all are given equal importance.

Dr. P. N. Krishna Moorthy : Whether mite infestation on polyhouse raised rose is due to excess water as seen in the slide?

Dr. Palaniappan : Mite infestation was mainly due to dry weather. Many farmers use water spray to reduce the temperature inside the polyhouse. While this has not contributed to reduction in mite infestation, stagnation of water resulted in poor uptake of K during the summer months. Low K and high N is likely to have contributed to increased mite infestation.

Dr. Prakash : Since K has a decisive role, pesticide load on crops such as grapes can be drastically reduced by carrying out detailed studies with nutrition-rootstock-pest incidence.

Dr. Palaniappan : Yes, I agree.

Representatives from Dupont and Syngenta expressed interest to combine the nutritional factors along with pesticide application in order to get effective use of chemical.

Dr. Abraham Verghese in his presentation *Issues in population biology of aphids: a synergy between ecology and genetics* stressed the need to understand in depth genetic and ecological factors influencing migration of sucking pests. He said this is critical as sucking pests in general have high biotic potential and are vectors of plant pathogens. Migration and dispersal determine the spread and colonization of sucking pests as well as epidemiology of plant pathogens.

Aphids are capable of long flights even across oceans. Even a single individual can found a colony. Migration of aphids is far less documented in South Asia than Europe, America or Australia. The study, however, needs close association between ecologists and geneticists to establish relationship between genetic divergence and geographical distance; this gives the migrating range and the source of the migrants.

Another important aspect affecting migration is the formation of alates, which are, many a times, in response to stimuli like tactile (in crowding) and chemo (in alarm pheromones release due to say, predators). Alate forms migrate and ensure gene flow within sympatric population. When gene flow is restricted, one would expect allopatric differentiation.

Another aspect which does affect population fluctuation, but not to be implicated to the usual weather impact is the genotypic populations of aphids with varying quantum of insecticide resistant genes. Resistant population, for example, are maladapted to an 'organic' system, and therefore decline. Unless the aphid genetics is understood, population upheavels cannot be correctly interpreted.

So, in sucking insects like aphids, the synergy between ecology and genetics can throw open, hitherto unexplored areas of research, in an Indian context.

Dr. Narayanan : Does predation reduce population densities in the next generation, thus producing alarm pheromones which would enforce migration of one residual population?

Dr. Abraham Verghese : Biocontrol should include density-dependent studies. Components of migration and transgenerational resistance need to be incorporated into IPM. Extent of predators inducing migration of aphids needs to be clearly elucidated.

Dr. C.A. Viraktamath : Sex ratio across the population being different, sampling laboratory population and applying to population level may not be adequate.

Dr. Abraham Verghese : Certain genetic and behavioural studies need to be done at diverse population levels than looking at small samples. Further, segregation frequency in population needs to be studied.

Dr. Mohan : Can poor nutrition in plant stimulate alate formation?

Dr. Verghese : Any stress on the sucking insects will induce migration.

Dr. Narayanan talked about EPN for the management of sucking pests. He said *Heterorhabditis indica* can identify and infest sedentary insects, whereas *Steinernema* can identify and infest moving stages of insects.

Dr. Mallik presented status and future scenario of mite infestation and damage. In his presentation he opined that mites are becoming important mainly because of development of resistance to pesticides, new susceptible varieties, increasing dry spell, monocropping, intensive agriculture, lack/elimination of biocontrol agents. One recent example is mite infestation on tomato. He felt because of high resistance in *Tetranychus urticae*, management is now relied only with rotation using new molecules. In tomato glandular trichomes play a crucial role. There is an opportunity to exploit natural enemies, fungal pathogens (acaricidal fungi) and phytoseiid mites.

In the last few years mites are serious on grapes particularly *T. urticae* and *T. macferlanii*

in Hyderabad, Bangarpet, Kuppam, Kolar, V. kota during January-February just before harvest affecting the quality drastically. In Nasik, by March harvest is over whereas in Pune during January-February mite is problem. There is future for biological control agents particularly of predatory mites and now there is realization in farmers too. But the limitation is supply of quality material.

Dr. Venkatesh : Whitefly colonies were lost due to predatory mite in the laboratory. Identification of this mite will be useful.

Dr. B. Mallik : I will help in its identification.

Dr. B.V. Patil : Among phytoseiids *A. longispinosus* has received lot of attention, but no work to conserve this species.

Dr. Malik : Its ability to adopt to various situations is quite impressive. It is an obligatory predator and does well under polyhouse conditions but in open conditions often results are not good. Private firms should come forward to commercialize it.

Dr. N. K. Krishna Kumar : Is *T. urticae* on tomato a new biotype?

Dr. Mallik : Physiological studies are not available in mites.

Dr. R. Sundararaj in his presentation on *Whiteflies biotypes: Reason, identification and economic importance* of whiteflies stated that out of about 1556 species of world Aleyrodidae now known, 333 species occur in India under 50 genera, which constitute 21.40% of world aleyrodids. The species that cause much damage are the greenhouse whitefly *Trialeurodes vaporariorum* (Westwood), the sugarcane whitefly, *Neomaskellia bergii* (Signoret) and *Aleurolobus barodensis* (Maskell), the jasmine aleyrodids, *Dialeurodes kirkaldyi* (Kotinsky) and *Kanakarajiella vulgaris* (Singh), the cardamom whitefly, *Singhiella cardamomi* (David & Subramaniam) and *Aleuroclava cardamomi* (David & Subramaniam), the betelvine whitefly, *Singhiella pallida* (Singh) and *Aleurocanthus rugosa* Singh, the citrus whitefly, *Aleurocanthus woglumi* Ashby and *Dialeurodes citri*

(Ashmead), the cotton whitefly, *Bemisia tabaci* (Gennadius), the babul whitefly, *Acaudaleyrodes rachipora* (Singh) and the spiralling whitefly, *Aleurodicus dispersus* Russell.

Recently, Begomoviral disease (Geminiviridae); a group recognized as the most important emerging plant virus group in sub-tropical and tropical world regions (Brown, 2000), transmitted by whiteflies particularly by *B. tabaci* is posing great threat to crops in many parts of the World and also in India. Plants of about 20 families are affected by Begomovirus transmitted by *B. tabaci*. Further, the recognition of genetic complexity within *B. tabaci* when morphologically indistinguishable populations were reported to differ in host range, host plant adaptability and plant virus-transmission capabilities led to the development of the concept that it was composed of a series of biotypes. The biotypes of *B. tabaci* are indistinguishable based on morphology but molecular markers have recognized more than 20 biotypes. Six distinct populations are recognized of which two unresolved groups are from Asia. However, the resolution of many questions surrounding the biotype status and characterization of *B. tabaci* will probably rely on the development of appropriate biochemical and molecular markers. Among the biotypes B & Q are the two best known biotypes which together have proven to be extremely invasive. Hence *B. tabaci* is considered a quarantine species to international trade on a range of plant and plant product commodities. The development of insecticide resistance in whiteflies has long been recognized around the world. While preliminary observations do not prove that insecticide resistance was a driving force in the evolution of the B-biotype, they do suggest that host-plant preference, and the corresponding likelihood of insecticide exposure, may play a central role in the evolution of resistance. Molecular methods are now being applied to investigate the diversity of the whitefly genome and subsequent population's structure to better understand its global diversity. Likewise, we may now address similar evolutionary questions concerning whitefly transmitted geminiviruses.

We need to resolve the present dilemma, “Is *B. tabaci* really *B. tabaci* worldwide?”. It is the time to study the existence of similar biotypes in other economically important whiteflies such as *Aleurolobus barodensis*, *Aleurocanthus woglumi*, *Aleurodicus disperses*, *Singhiella cardamomi* etc., and to explore the interaction between biotype-vector potential-host –natural enemies relationship and interactions which may guide us to develop efficient management practices.

The classification of aleyrodids is based not on the structure of adults but on the structure of fourth larval instar, the so called “puparium”. It seems almost certain that puparia will continue to be dominant in whitefly systematics and there is no particular reason for larval characters to be regarded as second-rate. Some polyphagous whitefly species vary in their puparium depending on the host plant cuticle on which they develop, and this has caused a considerable amount of misidentification. Hence, deduction from host plant associations must always be approached with caution.

Dr. S. Suresh, Professor, Plant Protection Department, TNAU presented *Problems & Management of Mealybugs, Scales and Psyllids*. He explained with the help of a field guide identification of, *Phenacoccus solenopsis* Tinsley with two important diagnostic features; a) two prominent dark, dorso-submedial bare spots, b) 9-segmented antennae. He discussed the importance of *Phenacoccus maderensis* as a pest on marigold *Tagetes erecta* and other crops.

He stressed on the risk assessment of scarlet mealybug, *Pseudococcus calceolariae* introduction into India via importation of fresh apples from China and discussed its taxonomic position, life cycle, host plant range and difficulties in its management. He pointed out the difficulties to manage this particular pest as it has a high fecundity, wide host range, resistance to OP compounds, especially methyl parathion. The habitat inside deep cracks and crevices of trees, or inside fruit or fruit bunches where they are protected from contact with insecticides and lack of any natural enemies against this pest render

management difficult. Further, he emphasized that any import of commodities must undergo phytosanitary certificate and measures should be taken specially while importing apples from China.

He discussed the mealybug complex problem; Solenopsis mealybug, *P. solenopsis* Tinsley, *P. maderensis*, Two tailed mealybug, *Ferrisia virgata* Ckll, Malvastrum mealybug, *F. malvastra* (McDaniel), Pink mealybug, *Maconellicoccus hirsutus* (Green), Mango mealybug, *Rastrococcus iceryoides* (Green), which create a problem in proper identification. He discussed about the characteristic identification keys for the important pest species discussed above.

He mentioned about the vector potential of some important mealybug species like Banana bract mosaic (*Dysmicoccus neobrevipes*), banana streak (*Planococcus citri*), Grape leafroll (*Pseudococcus jackbeardsleyi*, *P. longispinus*, *P. viburni*, cacao swollen shoot (*Planococcoides njalensis*), and pineapple root wilt (*Dysmicoccus brevipes* & *D. neobrevipe*).

From a management perspective, he stressed the importance of molecular taxonomy and virus-vector relationships and role of fish oil rosin soap, dichlorvos, profenophos, imidacloprid/thiamethoxam and combination of methods.

Dr. Narayanan : Water based formulations are not working, but oil based formulations are working. However, Fish oil rosin soap causes phytotoxicity if temperature is high, so correct dose should be maintained.

Dr. S. Suresh : Yes, I agree.

Dr. N. K. Krishna Kumar : In late pruned grapes during March-April all of a sudden mealybug infestation is observed and the problem exists from early to midsummer. May be 30-40°C is suitable for mealybug and studies on summation of heat units to be initiated.

Dr Joshi presented *Biological control of aphids* and mentioned that sugarcane wooly aphid is a successful example of biocontrol. Different predator species have done well in different regions of Maharashtra, Karnataka and

Tamil Nadu. Usually predators like syrphids are effective under protected conditions. Conserving the existing natural enemies and promoting them will help in the long run. The reason for population flare-up of *A. gossypii* should be studied independently crop and systemwise.

Dr. N. K. Krishna Kumar : A holistic ecological approach will only give meaningful solution. There is a need to encourage coccinellids by studying the parasitism of coccinellids by *Tetrastychus coccinellae*. The sudden spurt in *A. gossypii* during Jan-April needs in-depth study.

Dr. A. Krishnamoorthy : Use of pathogens play a vital role than predators.

Dr. N. K. Krishna Kumar : Vector aphids should be studied more in-depth than others. After all there are only a few species such as melon aphids that are major vectors. Even in whitefly more in-depth studies are required on vectors than others. In polyphagous aphids formation of sequential host shifts are to be studied. Though they are polyphagous, they prefer to feed on a particular host at a particular time of the year. Generating baseline information on other less studied aphids is needed.

Dr. Jhansi Rani presented the importance of sucking pests and their management under protected conditions. Thrips, whiteflies, aphids and mites are present almost round the year. Management is becoming uneconomical and unsustainable due to various reasons. The problems such as increase in cost of protection, development of resistance, year-round pest incidence, climate change and safety to non-target organisms are the major ones. Giving specific examples she narrated the problems of management of sucking pests under protected cultivation.

In general the following pests were highlighted

- Serious sucking pest infestation on rose, carnation, gerbera, chrysanthemum, capsicum, tomato and melons raised in polyhouses.

- Increase in cost of protection under polyhouse cultivation due to frequent sprays, prolonged pest infestation and use of costly chemicals. e.g., Vertimec, Cascade, Spinosad etc.
- Management techniques adopted in polyhouse involve mostly the use of chemicals, of which majority are becoming ineffective against problematic pests. e.g., thrips on rose and whitefly on gerbera.
- Lack of specific, highly effective, safe and cost effective chemicals for control of the pests.
- Development of resistance to majority of the insecticides/ acaricides used due to short life cycle of pest, repeated use of the few chemicals. e.g., thrips and mites on rose and whitefly and leaf miner on gerbera
- Lack of suitable IPM strategies which include botanicals, bio-agents, sticky traps etc., for effective management of these pests.
- Non-availability of quality botanicals and bio-agents on commercial scale which are promising alternatives for chemicals.
- Non-availability of immune or highly resistant source among existing cultivated germplasm for developing resistant varieties.
- Present management techniques (mainly use of chemicals) are not safe to natural enemies.

Dr. Asokan in his lecture on *Role of molecular markers in identification of sucking pests* said mitochondrial cytochrome oxidase I (mtCOI) could be used as a potential marker across different species of sucking pests. He showed the utility of the above marker in the identification of thrips and fruit flies. Using mtCOI, it was possible to elucidate crop associated genetic differences among various populations of *Thrips palmi*. In the second part of the talk he talked about the potential of RNAi (gene silencing) in the management of insect pests of horticultural crops. Some of the potential targeted genes included plant allelochemical detoxifying genes, transcription factors etc.

Dr. N. K. Krishna Kumar : In which orders of insects utility of RNAi has been demonstrated?

Dr. R. Asokan : RNAi has been demonstrated in three orders of insects viz. Lepidoptera silencing of CYP6; in Coleoptera silencing actin, tubulin, V-ATPase subunit A and in Orthoptera silencing nymphal RNAs.

Dr. Abraham Verghese : Is it possible to use gene pyramiding approach for silencing various isoforms of resistance conferring genes?

Dr. R. Asokan : Before going in for gene pyramiding the utility of RNAi must be

demonstrated in silencing individual genes and later gene pyramiding technique could be employed.

Dr. N. K. Krishna Kumar thanked everyone for their valuable contribution in the success of this group meeting.

Dr. Abraham Verghese, Chief Editor, *Pest Management in Horticultural Ecosystem*, proposed a vote of thanks. He stressed the need to have more of such interactions on specific topics and assured that this journal would lend all support to publish the proceedings.

NATIONAL GROUP MEETING

APPLICATION OF BIOINFORMATICS FOR PEST AND DISEASE MANAGEMENT

Date : 7 November, 2008

Venue : **Indian Institute of Horticultural research
Hessaraghatta Lake Post, Bangalore 560 089**

The competition between man and insects for precious resources is as old as the history of agriculture itself. At the cellular level this can be explained as differences in Transcription and Translation, the basic dogma of life. Similarities and differences in transcription and translation among species as influenced by selection pressure, competition, environmental factors etc fuel the process of evolution. Hence, the success or failure of an organism to adopt and evolve depends largely on its genetic code. In this process many of the organisms threaten human, animal and plant health. Management of some of these problems can be more effective if we understand and apply the complex organization and functioning of genetic code across species. Advances in IT and BT technology has helped us decipher the genetic code and functioning of genes.

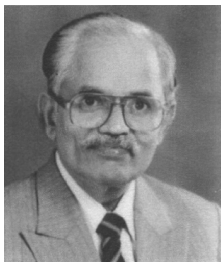
Recent advances in sequencing the human genome and a number of important, crop, insect/nematode and pathogens have given valuable insight into management of important pests and diseases. Small island of excellence are operating in medical, veterinary and plant sciences but a cohesive approach is lacking through everyone is aware there are more similarities than differences in genetic code across species. Further, an effective bridge between molecular biologists, software professionals and scientists is needed to harness the collective wisdom.

Bioinformatics is an optimized blend of interdisciplinary talents analyzing immense biological information computationally. Its productive output is adding different industries from agriculture to medicine in India and abroad, has immense economic potential. Bioinformatics is the use of mathematical statistical and computer methods to analyze biological, biochemical and biophysical data. It is the study of biological information as it passes from its storage site in the genome to the various gene products in the cell. It is often focused on obtaining biologically oriented data organizing this information into databases, developing methods to get useful information from such databases and devising methods to integrate related data from disparate sources.

The Association for Advancement of Horticultural Ecosystems (AAPMHE) would like to be that bridge in arranging a one day group meeting on Bioinformatics. Those who are interested to participate may contact Secretary, AAPMHE.

OBITUARY

Dr. S. Jayaraj



Dr. S. Jayaraj, former Vice Chancellor, Tamil Nadu Agricultural University, Coimbatore and Chairman, S. Jayaraj Research Foundation, Chennai, India reached heavenly abode on the 18th June, 2008. He was born on 22nd November,

1936 at Watrap, in Tamil Nadu, South India to Mrs. and Mr. Solaiappan. He is survived by his wife and two sons, Mr. Selvan and Dr. Diraviam, daughters-in-law and grandchildren.

Dr. Jayaraj pursued his studies in the Agricultural College & Research Institute, Coimbatore and obtained B.Sc. (Ag.) in 1958, M.Sc. (Ag.) in agricultural entomology in 1961 and Ph.D in 1964 from the University of Madras. During 1964-66 he was awarded a post-doctoral fellowship for advanced training and research at the Institute of Tropical Agriculture, Justus Liebig University, Giessen, Germany.

He started his career as Agricultural Extension Officer, Sivakasi during 1958-59 and then as Research Assistant, Paddy in Coimbatore in 1959. After his Ph.D he was a Pool Officer of CSIR at Coimbatore during 1966-68 and became Reader in Entomology in 1968. He was elevated to Professor & Head, Department of Entomology in which capacity he served in Madurai and Coimbatore till 1975. He held senior positions in Tamil Nadu Agricultural University (TNAU): Director of Extension Education (1975-78), Director of Research (1980-84), Registrar (1984-86), and Director, Centre for Plant Protection Studies (1986-1988). He was the Vice-Chancellor of TNAU during 1988-1993.

Post-retirement, he was DBT Professor (1993-94) and National Professor at the Agricultural Research Institute, Madurai and M.S. Swaminathan Research Foundation, Chennai (1994-2001) respectively. He founded the S. Jayaraj Research Foundation in Chennai in 2001 for sustainable farm and rural development. He has to his credit 12 books and 565 research papers. He has visited 23 countries and has guided 47 M.Sc./Ph.D. students.

Dr. Jayaraj was a Fellow of the National Academy of Agricultural Sciences, Plant Protection Association of India, Entomological Society of India, Insect Science Society and National Academy of Sericultural Science.

He was recipient of several awards: MASU Award, 1969; LR Award, 1972; HRF Award, 1974; ICAR Hari Om Ashram Award, 1980; TNAU Best Research Team Award, 1991; ICAR Best Research Team Award, 1996 etc. He has been the Principal Investigator of several schemes of ICAR, DBT, CSIR, Ford Foundation, FAO, Biotech Consortium of India, CAB, Central Silk Board, Coffee Board, etc.

He was Chairman, Scientific Panel in Entomology of Indian Council of Agricultural Research (ICAR) and QRT, Indian Lac Research Institute and member of ICAR education panel, governing body, accreditation committee, Member-Secretary of QRT of Indian Institute of Horticultural Research and Central Institute of Cotton Research, etc. He was also chairman of Task Force on Bio-pesticides, Sericulture and SC/ST R&D Projects, Review Committee on R&D in insect pheromones in national laboratories, etc. His significant contributions are on basic and applied research on biopesticides and IPM

modeling, host plant resistance to insects and mites, environmental protection, sustainable farming and biodiversity conservation besides teaching entomology.

The endurance with which Dr Jayaraj pursued entomology until he breathed his last is unparalleled and deserves to be emulated. His thoughts were ever enriched with entomology. His impetus for the different disciplines of entomology in particular and IPM in general were unrelenting. He was never tired of actions in these and would always look for targets and

achievements despite hurdles. Dr. Jayaraj had been a remarkable, and dynamic personality. Hard work, determination, sincerity and honesty were his hallmarks. His everlasting devotion and dedication to teaching and guiding of entomology attracted many to be true disciples of entomology. This devotion has left behind many entomologists and his contributions will remain immortal and keep testifying to his excellent deeds. In his passing away the country has lost an eminent entomologist and his contributions will ever remain immortal and inspire all.

Dr. B. Vasantharaj David
with inputs from Dr. V.V. Ramamurthy

Dr. S. Jayaraj

Condolences from AAPMHE

On behalf of the Association for *Advancement of Pest Management in Horticultural Ecosystems*, I convey our sincere condolences to the bereaved family of Dr. Jayaraj. As a mark of respect to the departed soul, members of the Association observed a two-minute silence on 2nd July, 2008 at the Division of Entomology, Indian Institute of Horticultural Research, Bangalore, and paid rich tributes to Dr. S. Jayaraj.

He was an entomologist with deep passion for insect management, a subject in which he excelled in knowledge and application. This passion was reflected in his talks, and his 'insecty' ideas were highly sought after by researchers in entomology. His lectures were often addressed to overflowing audiences, as entomologists yearned to listen to him.

Dr. Jayaraj was one man who identified too well several gaps in IPM and it seemed he was in a hurry to bridge them all. So, often we found him goading youngsters to get into such new areas. In one such pursuits of his, some members of

our Association found ourselves seated with him in a caucus on cerambycids. Rightly so, as we looked around, cerambycid borers were topically in limelight for all bad reasons. Cerambycid pestilence spurted, probably due to the diminishing forest trees and accompanying woodpeckers. But it was he who sensitised us to the current national importance of cerambycids. For a change, with him at the chair, familiar insects like *Helicoverpa* and *Spodoptera* and may be even *Bemisia*, all took a back seat. That was Dr. Jayaraj.

His love for the rural folks and their ways was exemplified adequately, when he integrated NPV technology into their low-cost insect control protocols via the humble 'earthen pot' method. This soon became a massive rural movement and continues to be so.

In the years to come, entomologists will miss his towering personality and IPM ideas, but I am sure, his entomologist son Dr. Diraviam, and several of his students will keep his passion aflame.

Dr. Abraham Verghese
Chief Editor, PMHE

BOOK REVIEW

THEORY AND PRACTICE OF ANIMAL TAXONOMY

By **V.C. Kapoor**, *Oxford & IBH Publishing Co.Pvt.Ltd. New Delhi.*

Since its first publication in 1983, this book by Dr. V.C. Kapoor has seen six editions, which obviously is a true reflection of its popularity. This is because of its high utility in teaching and research. Conversely, the book may have also elicited interest in animal taxonomy, which has been a field getting rarer by day thanks to the spurt in 'opportunities' in biotechnology; as students are making a bee line to anything under 'BT' at the cost of more basic life sciences like systematics. But, the last couple of years has seen a realization of the inevitable prerequisite of taxonomy in life sciences. So, a book of this nature with the latest re-edition is welcome. And, on the flip side, taxonomists have to peg on to biotechnology at molecular levels for identification of subspecies, biotype, strain, etc. This synergy however, has not evolved to the desirable level. The author therefore laments; sample the following:

"Taxonomy requires as much wisdom and intelligence as any other field of biology. But the progress in taxonomy is slow and steady and is without the brilliant discoveries which sometimes come quickly in other fields. Due to this it has never been an attractive profession. We are equally unfavorably placed in terms of scientific capabilities of identifying, working with and adding value to biodiversity resources. Every year more than 100,000 students get a bachelor's degree in one of the Life Sciences. But only a very small fraction of these get an exposure to

India's living wealth. Practically none of them are able to name more than 5 to 10 species of plants or animals put together.

This part of the 'Introduction' seemingly sounds dismal. But, Dr Kapoor, in the following eight chapters, addresses issues stirred by a passion to convert such gloomy tones to a challenge. And this, flows through the rest of the book.

The second chapter on 'Taxonomy and Biodiversity' is very readable. According to Dr. Kapoor, in the past 250 years, taxonomists have described 1.8 million species and this may go up to an estimated 40 million. The percentage of described species that belong to Arthropoda (read insects) is 75, and hence the review of this book in '*Pest Management in Horticultural Ecosystems*'. Biodiversity is a popular buzzword today, (only to be partially overshadowed by another buzzword 'Global Warming'). But, biodiversity cannot push beyond a point without the help of taxonomists. Realizing this the Global Taxonomic Initiatives (GRI) was created under the United Nations Convention of Biodiversity, to support the objectives of Convention of Biodiversity. Though a taxonomic book, Dr. Kapoor has added quite some information on biodiversity.

"Rise of taxonomy" is the third chapter, and is a kind of a forerunner to the essence of the book. This chapter starts off from Aristotle and

moves on to 18th century works of Linnaeus as a preamble. Then the chapter switches on to modern taxonomy dating from 1930's. Dr. Kapoor very ably convinces taxonomists the need to shift from tight compartmentability to multi-discipline approach.

This chapter, transits smoothly to the next (4), "Newer trends in Taxonomy" where embryological, ecological, behavioral, cytological, biochemical and numerical, approaches are explained well with photographs and figures. I am happy that the author ends this chapter with a para or two on differential systematics, a concept first proposed by Womble in 1951. It is a methodology for synthesizing multiple measurements, indices, and frequencies into a composite variable, the systematic function of which, for all loci, evaluates the average change with distance of a total reality. It will allow one to sum up the rates of change with distance (differential) of several characters to show zones of differentiation within a taxon.

The fifth chapter is in zoological classification, and is a review on aspects related to the common biosystematics, jargons including, the Linnaeus classification pattern. So the hierarchy from kingdom to subspecies is sequenced.

The sixth chapter on 'Concept of Species' from pages 70-89, is informative and is ideal for students preparing for competitive exams in life sciences. The chapter has a glossary like explanation on different terms associated with species.

Collection, Identification, Description and Publication is the seventh chapter. This runs from pages 90-149, and perhaps the longest. The book and the chapter are novice- directed. So, Dr. Kapoor takes pain to describe how a neophyte

should go about animal collection, and interestingly the examples and methods are insect based. This is understandable for two reasons; One, animal kingdom is dominated by insects and two, Dr. Kapoor is a renowned insect taxonomist himself. Further, I may add, that insect taxonomy deserves priority attention as there are huge number of insects yet to be identified, and new introductions (invasive species) are becoming a threat worldover, and Indian subcontinent, is not an exception.

The chapter eight deals with 'Reference works in Taxonomy.' This is a general article, ideal for undergraduate students, especially aspects for example related to "International Commission on Zoological Nomenclature". Dr. Kapoor has given examples of several books. However, the useful aspect here is a list of abbreviations of words in Latin used in taxonomy.

The last chapter is on 'Zoological Nomenclature'. As scientific naming is of crucial value, proper tracks have to be followed to name an organism. Kapoor has outlined the rules related to nomenclature. Herein we find taxonomic jargons like synonyms, homonyms, paronyms, cotype, paratype, homotype, homoeotype, primary type, secondary type, isotype, lectotype, etc. which are explained.

This chapter is followed by relevant references very useful to students, teachers and researchers and a long glossary running into almost 20 pages. This is quite useful especially to beginners. I have no hesitations in recommending this book to all graduate colleges in life sciences. I wish the publisher had mentioned the price of the book; by all estimates it can't be more than a few hundreds.

Dr. Abraham Verghese