

**STUDIES ON BIOLOGY, ECOLOGY AND MANAGEMENT  
OF INSECT PESTS OF SOYBEAN [*Glycine max* (L.) Merrill]**

THESIS SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS FOR THE AWARD  
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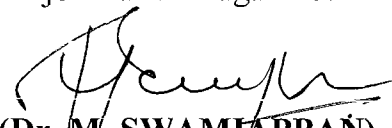
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## CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON BIOLOGY, ECOLOGY AND MANAGEMENT OF INSECT PESTS OF SOYBEAN [*Glycine max* (L) Merrill]**” submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a record of **BONAFIDE** research work carried out by **Mr. J. L. HARRY JEYAPRAKASH** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazines.

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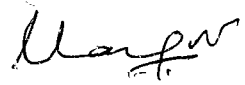
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## ABSTRACT

### STUDIES ON BIOLOGY, ECOLOGY AND MANAGEMENT OF INSECT PESTS OF SOYBEAN (*Glycine max* (L.) Merrill)

BY

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Field experiments were conducted in and around Coimbatore district to assess the seasonal occurrence of insect pests of soybean crop revealed that sucking pests like leafhopper, *Empoasca fabae* (Harris), whitefly, *Bemisia tabaci* (Gennadius), aphids, *Aphis craccivora* (Koch) and leafminer, *Aproaerema modicella* (Deventer) were prevalent in February, July and September seasons. The peak incidence of the above pests were noticed at 27 to 55 DAS, 48 to 75 DAS, 48 to 62 DAS and 41 to 62 DAS, respectively. Defoliators of soybean viz., the American bollworm, *Helicoverpa armigera* (Hubner) and the tobacco cutworm, *Spodoptera litura* (Fabricius) were noticed during July and September seasons and February and September seasons, with the peak incidence at 34 to 62 DAS and 41 to 48, DAS respectively. The pod sucking bug, *Nezara viridula* (Linn.) was prevalent during pod formation stage in all the three seasons. Monitoring of *H. armigera* and *S. litura* moths through sex-pheromone traps showed a significant positive correlation between the male moths collected in the traps and the larval population in the field.

Multiple regression analysis on the influence of weather parameters on the pest and natural enemies revealed the negative influence of minimum temperature, Growing Degree Day (GDD) and Photo Thermal Unit (PTU) on pests like leafhopper, whiteflies, *H. armigera* and coccinellid and spider predatory populations. Rainfall showed a positive effect over the whitefly and predator populations viz., *Menochilus sexmaculatus* (Linn.) and spiders, whereas maximum, minimum temperature and PTU had significant negative influence on leafminer population. Leaf temperature prevalent on 27, 37 and 47 DAS had significant correlation with leafhopper and whitefly populations, whereas the leaf temperature at 47 DAS had the same effect on leafminer population. The leaf humidity at 37 DAS, and at 37 and 47 DAS, had significant correlation with leafhopper, whitefly and leafminer populations, respectively.

Under cultural method of control, closer spacing (30 x 10 cm) recorded less number of *H. armigera* and maximum number of predatory population of coccinellid and spiders and high percentage of grain damage by *N. viridula*. Wider spacing (45 x 10 cm) recorded less number of leafhopper, whitefly, *S. litura*, leafminer, *N. viridula* populations and higher yield. Application of 80 kg P<sub>2</sub>O<sub>5</sub> as top dressing in two or three splits at 30 and 40 or 30, 40 and 50 DAS reduced significantly the population of leafhopper and whitefly but increased the incidence of *H. armigera*, *S. litura* and *N. viridula*. Higher level of P<sub>2</sub>O<sub>5</sub> application enhanced the predatory and pod sucking bug population, oil content and ultimately higher yield of the crop.

Intercropping soybean with 2 or 4 rows of maize, 2 or 4 rows of bhendi and 2 or 4 rows of sorghum reduced the populations of leafhopper, whitefly, leafminer, *S. litura* and *H. armigera* populations. Predatory population of coccinellid and spiders were maximum in soybean intercropped with 2 or 4 rows sorghum, 4 rows of maize as well as in the pure crop of soybean 2 or 4 rows of sorghum and 4 rows of maize intercropping recorded higher seed yield.

Application of endosulfan 0.07 per cent, monocrotophos 0.05 per cent, methyl-o-demeton 0.05 per cent, phosphamidon 0.04 per cent and dimethoate 0.03 per cent were highly effective against *H. armigera*, *S. litura*, leafhopper, whitefly and aphid populations, respectively. Higher cost benefit ratios were observed by using monocrotophos 0.05 per cent and endosulfan 0.07 per cent treatments to manage key pests of soybean.

Application of *Bacillus thuringiensis* var. *kurstaki* Berliner. @ 1.0 kg/ha, HaNPV (*Helicoverpa armigera* Nuclear Polyhedrosis Virus), SINPV (*Spodoptera litura* Nuclear Polyhedrosis Virus) @ 250 LE/ha and endosulfan 0.07 per cent were found to be effective in managing these key pests viz., *H. armigera* and *S. litura*. Larval populations of *H. armigera* and *S. litura* were significantly reduced by the application of HaNPV + endosulfan 0.07 per cent and *B.t.* var. *kurstaki* @ 1 kg/ha + endosulfan 0.07 per cent, respectively.

The damage caused by *H. armigera* was higher and the yield loss was 240.0 to 343.33 kg per hectare with an avoidable loss of 16.07 and 24.12 per cent during July and September sown crops, respectively. Leafminer could cause a yield loss of 276.67 to 303.14 kg per hectare in all the three seasons, whereas leafhopper effected an yield loss of 190.00 to 293.33 kg per hectare. The rate of yield loss was estimated as 1.270 g/plant due to 10 leafminer larvae by using Mitcherlich's curve. According to logistic curve method, the rate of yield loss was estimated as 0.1006 g/plant at the maximum of 50 per cent leaf damage caused by leafminer, *A. modicella*.

EIL was fixed as 2.50 to 2.70 number per ten plants for *H. armigera*, 1.24 to 2.68 number per plant for leafminer and 0.51 to 0.66 number per plant for leafhopper populations.

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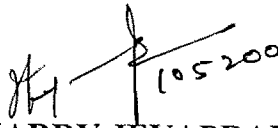
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# INTRODUCTION

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## INTRODUCTION

The soybean *Glycine max* (L.) Merrill. emerged as a domestic crop around the eleventh century BC in China (Hymowitz, 1970). World soybean production during 1997-98 was recorded upto 152.2 million tonnes and it was 16 per cent increase from 1996-97. Higher level of global demand led to favourable prices and increased soybean acreage and production in many countries (Provance, 1998). It was estimated that the marketable product in 2002 would be about 191 million tonnes. It's protein (43.2%) has a high biological value similar to that of meat, fish and egg. In India, the area under soybean was 4.00 million hectare with an annual production of 36.7 million tonnes and with productivity of 918 kg/ha in the year (Kant *et al.*, 1997). In TamilNadu during 1996-97, the area under soybean cultivation was 0.15 lakh hectares and a production of 0.13 lakh metric tonnes with a productivity of 860 kg/ha was recorded (Anon., 1996).

Irrespective of different geographical production centres, soybean inhabited by a diverse community of arthropods, although the pest pressure differs in form and intensity among the various geographical regions. Kogan and Turnipseed (1987) compiled a list of the principal arthropod pests across major agroecological regions and their relative impact to the global soybean production. More than 200 insect species are known to be associated with the crop right from germination to harvesting.

It was identified that one of the major constraints of low productivity of soybean in India, has been the insect pest complex associated with this crop. Based on an impact index developed by Kogan and Turnipseed (1987), the most significant losses to soybean are due to pest attack either to leaf tissue or to the pods.

Kundu and Srivastava (1992) have detailed different practices like cultural, physical, mechanical, chemical and biological methods in pest management of soybean. Different effects of cultural methods like date of sowing, spacing, fertilizer application and cropping system in soybean have been studied and recorded for major soybean growing area.

Similarly, at various geographic regions, the biology of insect pests of soybean has been studied and management with insecticides has been evaluated. Use of bio-control agents like parasitoids, predators, spraying of microbial organisms viz., *Bacillus thuringiensis* and nuclear polyhedrosis viruses were tried and found to be effective in reducing the pests of soybean. In certain cases, the bio-control agents as well as cultural practices were combined with insecticides to effectively manage the soybean pests.

Hutchins and Funderburk (1996) emphasised the development of decision making algorithms for insect pests with reference to soybean leaf and pod feeding insects, by the usage injury guilds as practical approach in soybean pest management. The yield loss due to these insect pests is also measurable and can be estimated through different mathematical models.

The present study was taken up to elicit information on the following objectives:

- I. To study the seasonal incidence of arthropod pests of soybean in its different growth stages.
- II. To investigate the influence of weather parameters on the incidence of insect pests of soybean.
- III. To study the changes in pest status due to cultural practices.
- IV. To formulate a balanced approach in IPM system for soybean crop.
- V. To assess the crop loss due to key pests and to study the economics of pest control with reference to economic injury and economic threshold levels.

# **REVIEW OF LITERATURE**

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## 2. REVIEW OF LITERATURE

### 2.1. SEASONAL OCCURRENCE OF INSECT PESTS OF SOYBEAN

Emphasis on increasing soybean production in India, has focused interest on insects which may cause economic damages. Seasonal populations of potential pest species of soybean must be determined before developing any effective management systems. The seasonal occurrence of insect pests of soybean crop has been reviewed here under.

#### 2.1.1. SUCKING PESTS

Talekar and Chen (1983) studied the seasonal distribution of several insect pests of soybean and mungbean in Taiwan and found that *Aphis glycine* Matsumura was the major pest during cooler months (October–March) of the year. The incidence of *B. tabaci* fluctuated throughout the year with peaks in March–April and September–October (Roychoudry and Jain, 1993). Yeargan *et al.* (1994) found in Essex soybean during 1988-89 that early season moisture stress may exacerbate the *Empoasca* sp. on soybean yield. In soybean crop, *A. glycine* and *A. craccivora* caused 75% and 40% infestation, respectively during April-June and June-August, 1985. (Quimio and Calilung, 1994).

Singh and Singh (1995) recorded that unusual incidence of *A. craccivora* during middle of December to last week of January, 1989 on soybean. In Georgia the abundance of two whiteflies viz., *Bemisia argentifolii* Bellows and Perring and *Trialeurodes abutiloneus* (Haldeman.) were noticed during early September 1993 and late September 1994 (McPherson and Lambert, 1995). The population build up of *A. glycine* was recorded at > 10000 aphids/100 plants during June, 1995 (Wang *et al.*, 1996). Lambert *et al.* (1997) found that the whitefly populations (*B. argentifolii* and *T. abutilonea*) were low in June and rose steadily to reach the peak in mid to late September. Chaturvedi *et al.* (1998)

reported the outbreak of aphids on soybean in the third and fourth weeks of August, 1995 but the population of the pest decreased in the second week of October.

The green stink bug *Nezara viridula* (Linn.) is highly polyphagous, attacking both monocots and dicots. At least 40 species of stink bugs were found to occur world wide on soybean. *N. viridula* was reported in India by Singh (1973) and Gangrade (1974). Thomas *et al.* (1974) studied the effect of green stink bug *N. viridula* on yield and quality of soybean. Soybean was attracted to pod bugs in late July and August after its migration from vegetable and leguminous crops during April to June primarily at flowering and pod set stages although a few individuals could be seen in the crop through out the year (Todd and Herzog 1980).

## 2.1.2.DEFOLIATORS

### 2.1.2.1: Leafminer (*Aproaerema modicella* (Deventer) )

Soybean leafminer (*A. modicella*) was found to be a regular pest in Jabalpur, Madhya Pradesh during June to October and November to April. (Gujarati *et al.*, 1973). Kothai (1974) reported severe outbreak of the leafminer in the months of September on soybean. Kapoor *et al.* (1975) reported an epidemic form of leafminer during September in Madhya Pradesh. Arunin (1978) reported that the leafminer was noticed throughout the year both in groundnut and soybean. Khan and Raodeo (1978) recorded that its infestation started during 1<sup>st</sup> week of August and reached maximum in September. Logiswaran and Madhava Rao (1982) found that the leafminer was more abundant with five brood emergences during the rainfed season than in irrigated season.

In India, the leafminer is often a problem towards the end of the rainy season (September – October) especially in drought or low rainfall years (Amin, 1983) and in Thailand leafminer population reached the peak in July and August (Campbell, 1983). In Bangladesh, leafminer occurred in severe form at the end

of post rainy season viz., March and April (Islam *et al.*, 1983). In Maharashtra, the groundnut leafminer (*A. modicella*) was active from early June until end of December (Khan and Raodeo, 1987). Soybean leafminer is a serious pest during kharif season in Madhya Pradesh (Singh and Singh, 1985). Jena and Kuila (1997) found that soybean leafminer's activity commenced at 35 DAS and peak infestation during 65 DAS.

#### **2.1.2.2. *Heliothis armigera* (Hubner) and *Spodoptera litura* (Fabricius)**

In United States, the corn earworm, *Heliothis zea* Boddie caused a greater impact on soybean production. *Heliothis* sp. on soybean caused damage on leaves, blooms and growing tips of the plant and to pods severely (Kogen and Turnipseed 1979). Carner *et al.* (1974) reported the occurrence of *H. armigera* in late August and early September and during blooming in early August on the coastal plains of North and South Carolina. Sprenkel *et al.* (1979) observed higher *Heliothis* population, in June than in July planting. Highest *H. zea* population on soybean was observed during blooming stage especially on Dare and Bragg Varieties in May Planting (Buschman *et al.* 1981). Herbert *et al.* (1991) reported that the peak activity of moths of *Heliothis* sp. occurred from 15-24 August and first week of September in soybean crop.

In a pheromone trap study, peak activity of *S. litura* moths was noticed last week of June, last week of August and during first week of October, 1989 (Misra and Sontakke 1992). Sushil Kumar and Patel (1995) in a monitoring studies using sex pheromone trap found that the maximum activity of *S. litura* was noticed during 40<sup>th</sup> standard week. The peak activity of *H. armigera* was noticed during February and March in soybean crop. (Dubey *et al.*, 1993).

## 2.2.MONITORING OF LEPIDOPTERN PESTS OF SOYBEAN THROUGH SEX PHEROMONE

Nyambo (1989) and Prasad (1996) used sex pheromone traps to monitor and assess the population of *H.armigera*. Sinha and Jain (1992) monitored seasonal abundance of *H.armigera* using pheromone traps and correlated the moth catches with weather parameters.

Using sex pheromone traps, the population peaks of *S.litura* was studied and correlated with weather parameters by Mishra and Sontakke (1992). Weightman *et al.* (1994) found that pheromone septum placed above a water trap set at 0.5m above the ground level was the most effective and the study indicated a good relationship between male flight activity followed by egg and larval populations.

Sushil Kumar and Patel (1995) used the sex pheromone traps of *S.litura* and related the population peaks with weather parameters. In a preliminary evaluation of traps for leaf miner *A.modicella*, Nandagopal (1995) recorded high trapping of male moths in square glue trap (110 males/trap/night).

## 2.3.INFLUENCE OF WEATHER FACTORS ON THE INCIDENCE OF INSECT PESTS OF SOYBEAN

### 2.3.1. SUCKING PESTS

The aphid species recorded on soybean in Asia and Africa are: *A. craccivora*(Koch.), *A. glycine* and *Aulacorthum solani*, Kalten Bach (Irwin 1980). Bhattacharjee (1990) recorded high population of whitefly (*B.tabaci*) during Kharif when both temperature and humidity were high. Roychoudhary and Jain (1993) observed a positive correlation with mean temperature and negative correlation with mean relative humidity.

Board and Puri(1994) found the adult emergence of *B.tabaci* on cotton, brinjal and soybean at 06.00 h with peak emergence between 8.00 and 10.00 hrs and no adults emerged between 14.00 and 18.00 hrs. Chaturvedi *et al.* (1998) reported adverse effect of rainfall on aphid population during September in Madhya Pradesh.

#### **2.3.1.1. POD STINK BUGS**

The abundance of stink bugs in soybean was determined by the climatic factors (Kirtini, 1964). Stam *et al.* (1987) reported the temperature to be an important limiting factor for the over wintering adult of *N.viridula*.

#### **2.3.2. DEFOLIATORS**

Gujarati *et al.* (1973) reported that high temperature accompanied by rainfall and dry weather following continuous rain, had direct effect on the outbreak of leafminer of soybean crop in Madhya pradesh. Lewin *et al.* (1979) observed a positive correlation of the mean temperature and a negative correlation of rainfall with the incidence of groundnut leafminer. Amin (1983) suggested that heavy rainfall reduced the leafminer populations. In a light trap study, the maximum and minimum temperature and wind speed were negatively correlated and a positive correlation was noticed between total rainfall and morning and evening relative humidity with the adults of leafminer *A.modicella*. (Logiswaran and Mohanasundaram 1987). Khan and Raodeo (1987) observed high leaf miner population in August – September during rainy season and the population declined in March. Ghile *et al.* (1989) recorded that heavy precipitation followed by break in monsoon and increase in sunshine hour was found to favour multiplication of leafminer (*A.modicella*) population.

Baskaran and Mahadevan (1994) in the field studies between 1987-89 found that the population of leafminer (*A.modicella*) was negatively correlated

with maximum and minimum temperatures and sunshine hours and positively correlated with relative humidity and rainfall. Dubey and Ballal (1995) found that the high maximum and minimum temperature and low humidity followed by continuous rain for about 3 weeks followed by a monsoon break conditions favoured the outbreak of leafminer (*A.modicella*). Muthiah (1995) reported that minimum temperature alone exerted a negative influence whereas maximum temperature exhibited a positive influence on the incidence of leafminer. Bagmore *et al.* (1995) found in a correlation analysis, a positive correlation of the mean temperature, sunshine hours with the population of *A.modicella* of soybean crop.

Verma *et al.* (1982) found that the temperature, relative humidity and rainfall had any significant effects on the flight activity of moths of gram pod borer, *H.armigera*. Devi *et al.* (1991) reported *H.armigera* activities during vegetative / flowering and late rabi crop growth stages and influenced by maximum temperature ranging from 25.9 to 27.5°C. Maximum and minimum temperatures were found to be positively correlated and negatively correlated with rainfall between the population of *Nacoleia* sp. on soybean respectively (Gangwar and Thakur, 1991). Venkataiah and Subbaratnam (1992) found pheromone trap catches of male noctuids *H.armigera* had a significant positive correlation with maximum and minimum temperatures and negative correlation with morning and evening relative humidities. An analysis of weather factors showed that rainfall was one of the key factors influencing the population level of *H.armigera* and minimum temperature and relative humidity had positive significant correlation. (Rao *et al.*, 1993).

In West Bengal, during 1986-1988, a significant positive relationship was obtained between pheromone trap catches of *S.litura* and maximum temperature (Senapati *et al.*, 1990). In a monitoring study, there was a correlation between meteorological variables and pheromone trap catches of *S.litura* and revealed that

only the relative humidity significantly influenced the trap catches (Misra and Sontakke, 1992). Sushil Kumar and Patel (1995) found peak *S.litura* population when the temperatures (minimum and average) and relative humidity were considerably higher.

### **2.3.3. EFFECT OF MICROCLIMATE ON SOYBEAN PEST COMPLEX**

#### **2.3.3.1. ON LEAF TEMPERATURE**

Anconeilli and Mannini (1993) used infrared thermometer in crop water stress index (CWSI) studies while scheduling irrigation in soybean crop. The leaf temperature of non irrigated soybean was slightly higher than ambient temperature (Wang *et al.*, 1993). Gao *et al.* (1994) found that increase in vapour pressure and leaf temperature at 1500h had a greater effect on photosynthesis than similar increase at 1300 h in soybean. The injury caused to the soybean stems and unifoliate buds by stainless steel needles resulted in an increase in leaf temperature for 2 days consecutively and recorded that soybean plant might have meridian system similar to that which existed in animals.

Gangwar *et al.* (1994) recorded comparatively low incidences of insects pests in intercrops involving rice, soybean, maize, etc., compared with monocrop of soybean and recorded that the effect was due to microclimate changes as a result of intercropping. Wang *et al.* (1994) used an infrared thermometer to investigate the effects of soil water content, percentage of canopy cover and individual leaf, leaf canopy emissivities of soybean, maize, potato and wheat crop.

## 2.4. EFFECT OF SPACING AND FERTILISER ON INSECT PESTS OF SOYBEAN

### 2.4.1. EFFECT OF SPACING

Webber *et al.* (1966) recorded the maximum soybean seed yield at lower population and narrower row spacing i.e., at 10-inch rows with 1,04,544 plants per acre. High density (32 plants/m<sup>2</sup>) planting of soybeans resulted in small plants but high dry weights per unit area of ground (Buttery, 1969). Eriyi (1973) reported that in soybeans, the total dry matter per plant, pod weight, number of pods per plant and grain weight were increased with an increase in plant density.

Buschman *et al.* (1981) found that population of the *Heliothis* larvae were about equal in narrow and wide row planting. Significantly lesser incidence of groundnut leafminer (*A.modicella*) was reported in closer spacing viz., 20 X 10 cm and 15 X 10 cm than normal spacing of 30 X 10 cm. (Logiswaran and Mohanasundaram, 1985). Sathish Kumar and Bhattacharya (1989) found more infestation of *Melanagromyza sojae* (Zehntner) at 30 DAS, in 30 and 45 cm row to row distance when compared to 60 and 75 cm in soybean crop, and also the population of *B.tabaci* was higher in 30 cm row and lower incidences in 45 and 75 cm spacing.

Aganon (1989) found that higher plant density created a humid and shaded microenvironment which favoured soybean pests (*Empoasca* sp., *S.litura*, and pod borer (*Etiella zinckanella* Treitschke). Lam and Pedigo (1998) found that no significant differences were detected between population densities of leafhoppers and bean leaf beetles from narrow versus wide row spacing in soybean. Anderson and Yeargan (1998) reported that planting soybean early and in narrow rows (0.46 m) was the most effective cultural method for preventing outbreaks of *H.zea* in soybean.

#### 2.4.2. EFFECT OF FERTILIZER

Narasimalu (1985) found that the applications of micro nutrients *viz.*,  $\text{ZnSO}_4$  and  $\text{MnSO}_4$  reduced the leafminer incidence significantly in soybean. Funderburk *et al.* (1994) found that high phosphorus fertilizer application had significantly increased the population of predators *viz.*, *Nabis* sp., *Hoplistoscelis* sp. *Geocoris* sp. and spiders. Devasthali and Viswakarma (1995) reported that the application of NPK fertilizers led to significant increase in the insect pests population in soybean in Madhya pradesh. Arora *et al.* (1997) compared the different levels of fertilizers and host crops and their effect on insects and suggested to optimise the dose of nitrogenous fertilizers and encourage the use of potassic fertilizer to keep the pest below economic threshold levels. Busch and Phelan (1999) studied the mixture models of soybean growth and herbivore performance in response to nitrogen, sulphur, phosphorous nutrient interactions.

#### 2.5. EFFECT OF INTERCROPPING ON PESTS OF SOYBEAN

Radke and Burrows (1970) reported that soybean temporarily sheltered by corn wind breaks did not perform well in all aspects of yield components due to shade effect. Satish Kumar and Bhattacharya (1986) observed that intercropping system based on the companion cropping pattern might be helpful in ecological manoeuvring, resulting in an escape or less infestation by insects. They found that defoliation was mainly caused by *S.litura* and per cent damage at 30 DAS was more on soybean than intercrop of blackgram but no damage was noticed in soybean intercropped with maize.

Studies on intercropping of soybean varieties revealed that intercropped soybean recorded significantly higher larval population of *Chrysodeixis* sp. than in pure crop of soybean but the whitefly (*B.tabaci*) population was found to be more in pure crop than in intercrop of soybean (Singh *et al.*, 1990). Kempraj (1992)

reported that the leafminer larvae per plant in soybean intercropped with other crops varied from 0.32 (soybean + cumbu) to 1.15 (soybean + groundnut). Significantly less number of leafminer (*A.modicella*) larvae per metre row and less percentage of leaflet damage and more percentage of parasitism by *Goniozus* sp. were recorded in groundnut and cumbu intercropping system 4 : 1 ratio and also the increased net return was obtained when compared to pure crop of groundnut (Murali Bhaskaran *et al.*, 1993). Rathore and Shanker Lal (1994) reviewed in detail about different cultural practices including intercropping of different crops and incidences of insect pests.

Muthiah (1995) observed that the number of leafminer larvae per ten plants varied from 8.17 (groundnut + pearl millet) to 21.67 (groundnut + soybean). Abundance of soybean green cloverworm, *Plathypena scabra* (F) did not differ significantly among 10 rows of soybean with 2 rows of sorghum and 6 rows of soybean with 6 rows of sorghum (Williams *et al.*, 1995).

Duffield and Reddy (1997) studied the distribution and movement of predators of *H.armigera* in intercropped sorghum and short duration pigeonpea. Mehetre *et al.* (1997) reviewed different literature and documented the different intercropping system and their effect of growth, economics and incidence of insect pests of soybean crop.

## **2.6. EFFECT OF INSECTICIDES ON THE INSECT PESTS OF SOYBEAN**

Number of workers have studied the effects of insecticides on soybean pest complex. Choudhary *et al.* (1981) found that aldicarb 10 per cent was the most effective against *B.tabaci* on soybean. Application of methoate at 20 g a.i/0.67 ha and fenvalerate 3 g ai/0.067 at seedling stage and diflubenzuron at 20 g ai/0.067 ha at flowering and at pod formation stages effectively controlled the *A.glycines* on soybean without harming to their natural enemies (Qu *et al.*, 1989).

Bhattacharjee (1990) reported that basal application of phorate 1.5 kg a.i. per ha at the time of sowing followed by three sprayings with endosulfan 0.07 per cent found to be effective in reducing the whitefly population in soybean. Spraying with monocrotophos 0.05 per cent at 31 and 51 DAS recorded higher yield of 3.3 kg/plot. (Latha *et al.*, 1993).

Venkatesan and Kundu (1994) found that endosulfan 0.07 per cent treated plots recorded higher yield and highest cost: benefit ratio (1:6.16) by controlling soybean stemfly and whitefly populations. Hussain *et al.* (1994) found that cypermethrin and fenvalerate were effective against *B.tabaci* on soybean. Singh and Singh (1994) found that three sprayings at 40, 55 and 70 DAS significantly reduced *A. maculosa* population on soybean in Madhyapradesh. Madhuban Gopal *et al.* (1997) found that seed treatment with imidacloprid followed by spraying of monocrotophos effectively controlled the whiteflies (*B.tabaci*) on soybean.

#### 2.6.1.1. ON POD SUCKING BUGS

Corseuil and Mayer (1979) reported that monocrotophos at 4 kg a.i./ha showed significant systemic activity against stink bug on soybean. Komori *et al.* (1995) found that fenthion, fenitrothion and phenthoate were effective against *N.viridula* on soybean. Soybean seed quality was found to be higher in the plots treated with pyrethroids including Lynda-cyhalothrin, cyfluthrin and cypermethrin by controlling pod bugs (McPherson *et al.*, 1995).

#### 2.6.2. ON DEFOLIATORS

Organophosphates with systemic had strong contact action and were quite effective against *A.modicella*.

Ghule *et al.* (1987) reported that application of carbaryl, HCH mixture effectively reduced the leafminer (*A.modicella*) population by 88.84 per cent.

Cypermethrin (0.01%) and deltamethrin (0.005%) with carbaryl (0.15%) were effective against leafminer, *A.modicella* (Misra *et al.*, 1995).

Neem based applications of endosulfan and neem seed kernal extract controlled *A.modicella* on soybean. (Gopal *et al.*, 1992). Umesh and Naik (1996) found that endosulfan 35 EC at 525 g a.i./ha was the most effective chemical in soybean crop ecosystem and also higher yield was obtained (1810 kg/ha).

## **2.7. ROLE OF BIOLOGICAL CONTROL ON THE INSECT PESTS OF SOYBEAN**

### **2.7.1. NUCLEAR POLYHEDROSIS VIRUS**

The occurrence of nuclear polyhedrosis virus on *H.armigera* was first reported by Patel *et al.* (1968) in Gujarat and Jacob and Subramanian (1972) recorded the NPV of *Heliothis* in Tamilnadu. Field application of granulosis virus was effective in reducing the populations of *Plathypena scabra* on soybean in Iowa, (Beegle *et al.*, 1973) Ignoffo *et al.* (1974) have studied the stability of *B.t* and *Heliothis* NPV on soybean foliage. Flusche *et al.* (1986) reported that NPV spray should be applied against 1<sup>st</sup> and 2<sup>nd</sup> instar larvae of *H.zea* in soybean.

### **2.7.2. PARASITIDS AND PREDATORS**

#### **2.7.2.1. ON SUCKING PESTS**

The potato leaf hopper *E.fabae* is a potential pest of soybean. Subba Rao *et al.* (1965) studied the beneficial parasites and predators viz., *Areson* sp., *Anagrus* sp., *Oligosita* sp., *Geocoris atricolour* (Montanson) and *G.jacundaus* lygaeid predators. Predators were more abundant in soybean ecosystem in the presence of leaf and stem sucking pests especially on *E.fabae* (Rodenhouse *et al.*, 1992). Chang *et al.* (1994) recorded *Aphidius cingulatus*, *Ephedrus persicae* and *E.plagiator* from soybean aphids *Aphis glycines*. McAuslane *et al.* (1995)

recorded the abundance of parasites like *Encarsia* sp. and *Eretmocerus* nr *Californicus* in whitefly of soybean. Berg *et al.* (1997) observed higher growth of coccinellid and of staphylinid predation in soybean aphids (*A.glycine*) on 21<sup>st</sup> day old plant and declined linearly with plant age.

### 2.7.2.3. ON DEFOLIATORS

Extensive field surveys on indigenous natural enemies complex of *H.armigera* were conducted mostly in South India during 1960 at the Indian Station of Commonwealth Institute of Biological Control (CIBC), Bangalore. A comprehensive list of 37 species of parasites associated with *Heliothis* sp. had been published (Achan *et al.*, 1968). Srinivasan and Siva Rao (1986) reported braconids, *Chelonus blackburni* Cameron, *Apanteles* sp., and *Microbracon* sp. and the Eulophid, *Tetrastichus* sp. and *Eurytoma* sp. on the leafminer *A.modicella*. Shekarappa *et al.* (1990) reported *Apanteles* sp. *Goniozus* sp., *Tetrastichus* sp. as important larval parasites of *A.modicella*.

McCutcheon and Turnipseed (1989) recorded the influence of cultural practices like sowing date of soybean crop on population of *P.scabra* and braconid parasites like *Cotesia marginiventris* Cresson.

Cabello (1989) reported eleven parasites from *H.armigera* on soybean and nine parasites from *S.ovifera* with a percentage of larval parasitism of 19.8 per cent and 37.3 per cent respectively. Shetgar and Thombu (1984) enlisted the natural enemies of soybean leaf miner, *A.modicella* on susceptible varieties. Muthiah (1991) reported *Brachymeria wittei* (Schmitz), *Bracon* sp., *Chelonus* sp. and *Apanteles* sp. on *A.modicella*. Higher level of parasitism (50 to 85.05%) by *Hyposoter didymator* Thunberg and 25.70 to 55.3% by *Cotesia kazak* Telege were recorded in cotton, soybean, sorghum and sunflower (Murray *et al.*, 1995).

Predaceous Hemiptera are usually abundant in soybean fields than all other predators combined (Kretzschmar, 1948). The predominant groups include Nabidae, (*Nabis* sp.), Lygaeidae (*Geoeoris* sp.), Anthocoridae (*Orius* sp.), Pentatomidae (*Podisus* sp.) and *Stiretrus* sp. and Reduviidae (*Zelus* sp. and *Sivea* sp.) (Irwin and Shephard 1980). Coccinellids viz., *Menochilus sexmaculatas* (Linn.), *Stichoeotes* sp. and *Arilus* sp., *Geocoris* sp., *Nabis* sp. were the most abundant predators in soybean fields (McPherson *et al.*, 1982, Young and Yearian, 1990 and Ferguson *et al.*, 1984).

### 2.7.3. EFFICACY OF *B.thuringiensis* ON THE INSECT PESTS OF SOYBEAN

#### 2.7.3.1. ON *H.armigera*

Natural occurrence of *B.thuringiensis* in *H.armigera* was reported as early as 1955 (Majumdar *et al.*, 1955). The effect of *B.t* against *H.armigera* was first reported by Sundarababu (1969). Further studies on the effect of *B.t* products on *H.armigera* were conducted by many workers (Kulkarni and Amonkar, 1988; Mote and Murthy, 1989, Justin *et al.*(1989) and Alimiah and Karim , (1993).

Field experiments conducted in Tamilnadu in rainfed and in irrigated condition revealed that *B.t* var. *kurstaki* in combination with NPV of *H.armigera* were as effective as endosulfan (Santharam, *et al.*, 1993). Thippaiah and Kumar (1998) observed in a field experiment conducted on soybean with *B.t* product that pod damage by *H.armigera* was less in Delfin applied which was on par with Biobit and Biolep. But Dabi *et al.* (1989) recorded that *B.t* var *kurstaki* when combined with endosulfan and monocrotophos gave 100 per cent mortality of *H.armigera* within 48 hrs after treatment.

### 2.7.3.2. ON *S.litura*

Oblisami *et al.* (1969) reported that *B.t* (B.333) caused high percentage of mortality (70 – 80%) on *Prodenia litura*. Nararyanan *et al.* (1970) evaluated *B.t* (Thuricide) against lepidopteran insects and found that larvae of *S.littoralis* were less susceptible and did not reach 100 per cent mortality. *B.t* as thuricide HP, Biotrol BTS 250 and thuricide dust were highly effective against second and third instars larvae of *S.litura* (Sundara Babu and Subramanian, 1973). Sareen *et al.* (1983) recorded high larval mortality of *S.litura* due to the application of *B.t*. In the field, the *B.t* was efficient, causing 81.25 per cent mortality of *S.litura*. (Kushwaha, 1985). Jeyanthi and Padmavathiamma (1996) observed that *B.t* was highly effective on lepidopteran pests in groundnut. Nakagome (1998) found that the rate of soybean leaf contamination with SINPV was high when released population consisted of mid and late instar larvae than when younger larvae were released. Jeyanthi and Padmavathiamma (1997) recorded higher mortality at higher concentration in all instars of *S.litura*. Higher dose (0.92 kg per ha) of Bioasp and Biolep were more effective against *S.litura* (Ramprasad *et al.*, 1997).

### 2.7.3.3. EFFICACY OF *B.t* IN COMBINATION WITH NPV OR INSECTICIDES AGAINST DEFOLIATORS IN SOYBEAN INSECT PESTS

Ignoffo *et al.* (1978) found *H.zea* NPV to be most effective along with *B.t* in suppressing *H.zea* larvae. *B.t* in combinations with insecticides had resulted effective mortality of *S.litura* (Vasudevan and Baskaran, 1979; Amonkar *et al.*, 1985).

A combined effect of *B.t* and *S.litura* NPV gave satisfactory control of *S.litura* (Komolpith and Ramakrishnan, 1978). Jayaraj *et al.* (1980) and Ramakrishnan and Chaudhary (1991) reported that *S.litura* NPV was very effective in reducing the larval population and also leaf damage. *B.t* + phosalone, *B.t* + carbaryl and *B.t* + endosulfan at lower dose could spare 5 per cent of

*H.armigera* population 7 days after treatment. (Sharma and Kushwaha, 1988). Butter *et al.* (1995) reported that the Dipel alternatively with endosulfan or quinalphos (or) tank mixture with fenvalerate, endosulfan was effective against *H.armigera*.

## 2.8. YIELD LOSS ASSESSMENT

The yield loss assessment due to pests was studied by a number of workers. Severely infested crops due to leafminer attack exhibited a burnt up appearance (Nayar *et al.*, 1976) and the leafminer caused 75-100 percent damage in soybean plants. In soybean, stink bug damage was evaluated by Daugherty *et al.* (1964) and Thomas *et al.* (1974). The seed quality was significantly affected by stink bug, resulting in lower per cent germination, decreased seedling vigour, smaller size seeds and reduced oil content in soybean.

Smith and Bass (1972) reported under caged condition that three *Heliothis* larvae per foot row caused a yield loss of 3.7 bushels per acre in soybean. The pests larvae of *Trichoplusia ni* (Hubner), *Pseudoplusia includens* (Walker) and *Spodoptera exigua* (Hubner) consumed 119, 114, 52 cm<sup>2</sup> of leaf area and each larva of *H.zea* damaged 8.2 pods and 7.1 seeds in soybean (Bolde *et al.* 1975). Yeargan (1977) reported that the green stink bug, *N.viridula* @ 2-4 bugs per 0.3 m of row caused significant damage and reduced the seed size and seed numbers in soybean. Thomas *et al.* (1978) studied the effects of single and sequential defoliation of soybeans and found that no significant yield reduction in yield by single defoliation at flowering stages but yield was affected at these stages by sequential leaf defoliation.

In another study, accurate yield loss relationship for *Cynthia cardui* (L) and *P.scabra* on soybean were established only for dry years and did not cause any yield reduction when there was ample supply of soil moisture. (Hammond and

pedigo., 1982). Higgins *et al.* (1984) reported that the 25 to 29 larvae per metre row of green clover worm *P.scabra* of soybean caused economic yield loss in full bloom in soybean and showed linear reduction in grain yield.

Logiswaran (1984) recorded that for an increase of one per cent in leaflets affected and one larva per plant resulted in a reduction of 32.7 kg dry pods per hectare. Kalyanasundaram and Sellammal Murugesan (1989) reported that the yield loss due to soybean leaf miner in pot culture on 30 DAS was 0.36 per cent while in field condition it was 2.13 and 3.55 percent at 30 and 45 DAS, respectively. Satpute *et al.* (1988) reported that the avoidable loss due *H.armigera* and other bollworms were high upto 52.9%.

Natural population densities of *H.zea* peaked at 27.6 larvae per 0.915 m row reduced the soybean yield by reducing pods. (McPherson and Moss, 1989). Singh *et al.* (1991) assessed the avoidable loss of 21.42 to 24.97 per cent in pod number, 18.80 per cent in pod weight, 23.90 to 24.90 per cent in grain number 24.30 to 29.70 per cent grain weight per plant and an avoidable loss of 21.46 to 35.37 per cent in grain yield, due to leafhopper *A. maculosa* on soybean in Madhya Pradesh.

Herbert *et al.* (1991) reported that the yield of soybean was decreased with an increase in estimated percentage of defoliation by *P.scabra*., *Anticarsia gemmatilis* (Hubner) and *P. includens* at flowering stages. The yield loss due to soybean leafminer was recorded as of 0.052 kg and 0.054 g/plant in the pot culture and field, respectively and was comparatively higher in the plants infested at 40 DAS than the plants infested at 25 DAS under field condition (Kempraj 1992).

Board *et al.* (1997) found that the defoliation caused by insect pests resulted in 20% and 40% yield loss at flowering and pod initiation stages of

soybean. Increased infestation of *E.fabae* in soybean caused significant reduction in plant height, number of nodes per plant and average nodal length resulting lower yield. (Yeargan *et al.*, 1994). Wang *et al.* (1996) found 27.8% yield reduction due to *A.glycine* on soybean. Haile *et al.* (1998) recorded 15-70% yield reduction due to the defoliation of insect pests in soybean.

## 2.9. SOYBEAN SEED OIL CONTENT

Goswami *et al.* (1991) recorded maximum yield and soybean oil content at fertilizer level of 60 kgs  $P_2O_5$  /ha and among different forms of 'P' fertiliser, DAP gave the highest yield and oil content.

In Soybean crop the oil concentration increased rapidly from 16-25 days after flowering (DAF) and highest levels of oil content were observed at 34-36 DAF (Zhang *et al.*, 1996). Ibrahim and Pillai (1993) observed that average rate of 30 kg P/ha gave highest seed yield (0.94) t/ha and highest protein and oil content.

Seed yield was increased with 60 kg N/ha and with 30 cm row spacing and 0.33 million plants per ha. Increasing the plant density decreased the protein concentration but increased oil content (Jadhav *et al.* 1994). Narayana *et al.* (1995) found that seed yield, protein, and oil contents were higher when applied with rockphosphates (RP) than single superphosphate (SSP) (or) DAP and they increased with rate of 'P' application. Seed oil content was highest with 80 kg  $P_2O_5$  + FYM (Bisht and Chandel, 1996). Seed yield protein and oil content were significantly increased with "S" rates upto 50 kg and similar effect was also noticed with 'P' (Dwivedi and Bapat, 1998).

## 2.10. ECONOMIC INJURY LEVEL (EIL) OF SOYBEAN INSECT PESTS

Judenko (1972) detailed about the different methods of assessment of economic losses in yield of annual crops caused by pests including the economic threshold. Theoretical economic injury levels of *P.scabra* on soybean in Iowa were calculated by using economic cost, market data, damage, yield data and insect feeding data (Stone and Pedigo, 1972). Pedigo *et al.* (1977) calculated the EILs, leaf consumption data on economic factors on the effect of *P.scabra* population intensity on soybean crop. Chiang (1979) developed a general model of economic threshold level of pest populations.

Ogulana and Pedigo (1974) studied on the effect of population of *E.fabae* and determined the economics for soybean growth stages of V1, R4 and R7 respectively. The economic injury level for first generation larvae of *P.scabra* was established at 23 larvae per metre of soybean row (Ostlie and Pedigo, 1985). Pedigo *et al.* (1986) in a review on economic injury levels in theory and practice detailed the perspectives, general EIL models, different components of EIL and implementation of the EIL through economic thresholds. (ET).

Onstad (1987) presented a general formula for calculating economic injury levels and economic thresholds and the new formulae that consider expanded concepts of EIL and ET calculation of multiple levels at a given time and dimensional levels that consist of more than one life stages or species. Hutchins *et al.* (1988) developed a technique for using multiple species economic injury levels (EILs) and the paradigm includes an extensive review of defoliators' yield loss relationships for soybean and soybean defoliators.

Kundu and Mehra (1989) determined the economic injury level of stemfly, *M.sojae* on soybean and recorded that the yield was significantly reduced when the percentage of stem tunnel goes beyond 26 percent.

Venkatesan and Kundu (1994) obtained significant negative correlation between stemfly infestation and grain yield and determined the EIL upto 6.40 and 11.23 per cent stem tunnelling by *M.sojae* with quadratic and linear form of relationships, respectively. An injury expansion coefficient matrix was developed to estimate leaf tissue loss caused by bean leaf beetle at V3 stage of soybean and estimated the EIL for different stages of soybean crop growth (Hunt *et al.* 1995).

Hutchins and Funderburk (1996) reviewed a practical approach for pest management programme and development of decision making algorithms like injury guilds for insect pest. A feed value approach for establishing the EIL for soybean pest was studied using biological variables and economic variables (Hutchins and Pedigo, 1998). Haile *et al.* (1998) reported that there were significant EIL differences among soybean cultivars for various defoliating insect pests of soybean.

#### **2.10.1. STATIC MODELS (SM) TO ASSESS THE ECONOMIC INJURY LEVEL (EIL) OF KEY PESTS OF SOYBEAN**

Simple models such as logistic equations were extensively used for the development of ecological theories (Pielou, 1969). Static models were developed to determine the economic injury level (EIL) for soybean defoliators by Stone and Pedigo (1972). Ogulana and Pedigo (1974) developed models to determine EIL for potato leaf hopper, *E.fabae* on soybean. Ruesink (1975) proposed a mathematical expression to compute economic injury level of leaf feeding species based on known correlations between defoliation and yield loss of various stages of soybean development. Linear, quadratic and loglinear models were worked out in assessing the EIL for sunflower capitulum borer *H.armigera* (Karuppuchamy *et al.*, 1993; Venketasan 1995).

## **MATERIALS AND METHODS**

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### **3. MATERIALS AND METHODS**

Studies conducted to investigate the seasonal occurrence and abundance of different insect pests on soybean, the effect of prevalent weather parameters on the incidence of insect pests, fixation of economic injury level, yield loss assessment of key pests and management strategies through different field experiments in and around Coimbatore district are detailed below.

#### **3.1. STUDIES ON THE SEASONAL INCIDENCE OF INSECT PESTS OF SOYBEAN**

Field experiments were laid out in 0.1 hectare (1000 m<sup>2</sup>) plot at Tamil Nadu Agricultural University (TNAU) Coimbatore during January to July, 1995 and seasonal incidence of pests at different crop growth stages were recorded at weekly intervals. Field experiments were laid out in 0.2 hectare (2000 m<sup>2</sup>) plot in Farmer's field at Udumalpet during February 1995, Aliyarnagar of Pollachi Taluk during July 1995 and at Avinashi and Bhavani during September 1998. Soyabean variety Co.1 was used in all the experiments.

Weekly observations on seasonal incidence of aphids, leafhoppers, whiteflies, leafminer, leafeating caterpillars and pod sucking bugs were recorded in five, one square metre microplots marked out in four corners and one in the centre of the field, leaving two meters from the bund on all the sides (Plate-1). In each microplot, five plants were randomly selected and observations on the incidence of pests and leaf damages were recorded. Thus, totally 25 plants were sampled. Observations on populations of different pests were recorded from 20 days after sowing (DAS) and continued upto 10 days before harvest.

## **PLATE - 1**

- A. Microplot for seasonal incidence of pests.
- B. Sex-pheromone trap for monitoring lepidopteran pest.

PLATE. I



Leaf damages by caterpillars were recorded by counting total number of leaves in sampled plants and number of leaves damaged by larvae and per cent leaf damage was worked out. Populations and per cent damage by pests on leaf and pods over seasons and years were compared using 't' test.

### **3.2. MONITORING *Helicoverpa armigera*. (Hubn.) and *Spodoptera litura* (Fabr) THROUGH SEX PHEROMONE TRAPS**

Field experiments were conducted at Aliyarnagar of Pollachi Taluk and TNAU, Coimbatore to study the effect of different bio - control agents for the management of lepidopteran pests like *Helicoverpa armigera* and *Spodoptera litura* during July 1995. In order to release the egg parasites in the experimental plot the emergence of moth population of these pests were monitored through sex pheromone traps. Funnel shaped pheromone traps supplied by M/s. Pest Control India Ltd. Coimbatore were installed in the field @ 12 nos. per hectare at 1.0m above the ground level (Plate-1). The rubber septa were replaced at every fourth week. A minimum of 100m distance was maintained between traps to avoid the risk of trap interference. The weekly observations on the moths collected in the traps were correlated with the pest population from the ten randomly selected plants at different stages of the crop development.

### **3.3. THE INFLUENCE OF WEATHER PARAMETERS ON THE KEY PESTS OF SOYBEAN**

The weather parameters viz., maximum temperature ( $t^{\circ}\text{C}$ ), minimum temperature ( $t^{\circ}\text{C}$ ), relative humidity in morning (%), relative humidity in evening (%) and rainfall (mm) were recorded at the Agricultural Research Station (RRS), Aliyarnagar (Pollachi Taluk) and the weather data for the trials laid out at TNAU farms were collected from the Department of Meteorology, TNAU, Coimbatore. Growing degree-day (GDD) and photothermal unit (PTU) were calculated from the data recorded. Simple correlation and regression, multiple correlation and regression analyses were worked out with different parameters and regression equations were fitted.

The growing degree day (GDD) was worked out as follows :

$$\text{GDD} = \frac{(\text{Max.Temp} + \text{Min.Temp})}{2} - \text{Base Temperature}$$

(Base temperature is taken as 11°C for Coimbatore District)

Photothermal Unit (PTU) = GDD x N = Whereas N = Daylength(hrs) for the fixed latitude 10° N.

January-11.6 hrs, March-12.0 hrs, May-12.6 hrs, July-12.6;

February-11.8 hrs, April-12.3 hrs, June-12.7 hrs, Aug-12.2 hrs;

Sep-12.1 hrs, Nov-11.6 hrs; Oct-11.8 hrs, Dec-11.5 hrs.

### **3.3.1 EFFECT OF LEAF TEMPERATURE ON THE INCIDENCE OF PESTS OF SOYBEAN**

Pot culture experiments were carried out at the insectary of TNAU, Coimbatore. Soybean seeds (Co.1) were sown in pots and totally 30 pots were maintained to record observations on leaf temperature and leaf humidity were taken at a time (n = 30). Care was taken to give 1.0m distance from pot to pot and row to row.

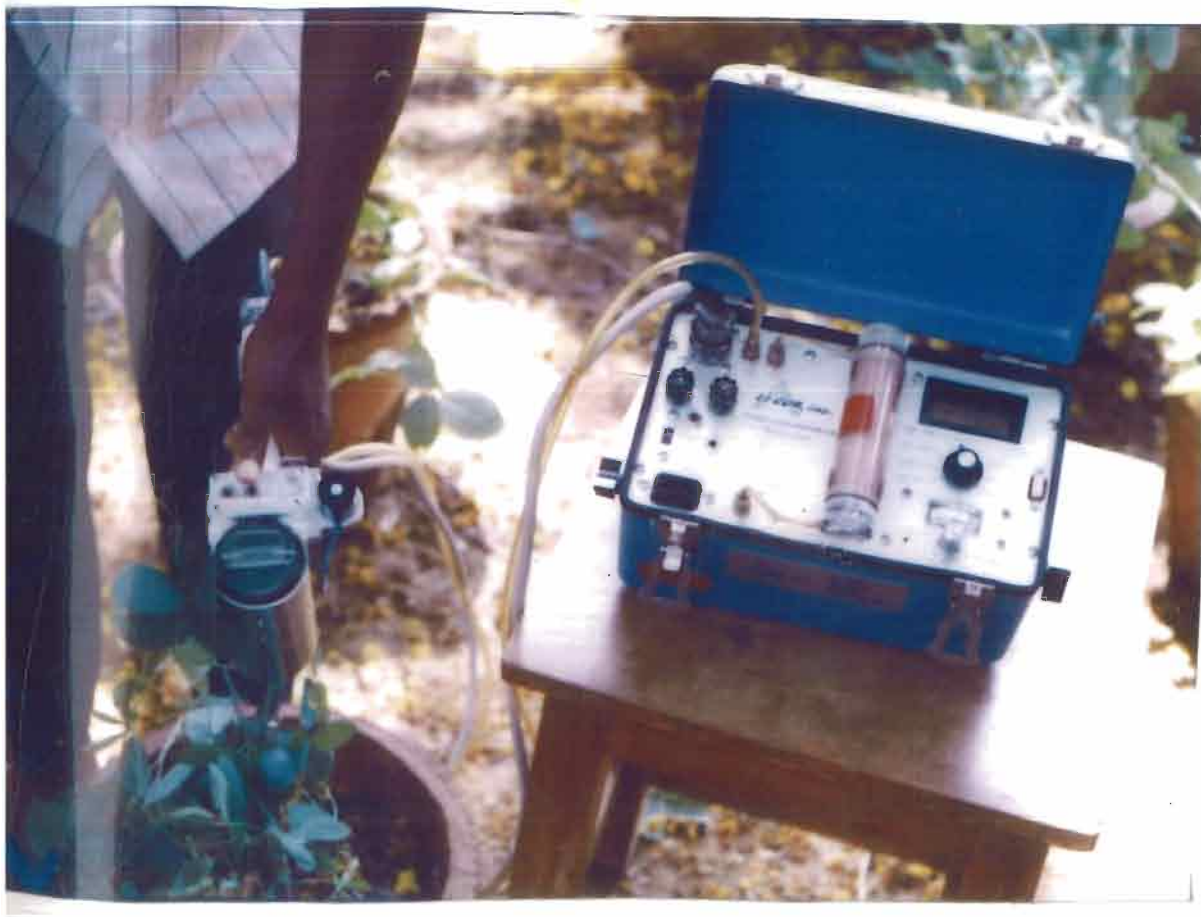
One healthy leaf sample not damaged by pests per plant was selected and kept for one minute in between the clamps of Steady State Porometer model LI - 1600 (LI - COR inc.)(Plate-2), the readings on leaf temperature (t) and leaf humidity (%) were observed. The observations were recorded once in ten days on the incidence of insect pests before and after recording the readings on the leaf temperature and humidity. The leaf temperature and humidity were correlated with the incidence of insect pests and regression equations were fitted out.

## **PLATE - 2**

Steady state porometer - Li-1600 (LICOR inc.)



PLATE.  
2.



### 3.4. PEST STATUS OF SOYBEAN DUE TO CULTURAL PRACTICES

#### 3.4.1. EFFECT OF SPACING AND FERTILISER ON THE INCIDENCE OF PESTS OF SOYBEAN

Field experiments were conducted during January 1995 at TNAU, Coimbatore and during September 1998 at Avinashi Taluk in Coimbatore district to study the effect of different levels of spacing and phosphatic fertiliser on the incidence of insect pests of soybean.

Five levels of phosphatic fertilisers per hectare (*viz.*, 0, 80, 100, 120, 140 kg  $P_2O_5$ ) were tried as basal and basal and foliar spraying and three levels of spacings *viz.*, 30x10 cm, 40x10 cm, 45x10 cm were evaluated in split plot design with three replications. The plot size was 9 x 4m (Plate-3). Three levels of spacing were treated as main plot treatments and five levels of phosphatic fertilisers were treated as subplots. Variety Co.1 soybean was used in the experiments and all the recommended crop management practices were followed uniformly.

Weekly observations on the incidence of pests were taken on ten randomly selected plants per plot. In addition to pest population, yield components like, number of pods, number of grains and yield per plant were recorded and analysed.

The treatment structure in the experiment is as follows:

##### Main plot

1. 30 x 10 cm
2. 40 x 10 cm
3. 45 x 10 cm

##### Sub plot

1. 80 kg  $P_2O_5$ /ha as basal
2. 60 kg  $P_2O_5$ /ha as basal +  
20 kg  $P_2O_5$  @ 30 and 40 DAS as foliar spraying

### **PLATE - 3**

- A. Field trial on the efficacy of different insecticides at TNAU, Coimbatore.
- B. Field trial on the efficacy of Bio-control agents at TNAU, Coimbatore.
- C. Field trial on the effect of spacing and fertiliser.



3. 60 kg  $P_2O_5$ /ha as basal +  
20 kg  $P_2O_5$  @ 30, 40 and 50 DAS as foliar spraying
4. 80 kg  $P_2O_5$ /ha as basal +  
20 kg  $P_2O_5$  @ 30 and 40 DAS as foliar spraying
5. 80 kg  $P_2O_5$ /ha as basal +  
20 kg  $P_2O_5$  @ 30,40 and 50 DAS as foliar spraying
6. No  $P_2O_5$  as control.

### 3.4.2. EFFECT OF INTERCROPPING ON SOYBEAN

Two field experiments were conducted at farmer's field during September, 1998 one at Pothampalayam village of Avinashi Taluk, and another at Irattaikaradu village of Bhavani Taluk. The plots were laid in randomised block design(RBD) with three replications. The plots were laid in such a manner that the intercrop raised, alongwith soybean acted as 'wind break' (or) 'barriers' during North East monsoon period. Each plot consisted of maximum of 8-10 rows consisting soybean (6 rows) + maize/sorghum/bhendi either 2 rows or 4 rows as intercrop along with one plot of six rows of pure crop of soybean. Thus, totally seven treatments were laid out in 10 m x 4 m plot each with three replications (Plate-4). Maize seeds were sown in ridges at 60 cm apart and soybean, cholam and bhendi seeds at 45 cm apart.

Observations of insect populations on ten plants selected at random in each plot were recorded at weekly interval commencing from 27 DAS to ten days before harvest. Incidence of natural enemies like spiders, coccinellid were also recorded.

Different yield components like, number of pods, number of grains, number of pods/grains affected by pod borers/pod sucking bugs were also recorded and the correlation on the incidence of pests with yield was worked out.

## **PLATE - 4**

- A. Intercropping system of soybean with maize.
- B. Intercropping system of soybean with sorghum.



PLATE . 4 .

Leaf damage was assessed by counting total number of leaves and number of leaves damaged in the randomly selected plants. Total number of pods per plant and number of pods affected by pod sucking bugs were also recorded and compared with yield data.

The treatments are as follows :

- Soybean (6 rows) + Maize (2 rows)
- Soybean (6 rows) + Sorghum (2 rows)
- Soybean (6 rows) + Bhendi (2 rows).
- Soybean (6 rows) + Maize (4 rows)
- Soybean (6 rows) + Sorghum (4 rows)
- Soybean (6 rows) + Bhendi (4 rows)
- Soybean alone (6 rows).

### **3.5. STUDIES TO FORMULATE AN IPM SYSTEM FOR SOYBEAN**

#### **3.5.1. FIELD EVALUATION OF INSECTICIDES**

Field trails were conducted during February 1995 at Udumalpet and during January'95 at TNAU, Coimbatore to evaluate the efficacy of different insecticides for the management of key insect pests of soybean. The different commercial formulations evaluated are detailed below:

|     | <b>Treatment</b> | <b>Formulation</b> | <b>Dosage tested</b> |
|-----|------------------|--------------------|----------------------|
| 1.  | Quinalphos       | 25 %EC             | 0.04 %               |
| 2.  | Sevinflo         | 42 %AF             | 0.07 %               |
| 3.  | Endosulfan       | 35 %EC             | 0.07 %               |
| 4.  | Phosolone        | 35 %EC             | 0.05 %               |
| 5.  | Phosphamidon     | 86 %EC             | 0.04 %               |
| 6.  | Methyl demeton   | 25 %EC             | 0.05 %               |
| 7.  | Dimethoate       | 30 %EC             | 0.03 %               |
| 8.  | Monocrotophos    | 36 %WSC            | 0.05 %               |
| 9.  | Fenubucarb       | 50 %EC             | 0.05 %               |
| 10. | Chlorpyrifos     | 20 %EC             | 0.05 %               |
| 11. | Untreated check. |                    |                      |

The above field experiment was conducted in a randomised block design with three replications. The plot size was 4 x 3m at TNAU and 5 x 4m at Udumalpet (Plate-3). Soybean variety Co.1. was used in the experiment. All the recommended packages were followed. Pretreatment counts of different pests were observed from ten randomly selected plants per plot. Insecticides at the recommended concentrations were sprayed on the plants using hand operated Knapsack Sprayer (Aspee<sup>R</sup>) using five hundred litres of spray fluid per hectare. Waterspray was given to untreated control. Post treatment counts on pests were recorded on 1st, 7th and 14th day after treatment (DAT). The per cent reduction in the population was worked out using the formula by Handerson and Tilton (1955).

$$Pm = 1 - \left[ \frac{Ta \times Cb}{Tb \times Ca} \right] \times 100$$

Pm = Percent mortality

Ta = Population in Nos. after treatment

Tb = Population in Nos. before treatment

Ca = Population in Nos. after treatment in control

Cb = Population in Nos. before treatment in control

The leaf damage by leaf miner was observed by counting the total leaves and leaves damaged in ten plants and the per cent leaf damage was worked out. Different yield components like number of pods per plant, grains per plant, percentage of pods damaged and percentage of grains affected by pod borers/pod sucking bugs were recorded and the data were statistically analysed.

The cost benefit ratios were also worked out by using the following method of analysis:

**METHOD I (Heinrichs *et al.*, 1981)**

$$C:B = \frac{\text{Value of treated crop} - \text{Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

**METHOD II : (Akila Selvaraj and Sundara Babu, 1994)**

$$C:B = \frac{\text{Treatment yield (kg/ha)} \times \text{Value of Soybean Seed (Rs/kg)}}{\text{Basic cost of cultivation} + \text{Cost of Protection}^*}$$

\* For control plot yield, cost of protection was excluded.

**3.6. STUDIES ON BIOLOGICAL CONTROL AGAINST THE PESTS OF SOYBEAN**

Two field experiments were conducted during July, 1995 one at farmer's field at Aliyarnagar of Pollachi Taluk, and another at TNAU farm at Coimbatore. The biological control agents and insecticides and their combinations were evaluated. The plot size was 100m<sup>2</sup> each. Experiment was conducted in randomised block design, with three replications using CO.1 Soybean variety (Plate-3).

The biocontrol agents like *Trichogramma chilonis* (Ishii). *Chrysoperla carnea* (Stephens) (Plate-5) and HaNPV, SiNPV were obtained from the Bio-control laboratory, TNAU, Coimbatore (Plate-6). *B.t* var. *kurstaki* (Delfin) was obtained from M/s. Sandoz India Ltd. Coimbatore (Plate-7). The insecticides were procured from the open market. The pheromone lures and traps for *Helicoverpa armigera* and *Spodoptera litura* were obtained from M/s. Pest Control India at Coimbatore. Teepol @ 0.5% and crude sugar at 20% were added to NPV treatment to increase sticking property and attraction. Larval population on ten randomly selected plants in each plot was recorded.

## PLATE - 5

- A. Egg parasitised by *Trichogramma chilonis* adult.
- B. Parasitised cards.
- C. Grubs of *Chrysoperla carnea*.

PLATE. 5.



Following are the treatments details :

| Treatments                                          | Application rate / ha <sup>-1</sup> |
|-----------------------------------------------------|-------------------------------------|
| <i>Trichogramma chilonis</i>                        | - 6.0 CC of parasitised egg cards   |
| <i>Chrysoperla carnea</i>                           | - 50000 Nos of Ist instar Larvae    |
| <i>Helicoverpa armigera</i> NPV (HaNPV)             | - 250 LE                            |
| <i>Spodoptera litura</i> NPV (SINPV)                | - 250 LE                            |
| <i>Bacillus thuringiensis</i>                       |                                     |
| var. <i>Kurstaki</i> (B.t)                          | - 1000 g                            |
| HaNPV + Endosulfan 0.07%                            | - 250 LE + 0.07%                    |
| SINPV + Endosulfan 0.07%                            | - 250 LE + 0.07%                    |
| B.t 1/2 dose + Endosulfan 0.07%                     | - 500 g + 0.07%                     |
| B.t 1/2 dose + 1/2 dose mixture<br>of HaNPV + SINPV | - 500 g + 125 LE + 125 LE           |
| Endosulfan                                          | - 0.07%                             |
| Farmer's practice                                   |                                     |
| Control                                             |                                     |

### 3.6.1.EVALUATION OF DIFFERENT COMPONENTS OF BIO-LOGICAL CONTROL AGENTS AND INSECTICIDAL TREATMENTS

An experiment was conducted during July, 1995 with an area of 120 m<sup>2</sup> each plot with three replications at TNAU, Coimbatore, using Co.1 soybean variety. All the recommended packages of practices were followed. The different treatment components evaluated in the field are furnished below

:Component 1 : Monitoring the moth activity through pheromone traps @ 12 traps per hectare. Three releases of *Trichogramma chilonis* @ 6.00 cc/ha<sup>-1</sup> at weekly interval. The first release of parasitoid was made at 3-4 days after noticing the moths in the pheromone traps. The parasitised (5 stripe = 1cc) cards were tied to the plant using plastic cup to protect against heat and rains.(Anon., 1994)(Plate-7).

## PLATE - 6

- A. *Spodoptera litura* NPV.
- B. *Helicoverpa armigera* NPV.

PLATE. 6.



Component 2 : Three releases of *Chrysoperla carnea* as 1st instar grubs @ 50000 Nos/ha<sup>-1</sup>, first release commencing at five days after the third release of *Trichogramma sp.* at ten days interval

Component 3 : Two Sprayings of *B.t* @ 1000 g/ha against I<sup>st</sup> and II<sup>nd</sup> instars larvae of *Helicoverpa armigera* and *Spodoptera litura* at weekly interval.

Component 4 : Three sprayings of NPV (HaNPV/SINPV) @ 250 LE/ha<sup>-1</sup> at weekly interval commencing at three days after *B.t.* spraying.

Component 5 : Three sprayings of endosulfan @ 0.07 per cent at weekly interval. taken up alongwith NPV spraying.

**Treatment structure :**

|                                |                            |
|--------------------------------|----------------------------|
| T <sub>1</sub> component       | 1 to 5                     |
| T <sub>2</sub> component       | 2 to 5                     |
| T <sub>3</sub> component       | 1,3,4 to 5                 |
| T <sub>4</sub> component       | 1,2,4 to 5                 |
| T <sub>5</sub> component       | 1,2,3 and 5                |
| T <sub>6</sub> component       | 1 ,2,3 and 4               |
| T <sub>7</sub> untreated check | (without component 1 to 5) |

Observations on the population of pests and per cent leaf damage were made on seventh day after treatment (DAT) on ten plants selected at random. Number of pods per plant and per cent pod damage were also recorded in situ before harvest. The final yield of grains obtained per hectare and cost-benefit ratio also worked out.

### 3.7. STUDIES ON THE YIELD LOSS ASSESSMENT AND FIXING OF ECONOMIC INJURY LEVEL (EIL) TO KEY PESTS OF SOYBEAN

#### 3.7.1. MASS CULTURING OF Leafminer : *Aproaerema modicella*

Soybean (var. Co.1) plants were raised in earthen pots at the rate of four plants per pot and the plants were confined in mylarfilm cage (25cm diameter and 60 cm height) top covered with netlon clothing. Five pairs of freshly emerged adults of the leafminer collected from the field were released on 30day old soybean plants. The adults were fed with 10% sucrose solution enriched with ABDEC<sup>®</sup> vitamin solution kept in glass vial (5 ml) with cotton wig. Plants were transferred to a wire mesh cage for oviposition and further development. The culture thus obtained was used for conducting yield loss assessment studies in pot culture experiment (Plate-8).

#### 3.7.2. ASSESSMENT OF YIELD LOSS IN POT CULTURE EXPERIMENT

Yield loss was assessed for soybean leafminer in pot culture as completely randomized block design (CRBD). Seeds were sown in pots using variety Co.1. At 30 days after sowing (DAS) laboratory reared leafminer larvae (second instar) were introduced as treatment at the rate of 1,2,3,4,5,6,7,8,9 and 10 larvae per plant and one pot without larvae maintained as check. All the treatments were replicated thrice. Pots were labeled and covered individually with circular iron cages with mylar film and on alternate days, the dead larvae if any were replaced, to maintain the population level (Plate-8). The number of leaves damaged four days after release of larvae was recorded and expressed as per cent leaf damage. At the time of harvest, the number of pods, number of grains and grain weight were recorded per plant. The data were analysed after arcsin transformation of percentage values. Correlation matrix was prepared and regression equation was fitted.

## PLATE - 7

Release of *Trichogramma chilonis* parasitised cards.

PLATE . 7



### 3.7.3. ASSESSMENT OF YIELD LOSS IN FIELD (UNCAGED)

Field experiments were conducted during September 1998 using Co.1 soybean variety, when the leafminer incidence was noticed heavily. The field was surveyed to grade the plants with leafminer damage of leaves which resulted in ten class intervals of leaf damage, each class varying at five per cent intervals, respectively. Fully protected plants without damage were maintained for the comparison of observations. Thus, there were totally 11 treatments with five replications with  $N=55$  ( $11 \times 5$ ).

In each treatment, leaf damage by visual method described by Kogen and Turnipseed (1979)(Plate-9). The yield related components viz., number of pods, number of grains and grain weight per plant were recorded, at the time of harvest. The reduction in grain weight per plant was worked out. The per cent damage of leaves and pods corresponding to the grain weight were used in the regression analysis.

### 3.7.4. PREDICTION OF YIELD LOSS USING MATHEMATICAL MODELS

Using the data collected as per sections 3.7.3, attempts were made using mathematical model for assessing the trend of loss and the rate of loss for unit increment in pest number/leaf damage/pod damage.

Various mathematical models viz., Mitscherlich's curve (Briggs, 1925, Balmukand, 1928; Hexem *et al.*, 1976) and Logistic curve (Meek *et al.*, 1991) were tried to establish the functional form between the population of leafminer (Lm) (number/plant) and yield loss (g/plant) and leaf damage (%). The Mitscherlich's curve was used between leafminer population and yield loss and the logistic curve was used between leaf damage (%) and yield loss (g/pl).

## PLATE - 8

- A. Cage for mass culturing of leafminer, *A. modicella*.
- B. Microfilm cage for yield loss assessment studies.

PLATE. 8



## MITSCHERLICH'S CURVE

The exponential form of Mitscherlich's model is of the form

$$Y_i = A (1 - B e^{-CI_i}) \dots\dots\dots (1)$$

Where

$Y_i$  = Yield loss (g/plant)

$I_i$  = Population of leafminer (number/plant)

$A$  = Maximum crop yield loss where  $I$  is increased  
to maximum limit

$B$  and  $C$  = Parameters to be estimated.

## LOGISTIC CURVE

The logistic curve is of the form

$$Y_i = A (1 + B e^{-CD_i})^{-1} \dots\dots\dots (2)$$

where

$Y_i$  = Yield loss (g/plant)

$D_i$  = Leaf damage (%)

$A$  = Maximum crop yield loss when  $D$  is increased to the  
maximum limit

$B$  and  $C$  = Parameters to be estimated.

The Mitscherlich's curve (equation 1) and logistic curve (equation 2) were estimated by the method of ordinary least squares (OLS).

The rate of yield loss (g/plant) in respect to different population levels of  $lm$  was estimated from equating the equation 1 using the formula

$$RyL_i = \alpha e^{-CI_i}$$

where

$RyL_i$  = Rate of yield loss at  $i^{th}$  level of  $Lm/Ha$  population.

$I_j$  =  $i^{th}$  level of  $Lm/Ha$

$\alpha$  = Parameters to be estimated

The rate of yield loss due to leaf damage (%) was estimated from the logistic curve. The rate of yield loss due to per cent leaf damage were worked out by the formula

The logistic curve is of the formula

$$R_y L_j = \beta_e - CD_j (1 + B_e - CD_j)^{-2}$$

where

$R_y L_j$  = Rate of yield loss at  $j^{\text{th}}$  level of leaf  
damage percent per plant

$D_j$  =  $j^{\text{th}}$  level of leaf damage percent (%)

$\beta$  = Parameters to be estimated.

### 3.8. ECONOMIC INJURY LEVEL (EIL) FOR THE KEY BESTS OF SOYBEAN

The Economic injury levels (EILs) for the key pests of soybean were calculated based on the methods developed by Stone and Pedigo (1972), which included both economic and biological components (or) variables.

The Gain Threshold (GT) expresses economic damage as physical commodity loss, the required data on the cost of the proposed management tactic as well as the market value of the soybean seed

$$GT = C/V$$

where C is the cost of management for the anticipated control tactics and V is the anticipated market value for the soybean seeds.

The general EIL model as developed by Stone and Pedigo (1972) is expanded to account for the expected level of control from the curative control tactic :

$EIL = GT/DI$  where I is the expected injury of the pest over its life and D is the expected yield loss per unit injury (Pedigo *et al.*, 1986).

### 3.8.1. FIXING OF EIL THROUGH STATIC MODELS

In order to work out the economic injury levels for the key pests of soybean, static models were computed from the data generated through field experiments conducted at Udumalpet (Feb'95), Aliyarnagar (July '95) and Avinashi (Sep '98). Macroplot of 0.24 hectare (2400 m<sup>2</sup>) plot was subdivided into three micro plots of 0.08 hectare (800 m<sup>2</sup>) representing three replications. Twenty plants were selected for each pest at random and tagged. Key pests like leafhopper, leafminer and podborer were recorded at different crop growth stages.

In the twenty tagged plants per replication, the total number of leaves and leaves defoliated were counted and per cent leaf damage was assessed. The yield data were correlated and EIL was calculated. The plants marked for each pest category were protected by using respective recommended insecticides to contain the other pests.

From the data collected from the field experiment, the expected yield in the absence of the pest infestation and the calculated yield in the presence of pests at different population levels were worked out by the method described by Rajendra Choudhary *et al.* (1987).

Graph showing quadratic, linear ( $Y = a + bx$ ) and log linear ( $Y = [a] e^{-bx}$ ) equations was plotted by different levels of leaf/pod damage/plant on 'x' axis and yield per plant on 'y' axis.

The EIL through quadratic equation ( $Y = a + bx + cx^2$ ) was calculated using the formula

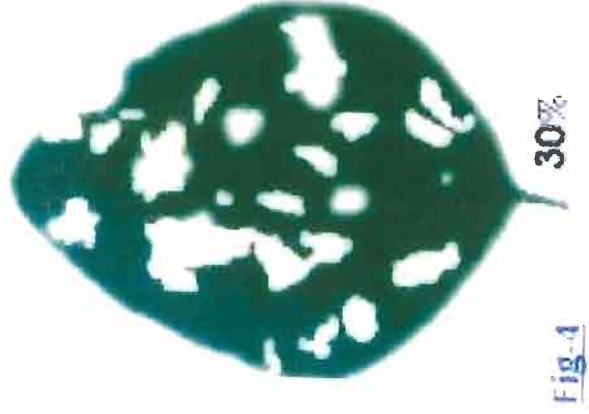
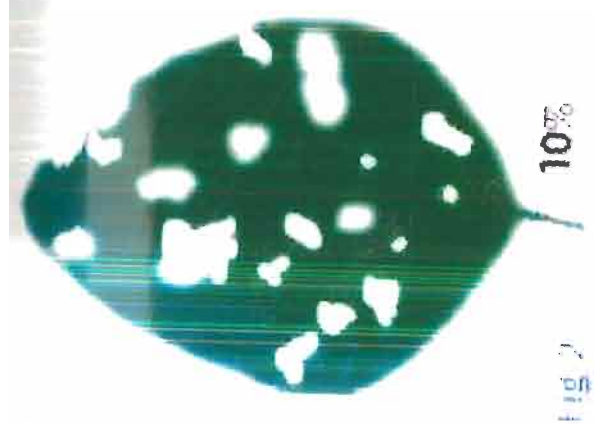
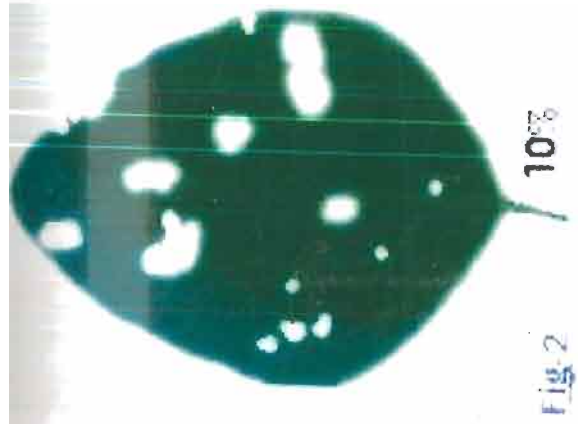
$$\text{EIL} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- where b = regression coefficient in quadratic equation (x)  
 a = regression coefficient in quadratic equation (x<sup>2</sup>)  
 c = GT (Grain Threshold).

## **PLATE - 9**

Grading of leaf damage by leaf feeders.





# **PLATE-9**

### 3.9. ASSESSMENT OF DAMAGE BY INSECT PESTS

#### 3.9.1 ASSESSMENT OF DAMAGE DUE TO DEFOLIATING INSECT PESTS

Larval population counts were taken from ten plants selected at random. Observations on larval counts in general for all field experiments were taken at different crop growth stages starting from 25 days after sowing (DAS) at weekly intervals. In the case of chemical control studies, precount population and post population counts of larvae were taken on 1<sup>st</sup>, 7<sup>th</sup> and 14<sup>th</sup> day after treatments. (DAT)

Per cent leaf damage was assessed for yield loss study from eleven randomly selected plants with five replications by visual estimates. The visual estimates of leaf damage were estimated as prescribed by Kogen and Turnipseed (1979). A series of photographs showing the leaflets with increments of five per cent of the total area removed by the defoliating insects, were maintained (Plate-9). Ten leaflets from middle or upper nodes were picked and compared to the pictures and scored within five per cent defoliation classes. The percentages are then averaged and the mean reflected the estimated level of defoliation in the field and compared with yield.

#### 3.9.2 ASSESSMENT OF DAMAGE DUE TO SUCKING PESTS

##### 3.9.2.1 LEAFHOPPERS : *Empoasca fabae*

The counts on leafhoppers (both nymphs and adults) population were made on three leaves one each from upper, middle and lower canopy from ten plants selected at random in the field.

##### 3.9.2.2 APHIDS : *Aphis craccivora*

Counting of aphid population was done by direct visual count of total number of aphids from ten randomly selected plants from each plot. Observations for recording the seasonal incidence of aphids were made at weekly interval starting from 20 DAS, In case of insecticide treatment studies, precount observation and observations on 1<sup>st</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAT were also

made.

### 3.9.2.3 WHITE FLIES : *Bemisia tabaci*

In all field experiments, weekly observations were made on ten randomly selected plants. The number of whitefly population were recorded in upper, middle and lower leaf canopy on each plant by carefully turning the leaf over by rotating the petiole (or) the tip of the leaf blade. In case of insecticide treatment studies, precount populations and counts on 1<sup>st</sup>, 7<sup>th</sup> and 14<sup>th</sup> DAT were made from the ten randomly selected plants.

### 3.9.2.4 GREEN STINK BUGS : *Nezara viridula*

Both adults and nymphs were observed at weekly intervals from the flowering stage of the crop. Ten plants were selected at random and observations were recorded till ten days before harvest. Since pods are damaged by this pest, the total number of pods and number of pods damaged were also recorded as per cent pod damage. One hundred grains were collected on the pods and per cent grain damaged was also worked out and recorded.

### 3.9.3. ASSESSMENT OF NATURAL ENEMIES :

Samplings were done in different field experiments conducted during 1995 and 1998 to assess the population of natural enemies along with pest population. The data on population of natural enemies were correlated and regression equations were fitted against the pest population and as well with the different treatments tried in the field experiments. In each treatment plot, ten sweeps were made by using 30 cm sweep net in five randomly selected places per plot. The populations were collected in polythene bags and the populations were categorised to different orders like Coleoptera, Hemiptera, Araneids and Neuroptera.

### 3.10. OILCONTENT ANALYSIS.

In order to find out the effect of spacing and fertilizer on the oil content of soybean seed, estimation of oil was carried out as described by Sadasivam

and Manickam(1991). Samples from each plot of the experiment were taken and air dried well before keeping the seed over night in the oven at 80°C. The seeds were ground thoroughly by feeding the seeds slowly to prevent expulsion of oil. The ground seeds were mixed and weighed 5 g of the ground seed sample was placed inside a filter paper fold. Another filter paper was wrapped around and open at the top to evenly distribute the solvent in it. Then, the sample was placed in the butt tubes of the Soxhlet extractor. Oil was extracted with petroleum ether (150 drops/min) for 6 hours without disruption by gentle heating. Then it was allowed to cool and the flask dismantled. The ether was evaporated on the waterbath until no odour of ether remained in the oil. Then it was cooled at room temperature and the debris were removed. The flask was weighed and heating was repeated to get constant weight. The oil content was calculated.

$$\text{Oil in ground sample} = \frac{\text{weight of oil(g)}}{\text{weight of sample(g)}} \times 100$$

### 3.11. STATISTICAL ANALYSIS

From the field experiments, the data gathered on larval counts were transformed into  $\sqrt{x + 0.5}$ , log transformation and the data expressing percentage of leaf damage, pod damage, per cent mortality were transformed into corresponding angles (Arcsin percentage). Analysis of variance was carried out for the field experiments by randomised block design, split plot design and means were separated by Duncan's Multiple Range Test (DMRT) (Duncan, 1955). Multiple correlation and regression analyses were performed as per Gomez and Gomez (1984).

## EXPERIMENTAL RESULTS

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## 4. EXPERIMENTAL RESULTS

### 4.1. SEASONAL INCIDENCE OF INSECT PESTS OF SOYBEAN

Fixed plot survey at farmer's field on insect pests of soybean crop was taken up to find out the occurrence of some important insect pests that cause economic damage. The mean differences of population of different insect pests of soybean between the locations and seasons were tested using t-test.

#### 4.1.1. Sucking pests

The most abundant sucking pests observed were leafhoppers, whiteflies and aphids during the weekly observations taken at TNAU, Coimbatore, Udumalpet, Aliyarnagar, Avinashi and Bhavani during 1995 and 1998.

##### 4.1.1.1. Leaf hopper – *Empoasca fabae*

The seasonal incidences observed were compared between locations and seasons (Table 1.) The leaf hoppers were prevalent in all three seasons viz., February, July and September. Highest incidences (4.08) were observed in July at TNAU, Coimbatore followed by September (3.31) at Avinashi and the lowest (2.15) was observed during February at Udumalpet.

The incidence during February'95 was more at Coimbatore, TNAU when compared to Udumalpet. However, the differences were not significant. In July'95 season, the incidence was more at Coimbatore, TNAU when compared to Aliyarnagar and the differences were significant. In September'98, the incidence was more at Avinashi when compared to Bhavani and the differences were significant.

Incidence was more at Coimbatore, TNAU during July than in February season and the maximum incidence was observed on 34 DAS at Coimbatore,

Table 1. Seasonal incidence of soybean insect pests – Sucking pests

| Sl. No. | Parameters                                                            | Mean Population / Plant @ |                      |           |           |                      |                |          |                      |         |
|---------|-----------------------------------------------------------------------|---------------------------|----------------------|-----------|-----------|----------------------|----------------|----------|----------------------|---------|
|         |                                                                       | February 1995             |                      |           | July 1995 |                      | September 1998 |          |                      |         |
|         |                                                                       | TNAU                      | -                    | Udumalpet | TNAU      | -                    | Aliyar Nagar   | Avinashi | -                    | Bhavani |
| 1.      | Population of nymphs and adults of leafhopper - <i>Empoasca fabae</i> | 2.31                      | -                    | 2.15      | 4.08      | -                    | 2.91           | 3.31     | -                    | 2.72    |
|         | t                                                                     |                           | 1.052                |           |           | 2.397*               |                |          | 3.074*               |         |
| 2.      | Population of nymphs and adults of whiteflies - <i>Bemisia tabaci</i> | 4.62                      | -                    | 4.31      | 1.43      | -                    | 1.47           | 3.47     | -                    | 3.20    |
|         | t                                                                     |                           | 1.092 <sup>ns</sup>  |           |           | 0.1918 <sup>ns</sup> |                |          | 1.202 <sup>ns</sup>  |         |
| 3.      | Population of nymphs and adults aphids - <i>Aphis craccivora</i>      | 27.87                     | -                    | 27.28     | 28.42     | -                    | 35.60          | 25.08    | -                    | 21.46   |
|         | t                                                                     |                           | 0.1707 <sup>ns</sup> |           |           | 1.901 <sup>ns</sup>  |                |          | 0.6607 <sup>ns</sup> |         |

@Mean of 25 observations

ns – not significant

\*-Significant at 5% level

\*\* -Significant at 1% level

TNAU and Udumalpet. During July season the maximum incidence was observed at 55 DAS in Coimbatore, TNAU and 48 DAS at Aliyarnagar. In September season the peak incidence was observed on 27 DAS at Bhavani and 34 DAS at Avinashi (Fig.1).

#### **4.1.1.2. Whitefly – *Bemisia tabaci***

The peak incidence was noticed during February season on 69 DAS at Udumalpet and on 76 DAS at TNAU. In July season the peak incidence was noticed on 76 DAS both at TNAU and Aliyarnagar. No significant differences were found between locations (Table 1). In all the cases an ever increasing trend was observed up to 76 DAS. In September 98 the maximum incidence was observed on 48 DAS both at Avinashi and Bhavani and declined there of (Fig.2.)

#### **4.1.1.3. Aphid – *Aphis craccivora***

Highest incidence (35.60) was observed at Aliyarnagar during July season followed by TNAU (28.42) during July'95 and the lowest (21.46) was recorded at Bhavani during September'98. In all these seasons, no significant differences were found between locations (Table1). Peak incidence was observed on 48 DAS during February season at Udumalpet and on 55 DAS at TNAU. In July season the maximum population was recorded at 55 DAS at TNAU and Aliyarnagar. In September season, the highest incidence was observed on 62 DAS at Avinashi and on 69 DAS at Bhavani (Fig.3)

### **4.1.2. DEFOLIATORS**

#### **4.1.2.1. Leafminer - *Aproaerema modicella***

The leafminer incidences were noticed in all the three seasons viz., February, July and September. Highest per cent leaf damages (25.67%) was recorded at Udumalpet during February'95, compared to TNAU (20.49%) and

**Fig.3 Seasonal incidence of soybean insect pests -  
Aphid - *Aphis craccivora***

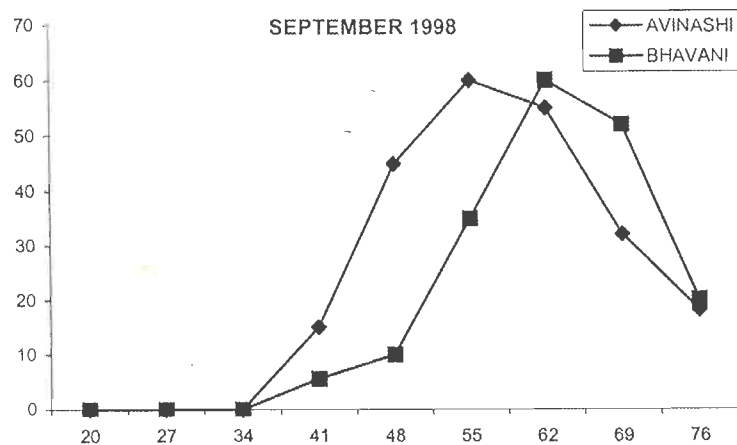
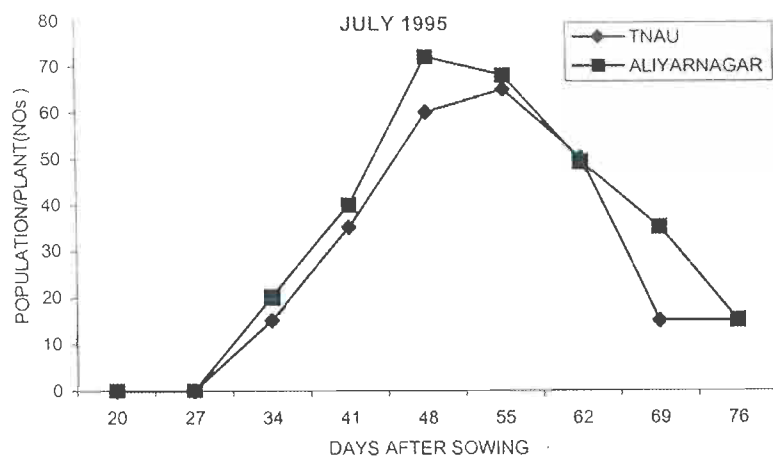
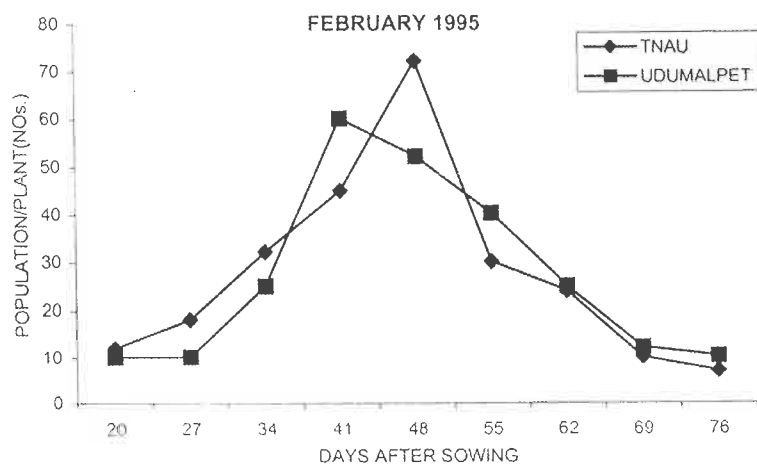


**Fig.2 Seasonal incidence of soybean insect pest -  
Whitefly - *Bemisia tabaci***

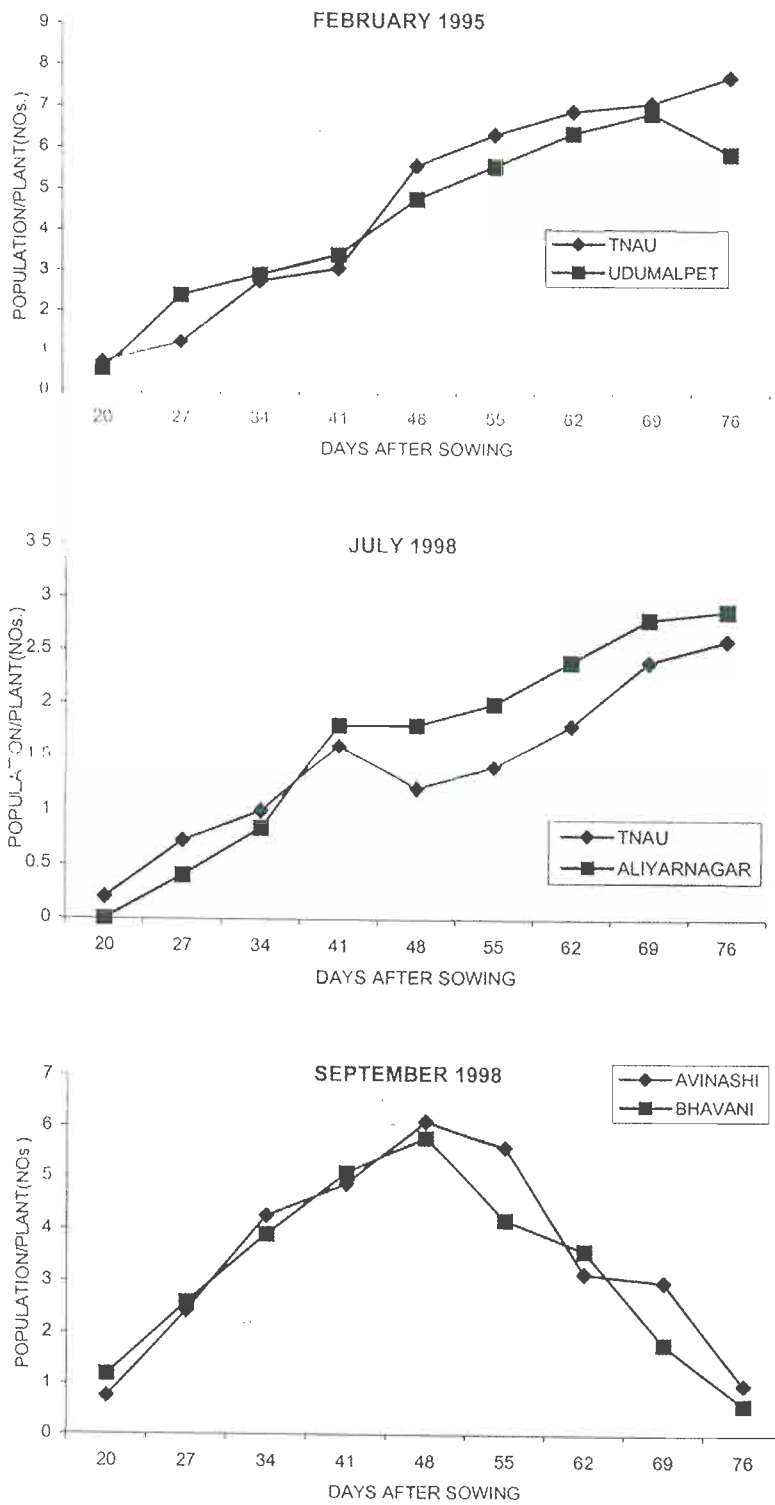
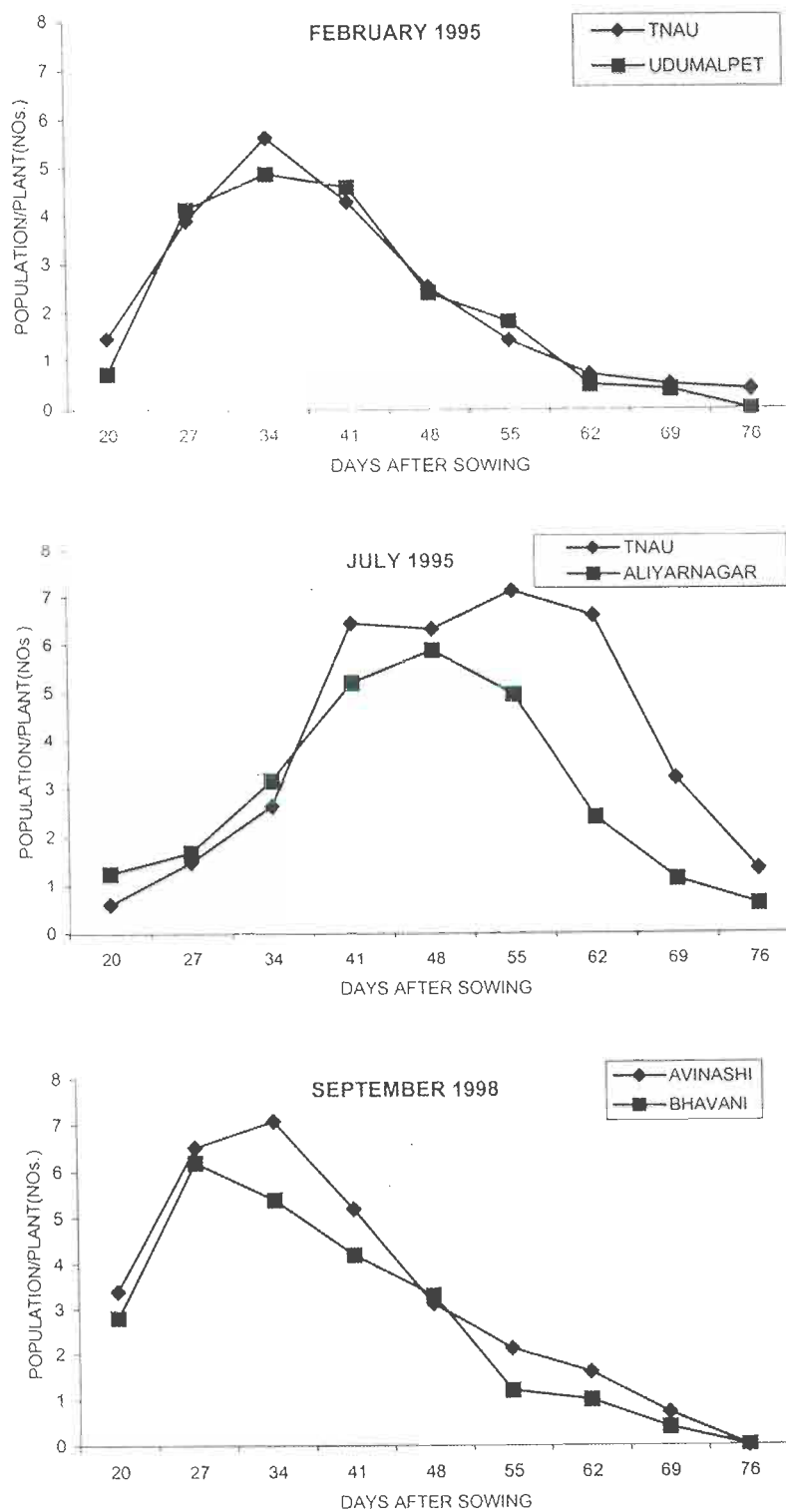


Fig.1 Seasonal incidence of soybean insect pest -  
Leafhopper - *Empoasca fabae*



there were significant differences between TNAU, Coimbatore and Udumalpet. In July season, the incidence of leafminer was more or less same both at Aliyarnagar and TNAU, but no significant difference was noticed during July season. However, there was significant difference on leafminer incidence at Avinashi and Bhavani (Table 2). In February season, the leaf damage was noticed at 55 DAS both at TNAU and Aliyarnagar. During July season, maximum leaf damage was observed at 41 DAS at TNAU and on 48 DAS at Aliyarnagar. In September season, the maximum leaf damage was observed at 48 and 62 DAS at Avinashi and Bhavani respectively. The leaf damage was declining subsequently in both the places ( Fig.4 ).

#### 4.1.2.2. *Helicoverpa armigera*

The pest incidences was observed during July'95 and September'98 and there was no incidence during February'95. Highest incidence per ten plants (3.14) was observed at Aliyarnagar during July'95 and the lowest incidence (2.26) was noticed at TNAU during July'95. During July'95 the incidences recorded were higher at Aliyarnagar than that at TNAU which were statistically significant. The population was less (2.26) at Avinashi when compared to Bhavani during September'98 (Table 2) and the difference in population of these two locations was statistically significant. During July, the maximum incidence of *H.armigera* was observed at 48 DAS both at Aliyarnagar and TNAU. In the case of September season, the maximum incidences were noticed at 62 DAS both at Avinashi and Bhavani (Fig.5).

#### 4.1.2.3. *Spodoptera litura*

The incidence was noticed during February and September seasons. During July'95 very negligible incidence was observed.

Table 2. Seasonal incidence of soybean insect pests – Defoliators

| Sl. No. | Parameters                                                         | Mean Population/Plant @ |          |           |       |                      |              |                    |
|---------|--------------------------------------------------------------------|-------------------------|----------|-----------|-------|----------------------|--------------|--------------------|
|         |                                                                    | February 1995           |          | July 1995 |       | September 1998       |              |                    |
|         |                                                                    | TNAU                    | -        | Udumalpet | TNAU  | -                    | Aliyar Nagar | Avinashi - Bhavani |
| 1.      | Per cent leaf damage by leafminer<br>- <i>Aproaerema modicella</i> | 20.49                   | -        | 25.67     | 19.65 | -                    | 23.54        | 21.25 - 24.64      |
|         | t                                                                  |                         | -3.786** |           |       | -1.087 <sup>ns</sup> |              | -1.416*            |
| 2.      | Population of <i>Helicoverpa armigera</i> larvae                   | -                       | -        | -         | 2.26  | -                    | 3.14         | 2.26 - 3.10        |
|         | t                                                                  |                         | -        |           |       | -3.243*              |              | -3.860**           |
| 3.      | Population of <i>Spodoptera litura</i> larvae                      | 3.23                    | -        | 2.23      | -     | -                    | -            | 3.34 - 2.06        |
|         | t                                                                  |                         | 3.171*   |           |       | -3.243*              |              | 3.523**            |

@Mean of 25 observations

ns – not significant

\*-Significant at 5% level

\*\*-Significant at 1% level

**Fig. 4 Seasonal incidence of soybean insect pest -  
*Helicoverpa armigera***

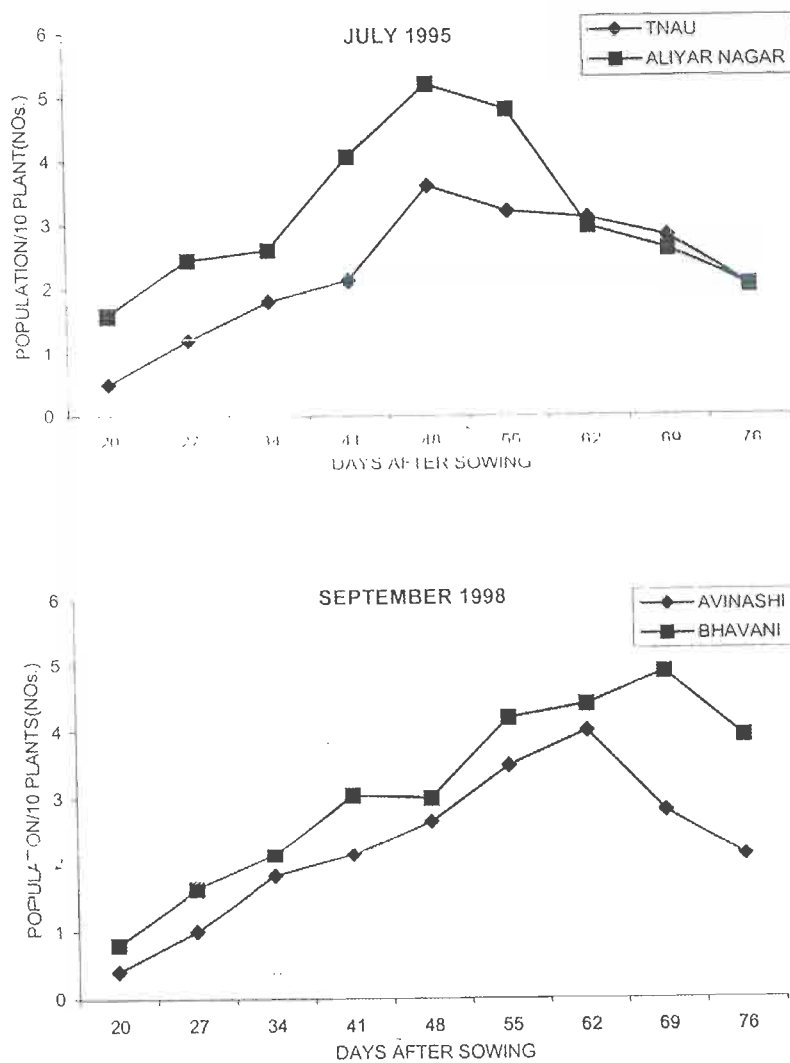
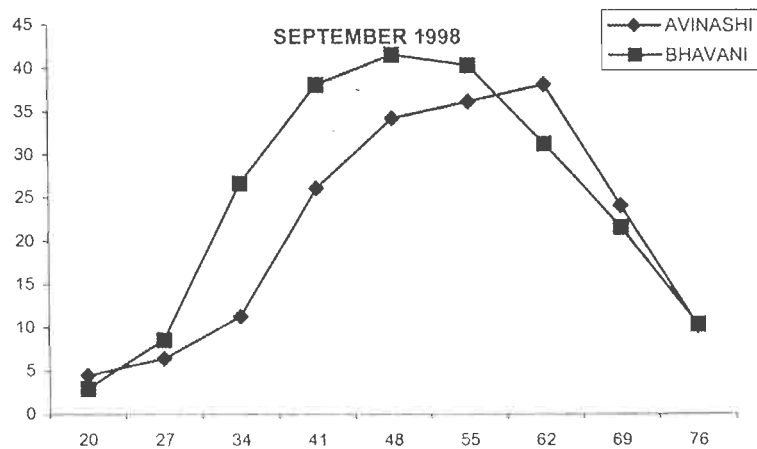
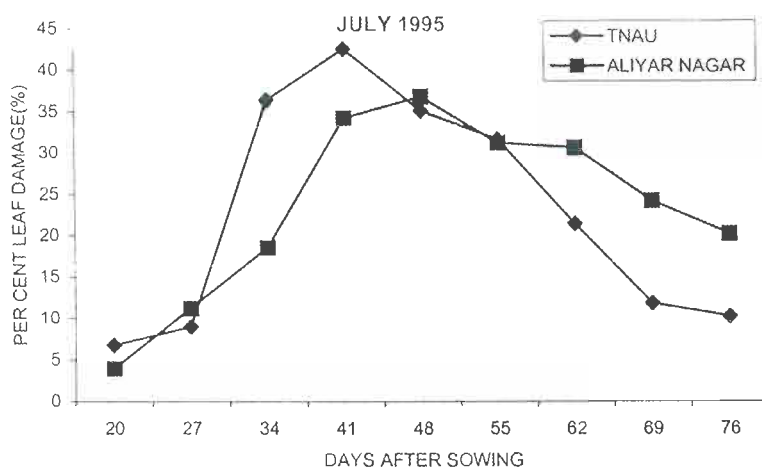
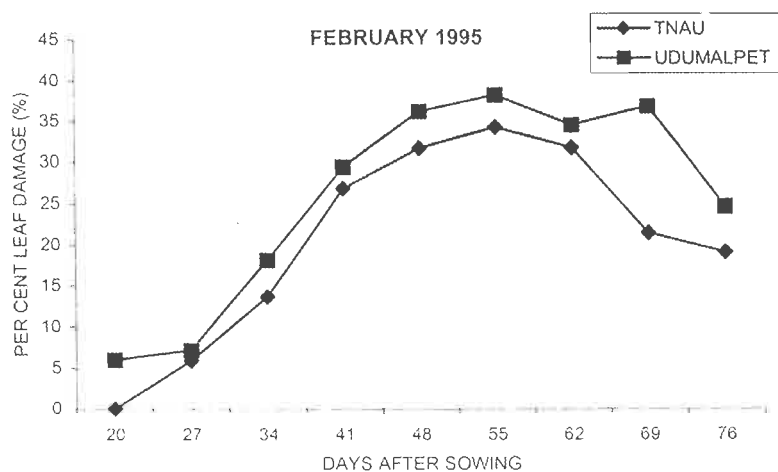


**Fig. 6. Seasonal incidence of soybean insect pest -  
Leafminer - *Aproaerema modicella***



Highest population of *S.litura* larvae per ten plants (3.34) was seen at Avinashi and the lowest (2.06) at Bhavani during September'98. During February'95 the population was higher (3.23) at Coimbatore, TNAU than at Udumalpet whereas it was higher (3.34) at Avinashi than at Bhavani during September'98. (Table 2). The pest incidence was maximum at 48 DAS during February'95 at TNAU and Udumalpet. In September season maximum incidence was noticed on 41 DAS at Bhavani and on 48 DAS at Avinashi. In all the seasons, there was declining trend after the peak incidence (Fig.6).

#### 4.1.3. Pod sucking bug – *Nezara viridula*

The incidences of pod sucking bugs were noticed in all the seasons and locations. In February season, significantly higher population of bugs per ten plants was observed at TNAU (5.78) compared to Udumalpet (3.45). During July season, the difference in the population at TNAU and Udumalpet was not significant (Table 3). An increasing trend in the incidence was seen during February at TNAU, during July at TNAU and September at Bhavani. The maximum incidence was noticed on 76 DAS. Peak incidence was seen on 69 DAS during February at Udumalpet, during July at Aliyarnagar and at Bhavani during September, thereafter a slight decline was observed in all three seasons (Fig.7).

## 4.2 FIELD STUDIES ON PHEROMONE TRAP CATCHES

### 4.2.1 *H. armigera*

The activity of *H. armigera* was monitored by moth catches in pheromone trap and by larval counts on soybean crop at TNAU during July'95, Aliyarnagar during July'95 and at Avinashi and Bhavani during September 1998 seasons.

Simple correlations were worked out and linear regression and equations were fitted to find out the relationship of larval population in the field and pheromone catches. The correlation between the above two variables was highly

Table 3. Seasonal incidence of pod sucking bugs – *Nezara viridula*

| Sl. No. | Parameters                      | Mean Population/Plant @ |         |           |                     |                |                     |
|---------|---------------------------------|-------------------------|---------|-----------|---------------------|----------------|---------------------|
|         |                                 | February 1995           |         | July 1995 |                     | September 1998 |                     |
|         |                                 | TNAU                    | -       | Udumalpet | TNAU                | -              | Bhavani             |
| 1.      | Population of adults and nymphs | 5.78                    | -       | 3.45      | 2.85                | -              | 1.64                |
|         | t                               |                         | 3.436** |           | 1.535 <sup>ns</sup> |                | 1.765 <sup>ns</sup> |

@Mean of 25 observations

ns – not significant

\*-Significant at 5% level

\*\*-Significant at 1% level

**Fig. 6** Seasonal incidence of soybean insect pest -  
*Spodoptera litura*

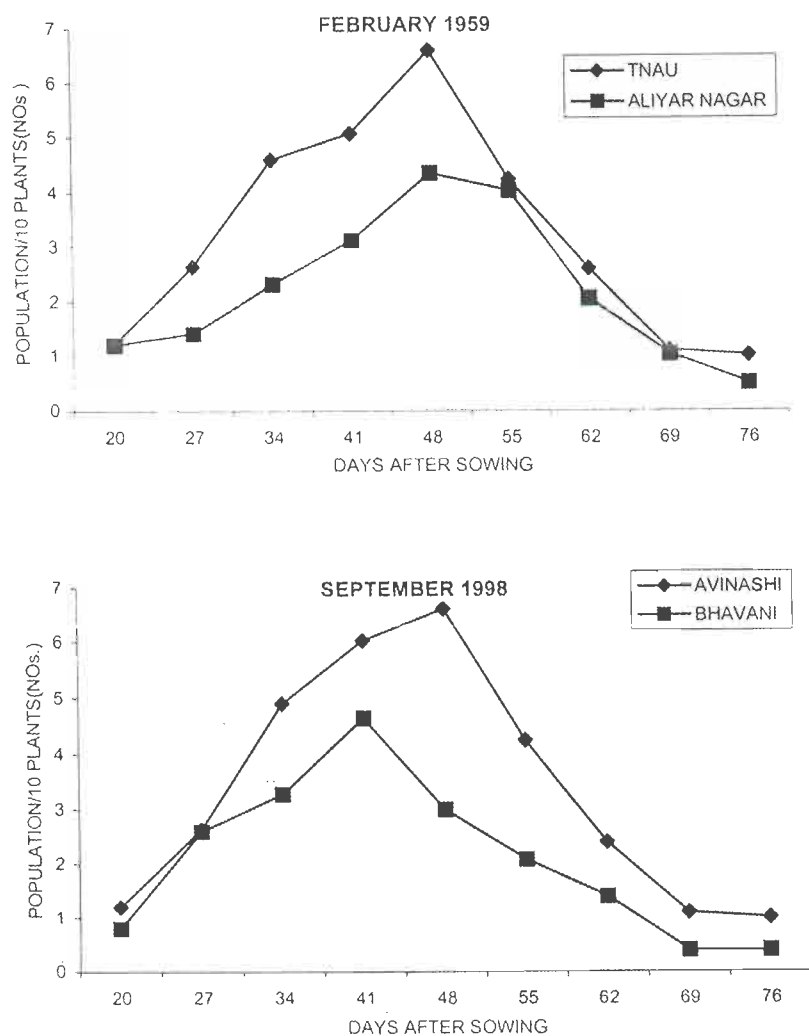
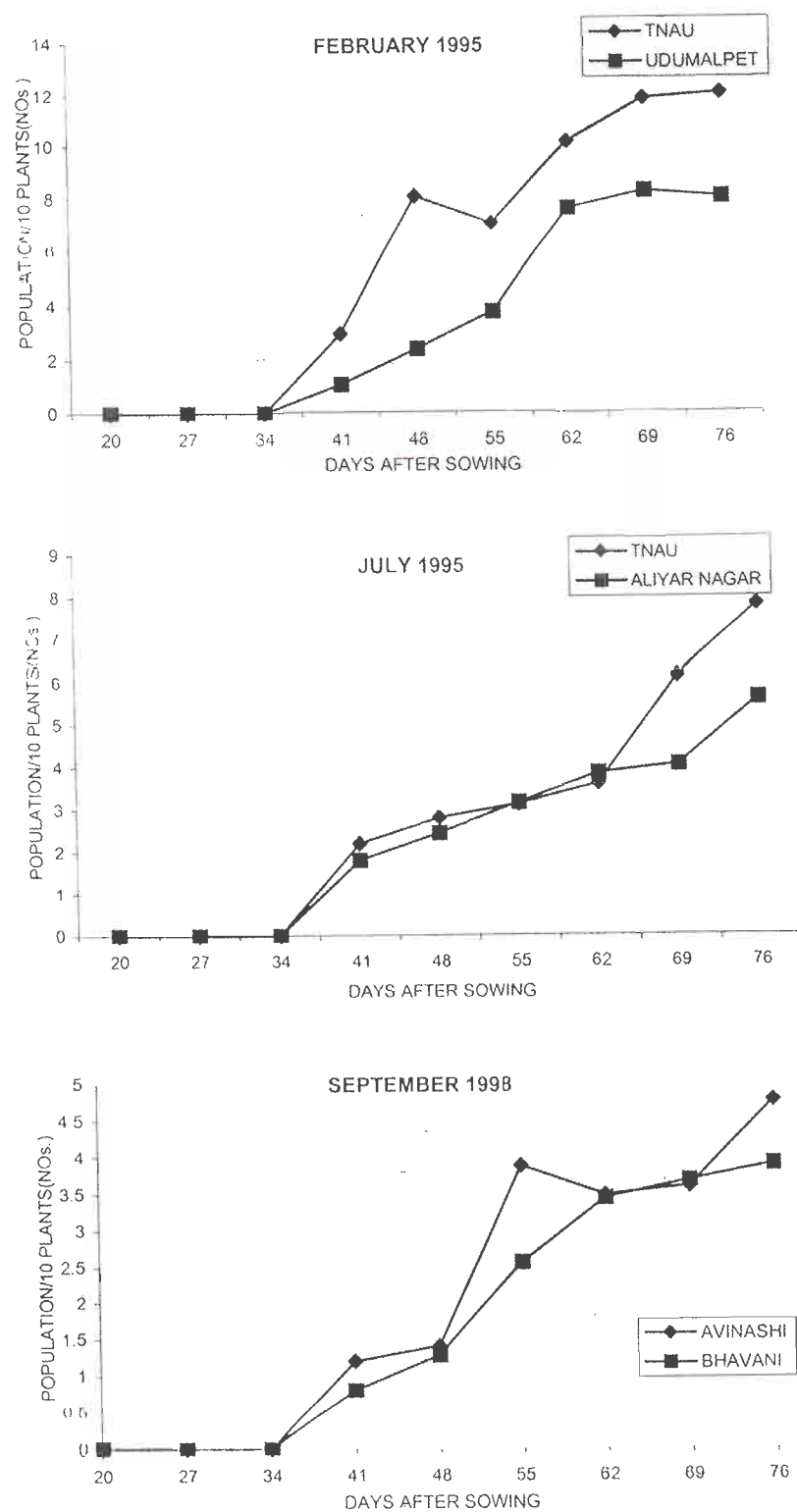


**Fig. 7 Seasonal incidence of soybean insect pest -  
Pod sucking bug, *Nezara viridula***



positive ( $r^2 = 0.96^{**}$  and  $0.78^{**}$ ). During this peak period, soybean crop was in flowering to pod formation stage. Highly significant correlation existed during July season also at Aliyarnagar. The peak activity of the moth was noticed during September'98 at Avinashi and Bhavani and a highly positive correlation ( $r^2 = 0.70^{**}$  and  $0.78^{**}$ ) existed between moth traps collection and field population in both the locations (Table 4).

#### 4.2.2. *S litura*

Pheromone traps developed by Bio-Control Research Laboratory (BCRL), Bangalore were installed at TNAU and in farmer's field at Udumalpet during February'95 and at Avinashi and Bhavani during September'98.

Field observations collected during February'95 from 20 DAS onwards indicated that there was a highly significant positive correlation ( $r^2 = 0.51^*$  and  $0.60^*$ ) existed between the moth activity and the field population. Similarly highly positive relations ( $r^2 = 0.63^*$  and  $0.56^*$ ) existed between the population of larvae and with moth collection both at Avinashi and Bhavani (Table 4).

### 4.3 STUDIES ON THE INFLUENCE OF WEATHER PARAMETERS ON THE POPULATION / DAMAGE OF KEY PESTS OF SOYBEAN

Field experiments were conducted at farmer's field at Aliyarnagar and TNAU to assess the insect pests population in soybean crop. Weather factors viz., maximum temperature ( $x_1$ ), minimum temperature ( $x_2$ ), growing degree day (GDD) ( $x_3$ ), photothermal unit (PTU) ( $x_4$ ), rainfall ( $x_5$ ) and relative humidity morning ( $x_6$ ) and relative humidity evening ( $x_7$ ) play vital role on the growth and movement of the insect populations.

**Table 4. Linear regression and correlation between pheromone trap catches of male moths and number of larvae in the field**

| Name of insect pests        | Location and Seasons  | Regression equation | F        | r <sup>2</sup> |
|-----------------------------|-----------------------|---------------------|----------|----------------|
| <i>Helicoverpa armigera</i> | July 1995<br>TNAU     | $Y=11.81 + 1.0962x$ | 165.73** | 0.96**         |
|                             | Aliyarnagar           | $Y=8.83 + 0.6894x$  | 25.03**  | 0.78**         |
|                             | Sep 1998<br>Avinashi  | $Y=11.26 + 0.4451x$ | 15.98**  | 0.70**         |
|                             | Bhavani               | $Y=5.60 + 0.7925x$  | 25.36**  | 0.78**         |
| <i>Spodoptera litura</i>    | Feb'1995<br>Udumalpet | $Y=9.31 + 0.6155x$  | 7.36*    | 0.51*          |
|                             | TNAU                  | $Y=4.37 + 0.9064x$  | 13.79*   | 0.60*          |
|                             | Sep'1998<br>Avinashi  | $Y=0.82 + 0.8646x$  | 12.14*   | 0.63*          |
|                             | Bhavani               | $Y=3.14+1.0123x$    | 7.80*    | 0.56*          |

ns-not significant

\*-Significant at 5% level

\*\*.-Significant at 1% level

The multiple regression analyses of these weather factors, were worked out using the data collected during 1995 in the Agricultural Research Station at Aliyarnagar, Pollachi and at the Meteorological Observatory, TNAU, Coimbatore against different insect pests prevalent in the experimental fields at Aliyarnagar and TNAU during July 1995.

#### 4.3.1. Sucking pests

The weather parameters had no significant influence over the sucking pests. But, at Aliyarnagar the minimum temperature, GDD, PTU and rainfall showed significant negative influence over the leafhopper population (Table 5). Similarly, the maximum temperature had negative effect on the population and other factors had no significant effect over the population at Aliyarnagar and at TNAU, Coimbatore during July '95 (Table 5).

Even though the regression fitted was not significant, (Table 8) the maximum temperature, GDD and PTU had significant negative influence on the whitefly population at TNAU, Coimbatore and rainfall had significant positive correlation with the population, whereas at Aliyarnagar, minimum temperature alone had significant negative correlation with population (Table 5).

#### 4.3.2. Leafminer - *A. modicella*

The study indicated that the combined effect of maximum temperature, minimum temperature, GDD, PTU, rainfall and relative humidity had significant influence over the soybean leafminer ( $R^2 = 0.83^*$ ) (Tables 5&8). Among the different weather parameters at Aliyarnagar, maximum temperature, minimum temperature, and PTU had a negative and significant effect on *A.modicella* while the influence of other factors was not significant. The correlation matrix is given in (Tables 5&8).

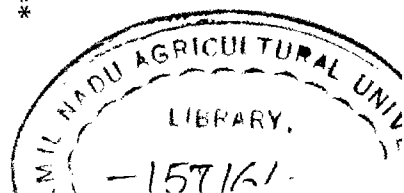
Table 5 : Correlation between weather factors and incidences of insect pests of soybean at Aliyarnagar and TNAU

| Insect Pests                                   | Station | Max. Temp | Min. Temp. | GDD      | PTU      | Rainfall | RHM    | RHE    |
|------------------------------------------------|---------|-----------|------------|----------|----------|----------|--------|--------|
| Leafhopper-<br><i>Empoasca fabae</i>           | Aliyar  | -0.511    | -0.682**   | -0.590*  | -0.581*  | -0.019   | -0.148 | -0.208 |
|                                                | TNAU    | -0.023    | -0.093     | -0.356   | -0.297   | -0.234   | 0.261  | -0.101 |
| Whitefly-<br><i>Bemisia tabaci</i>             | Aliyar  | -0.383    | -0.643**   | -0.456   | -0.441   | -0.033   | 0.008  | -0.049 |
|                                                | TNAU    | -0.696**  | 0.012      | -0.743** | -0.571*  | 0.613*   | -0.046 | 0.220  |
| Leaf miner-<br><i>Aproaerema<br/>modicella</i> | Aliyar  | -0.534*   | -0.691**   | -0.509   | -0.529** | -0.055   | 0.113  | -0.139 |
|                                                | TNAU    | 0.137     | -0.136     | -0.150   | -0.459   | -0.026   | 0.356  | 0.157  |
| <i>Helicoverpa<br/>armigera</i>                | Aliyar  | 0.174     | -0.488     | -0.010   | -0.011   | -0.351   | 0.216  | -0.018 |
|                                                | TNAU    | -0.254    | -0.335     | -0.574*  | -0.576*  | 0.190    | 0.395  | -0.139 |

ns - not significant

\* - Significant at 5% level

\*\* - Significant at 1% level



Similarly, the multiple regression analysis of the weather factors at TNAU showed significant influence on the leafminer population. Even though the effect was not significant, a negative influence was seen between minimum temperature, GDD and PTU. The interrelationship among the different weather variables showed significant regression ( $R^2 = 0.76$ ) (Tables 5&7).

#### **4.3.3 *H. armigera***

Significant influence of the weather factors observed at TNAU, Coimbatore was regressed with various independent variables of weather parameters. The regression was significant ( $r^2 = 0.84^*$ ). GDD and PTU had significant negative influence on the population. The other parameters showed no significant influence (Tables 5&8).

The influence of weather factors was not significant at Aliyarnagar and Coimbatore for *H. armigera* population (Table 5).

#### **4.3.4. NATURAL ENEMIES**

##### **4.3.4.1. Spiders**

At Aliyarnagar, the weather factors viz., maximum temperature, minimum temperature, GDD and PTU had significant negative influence over the natural enemies like spiders ( $R^2 = 0.83^*$ ) whereas other factors showed no significant influences over the spiders population (Tables 6&9).

But at TNAU, Coimbatore maximum temperature, GDD and rainfall had significant negative influence over predators and other factors had no significant effect except rainfall which showed some positive significant effect on the spider population. (Tables 6&9).

Table 6 : Correlation between weather factors and incidences of natural enemies of soybean at Aliyarnagar and TNAU

| Natural enemies | Station | Max.Temp | Min.Temp. | GDD      | PTU      | Rainfall | RHM    | RHE    |
|-----------------|---------|----------|-----------|----------|----------|----------|--------|--------|
| Spiders         | Aliyar  | -0.567*  | -0.688**  | -0.681** | -0.695** | 0.151    | -0.209 | 0.257  |
|                 | TNAU    | -0.653** | -0.028    | -0.767** | -0.584   | 0.583*   | 0.269  | 0.134  |
| Coccinellid     | Aliyar  | +0.369   | -0.631*   | -0.564   | -0.580*  | 0.164    | -0.037 | -0.197 |
|                 | TNAU    | -0.666** | -0.112    | -0.738** | -0.475   | 0.542*   | 0.053  | 0.454  |

ns - not significant

\* - Significant at 5% level

\*\* - Significant at 1% level

Table 7 : Correlation among weather factors for Aliyarnagar and TNAU

| Station     | Max.Temp<br>(X1) | Min.Temp.<br>(X2) | GDD<br>(X3) | PTU<br>(X4) | Rainfall<br>(X5) | RHM<br>(X6) | RHE<br>(X7) |
|-------------|------------------|-------------------|-------------|-------------|------------------|-------------|-------------|
| Aliyarnagar | X1               | 0.574*            | 0.552*      | 0.582*      | -0.150           | 0.482       | 0.384       |
|             | X2               | 1.000             | 0.224       | 0.239       | 0.248            | 0.161       | 0.490       |
|             | X3               | 0.224             | 1.000       | 0.996**     | -0.270           | 0.407       | 0.100       |
|             | X4               | 0.239             | 0.996       | 1.000       | -0.268           | 0.394       | -0.142      |
|             | X5               | 0.248             | -0.270      | -0.268      | 1.000            | -0.145      | 0.339       |
|             | X6               | 0.161             | 0.407       | 0.394       | -0.145           | 1.000       | 0.248       |
|             | X7               | 0.490             | 0.100       | 0.142       | 0.339            | 0.248       | 1.000       |
| TNAU        | X1               | 0.130             | 0.887**     | 0.683**     | -507*            | 0.117       | -0.514*     |
|             | X2               | 1.000             | 0.241       | 0.119       | 0.589*           | 0.134       | -0.179      |
|             | X3               | 0.241             | 1.000       | 0.758**     | -0.401           | -0.616      | -0.409      |
|             | X4               | 0.119             | 0.758       | 1.000       | -0.362           | -0.199      | -0.217      |
|             | X5               | 0.589             | -0.401      | -0.362      | 1.000            | 0.079       | 0.070       |
|             | X6               | 0.134             | -0.116      | -0.199      | 0.079            | 1.000       | 0.087       |
|             | X7               | -0.179            | -0.409      | -0.217      | 0.070            | 0.087       | 1.000       |

ns - not significant

\* - Significant at 5% level

\*\* - Significant at 1% level

#### 4.3.4.2. Coccinellid

The natural enemies population like coccinellids viz., *Menochilus sexmaculatas* were abundant during observations made at Aliyarnagar and TNAU during July season.

The coccinellid populations prevalent in Aliyarnagar and TNAU were also correlated and the results are presented in Tables 6&9. The maximum temperature, and GDD had highly significant negative influence with coccinellid population whereas the rainfall had significant positive correlation with the population. But, only minimum temperature and PTU had significant negative correlation with the population prevalent at Aliyarnagar. Rainfall had no significant influence over the population.

The multiple regression equations for these natural enemies are presented in Table 8.

#### 4.3.5. STUDY ON THE EFFECT OF LEAF TEMPERATURE ON INSECT PESTS OF SOYBEAN

##### 4.3.5.1.ON SUCKING PESTS

##### 4.3.5.1.1. Leaf hopper - *Empoasca fabae*

In this experiment, significant positive correlation was observed between the population and leaf temperature. The leaf temperature at 27 DAS was found to have significant effect on the population on 30 DAS. The temperature recorded during 37 DAS had highly significant correlation with the population observed during 40 DAS. Subsequent population recorded at 50 DAS was also greatly influenced by the leaf temperature at 47 DAS. The leaf temperature at 57 DAS was found to have no influence over the population during 60 DAS. At the later stage of the crop the leaf temperature at 67 DAS had effective correlation with

Table 8 : Multiple regression of incidences of insect pests of soybean(Y) on weather factors (X)

| Insect Pests                               | Station | Regression equation                                                                              | R <sup>2</sup> |
|--------------------------------------------|---------|--------------------------------------------------------------------------------------------------|----------------|
| Leafhopper-<br><i>Empoasca fabae</i>       | Aliyar  | $Y = 48.62 - 0.0958x_1 - 1.2136x_2 - 0.9117x_3 + 0.0563x_4 + 0.0233x_5 + 0.1395x_6 + 0.0031x_7$  | 0.73ns         |
|                                            | TNAU    | $Y = -18.89 + 6.5988x_1 - 0.7745x_2 - 1.3045x_3 - 0.0063x_4 + 0.5148x_5 - 0.2193x_6 + 0.0982x_7$ | 0.76*          |
| White fly-<br><i>Bemisia tabaci</i>        | Aliyar  | $Y = 15.93 - 0.0196x_1 - 0.5682x_2 - 0.3491x_3 + 0.0221x_4 + 0.0005x_5 + 0.0773x_6 + 0.0303x_7$  | 0.68ns         |
|                                            | TNAU    | $Y = 25.54 + 0.6310x_1 - 0.1362x_2 - 0.2906x_3 - 0.0007x_4 + 0.1007x_5 - 0.0874x_6 + 0.0122x_7$  | 0.72ns         |
| Leaf miner-<br><i>Aproaerema modicella</i> | Aliyar  | $Y = 12.53 - 0.0922x_1 - 0.5876x_2 + 0.1889x_3 - 0.0194x_4 - 0.0057x_5 + 0.11x_6 + 0.0565x_7$    | 0.83*          |
|                                            | TNAU    | $Y = -25.26 + 3.3442x_1 - 0.4932x_2 - 0.3263x_3 - 0.0203x_4 + 0.1310x_5 - 0.0685x_6 + 0.0627x_7$ | 0.76*          |
| <i>Helicoverpa armigera</i>                | Aliyar  | $Y = 3.00 + 0.6595x_1 - 0.9200x_2 + 0.4984x_3 - 0.0410x_4 - 0.0197x_5 - 0.0312x_6 + 0.0787x_7$   | 0.71ns         |
|                                            | TNAU    | $Y = 1.62 + 0.9464x_1 - 0.2918x_2 - 0.1863x_3 - 0.0029x_4 + 0.0583x_5 + 0.067x_6 + 0.0073x_7$    | 0.84*          |

ns - not significant  
 \* - Significant at 5% level  
 \*\* - Significant at 1% level

Table 9 : Multiple regression of incidences of natural enemies (Y) of soybean pests on weather factors (X)

| Insect Pests | Station | Regression equation                                                                               | r <sup>2</sup> |
|--------------|---------|---------------------------------------------------------------------------------------------------|----------------|
| Spiders      | Aliyar  | $Y = 209.71 + 1.9275x_1 - 7.4269x_2 + 1.9885x_3 - 0.2216x_4 + 0.1929x_5 + 0.0898x_6 + 0.1869$     | 0.83*          |
|              | TNAU    | $Y = 153.57 + 12.5539x_1 - 0.9740x_2 - 3.9623x_3 - 0.0150x_4 + 0.9593x_5 - 0.9017x_6 + 0.6001x_7$ | 0.74ns         |
| Coccinellid  | Aliyar  | $Y = 138.16 + 3.3829x_1 - 8.0251x_2 + 2.8678x_3 - 0.2841x_4 + 0.2689x_5 + 0.3714x_6 + 0.1799$     | 0.76ns         |
|              | TNAU    | $Y = 28.54 + 2.7889x_1 - 0.9153x_2 - 0.8620x_3 + 0.0041x_4 + 0.3504x_5 - 0.1717x_6 + 0.2146x_7$   | 0.78*          |

ns - not significant

\* - Significant at 5% level

\*\* - Significant at 1% level

the population observed on 70 DAS (Table 10). The effect of leaf temperature on the population during crop growth stages from 27 to 67 DAS was very significant which had significant influence over the leaf hoppers population observed from 30 to 70 DAS.

#### **4.3.5.1.2 Whiteflies : *Bemisia tabaci***

The leaf temperature recorded during 27 DAS had significant correlation with the population at 30 DAS. The leaf temperature recorded during 37 DAS had highly significant correlation with the population recorded during 40 DAS. Subsequent temperature recorded at 57 DAS had significant impact over the population developed at 60 DAS (Table 11).

### **4.3.6. DEFOLIATORS**

#### **4.3.6.1. Leafminer : *Approaerema modicella***

The leafminer incidence was observed from 37 DAS. Hence the population count was recorded from 40 DAS onwards and data were correlated. It was found that the leaf temperature recorded at 47 DAS had highly significant correlation with the population of 50 DAS. The subsequent leaf temperature recorded at 57 DAS and 67 DAS had no significant correlation with the population at 60 DAS and 70 DAS (Table 12).

### **4.3.6. STUDY ON THE EFFECT OF LEAF HUMIDITY ON THE INSECT PESTS OF SOYBEAN**

#### **4.3.7.1. ON SUCKING PESTS**

##### **4.3.7.1.1. Leaf hopper - *Empoasca fabae***

The leaf humidity recorded at 27 DAS had no significant effect over the population observed during 30 DAS. But, the leaf humidity prevalent on 37 DAS had significant correlation with the population of 40 DAS. The leaf humidity

Table 10. Effect of leaf temperature on the incidence of leafhopper – *Empoasca fabae* on soybean

(n=30)

| Temperature reading | Population | Correlation coefficient | Regression coefficient | 't'     | 'r <sup>2</sup> ' | 'F'     |
|---------------------|------------|-------------------------|------------------------|---------|-------------------|---------|
| 27 DAS              | 20 DAS     | 0.383*                  | Y=-5.63+0.2258x*       | 2.20*   | 0.15*             | 4.82*   |
|                     | 30 DAS     | 0.736**                 | Y=-21.82+0.8423x**     | 5.76*   | 0.54**            | 33.17** |
| 37 DAS              | 30 DAS     | 0.053ns                 | Y=-2.92+0.2161xns      | 0.28ns  | 0.003ns           | <1      |
|                     | 40 DAS     | -0.583**                | Y=37.57-1.4562x**      | -3.79** | 0.34**            | 14.38** |
| 47 DAS              | 40 DAS     | -0.602**                | Y=12.50-0.4285x**      | -3.99** | 0.36**            | 15.93** |
|                     | 50 DAS     | -0.594**                | Y=23.0-0.8302x**       | -3.91** | 0.35**            | 15.28** |
| 57 DAS              | 50 DAS     | -0.737**                | Y=23.0-0.6960x**       | -5.78** | 0.54**            | 33.36** |
|                     | 60 DAS     | 0.45ns                  | Y=0.3+0.0106xns        | 0.24ns  | 0.002ns           | <1      |
| 67 DAS              | 60 DAS     | 0.149ns                 | Y=0.2+0.1359xns        | 0.80ns  | 0.02ns            | <1      |
|                     | 70 DAS     | -0.468**                | Y=2.0-0.448x**         | -2.80*  | 0.22**            | 7.83**  |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

Table 11: effect of leaf temperature on the incidence of whitefly – *Bemisia tabaci* on soybean

| (n=30)              |            |                         |                        |         |                   |         |
|---------------------|------------|-------------------------|------------------------|---------|-------------------|---------|
| Temperature reading | Population | Correlation Coefficient | Regression coefficient | 't'     | 'r <sup>2</sup> ' | 'F'     |
| 27 DAS              | 20 DAS     | -0.129ns                | Y=4.07-0.4007xns       | -0.69ns | 0.02ns            | <1      |
|                     | 30 DAS     | -0.456*                 | Y=-5.77+0.2291x*       | 2.71    | 0.21*             | 7.35*   |
| 37 DAS              | 30 DAS     | -0.285ns                | Y=-11.84+0.5119ns      | 1.57ns  | 0.08ns            | 2.48ns  |
|                     | 40 DAS     | -0.795**                | Y=-48.67+2.0136x**     | 6.94**  | 0.63**            | 48.23** |
| 47 DAS              | 40 DAS     | -0.595**                | Y=-10.10+0.4287x**     | 3.92**  | 0.35**            | 15.34** |
|                     | 50 DAS     | -0.334ns                | Y=-4.0+0.2000xns       | 1.87ns  | 0.11ns            | 3.51ns  |
| 57 DAS              | 50 DAS     | -0.535**                | Y=-5.0+0.2167x**       | 3.35**  | 0.29**            | 11.23** |
|                     | 60 DAS     | -0.505**                | Y=-11.0+0.4121x**      | 3.10**  | 0.26**            | 9.61**  |
| 67 DAS              | 60 DAS     | 0.613**                 | Y=-5.0+0.1913x**       | 4.11**  | 0.38**            | 16.85** |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

Table 12. Effect of leaf temperature on the incidence of leaf miner-*Apraerema modicella* on soybean

| Temperature reading | Population | Correlation Coefficient | Regression coefficient | 't'     | 'r <sup>2</sup> ' | 'F'     |
|---------------------|------------|-------------------------|------------------------|---------|-------------------|---------|
| (n=30)              |            |                         |                        |         |                   |         |
| 47 DAS              | 40 DAS     | 0.714**                 | Y=-9+0.4049x**         | 5.39**  | 0.51**            | 29.04** |
|                     | 50 DAS     | 0.555**                 | Y=-11.0+0.4971x**      | 3.53**  | 0.31**            | 12.48** |
| 57 DAS              | 50 DAS     | -0.483**                | Y=-7+0.2920x**         | 2.92**  | 0.23**            | 8.51**  |
|                     | 60 DAS     | -0.266ns                | Y=-2+0.1560xns         | 1.46ns  | 0.07ns            | 2.14ns  |
| 67 DAS              | 60 DAS     | -0.320ns                | Y=0.3+0.0718xns        | 1.79ns  | 0.10ns            | 3.20ns  |
|                     | 70 DAS     | -0.151ns                | Y=4-0.03ns             | -0.81ns | 0.02ns            | <1      |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

prevailed during 47 DAS, had no significant effect on the population of 50 DAS. It was found that the leaf humidity at the later stages at 57 DAS and 67 DAS had high significant correlation with the population at 60 and 70 DAS (Table 13).

#### **4.3.7.1.2. Whiteflies - *Bemisia tabaci***

The leaf humidity prevalent at the earlier stage (27 days) of the crop had no significant effect on the population observed on 30 DAS. The leaf humidity at 37 and 47 DAS had significant correlation with the population of 40 and 50 DAS. Similarly, the leaf humidity at 57 DAS had no significant influence over population at 60 DAS. Subsequently, leaf humidity had no effect on the population recorded at 70 DAS (Table 14).

### **4.3.7.2. ON DEFOLIATORS**

#### **4.3.7.2.1. Leafminer - *A.modicella***

The leaf humidity prevalent during 47 DAS had high by significant correlation with the leafminer population during 50 DAS. But the leaf humidity observed at 57 DAS had no influence over the population at 60 DAS. The leaf humidity at 67 DAS had significant effect on the population at 70 DAS (Table 15).

## **4.4. EFFECT OF SPACING AND FERTILIZERS ON THE INCIDENCE OF INSECT PESTS OF SOYBEAN**

### **4.4.1 EFFECT OF SPACING ON SUCKING PESTS**

#### **4.4.1.1. Leaf hopper - *Empoasca fabae***

Results from the experiment conducted at Udumalpet are furnished in Table 16. Soybean planted with wider spacing (45x10cm) recorded significant by lowest incidence of population per plant (5.40) when compared to other spacing levels. The mean population observed was higher in closer spacing (30x10 cm) (12.30) followed by 7.10 population in 40 x 10 cm spacing.

Table 13. Effect of leaf relative humidity on the incidence of leafhopper – *Empoasca fabae* on soybean

| (n=30)              |            |                         |                        |        |                   |         |
|---------------------|------------|-------------------------|------------------------|--------|-------------------|---------|
| Temperature reading | Population | Correlation coefficient | Regression coefficient | 't'    | 'r <sup>2</sup> ' | 'F'     |
| 27 DAS              | 20 DAS     | -0.342ns                | Y=-5.71+0.1859xns      | 1.92ns | 0.12ns            | 3.70ns  |
|                     | 30 DAS     | -0.063ns                | Y=0.02+0.0219ns        | 0.33ns | 0.004ns           | <1      |
| 37 DAS              | 30 DAS     | -0.24 ns                | Y=4.20+0.1623xns       | 1.03ns | 0.21ns            | 2.68ns  |
|                     | 40 DAS     | 0.568**                 | Y=-6.17+0.1532x**      | 3.65** | 0.32**            | 13.35** |
| 47 DAS              | 40 DAS     | 0.352ns                 | Y=-5+0.1476ns          | 1.96ns | 0.12ns            | 3.84ns  |
|                     | 50 DAS     | 0.196ns                 | Y=-1+0.0725ns          | 1.04ns | 0.038ns           | 1.08ns  |
| 57 DAS              | 50 DAS     | 0.442*                  | Y=-1.0+0.903x*         | 2.61*  | 0.20*             | 6.81*   |
|                     | 60 DAS     | 0.452*                  | Y=-4+0.1855x*          | 2.68*  | 0.20*             | 7.17*   |
| 67 DAS              | 60 DAS     | 0.493**                 | Y=-6+0.2073x**         | 3.00** | 0.24**            | 8.99**  |
|                     | 70 DAS     | -0.393*                 | Y=5.0-0.1043x*         | -2.26* | 0.15*             | 5.11*   |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

Table 14 : Effect of leaf relative humidity on the incidence of whitefly – *Bemisia tabaci* on soybean

(n=30)

| Temperature reading | Population | Correlation Coefficient | Regression coefficient | 't'     | 'r <sup>2</sup> ' | 'F'     |
|---------------------|------------|-------------------------|------------------------|---------|-------------------|---------|
| 27 DAS              | 20 DAS     | 0.227ns                 | Y=-2.58+0.0931xns      | 1.23ns  | 0.05ns            | 1.52ns  |
|                     | 30 DAS     | 0.130ns                 | Y=-1.40+0.1037xns      | 0.69ns  | 0.02ns            | <1      |
| 37 DAS              | 30 DAS     | -0.752**                | Y=11.12-0.2002x**      | -6.04** | 0.57**            | 36.46** |
|                     | 40 DAS     | -0.361*                 | Y=9.23-0.1076x*        | -2.81*  | 0.19*             | 6.76*   |
| 47 DAS              | 40 DAS     | -0.743**                | Y=13.50-0.3136x**      | -5.76** | 0.55**            | 33.18** |
|                     | 50 DAS     | -0.457*                 | Y=17.0-3896x*          | -2.67*  | 0.21*             | 7.13*   |
| 57 DAS              | 50 DAS     | -0.672**                | Y=12.0-0.3194x**       | -4.80** | 0.45**            | 23.00** |
|                     | 60 DAS     | -0.301ns                | Y=-1+0.0359ns          | 1.67ns  | 0.09ns            | 2.80ns  |
| 67 DAS              | 60 DAS     | 0.180ns                 | Y=-0.1+0.0220xns       | 0.97ns  | 0.032ns           | <1      |
|                     | 70 DAS     | -0.304ns                | Y=2.0-0.0393ns         | -1.69ns | 0.09ns            | 2.86ns  |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

Table 15 : Effect of leaf relative humidity on the incidence of leaf miner-*Approaerema modicella* on soybean

(n=30)

| Temperature reading | Population | Correlation Coefficient | Regression coefficient | 't'    | 'r <sup>2</sup> ' | 'F'    |
|---------------------|------------|-------------------------|------------------------|--------|-------------------|--------|
| 47 DAS              | 40 DAS     | 0.465*                  | Y=-5+0.1577x*          | 2.73*  | 0.22*             | 7.45*  |
|                     | 50 DAS     | 0.475**                 | Y=-8+0.2444x**         | 2.80** | 0.23**            | 7.86** |
| 57 DAS              | 50 DAS     | 0.456*                  | Y=-3+0.1391x*          | 2.71*  | 0.21*             | 7.36*  |
|                     | 60 DAS     | 0.229ns                 | Y=1+0.0677xns          | 1.25ns | 0.05ns            | 1.56ns |
| 67 DAS              | 60 DAS     | 0.226ns                 | Y=0.3+0.0682xns        | 1.23ns | 0.05ns            | 1.51ns |
|                     | 70 DAS     | -0.422**                | Y=7.0-0.1095x*         | -2.47* | 0.18*             | 6.08*  |

ns-Non significant

\*Significant at 5% level

\*\*Significant at 1% level

DAS-Days After Sowing

**Table 16 . Effect of spacing and fertiliser on the incidence of leafhopper - *Empoasca fabae* on soybean\***

**Location : Udumalpet**

| Treatments                                                                                                       | Nos. / 3 Leaves              |                             |                             | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|-----------------------------|-----------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                  | 45 x 10 cm                  |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal                                                              | 12.40<br>(3.39)              | 7.90<br>(2.71)              | 5.90<br>(2.37)              | 8.70<br>(2.82) <sup>cd</sup> |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 11.60<br>(3.28)              | 6.80<br>(2.55)              | 4.80<br>(2.21)              | 7.70<br>(2.68) <sup>b</sup>  |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 14.00<br>(3.58)              | 8.00<br>(2.76)              | 6.00<br>(2.42)              | 9.30<br>(2.92) <sup>dc</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 10.70<br>(3.14)              | 6.60<br>(2.52)              | 4.60<br>(2.14)              | 7.30<br>(2.61) <sup>ab</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 10.70<br>(3.14)              | 6.00<br>(2.42)              | 4.30<br>(2.11)              | 7.00<br>(2.55) <sup>a</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 14.70<br>(3.84)              | 7.50<br>(2.71)              | 6.80<br>(2.61)              | 9.70<br>(3.01) <sup>c</sup>  |
| Mean                                                                                                             | 12.30<br>(3.39) <sup>c</sup> | 7.10<br>(2.61) <sup>b</sup> | 5.40<br>(2.31) <sup>a</sup> | 8.28<br>(2.77)               |

|       |   |        |   |            |
|-------|---|--------|---|------------|
|       |   | Space  |   | Fertiliser |
| SE(d) | - | 0.0403 | - | 0.059      |
| CD    | - | 0.112  | - | 0.118      |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

Table 17 indicates the results of the effect of spacing on the population of leaf hoppers on soybean at Avinashi. The mean incidence recorded in all the three spacing levels were on par. The different spacing levels had no effect on the population of leaf hoppers.

#### **4.4.1.2 Whiteflies - *Bemisia tabaci***

The results on the effect of different levels of spacing on the incidence of whiteflies of soybean crop in the field experiments conducted at Udumalpet and Avinashi are furnished in Table 18 and Table 19, respectively.

There was no significant difference on the mean population level between the three levels of spacing in the experiment conducted at Udumalpet. The mean population ranged from 7.41 to 8.33 per plant (Table 18). But, at Avinashi lower mean population (2.37) was recorded in wider spacing. Higher population of 4.23 per plant was observed with closer spacing (30 x 10 cm) (Table 19).

### **4.4.2. EFFECT SPACING ON DEFOLIATORS**

#### **4.4.2.1. Leafminer (*A.modicella*)**

Table 20 indicates the effect of different levels of spacing on the incidence of soybean leafminer at Udumalpet.

Wider spacing (45x10 cm) recorded significantly lower mean per cent leaf damage (11.08) when compared to other spacing levels. The closer spacing (30x10 cm) and the medium spacing (40x10 cm) had recorded the mean leaf damage upto 15.74 and 13.36 per cent, respectively which were on par with each other.

**Table 17 . Effect of spacing and fertiliser on the incidence of leafhopper - *Empoasca fabae* on soybean\***

**Location : Avinashi**

| Treatments                                                                                                       | Nos / 3 leaves              |                             |                             | Mean                         |
|------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                  | 40 x 10 cm                  | 45 x 10 cm                  |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 11.50<br>(3.25)             | 8.50<br>(2.87)              | 7.42<br>(2.67)              | 9.14<br>(2.93) <sup>d</sup>  |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 10.25<br>(3.13)             | 8.17<br>(2.85)              | 7.38<br>(2.73)              | 8.60<br>(2.91) <sup>d</sup>  |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 9.17<br>(2.96)              | 7.58<br>(2.76)              | 6.29<br>(2.55)              | 7.68<br>(2.76) <sup>c</sup>  |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 4.21<br>(2.09)              | 4.13<br>(2.11)              | 3.08<br>(1.85)              | 3.81<br>(2.01) <sup>a</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 4.17<br>(2.08)              | 4.42<br>(2.15)              | 3.83<br>(2.03)              | 4.14<br>(2.08) <sup>b</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 13.50<br>(3.55)             | 8.88<br>(2.97)              | 9.17<br>(3.03)              | 10.51<br>(3.18) <sup>c</sup> |
| Mean                                                                                                             | 8.80<br>(2.84) <sup>a</sup> | 6.94<br>(2.62) <sup>a</sup> | 6.19<br>(2.48) <sup>a</sup> | 7.31<br>(2.65)               |

|       |   |       |   |            |
|-------|---|-------|---|------------|
|       |   | Space |   | Fertiliser |
| SE(d) | - | 1.009 | - | 1.406      |
| CD    | - | 0.987 | - | 0.027      |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

Table 18 . Effect of spacing and fertiliser on the incidence of whitefly - *Bemisia tabaci* on soybean\*

Location : Udumalpet

| Treatments                                                                                                       | Nos / 3 Leaves              |                             |                             | Mean                         |
|------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                  | 40 x 10 cm                  | 45 x 10 cm                  |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 6.99<br>(1.90)              | 8.10<br>(2.02)              | 7.86<br>(1.99)              | 7.65<br>(1.97) <sup>cd</sup> |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 7.76<br>(1.96)              | 8.40<br>(2.06)              | 9.44<br>(2.11)              | 8.53<br>(2.04) <sup>de</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 8.22<br>(1.99)              | 9.10<br>(2.10)              | 10.30<br>(2.13)             | 9.21<br>(2.07) <sup>e</sup>  |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 5.85<br>(1.73)              | 6.46<br>(1.83)              | 5.22<br>(1.59)              | 5.84<br>(1.72) <sup>a</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 7.14<br>(1.88)              | 7.80<br>(1.99)              | 7.07<br>(1.83)              | 7.33<br>(1.90) <sup>b</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 8.48<br>(2.05)              | 10.10<br>(2.18)             | 9.60<br>(2.10)              | 9.40<br>(2.10) <sup>e</sup>  |
| Mean                                                                                                             | 7.41<br>(1.92) <sup>a</sup> | 8.33<br>(2.03) <sup>a</sup> | 8.25<br>(1.96) <sup>a</sup> | 7.99<br>(1.97)               |

|       |   |       |   |            |
|-------|---|-------|---|------------|
|       |   | Space |   | Fertiliser |
| SE(d) | - | 0.075 | - | 0.024      |
| CD    | - | 0.973 | - | 0.067      |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

**Table 19. Effect of spacing and fertiliser on the incidence of whitefly - *Bemisia tabaci* on soybean\***

**Location : Avinashi**

| Treatments                                                                                                       | Nos / 3 Leaves               |                             |                             | Mean                          |
|------------------------------------------------------------------------------------------------------------------|------------------------------|-----------------------------|-----------------------------|-------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                  | 45 x 10 cm                  |                               |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal                                                              | 6.00<br>(2.49)               | 3.81<br>(2.10)              | 2.81<br>(1.78)              | 4.20<br>(2.09) <sup>d</sup>   |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 3.23<br>(1.90)               | 2.81<br>(1.78)              | 2.64<br>(1.72)              | 2.92<br>(1.80) <sup>c</sup>   |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 3.21<br>(1.89)               | 2.61<br>(1.72)              | 2.84<br>(1.79)              | 2.92<br>(1.80) <sup>c</sup>   |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 1.66<br>(1.44)               | 2.51<br>(1.71)              | 1.43<br>(1.37)              | 1.80<br>(1.51) <sup>a</sup>   |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 2.52<br>(1.70)               | 3.13<br>(1.89)              | 1.30<br>(1.34)              | 2.30<br>(1.65) <sup>abc</sup> |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 8.81<br>(3.01)               | 5.82<br>(2.44)              | 3.44<br>(1.93)              | 6.00<br>(2.47) <sup>e</sup>   |
| Mean                                                                                                             | 4.23<br>(2.07) <sup>bc</sup> | 3.45<br>(1.94) <sup>b</sup> | 2.37<br>(1.66) <sup>a</sup> | 3.30<br>(1.88)                |

|       |         |            |
|-------|---------|------------|
|       | Space   | Fertiliser |
| SE(d) | - 0.070 | - 0.025    |
| CD    | - 0.141 | - 0.158    |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

**Table 20. Effect of spacing and fertiliser on the incidence of leafminer - *Approaerema modicella* on soybean\***

**Location : Udumalpet**

| Treatments                                                                                                       | Leaf damage/Plant (%)        |                               |                              | Mean                          |
|------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------------------|------------------------------|-------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                    | 45 x 10 cm                   |                               |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 10.64<br>(3.26)              | 8.94<br>(3.03)                | 7.08<br>(2.72)               | 8.89<br>(3.00) <sup>a</sup>   |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 13.21<br>(3.63)              | 10.49<br>(3.28)               | 8.14<br>(2.91)               | 10.61<br>(3.26) <sup>b</sup>  |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.72<br>(4.09)              | 14.22<br>(3.75)               | 12.23<br>(3.51)              | 14.39<br>(3.78) <sup>cd</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 17.24<br>(4.13)              | 15.31<br>(3.88)               | 12.52<br>(3.55)              | 15.19<br>(3.85) <sup>d</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 17.58<br>(4.11)              | 15.16<br>(3.86)               | 12.20<br>(3.51)              | 14.98<br>(3.83) <sup>d</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 17.79<br>(4.13)              | 16.05<br>(3.98)               | 14.29<br>(3.78)              | 16.04<br>(3.96) <sup>e</sup>  |
| Mean                                                                                                             | 15.74<br>(3.89) <sup>c</sup> | 13.36<br>(3.63) <sup>bc</sup> | 11.08<br>(3.33) <sup>a</sup> | 13.39<br>(3.61)               |

|       |   |       |   |            |
|-------|---|-------|---|------------|
|       |   | Space |   | Fertiliser |
| SE(d) | - | 0.137 | - | 0.038      |
| CD    | - | 0.279 | - | 0.105      |

\* Mean of three replications

Figures in parentheses are arcsin percentage transformed values.

In another experiment conducted at Avinashi, significant differences were observed on the leaf damaged by the leafminer on soybean. The mean per cent leaf damage was significantly lower (10.02) in wider spacing than the other spacing levels. The damage levels were on par in 40x10 cm and 30x10 cm spacing levels (Table 21)

#### **4.4.2.2. *Helicoverpa armigera***

In the experiment conducted at Avinashi, significantly a lower incidence of *H. armigera* per ten plants was recorded in the closer spacing (30x10 cm) (15.45) followed by 40x10 cm (17.18) and 45x10 cm (17.33) (Table 22).

#### **4.4.2.3. *Spodoptera litura***

The effect of different spacings on the incidence of *S.litura* on soybean are given in Table 23.

Significantly a lowest mean population of 19.13 per ten plants was observed in the wider spacing (45x10cm) whereas higher mean populations of 22.93 and 22.43 per ten plants were observed in 30x10 cm and 40x10 cm respectively and they were on par.

#### **4.4.2.4. Pod Sucking Bug - *Nezara viridula***

There were no significant differences in the mean population of the bugs in the different spacing levels studied at Udumalpet (Table 24).

In the experiment conducted at Avinashi, wider spacing (45x10 cm) recorded significantly lesser incidence of pod sucking bugs (10.02) whereas closer spacing of 30 x 10 cm recorded significantly higher population (15.39) (Table 25).

**Table 21. Effect of spacing and fertiliser on the incidence of leafminer - *Aproaerema modicella* on soybean\***

**Location : Avinashi**

| Treatments                                                                                                       | Leaf damage/Plant (%)         |                              |                              | Mean                          |
|------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------|------------------------------|-------------------------------|
|                                                                                                                  | 30 X 10 cm                    | 40 x 10 cm                   | 45 x 10 cm                   |                               |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 10.73<br>(3.36)               | 9.21<br>(3.15)               | 6.71<br>(2.73)               | 8.87<br>(3.08) <sup>a</sup>   |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 12.48<br>(3.59)               | 11.27<br>(3.46)              | 7.95<br>(2.95)               | 10.57<br>(3.33) <sup>b</sup>  |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 15.34<br>(3.93)               | 14.71<br>(3.87)              | 10.98<br>(3.42)              | 13.68<br>(3.74) <sup>cd</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 17.31<br>(4.16)               | 14.44<br>(3.86)              | 11.74<br>(3.52)              | 14.50<br>(3.85) <sup>d</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.86<br>(4.07)               | 13.75<br>(3.76)              | 11.54<br>(3.48)              | 14.05<br>(3.77) <sup>d</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 19.61<br>(4.39)               | 12.39<br>(3.60)              | 11.21<br>(3.43)              | 14.40<br>(3.81) <sup>d</sup>  |
| Mean                                                                                                             | 15.39<br>(3.92) <sup>bc</sup> | 12.63<br>(3.62) <sup>b</sup> | 10.02<br>(3.25) <sup>a</sup> | 12.68<br>(3.60)               |

|       |         |            |
|-------|---------|------------|
|       | Space   | Fertiliser |
| SE(d) | - 2.576 | - 0.612    |
| CD    | - 0.307 | - 0.233    |

\* Mean of three replications

Figures in parentheses are arcsin percentage transformed values.

**Table 22. Effect of spacing and fertiliser on the incidence of *Helicoverpa armigera* on soybean\***

**Location : Avinashi**

| Treatments                                                                                                       | Nos / 10 Plants              |                              |                              | Mean                          |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|-------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                               |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 13.83<br>(0.87)              | 15.86<br>(0.94)              | 17.90<br>(1.08)              | 15.86<br>(0.96) <sup>a</sup>  |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 14.53<br>(0.89)              | 15.40<br>(0.93)              | 18.10<br>(1.00)              | 16.01<br>(0.97) <sup>a</sup>  |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 15.16<br>(0.91)              | 16.56<br>(0.96)              | 17.03<br>(1.07)              | 16.25<br>(0.98) <sup>a</sup>  |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 13.66<br>(0.90)              | 16.60<br>(1.05)              | 14.86<br>(1.03)              | 15.04<br>(0.99) <sup>a</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.67<br>(0.97)              | 18.30<br>(1.09)              | 17.00<br>(1.07)              | 17.34<br>(1.04) <sup>b</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 18.80<br>(0.99)              | 20.36<br>(1.12)              | 19.10<br>(1.13)              | 19.42<br>(1.08) <sup>bc</sup> |
| Mean                                                                                                             | 15.45<br>(0.92) <sup>a</sup> | 17.18<br>(1.01) <sup>b</sup> | 17.33<br>(1.08) <sup>c</sup> |                               |

|       |         |            |
|-------|---------|------------|
|       | Space   | Fertiliser |
| SE(d) | - 0.019 | - 0.016    |
| CD    | - 0.038 | - 0.046    |

\* Mean of three replications

Figures in parentheses are log (x+1) transformed values.

**Table 23. Effect of spacing and fertiliser on the incidence of *Spodoptera litura* on soybean\***

**Location : Udumalpet**

| Treatments                                                                                                       | Nos / 10 Plants              |                              |                              | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 9.37<br>(1.97)               | 9.73<br>(1.98)               | 6.93<br>(1.84)               | 8.98<br>(0.99) <sup>a</sup>  |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 20.63<br>(2.13)              | 18.93<br>(2.28)              | 14.43<br>(2.16)              | 18.00<br>(2.25) <sup>b</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 21.57<br>(2.50)              | 20.49<br>(2.49)              | 25.10<br>(2.39)              | 28.72<br>(2.35) <sup>c</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 22.70<br>(2.35)              | 23.40<br>(2.37)              | 19.57<br>(2.29)              | 21.89<br>(2.36) <sup>c</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 28.10<br>(2.45)              | 23.63<br>(2.37)              | 24.00<br>(2.38)              | 25.24<br>(2.40) <sup>d</sup> |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 31.23<br>(2.49)              | 32.40<br>(2.51)              | 29.75<br>(2.39)              | 30.46<br>(2.47) <sup>c</sup> |
| Mean                                                                                                             | 22.93<br>(1.39) <sup>b</sup> | 22.43<br>(1.37) <sup>b</sup> | 19.13<br>(1.30) <sup>a</sup> |                              |

|     |         |            |
|-----|---------|------------|
|     | Space   | Fertiliser |
| SED | - 0.009 | - 0.025    |
| CD  | - 0.026 | - 0.049    |

\* Mean of three replications

Figures in parentheses are log (x+1) transformed values.

**Table 24. Effect of spacing and fertiliser on the incidence of pod sucking bug - *Nezara viridula* on soybean\***

**Location : Udumalpet**

| Treatments                                                                                                       | Nos/10 Plants                |                              |                             | Mean                          |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                  |                               |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 8.58<br>(2.94)               | 7.33<br>(2.71)               | 6.42<br>(2.57)              | 7.74<br>(2.74) <sup>ab</sup>  |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 12.38<br>(3.41)              | 12.13<br>(3.41)              | 8.83<br>(2.94)              | 11.11<br>(3.25) <sup>bc</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 13.92<br>(3.62)              | 13.13<br>(3.50)              | 10.08<br>(3.15)             | 12.38<br>(3.42) <sup>cd</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 15.00<br>(3.70)              | 14.42<br>(3.60)              | 10.42<br>(3.20)             | 13.28<br>(3.50) <sup>cd</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.50<br>(3.96)              | 14.21<br>(3.67)              | 15.46<br>(3.87)             | 15.39<br>(3.93) <sup>de</sup> |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 7.08<br>(2.66)               | 6.88<br>(2.63)               | 6.25<br>(2.54)              | 6.74<br>(2.61) <sup>a</sup>   |
| Mean                                                                                                             | 12.24<br>(3.38) <sup>a</sup> | 11.35<br>(3.25) <sup>a</sup> | 9.58<br>(3.09) <sup>a</sup> | 11.06<br>(3.10)               |

|       | Space | Fertiliser |
|-------|-------|------------|
| SE(d) | 0.271 | 0.258      |
| CD    | 0.753 | 0.508      |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

**Table 25. Effect of spacing and fertiliser on the incidence of pod sucking bug - *Nezara viridula* on soybean\***

**Location : Avinashi**

| Treatments                                                                                                       | Nos/10 Plants                |                              |                              | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 16.86<br>(4.07)              | 13.75<br>(3.76)              | 11.54<br>(3.48)              | 14.05<br>(3.77) <sup>a</sup> |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 15.34<br>(3.93)              | 14.71<br>(3.87)              | 10.98<br>(3.42)              | 13.68<br>(3.74) <sup>a</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 10.73<br>(3.36)              | 9.21<br>(3.15)               | 6.71<br>(2.73)               | 8.87<br>(3.08) <sup>a</sup>  |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 17.31<br>(4.16)              | 14.44<br>(3.86)              | 11.74<br>(3.52)              | 14.50<br>(3.85) <sup>a</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 12.48<br>(3.59)              | 11.27<br>(3.46)              | 7.95<br>(2.95)               | 10.57<br>(3.33) <sup>a</sup> |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 19.61<br>(4.39)              | 12.39<br>(3.60)              | 11.21<br>(3.43)              | 14.40<br>(3.81) <sup>a</sup> |
| Mean                                                                                                             | 15.39<br>(3.92) <sup>c</sup> | 12.63<br>(3.62) <sup>b</sup> | 10.02<br>(3.26) <sup>a</sup> | 12.68<br>(3.60)              |

|       |   |       |   |            |
|-------|---|-------|---|------------|
|       |   | Space |   | Fertiliser |
| SE(d) | - | 1.344 | - | 2.460      |
| CD    | - | 0.291 | - | 0.782      |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

#### 4.4.2.5 NATURAL ENEMIES (Predators - Spiders and Coccinellid)

In the field experiment conducted at Udumalpet, it was found that closer spacing with (30 x 10 cm) recorded significantly higher mean population of predators per ten plants (17.73) while the wider spacing (45 x 10 cm) recorded lesser incidence (12.48) which was on par with 40 x 10 cm spacing (Table.26).

In an experiment conducted at Avinashi it was evident that the spacing had significant effect on the population of the spiders, coccinellid and Geocorids. Highest mean population (20.91) was recorded in closer spacing (30 x 10 cm) than other spacing levels and lowest mean population (11.98) was recorded in wider spacing (45 x 10 cm) (Table 27).

#### 4.4.3 EFFECT OF FERTILISER ON THE INSECT PESTS OF SOYBEAN

##### 4.4.3.1 ON SUCKING PESTS

##### 4.4.3.1.1 Leaf hopper – *Empoasca fabae*

The results on the effect of different phosphatic fertiliser levels in the experiment conducted at Udumalpet are presented in Table 16. Significant differences in the mean populations were observed on different levels of  $P_2O_5$  application over control. Lowest mean population (7.00) was recorded in the plots treated with 80 kg of  $P_2O_5$  as basal and 20 kg  $P_2O_5$  as three splits of top dressing at 30, 40 and 50 DAS. This effect was significantly superior than other treatments, but was at par (7.30) with the treatment where the  $P_2O_5$  was given at 80 kg as basal with two splits of top dressing at 30 and 40 DAS and 60 kg  $P_2O_5$  as basal and 20 kg in two splits at 30 and 40 DAS (Table 16).

In another experiment conducted at Avinashi, significantly lesser population was observed in the plots treated with 80 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  two split doses of  $P_2O_5$  at 30 and 40 DAS (3.81) followed by the treatment

**Table - 26. Effect of spacing and fertiliser on the incidence of predators (coccinellid and spiders) on soybean\***

**Location : Udumalpet**

| Treatments                                                                                                       | Nos/ 10 Plants               |                              |                              | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                  | 30 X 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal                                                              | 17.78<br>(1.22)              | 10.17<br>(1.02)              | 7.89<br>(0.86)               | 11.94<br>(1.03) <sup>c</sup> |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 14.11<br>(1.14)              | 11.83<br>(1.05)              | 9.89<br>(0.98)               | 11.94<br>(1.06) <sup>b</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.83<br>(1.19)              | 15.00<br>(1.15)              | 13.67<br>(1.11)              | 15.17<br>(1.15) <sup>c</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 20.83<br>(1.29)              | 18.72<br>(1.24)              | 16.50<br>(1.19)              | 18.69<br>(1.24) <sup>a</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal +<br>20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 24.11<br>(1.35)              | 21.22<br>(1.29)              | 19.22<br>(1.25)              | 21.52<br>(1.29) <sup>a</sup> |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                       | 12.72<br>(1.09)              | 9.39<br>(0.95)               | 7.72<br>(0.86)               | 9.94<br>(0.97) <sup>c</sup>  |
| Mean                                                                                                             | 17.73<br>(1.21) <sup>a</sup> | 14.39<br>(1.11) <sup>b</sup> | 12.48<br>(1.04) <sup>b</sup> | 14.87<br>(1.13)              |

|       |         |            |
|-------|---------|------------|
|       | Space   | Fertiliser |
| SE(d) | - 4.038 | - 2.086    |
| CD    | - 0.112 | - 0.084    |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

**Table 27. Effect of spacing and fertiliser on the incidence of natural enemies (coccinellid and spiders) on soybean\***

**Location : Avinashi**

| Treatment/ Fertiliser                                                                                            | Nos. / 10 Plants             |                              |                              | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                  | 30 x 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal                                                              | 10.78<br>(3.78)              | 7.22<br>(3.19)               | 6.22<br>(2.59)               | 8.07<br>(2.93) <sup>c</sup>  |
| T2-60kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20 kg<br>P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS      | 14.73<br>(4.34)              | 10.12<br>(3.36)              | 8.83<br>(3.05)               | 11.27<br>(3.43) <sup>d</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20 kg<br>P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 22.33<br>(5.22)              | 14.65<br>(4.33)              | 11.78<br>(3.56)              | 16.32<br>(4.10) <sup>c</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20 kg<br>P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 29.27<br>(5.95)              | 19.38<br>(4.90)              | 17.17<br>(4.20)              | 21.94<br>(4.74) <sup>b</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20 kg<br>P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 31.98<br>(6.15)              | 19.27<br>(4.89)              | 19.98<br>(4.52)              | 23.74<br>(4.92) <sup>a</sup> |
| T6-No P <sub>2</sub> O <sub>5</sub>                                                                              | 16.38<br>(4.55)              | 8.17<br>(3.36)               | 7.72<br>(2.87)               | 10.75<br>(3.35) <sup>c</sup> |
| Mean                                                                                                             | 20.91<br>(5.07) <sup>a</sup> | 13.13<br>(3.69) <sup>b</sup> | 11.98<br>(3.54) <sup>c</sup> | 15.38<br>(4.09)              |

|          | Space | Fertiliser |
|----------|-------|------------|
| SE (d) - | 2.484 | 4.012      |
| CD -     | 0.164 | 0.586      |

\*Mean of three replications

Figures in parenthesis are  $\sqrt{x+0.5}$  transformed values.

with 80 kg  $P_2O_5$  as basal + 3 splits of  $P_2O_5$  at 30,40 and 50 DAS (4.14). Highest mean population of 10.51 per plant was observed in the plots where no  $P_2O_5$  was applied. (Table 17).

Significant interaction was found to exist between different levels of fertilisers and spacings on the leafhopper population. All the fertiliser treatments were known to influence in the reduction of population of hopper when the spacing levels were increased.

#### 4.4.3.1.2 White Fly - *Bemisia tabaci*

The study conducted at Udumalpet during 1995 indicated significant differences on the mean populations of the whitefly over control (Table 18). The mean population was significantly reduced (5.84) in the plots where '80' kg  $P_2O_5$  was applied as basal and 20 kg  $P_2O_5$  as two splits of top dressing on 30 and 40 DAS followed by (7.33) 80 kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  as three splits of top dressings at 30, 40 and 50 DAS. The mean populations in other treatments were at par with each other (Table 18).

Similar field experiment was conducted at Avinashi and the results are presented in Table 19. The mean populations observed in different levels of phosphorous application had significant differences over control. Lowest mean population (1.80) was observed in the plots where 80 kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  in two splits of top dressing at 30 and 40 DAS was applied. The mean population level was at par with the plots where 80 kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  applied in three splits of top dressings on 30, 40 and 50 DAS.

Significant interaction effect was noticed between spacing levels and fertiliser treatments. Decreasing trend in population was observed when the spacing levels were increased in the plots, receiving 80 kg  $P_2O_5$  alone was

applied as basal, 80 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in two splits 30 and 40 DAS and as well in the plots where 80 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in three splits 30, 40 and 50 DAS.

#### 4.4.3.2 EFFECT OF FERTILISERS ON THE DEFOLIATORS OF SOYBEAN

##### 4.4.3.2.1 Leaf miner – *Aproaerema modicella*

There were significant differences between treatments over control. Mean per cent leaf damages recorded was significantly low (8.89) in the plot applied with 80 kg  $P_2O_5$  as basal alone followed by 60 kg  $P_2O_5$  + with two splits of 20 kg  $P_2O_5$  applied on 30 and 40 DAS. This was followed by the application of 60 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  applied in three splits on 30, 40 and 50 DAS. (15.19) Highest incidence (16.04) was recorded in the control where no  $P_2O_5$  was applied (Table 20). In the experiment conducted at Avinashi, lowest mean per cent leaf damage was recorded (8.87) where the plots were treated with 80 kg  $P_2O_5$  alone followed by 60 kg  $P_2O_5$  as a basal + 2 splits of  $P_2O_5$  at 30, and 40 DAS. (10.57). This was followed by 60 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in three splits at 30, 40 and 50 DAS (14.05) (Table 21).

Interaction effect was seen in the experiment conducted at Avinashi where in all the treatments were able to reduce the leaf damage and spacing levels were increased.

##### 4.4.3.2.2 *Helicoverpa armigera*

The results on the study of different fertiliser levels of phosphorous and their effects on the incidence of *H.armigera* at Avinashi are furnished in Table 22. There were no incidence of *H.armigera* at Udumalpet during February, 1995.

The study revealed that the different levels of  $P_2O_5$  had significant effect on the mean population of larvae of *H.armigera* over control. There were no significant differences between the mean population in the plots treated with different levels of phosphorous except at 80 kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  in three splits at 30, 40 and 50 DAS.

Significant interaction effect was observed between fertiliser and spacing levels which showed that when the spacing levels were increased from 30 x 10 to 45 x 10 cm, the population level was increased. These effects were noticed only in the plots where 80 kg  $P_2O_5$  applied alone and also in the plots with 60 kg  $P_2O_5$  as basal + two splits at 30 and 40 DAS or three split doses of  $P_2O_5$  at 30, 40 and 50 DAS.

#### 4.4.3.2.3 *Spodoptera litura*

The effect of different levels of  $P_2O_5$  on the incidence of *S.litura* was studied at Udumalpet and the results are furnished in Table 23.

The mean population was significantly lower (8.98) in the plot where 80 kg  $P_2O_5$  was applied as basal alone followed by 60 kg  $P_2O_5$  + 20 kg  $P_2O_5$  as two splits at 30 and 40 DAS (18.00). Higher population was noticed in the treatments where 80 kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  in two splits at 30 and 40 DAS and three splits at 30, 40 and 50 DAS.

Significant interaction was seen in the reduction of population when spacing levels were increased in the plots where 80 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  was applied in three split doses at 30, 40 and 50 DAS.

#### 4.4.3.2.4 Pod sucking bug - *Nezara viridula*

In the experiment conducted at Udumalpet, there was significant effect of fertiliser  $P_2O_5$  application on the incidence of pod sucking bugs over control. Significantly lesser mean population per ten plants (6.74) was recorded in the plots where no  $P_2O_5$  was applied. Higher population was recorded where 80 kg  $P_2O_5$  as basal and two splits of 20 kg at 30 and 40 DAS was applied, and in the plots were 80kg  $P_2O_5$  as basal with three splits of 30kg  $P_2O_5$  on 30,40 and 50 DAS(Table 24).

In another experiment conducted at Avinashi, there were no significant differences observed between all the treatments. (Table 25).

No significant interaction effect was also noticed between fertiliser levels and spacing levels.

#### 4.4.3.2.5 Predators (Spiders and Coccinellids)

In the experiment conducted at Udumalpet, the natural enemies viz., total predators' populations were higher (21.52 and 18.69) in the plots where 80 kg  $P_2O_5$  was applied as basal and 20 kg  $P_2O_5$  each as top dressing on 30, 40 DAS and 30, 40 and 50 DAS. This was followed by 60 Kg  $P_2O_5$  as basal and 20 kg  $P_2O_5$  as top dressing on 30, 40 and 50 DAS and 30 and 40 DAS (Table 26).

At Avinashi, significantly higher population per 10 plants (23.74) was noticed in the plots where 80 Kg  $P_2O_5$  + 20 kg  $P_2O_5$  in three split doses at 30, 40 and 50 DAS followed by 80 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in two splits, on 30 and 40 DAS (Table 27)(Fig.10).

PLATE - 10

Coccinellid *Menochilus sexmaculatus* population.

PLATE .10.



#### 4.4.4. EFFECT OF SPACING ON THE YIELD COMPONENTS OF SOYBEAN

##### 4.4.4.1 Development of PODS per plant

Soybean plants sown with wider spacing (45 x 10 cm) recorded maximum number of pods per plant (63.2) and significantly superior to other spacings wherein, the production of pods per plant was on par (Table 28 ).

##### 4.4.4.2 Number of Grains per Plant

More number of soybean grains per plant (75.8) were recorded in the plants sown under wider spacing (45x10 cm ) which was significantly superior to other spacings. Among the three spacings tried, closer spacing recorded the lowest number of grains per plant (55.4) (Table 28).

##### 4.4.4.3. Per cent Pod Damage by *Helicoverpa armigera*

Even though the three spacings viz., 30x10 cm, 40x10 cm and 45x10 cm recorded the per cent pod damages to an extent of 14.23, 12.14 and 11.66 respectively, statistically the mean per cent pod damages were on par with each other, indicating that the different spacings had no effect, on the per cent pod damages in soybean (Table 29).

##### 4.4.4.4. Per cent Grains Affected by Pod Sucking bug - *Nezara viridula*

The soybean seeds were seriously affected by the injury caused by *N.viridula*. The per cent grains damaged were high in closer spacing (30 x 10 cm) (15.06) followed by 40x10 cm (12.48) which were on par with 45 x 10cm (9.12) per cent grain damage (Table 29).

**PLATE - 11**

Grain damage by pod sucking bug *Nezara viridula*.

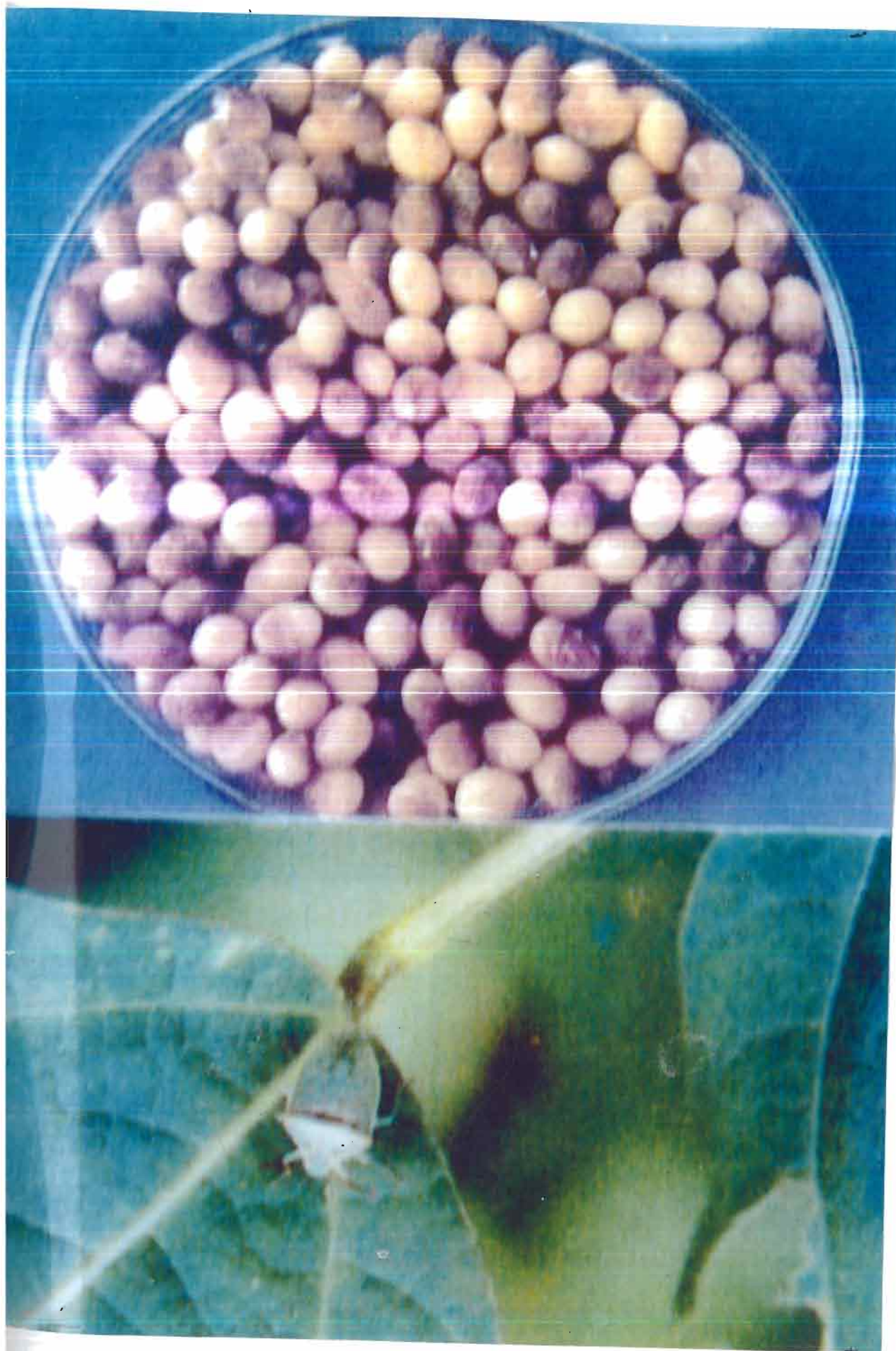


Table 28. Effect of spacing and fertiliser on yield components of soybean crop\*

Location : Avinashi

| Treatments                                                                                                   | No. of Pods / Plants        |                             |                             | Mean                        | No. of grains / Plant       |                             |                             | Mean                         |
|--------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
|                                                                                                              | 30x10cm                     | 40x10cm                     | 45x10cm                     |                             | 30x10cm                     | 40x10cm                     | 45x10cm                     |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal                                                           | 46.0<br>(1.66)              | 48.3<br>(1.64)              | 48.7<br>(1.68)              | 46.0<br>(1.66) <sup>d</sup> | 43.0<br>(1.63)              | 55.3<br>(1.74)              | 65.3<br>(1.81)              | 54.6<br>(1.73) <sup>e</sup>  |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 52.0<br>(1.72)              | 52.0<br>(1.71)              | 62.0<br>(1.79)              | 55.3<br>(1.74) <sup>c</sup> | 46.0<br>(1.66)              | 58.0<br>(1.76)              | 68.0<br>(1.83)              | 57.3<br>(1.75) <sup>de</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 46.3<br>(1.66)              | 52.7<br>(1.72)              | 58.7<br>(1.77)              | 52.6<br>(1.72) <sup>c</sup> | 49.30<br>(1.69)             | 64.7<br>(1.81)              | 74.0<br>(1.87)              | 62.7<br>(1.79) <sup>c</sup>  |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 61.7<br>(1.79)              | 66.0<br>(1.82)              | 77.3<br>(1.89)              | 68.3<br>(1.83) <sup>b</sup> | 71.3<br>(1.85)              | 90.7<br>(1.96)              | 92.3<br>(1.97)              | 84.8<br>(1.92) <sup>b</sup>  |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 75.3<br>(1.88)              | 81.3<br>(1.91)              | 85.3<br>(1.93)              | 80.7<br>(1.90) <sup>a</sup> | 82.0<br>(1.91)              | 90.7<br>(1.6)               | 104.3<br>(2.02)             | 92.3<br>(1.96) <sup>a</sup>  |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                   | 40.0<br>(1.72) <sup>b</sup> | 43.3<br>(1.64)              | 47.0<br>(1.67)              | 48.4<br>(1.64) <sup>d</sup> | 40.7<br>(1.61)              | 50.0<br>(1.69)              | 50.7<br>(1.80)              | 47.1<br>(1.67) <sup>f</sup>  |
| Mean                                                                                                         | 53.6<br>(1.72) <sup>b</sup> | 56.4<br>(1.74) <sup>b</sup> | 63.2<br>(1.79) <sup>a</sup> | 57.7<br>(1.75)              | 55.4<br>(1.73) <sup>c</sup> | 68.2<br>(1.82) <sup>b</sup> | 75.8<br>(1.87) <sup>a</sup> | 66.5<br>(1.80)               |

| SE(d) | Space | Fertiliser | SE(d) | Space | Fertiliser |
|-------|-------|------------|-------|-------|------------|
| CD    | 0.011 | 0.017      | CD    | 0.017 | 0.077      |
|       | 0.021 | 0.035      |       | 0.035 | 0.020      |

\*Mean of three replications, figures in parentheses are log transformed value

Wider spacing (45x10cm) recorded significantly higher mean yield of 1841 and 1587 kg/ha at Udumalpet and Avinashi respectively, which was superior to the other spacing levels viz., 40 x 10 cm and 30 x 10 cm (Table 29).

#### **4.4.5. EFFECT OF SPACING AND FERTILISER ON THE OIL CONTENT IN SOYBEAN**

Higher per cent oil content (15.72) was recorded from the seeds when sown with wider spacing (45 x 10 cm) but there were no significant differences between the other two spacing levels.

The application of different levels of  $P_2O_5$  fertiliser had significant effect on the percentage of oil content. Maximum per cent oil content was noticed (16.97) in the plots where 80 kg of  $P_2O_5$  was applied as basal and 20 Kg of  $P_2O_5$  was top dressed on 30, 40 and 50 DAS followed by two splits of 20 kg  $P_2O_5$  as top dressing at 30 and 40 DAS. Lower oil content (14.19%) was noticed where no  $P_2O_5$  was applied. Hence, the results indicated that higher  $P_2O_5$  application had significant effect on the increased percentage of oil content (Table 30).

#### **4.4.6. EFFECT OF FERTILISER ON YIELD COMPONENT WITH REFERENCE TO DEVELOPMENT OF PODS PER PLANT**

##### **4.4.6.1. Number of Pods per plant**

Mean number of pods recorded per plant were significantly higher (80.7) in the plots treated with 80 kg  $P_2O_5$  as basal with three splits of  $P_2O_5$  at 30, 40 and 50 DAS followed by 80 kg  $P_2O_5$  as basal + three splits of  $P_2O_5$  at 30, 40 and 50 DAS. Plots which received 60 kg  $P_2O_5$  as basal were on par with 80 kg  $P_2O_5$  as basal plots and control plots without  $P_2O_5$  (Table 28).

Table - 29 Effect of fertilizer and spacing on the percentage of infected pods and grains

Location : Avinashi

|      | % Pods affected by <i>Helicoverpa</i> sp. spacing |                               |                               |                              | % Grains affected by <i>Nezara</i> sp. spacing |                              |                              |                               |
|------|---------------------------------------------------|-------------------------------|-------------------------------|------------------------------|------------------------------------------------|------------------------------|------------------------------|-------------------------------|
|      | 30x10cm                                           | 40x10cm                       | 45x10cm                       | Mean                         | 30x10cm                                        | 40x10cm                      | 45x10cm                      | Mean                          |
| T1   | 11.87<br>(3.52) <sup>b</sup>                      | 10.35<br>(3.27) <sup>bc</sup> | 10.73<br>(3.32) <sup>bc</sup> | 10.98<br>(3.37) <sup>a</sup> | 14.33<br>(3.84) <sup>ab</sup>                  | 12.29<br>(3.53) <sup>a</sup> | 9.39<br>(3.02) <sup>a</sup>  | 12.00<br>(3.46) <sup>ab</sup> |
| T2   | 12.45<br>(3.59) <sup>b</sup>                      | 7.24<br>(2.76) <sup>c</sup>   | 8.19<br>(2.94) <sup>c</sup>   | 9.29<br>(3.10) <sup>a</sup>  | 19.03<br>(4.41) <sup>a</sup>                   | 11.12<br>(3.63) <sup>a</sup> | 7.19<br>(2.74) <sup>a</sup>  | 12.28<br>(3.48) <sup>ab</sup> |
| T3   | 13.45<br>(3.67) <sup>b</sup>                      | 13.92<br>(3.79) <sup>ab</sup> | 16.47<br>(4.12) <sup>a</sup>  | 14.61<br>(3.86) <sup>a</sup> | 12.02<br>(3.52) <sup>ab</sup>                  | 14.49<br>(3.83) <sup>a</sup> | 7.65<br>(2.84) <sup>a</sup>  | 11.39<br>(3.40) <sup>ab</sup> |
| T4   | 11.78<br>(3.48) <sup>b</sup>                      | 7.76<br>(2.86) <sup>c</sup>   | 7.26<br>(2.76) <sup>c</sup>   | 8.93<br>(3.03) <sup>b</sup>  | 10.93<br>(3.38) <sup>b</sup>                   | 10.99<br>(3.38) <sup>a</sup> | 9.21<br>(2.74) <sup>a</sup>  | 13.10<br>(3.61) <sup>a</sup>  |
| T5   | 16.78<br>(4.13) <sup>ab</sup>                     | 15.03<br>(3.19) <sup>ab</sup> | 13.97<br>(3.80) <sup>ab</sup> | 15.26<br>(3.95) <sup>a</sup> | 18.52<br>(4.34) <sup>a</sup>                   | 11.12<br>(3.37) <sup>a</sup> | 7.19<br>(3.01) <sup>a</sup>  | 12.28<br>(3.48) <sup>a</sup>  |
| T6   | 19.07<br>(4.41) <sup>a</sup>                      | 18.56<br>(4.36) <sup>a</sup>  | 13.35<br>(3.69) <sup>ab</sup> | 16.99<br>(4.15) <sup>c</sup> | 18.7<br>(4.37) <sup>a</sup>                    | 13.26<br>(3.70) <sup>a</sup> | 12.69<br>(3.63) <sup>a</sup> | 13.54<br>(3.67) <sup>a</sup>  |
| Mean | 14.23<br>(3.79) <sup>a</sup>                      | 12.14<br>(3.49) <sup>a</sup>  | 11.66<br>(3.43) <sup>a</sup>  | 12.68<br>(3.58)              | 15.06<br>(3.98) <sup>a</sup>                   | 12.48<br>(3.57) <sup>b</sup> | 9.12<br>(3.06) <sup>b</sup>  | 12.48<br>(3.54)               |

|       | Space   | Fertiliser | SPACE | FERTILISE |
|-------|---------|------------|-------|-----------|
| SE(d) | - 0.187 | - 0.242    | 0.242 | 0.240     |
| CD    | - 0.362 | - 0.644    | 0.395 | 0.420     |

\* Mean of three replications

Figures in parentheses are  $\sqrt{x + 0.5}$  transformed values.

Table 30. Effect of spacing and fertiliser on the oil content (%) of soybean\*

| Treatment/ Fertiliser                                                                                            | Spacing                      |                              |                              | Mean                         |
|------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                  | 30 x 10 cm                   | 40 x 10 cm                   | 45 x 10 cm                   |                              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> / ha - Basal                                                              | 14.00<br>(3.81)              | 14.32<br>(3.85)              | 14.34<br>(3.85)              | 14.22<br>(3.83) <sup>c</sup> |
| T2-60kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20<br>kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS      | 15.58<br>(3.88)              | 14.18<br>(3.83)              | 15.44<br>(3.99)              | 14.74<br>(3.90) <sup>d</sup> |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20 kg P <sub>2</sub><br>O <sub>5</sub> @ 30, 40 and 50 DAS | 15.22<br>(3.96)              | 15.09<br>(3.94)              | 16.17<br>(4.08)              | 15.49<br>(3.99) <sup>c</sup> |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20<br>kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 15.36<br>(3.98)              | 15.92<br>(4.05)              | 16.87<br>(4.160)             | 16.05<br>(4.06) <sup>b</sup> |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> / ha – Basal + 20<br>kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 16.86<br>(4.16)              | 16.45<br>(4.11)              | 17.62<br>(4.25)              | 16.97<br>(4.18) <sup>a</sup> |
| T6-No P <sub>2</sub> O <sub>5</sub>                                                                              | 14.62<br>(3.88)              | 14.10<br>(3.82)              | 13.87<br>(3.79)              | 14.19<br>(3.83) <sup>c</sup> |
| Mean                                                                                                             | 15.11<br>(3.95) <sup>b</sup> | 15.01<br>(3.93) <sup>b</sup> | 15.72<br>(4.02) <sup>a</sup> | 15.28<br>(3.96)              |

|          | Space | Fertiliser |
|----------|-------|------------|
| SE (d) - | 0.019 | 0.020      |
| CD -     | 0.040 | 0.044      |

\*Mean of three replications

Figures in parenthesis are arcsin percentage transformed values.

#### 4.4.6.2. Number of grains per plant

Significant differences were noticed in the different treatments and untreated control plots recorded the lowest number of grains per plant (47.1). Plots which received 80 kg  $P_2O_5$  as basal with three split doses of  $P_2O_5$  at 30, 40 and 50 DAS had recorded maximum number of grains/plant (92.3) which was statistically significant than other fertiliser treatments. This was followed by the plots which received 80 kg  $P_2O_5$  as basal with three splits of 20 kg  $P_2O_5$  at 30 and 40 DAS (Table 28).

#### 4.4.6.3. Per cent pods affected by *Helicoverpa armigera*

Significant reduction of per cent pod damage was seen in the plots which were treated with 80 kg  $P_2O_5$  alone, 60 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in two or three splits doses and 60 kg  $P_2O_5$  as basal + 20 kg  $P_2O_5$  in three splits doses (Table 29).

#### 4.4.6.4. Per cent grain damage by pod sucking bug - *Nezara viridula*

Highest per cent grain damage by *N. viridula* was recorded where no  $P_2O_5$  was applied. The damage levels were equal in all the  $P_2O_5$  applied plots with different doses (Table 29).

### 4.4.7. EFFECT OF SPACING AND PHOSPHATIC FERTILISER ON YIELD PER HECTARE

#### 4.4.7.1 Effect of spacing

The effect of spacing on yield was significant at Udumalpet wherein wider spacing (45 x 10 cm) recorded the maximum seed yield of (1841 kg) per ha<sup>-1</sup> followed by 40 x 10 cm spacing levels (1471 kg) per ha<sup>-1</sup> (Table 31). Likewise, at Avinashi, the widerspacing gave significantly higher yield (1587 kg) per ha<sup>-1</sup> when compared to other spacing levels (Table 31).

#### 4.4.7.2 Effect of fertiliser

At Udumalpet, significantly higher yield (1946 kg) per ha<sup>-1</sup> was recorded in the plots where 80 kg P<sub>2</sub>O<sub>5</sub> as basal and 20 kg P<sub>2</sub>O<sub>5</sub> as top dressing in three split doses on 30, 40 and 50 DAS was given followed by two split doses at 30 and 40 DAS. Likewise, reducing trend in yield was noticed in the lower levels of P<sub>2</sub>O<sub>5</sub> applications (Table 31). At Avinashi, higher yield (1854 kg) per ha<sup>-1</sup> was obtained in the plots wherein 80 kg P<sub>2</sub>O<sub>5</sub> as basal + 20 kg P<sub>2</sub>O<sub>5</sub> as top dressing in two split doses on 30 and 40 DAS followed by three split doses at 30 40 and 50 DAS (Table 31).

### 4.5. EFFECT OF INTERCROPPING SYSTEM ON THE INSECT PESTS OF SOYBEAN

The different intercropping systems were followed along with soybean wherein the soybean was planted in six rows. The following results represent the effect of six rows of soybean with other companion crops when raised with varied number of rows on incidence of pests.

#### 4.5.1. SUCKING PESTS

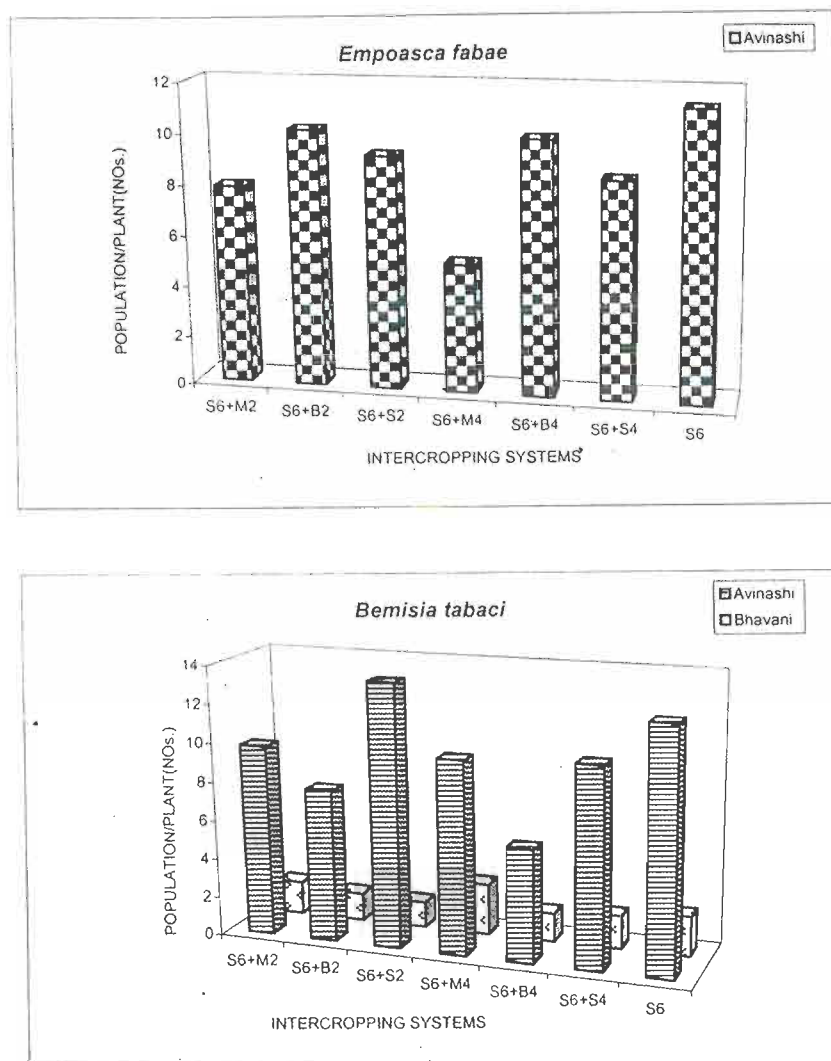
##### 4.5.1.1. Leaf hopper - *Empoasca fabae*

Weekly observations made from 25 DAS to 74 DAS revealed the abundance of leaf hoppers' population in different intercropping systems of soybean. The mean population was found to be significantly lower (5.15) in the soybean crop when intercropped with 4 rows of maize followed by soybean + 2 rows of maize (6.18). Highest mean population of (11.35) per plant was observed in soybean alone (Table 32) (Fig.8).

##### 4.5.1.2. Whitefly - *Bemisia tabaci*

At Avinashi, significantly lowest mean population (5.75) was recorded in the soybean intercropped with four rows of bhendi followed by (7.79) in two rows of bhendi. Highest population (13.50) was observed in soybean intercropped with

Fig. 8. Effect of intercropping system and incidence of sucking pests (*Empoasca fabae* and *Bemisia tabaci*)



S6+M2-Soybean 6rows+Maize 2 rows; S6+B2-Soybean 6rows+Bhendi 2 rows;  
 S6+B2-Soybean 6rows+Bhendi 2 rows; S6+M2-Soybean 6rows+Maize 2 rows;  
 S6+B4-Soybean 6rows+Bhendi 4 rows; S6+S2-Soybean 6rows+Sorghum 2 rows;  
 S6-Soybean 6 rows only.

Table 31. Effect of spacing and fertiliser on yield per ha<sup>-1</sup> of soybean crop\*

| Treatments                                                                                                   | Udumalpet            |                      |                      | Avinashi             |                      |                      |
|--------------------------------------------------------------------------------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                                                                                                              | Kg ha <sup>-1</sup>  |                      |                      | Kg ha <sup>-1</sup>  |                      |                      |
|                                                                                                              | 30x10cm              | 40x10cm              | 45x10cm              | 30x10cm              | 40x10cm              | 45x10cm              |
| T1-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal                                                           | 965.60               | 1200.00              | 1324.00              | 1065.67              | 1211.33              | 1384.00              |
| T2-60 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 1206.50              | 1406.20              | 1576.00              | 1196.33              | 1326.33              | 1476.00              |
| T3-60 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 1309.20              | 1569.70              | 1798.00              | 1426.00              | 1479.67              | 1598.67              |
| T4-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30 and 40 DAS     | 1508.10              | 1817.20              | 2045.00              | 1602.33              | 1817.00              | 2143.00              |
| T5-80 kg P <sub>2</sub> O <sub>5</sub> /ha - Basal + 20 kg P <sub>2</sub> O <sub>5</sub> @ 30, 40 and 50 DAS | 1915.20              | 1914.50              | 2014.00              | 1548.67              | 1629.33              | 1913.00              |
| Control - No P <sub>2</sub> O <sub>5</sub>                                                                   | 815.00               | 1020.00              | 1289.00              | 1020.00              | 950.00               | 1008.33              |
| Mean                                                                                                         | 1286.50 <sup>c</sup> | 1471.00 <sup>b</sup> | 1841.12 <sup>a</sup> | 1309.33 <sup>c</sup> | 1402.28 <sup>b</sup> | 1587.17 <sup>a</sup> |

\*Mean of 3 replications

In a column means followed by common letter are not significantly different at 5% level by DMRT.

Table 32. Effect of intercropping system on the incidence on leafhopper - *Empoasca fabae* of soybean\*  
Location : Avinashi

| Location : Avinashi | Treatments                          | Nos/ 3 Leaves  |                 |                 |                 |                 |                | Mean                          |
|---------------------|-------------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|----------------|-------------------------------|
|                     |                                     | DAS            |                 |                 |                 |                 |                |                               |
|                     |                                     | 39             | 46              | 53              | 60              | 67              | 74             |                               |
|                     | Soybean (6 rows) + Maize (2 rows)   | 4.20<br>(2.14) | 4.97<br>(2.32)  | 11.76<br>(3.42) | 7.80<br>(2.82)  | 4.13<br>(2.15)  | 3.67<br>(2.02) | 6.18<br>(2.48) <sup>b</sup>   |
|                     | Soybean (6 rows) + Bhendi (2 rows)  | 5.37<br>(2.42) | 9.03<br>(3.08)  | 9.30<br>(3.11)  | 8.87<br>(3.03)  | 10.27<br>(3.24) | 4.30<br>(2.16) | 10.17<br>(3.19) <sup>ef</sup> |
|                     | Soybean (6 rows) + Sorghum (2 rows) | 9.87<br>(3.21) | 13.60<br>(3.75) | 18.20<br>(4.32) | 24.83<br>(5.02) | 14.97<br>(3.93) | 3.90<br>(2.10) | 9.24<br>(3.04) <sup>c</sup>   |
|                     | Soybean (6 rows) + Maize (4 rows)   | 4.40<br>(2.1)  | 13.00<br>(3.65) | 22.20<br>(4.76) | 23.57<br>(4.90) | 15.90<br>(4.02) | 3.57<br>(2.01) | 5.15<br>(2.34) <sup>a</sup>   |
|                     | Soybean (6 rows) + Bhendi (4 rows)  | 4.13<br>(2.13) | 10.03<br>(3.24) | 13.13<br>(3.42) | 11.23<br>(3.42) | 9.83<br>(3.18)  | 3.60<br>(2.00) | 10.05<br>(3.17) <sup>e</sup>  |
|                     | Soybean (6 rows) + Sorghum (4 rows) | 6.24<br>(2.49) | 8.48<br>(2.90)  | 4.01<br>(2.00)  | 7.31<br>(2.70)  | 13.42<br>(3.66) | 3.43<br>(1.85) | 6.79<br>(2.60) <sup>bc</sup>  |
|                     | Soybean alone (6 rows)              | 7.93<br>(2.90) | 11.03<br>(3.38) | 16.20<br>(4.08) | 21.43<br>(4.68) | 18.33<br>(4.33) | 3.80<br>(2.07) | 11.35<br>(3.37) <sup>g</sup>  |
|                     | Mean                                | 6.81<br>(2.64) | 10.94<br>(3.33) | 15.70<br>(3.92) | 18.53<br>(4.22) | 13.56<br>(3.65) | 3.68<br>(2.03) | 9.84<br>(3.15)                |

Treatment

SE (d) 0.117

CD 0.126

\*Mean of 3 replications

DAS : Days After Sowing

Figures in parenthesis are  $\sqrt{x + 0.5}$  transformed values.

2 rows of sorghum. The population was 12.38 in soybean alone (Table 33).

In another experiment conducted at Bhavani, it was found that the population was significantly less in soybean intercropped with 2 rows (or) 4 rows of bhendi followed by 2 rows (or) 4 rows of maize and 2 or 4 rows of sorghum (Table 34)(Fig.8).

#### 4.5.2 DEFOLIATORS

##### 4.5.2.1 Leafminer – *Aproaerema modicella*

Population of leaf miner on soybean was found to be abundant throughout the different crop growth stages at Avinashi. The mean leaf per cent damage was significantly less in soybean + 2 rows of maize (7.95) and in soybean + 4 rows of maize (9.15) followed by soybean + 4 rows of sorghum (11.50) 4 rows of bhendi (10.66) and 4 rows of maize (10.73). All other intercropped systems and soybean alone showed no significant differences in the per cent leaf damage (Table 35).

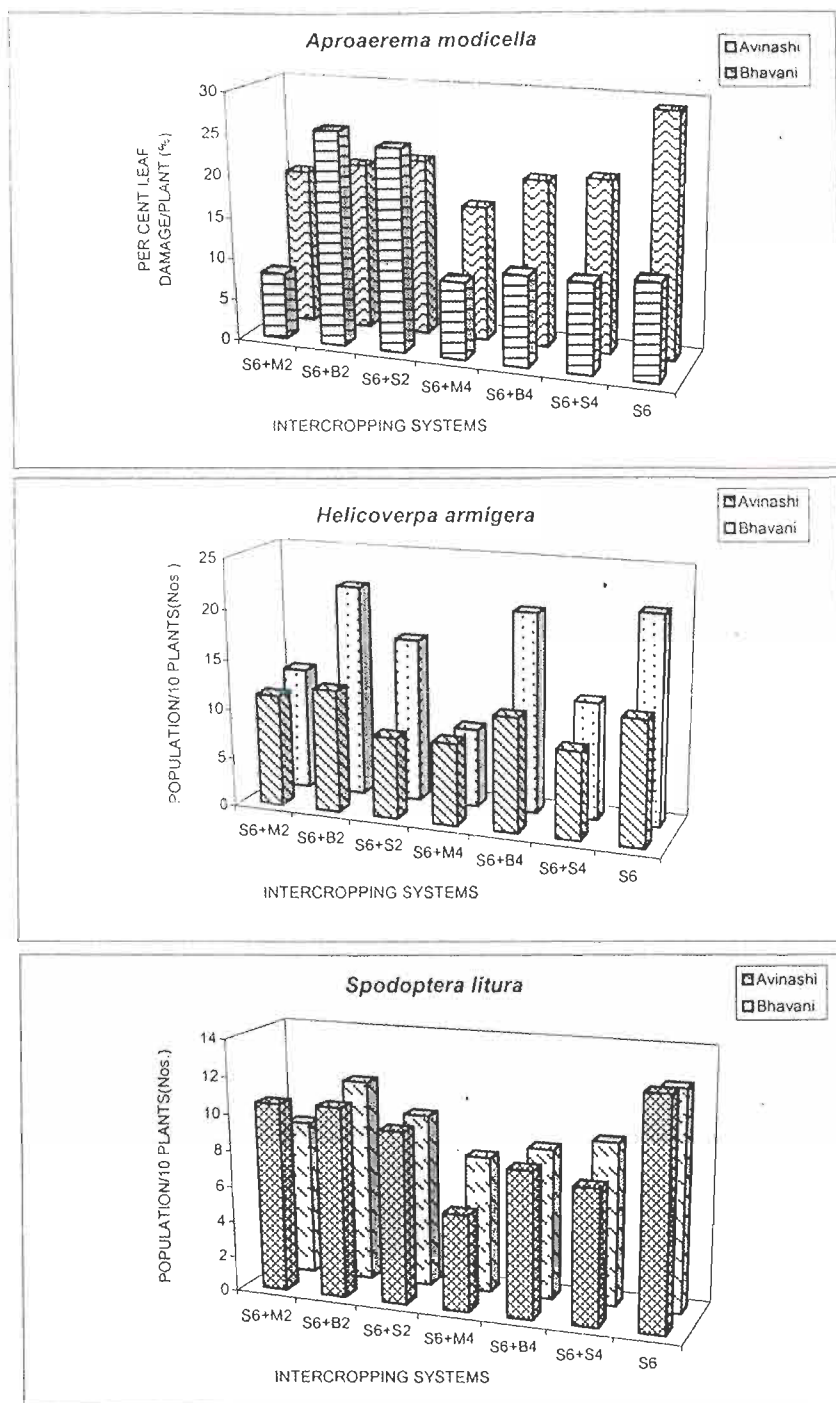
At Bhavani, the mean leaf damage of leaf miner was significantly low in soybean + 4 rows of maize (16.10) followed by soybean + 2 rows of maize (18.63). Highest incidence was noticed in soybean + 2 rows and 4 rows of sorghum and soybean alone (Table 36)(Fig.9).

##### 4.5.2.2 *Helicoverpa armigera*

The study conducted at Avinashi revealed that the mean population of *H.armigera* was significantly lower in soybean + 4 rows of maize (8.28), soybean + 2 rows of sorghum (8.20) and soybean + 4 rows of sorghum (8.81) followed by the other intercropped system which were on par (Table 37).

At Bhavani it was observed that the mean population was low per 10 plants in soybean + 4 rows of maize intercrop system (8.15) followed by soybean + 2 rows of maize (11.87) and soybean + 4 rows of sorghum (10.54). Soybean alone

**Fig.9. Effect of intercropping system and incidence of defoliators(*Aproaerema modicella*, *Helicoverpa armigera*) and *Spodoptera litura* )**



S6+M2-Soybean 6rows+Maize 2 rows; S6+B2-Soybean 6rows+Bhendi 2 rows;  
 S6+B2-Soybean 6rows+Bhendi 2 rows; S6+M2-Soybean 6rows+Maize 2 rows;  
 S6+B4-Soybean 6rows+Bhendi 4 rows; S6+S2-Soybean 6rows+Sorghum 2 rows;  
 S6-Soybean 6 rows only.

**Table 33 EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF WHITEFLY *Bemisia tabaci* ON SOYBEAN\***  
**LOCATION : AVINASHI**

| Treatments                          | Nos./ 3 Leaves              |                              |                               |                              |                              |                             |                             |                             | Mean                          |
|-------------------------------------|-----------------------------|------------------------------|-------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|
|                                     | DAS                         |                              |                               |                              |                              |                             |                             |                             |                               |
|                                     | 25                          | 32                           | 39                            | 46                           | 53                           | 60                          | 67                          | 74                          |                               |
| Soybean (6 rows) + Maize (2 rows)   | 8.67<br>(2.95)              | 12.00<br>(3.53)              | 12.67<br>(3.51)               | 18.33<br>(4.34)              | 15.00<br>(3.93)              | 9.97<br>(3.17)              | 4.00<br>(2.03)              | 4.00<br>(1.52)              | 9.79<br>(3.13) <sup>cd</sup>  |
| Soybean (6 rows) + Bhendi (2 rows)  | 3.33<br>(1.95)              | 8.67<br>(3.00)               | 16.00<br>(4.05)               | 14.00<br>(3.77)              | 10.33<br>(3.26)              | 5.00<br>(2.34)              | 3.67<br>(2.00)              | 1.33<br>(1.34)              | 7.79<br>(2.71) <sup>b</sup>   |
| Soybean (6 rows) + Sorghum (2 rows) | 13.67<br>(3.75)             | 10.67<br>(3.34)              | 16.00<br>(4.06)               | 20.00<br>(4.49)              | 26.00<br>(5.15)              | 11.67<br>(3.48)             | 7.33<br>(2.74)              | 2.67<br>(1.77)              | 13.50<br>(3.60) <sup>e</sup>  |
| Soybean (6 rows) + Maize (4 rows)   | 6.67<br>(2.67)              | 8.67<br>(3.02)               | 16.67<br>(4.13)               | 17.00<br>(4.13)              | 12.67<br>(3.63)              | 8.33<br>(2.97)              | 6.33<br>(2.59)              | 2.67<br>(1.76)              | 9.88<br>(3.11) <sup>cd</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 3.67<br>(2.00)              | 5.00<br>(2.30)               | 11.67<br>(3.48)               | 8.67<br>(3.02)               | 7.33<br>(2.76)               | 6.00<br>(2.53)              | 2.33<br>(1.68)              | 1.33<br>(1.34)              | 5.75<br>(2.39) <sup>a</sup>   |
| Soybean (6 rows) + Sorghum (4 rows) | 11.00<br>(3.38)             | 12.00<br>(3.52)              | 14.00<br>(3.80)               | 14.67<br>(3.88)              | 12.00<br>(3.53)              | 10.67<br>(3.31)             | 5.00<br>(2.29)              | 2.00<br>(1.52)              | 10.17<br>(3.16) <sup>cd</sup> |
| Soybean alone (6 rows)              | 13.33<br>(3.70)             | 15.00<br>(3.93)              | 20.67<br>(4.59)               | 24.00<br>(4.93)              | 13.33<br>(3.72)              | 8.00<br>(2.90)              | 3.00<br>(1.86)              | 1.67<br>(1.46)              | 12.38<br>(3.51) <sup>e</sup>  |
| Mean                                | 8.62<br>(2.92) <sup>c</sup> | 10.29<br>(3.24) <sup>d</sup> | 15.38<br>(3.96) <sup>de</sup> | 16.67<br>(4.08) <sup>e</sup> | 13.81<br>(3.71) <sup>d</sup> | 8.48<br>(2.96) <sup>c</sup> | 4.52<br>(2.17) <sup>b</sup> | 1.95<br>(1.53) <sup>a</sup> | 9.96<br>(3.07)                |

**TREATMENT      DAYS**

SE (d)      0.117      0.125  
 CD      0.232      0.248

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

Table 34 EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF *Bemisia tabaci* ON SOYBEAN\*

| Treatments                          | Nos / 3 Leaves              |                             |                             |                             |                              |                             |                              | Mean                        |
|-------------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|-----------------------------|------------------------------|-----------------------------|
|                                     | DAS                         |                             |                             |                             |                              |                             |                              |                             |
|                                     | 32                          | 39                          | 46                          | 53                          | 60                           | 67                          | 74                           |                             |
| Soybean (6 rows) + Maize (2 rows)   | 1.40<br>(1.35)              | 1.57<br>(1.43)              | 1.23<br>(1.32)              | 1.57<br>(1.44)              | 1.93<br>(1.56)               | 2.17<br>(1.63)              | 1.90<br>(1.55)               | 1.68<br>(1.47) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (2 rows)  | 1.33<br>(1.34)              | 0.90<br>(1.18)              | 0.60<br>(1.05)              | 1.03<br>(1.24)              | 1.50<br>(1.41)               | 2.40<br>(1.70)              | 2.17<br>(1.63)               | 1.42<br>(1.36) <sup>a</sup> |
| Soybean (6 rows) + Sorghum (2 rows) | 1.03<br>(1.23)              | 0.93<br>(1.17)              | 0.53<br>(1.00)              | 1.27<br>(1.32)              | 1.60<br>(1.44)               | 2.17<br>(1.63)              | 1.70<br>(1.48)               | 1.32<br>(1.49) <sup>c</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 1.10<br>(1.26)              | 3.20<br>(1.92)              | 2.67<br>(1.76)              | 3.30<br>(1.94)              | 3.73<br>(2.06)               | 2.93<br>(1.85)              | 1.47<br>(1.40)               | 2.63<br>(1.74) <sup>e</sup> |
| Soybean (6 rows) + Bhendi (4 rows)  | 0.60<br>(1.03)              | 0.67<br>(1.07)              | 0.90<br>(1.18)              | 1.90<br>(1.55)              | 2.10<br>(1.61)               | 2.13<br>(1.62)              | 2.00<br>(1.58)               | 1.47<br>(1.38) <sup>a</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 1.10<br>(1.25)              | 1.00<br>(1.22)              | 1.23<br>(1.31)              | 1.93<br>(1.56)              | 2.10<br>(1.61)               | 2.40<br>(1.70)              | 2.23<br>(1.65)               | 1.71<br>(1.47) <sup>b</sup> |
| Soybean alone (6 rows)              | 1.10<br>(1.26)              | 1.30<br>(1.34)              | 1.73<br>(1.49)              | 2.23<br>(1.65)              | 2.60<br>(1.76)               | 2.90<br>(1.83)              | 2.50<br>(1.73)               | 2.05<br>(1.58) <sup>d</sup> |
| Mean                                | 1.10<br>(1.25) <sup>a</sup> | 1.37<br>(1.33) <sup>a</sup> | 1.27<br>(1.30) <sup>a</sup> | 1.89<br>(1.53) <sup>c</sup> | 2.22<br>(1.64) <sup>de</sup> | 2.44<br>(1.71) <sup>e</sup> | 2.00<br>(1.57) <sup>cd</sup> | 1.76<br>(1.48)              |

TREATMENT      DAYS  
SE (d)      0.0044  
CD      0.089

\* Mean of 3 replications  
DAS : Days after sowing  
Figures in parenthesis are transformed values.

**Table 35 EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF LEAFMINER *Apraoerema modicella* ON SOYBEAN\***  
**LOCATION : AVINASHI**

| Treatments                          | Percent Leaf Damage/Plant |                  |                  |                  |                  |                  |                  |                  | Mean                          |
|-------------------------------------|---------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-------------------------------|
|                                     | DAS                       |                  |                  |                  |                  |                  |                  |                  |                               |
|                                     | 25                        | 32               | 39               | 46               | 53               | 60               | 67               | 74               |                               |
| Soybean (6 rows) + Maize (2 rows)   | 6.80<br>(15.06)           | 9.65<br>(17.89)  | 9.20<br>(17.66)  | 8.00<br>(16.43)  | 7.45<br>(15.89)  | 8.00<br>(16.43)  | 7.50<br>(15.90)  | 7.00<br>(15.34)  | 7.95<br>(16.32) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (2 rows)  | 7.71<br>(16.12)           | 14.95<br>(22.59) | 30.23<br>(33.33) | 39.52<br>(38.89) | 38.21<br>(38.16) | 41.49<br>(40.10) | 45.96<br>(42.68) | 50.38<br>(45.22) | 25.80<br>(34.64) <sup>c</sup> |
| Soybean (6 rows) + Sorghum (2 rows) | 8.09<br>(16.48)           | 14.89<br>(22.69) | 32.11<br>(34.47) | 40.76<br>(39.64) | 39.52<br>(38.89) | 47.65<br>(43.64) | 45.36<br>(42.33) | 45.85<br>(42.62) | 24.20<br>(35.09) <sup>c</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 12.11<br>(20.36)          | 12.82<br>(20.96) | 9.95<br>(18.84)  | 9.05<br>(17.46)  | 8.55<br>(16.95)  | 8.60<br>(17.05)  | 5.76<br>(13.81)  | 3.37<br>(10.62)  | 9.15<br>(17.56) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 15.22<br>(22.95)          | 14.39<br>(22.30) | 10.21<br>(18.63) | 10.71<br>(19.09) | 9.49<br>(17.95)  | 8.87<br>(17.26)  | 8.73<br>(17.15)  | 7.19<br>(15.45)  | 10.73<br>(19.09) <sup>b</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 16.50<br>(23.09)          | 16.70<br>(24.12) | 13.00<br>(21.10) | 10.50<br>(18.91) | 9.53<br>(18.05)  | 8.44<br>(16.85)  | 7.45<br>(15.85)  | 3.76<br>(11.24)  | 10.66<br>(19.10) <sup>b</sup> |
| Soybean alone (6 rows)              | 15.98<br>(23.60)          | 13.00<br>(21.22) | 11.25<br>(19.55) | 10.38<br>(18.80) | 11.04<br>(19.46) | 11.25<br>(19/64) | 9.85<br>(18.34)  | 9.25<br>(17.70)  | 11.50<br>(19.90) <sup>b</sup> |
| MEAN                                | 11.77<br>(20.05)          | 11.71<br>(20.00) | 16.50<br>(23.96) | 18.42<br>(25.40) | 17.68<br>(24.80) | 19.17<br>(25.99) | 18.65<br>(25.55) | 18.11<br>(25.20) | 25.50<br>(33.99)              |

TREATMENT      DAYS  
SE (d)      0.994      1.063  
CD      1.971      2.107  
\* - Mean of 3 replications  
DAS : Days after sowing  
Figures in parenthesis are transformed values.

Table 36 EFFECT OF INTERCROPPING AND THE INCIDENCE OF LEAFMINER (*Aproaerema modicella*)

LOCATION : BHAVANI

| Treatments                          | Percentage Of Leaf Damage /Plant (%) |                               |                               |                               |                               |                               |                               | Mean                           |
|-------------------------------------|--------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|
|                                     | DAS                                  |                               |                               |                               |                               |                               |                               |                                |
|                                     | 25                                   | 39                            | 46                            | 53                            | 60                            | 67                            | 74                            |                                |
| Soybean (6 rows) + Maize (2 rows)   | 9.05<br>(17.56)                      | 10.65<br>(19.04)              | 18.30<br>(25.35)              | 22.90<br>(28.58)              | 23.35<br>(28.89)              | 24.89<br>(29.88)              | 21.21.<br>(27.41)             | 18.63<br>(25.24) <sup>b</sup>  |
| Soybean (6 rows) + Bhendi (2 rows)  | 10.39<br>(18.80)                     | 12.87<br>(21.03)              | 21.56<br>(27.66)              | 27.52<br>(31.63)              | 22.83<br>(28.49)              | 22.57<br>(28.32)              | 22.24<br>(28.09)              | 20.00<br>(26.29) <sup>c</sup>  |
| Soybean (6 rows) + Sorghum (2 rows) | 14.98<br>(22.77)                     | 13.37<br>(21.45)              | 23.55<br>(31.65)              | 23.87<br>(29.24)              | 23.68<br>(29.11)              | 23.53<br>(26.82)              | 20.40<br>(26.82)              | 21.05<br>(27.15) <sup>d</sup>  |
| Soybean (6 rows) + Maize (4 rows)   | 6.68<br>(14.98)                      | 8.24<br>(16.68)               | 9.53<br>(17.94)               | 18.18<br>(25.19)              | 23.08<br>(28.69)              | 25.54<br>(27.88)              | 21.89<br>(27.88)              | 16.10<br>(23.19) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 8.15<br>(16.59)                      | 13.36<br>(21.39)              | 17.69<br>(24.85)              | 27.10<br>(31.35)              | 24.35<br>(29.54)              | 25.62<br>(28.34)              | 22.57<br>(28.43)              | 19.85<br>(26.96) <sup>bc</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 9.87<br>(18.31)                      | 19.22<br>(25.98)              | 22.62<br>(28.39)              | 25.54<br>(30.35)              | 21.98<br>(27.81)              | 21.89<br>(28.46)              | 22.72<br>(28.46)              | 20.55<br>(26.74) <sup>cd</sup> |
| Soybean alone (6 rows)              | 14.06<br>(22.00)                     | 28.62<br>(32.33)              | 27.42<br>(31.56)              | 27.52<br>(31.63)              | 21.61<br>(27.60)              | 24.73<br>(29.80)              | 22.51<br>(28.30)              | 29.00<br>(32.58) <sup>c</sup>  |
| Mean                                | 10.46<br>(18.71) <sup>a</sup>        | 15.19<br>(22.56) <sup>b</sup> | 20.67<br>(26.76) <sup>c</sup> | 24.66<br>(29.71) <sup>d</sup> | 22.98<br>(28.59) <sup>d</sup> | 24.11<br>(29.38) <sup>c</sup> | 21.93<br>(27.90) <sup>c</sup> | 20.00<br>(26.23)               |

| TREATMENT | DAYS  |
|-----------|-------|
| SE (d)    | 1.063 |
| CD        | 2.107 |

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

**Table 37. EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF *Heliothis armigera* On SOYBEAN\***

| Treatments                          | Nos./10 Plants               |                              |                              |                              |                              |                             |                             | Mean                         |
|-------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|------------------------------|
|                                     | 25                           | 32                           | 39                           | 46                           | 53                           | 60                          | 67                          |                              |
| Soybean (6 rows) + Maize (2 rows)   | 11.23<br>(3.42)              | 13.57<br>(3.75)              | 13.60<br>(3.75)              | 15.37<br>(3.98)              | 16.33<br>(4.10)              | 6.90<br>(2.72)              | 1.93<br>(1.53)              | 11.28<br>(3.32) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (2 rows)  | 16.60<br>(4.13)              | 13.80<br>(3.77)              | 14.70<br>(3.87)              | 10.97<br>(3.38)              | 19.67<br>(4.44)              | 8.93<br>(3.07)              | 1.70<br>(1.48)              | 12.34<br>(3.45) <sup>b</sup> |
| Soybean (6 rows) + Sorghum (2 rows) | 9.07<br>(3.09)               | 9.23<br>(3.12)               | 10.43<br>(3.30)              | 12.27<br>(3.55)              | 11.10<br>(3.37)              | 4.57<br>(2.25)              | 1.33<br>(1.35)              | 8.20<br>(2.86) <sup>a</sup>  |
| Soybean (6 rows) + Maize (4 rows)   | 9.67<br>(3.17)               | 9.60<br>(3.19)               | 11.53<br>(3.44)              | 11.77<br>(3.49)              | 8.57<br>(3.00)               | 5.40<br>(2.39)              | 1.43<br>(0.39)              | 8.28<br>(2.88) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 15.90<br>(4.04)              | 14.33<br>(3.85)              | 16.33<br>(4.10)              | 14.73<br>(3.89)              | 12.30<br>(3.58)              | 4.60<br>(2.25)              | 2.10<br>(1.61)              | 11.47<br>(3.33) <sup>b</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 9.00<br>(3.08)               | 10.07<br>(3.25)              | 10.60<br>(3.33)              | 12.87<br>(3.66)              | 11.67<br>(3.48)              | 5.60<br>(2.47)              | 1.87<br>(1.54)              | 8.81<br>(2.97) <sup>a</sup>  |
| Soybean alone (6 rows)              | 10.57<br>(3.32)              | 12.60<br>(3.62)              | 19.13<br>(4.43)              | 21.63<br>(4.70) <sup>b</sup> | 15.87<br>(4.04)              | 5.90<br>(2.49)              | 1.67<br>(1.47)              | 12.48<br>(3.44) <sup>c</sup> |
| Mean                                | 11.72<br>(3.46) <sup>c</sup> | 11.89<br>(3.50) <sup>c</sup> | 13.76<br>(3.74) <sup>d</sup> | 14.23<br>(3.81) <sup>d</sup> | 13.64<br>(3.71) <sup>d</sup> | 5.99<br>(2.52) <sup>b</sup> | 1.72<br>(1.48) <sup>b</sup> | 10.42<br>(3.18)              |

| TREATMENT | DAYS  |
|-----------|-------|
| SE (d)    | 0.092 |
| CD        | 0.183 |

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

without intercrop recorded highest population (15.90) (Table 38)(Fig.9).

#### 4.5.2.3 *Spodoptera litura*

In the experiment conducted at Avinashi the mean population was found to be significantly low in soybean + 4 rows of maize (5.39) followed by soybean + 4 rows of sorghum (7.52). Highest population (12.60) was noticed in pure crop of soybean (Table 39).

At Bhavani, the mean population was significantly low in soybean + 4 rows of maize (7.64), soybean + 4 rows of bhendi ( 8.39) followed by 2 rows of maize (8.72). The populations were on par in soybean + 2 rows of sorghum and 2 rows of bhendi intercrop. Highest population (12.18) was noticed in pure soybean plot. (Table 40) (Fig.9).

### 4.5.3 EFFECT ON NATURAL ENEMIES

#### 4.5.3.1 Coccinellid - *Menochilus sexmaculatus*

The predatory population like coccinellids and spiders etc., were prevalent in the intercropped system. The study on the predatory coccinellid population at Avinashi revealed that significantly highest mean population were recorded in soybean + 4 rows sorghum (23.90), soybean + 4 rows maize (23.60) and soybean + 2 rows sorghum (22.30) which were on par with each other. Lowest coccinellids population was observed in soybean + 2 and 4 rows of bhendi (Table 41).

At Bhavani the mean population of coccinellid were found to be significantly more in soybean + 4 rows of maize (20.89) and pure crop of soybean (18.40) followed by soybean + 4 rows of sorghum (16.03), soybean + 2 rows of maize (15.75) and soybean + 4 rows of bhendi (15.42) (Table 42)(Fig.10).

Table 38 EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF *Heliothis armigera* ON SOYBEAN\*

LOCATION : BHAVANI

| Treatments                          | Nos / 10 Plants   |                   |                   |                   |                   |                   |                   |                   | Mean                         |
|-------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|------------------------------|
|                                     | DAS               |                   |                   |                   |                   |                   |                   |                   |                              |
|                                     | 25                | 32                | 39                | 46                | 53                | 60                | 67                | 74                |                              |
| Soybean (6 rows) + Maize (2 rows)   | 5.70<br>(2.46)    | 9.00<br>(3.07)    | 15.00<br>(3.92)   | 15.30<br>(3.97)   | 21.30<br>(4.65)   | 22.00<br>(4.97)   | 7.70<br>(2.84)    | 3.00<br>(1.85)    | 12.40<br>(3.44) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (2 rows)  | 10.70<br>(3.33)   | 15.70<br>(4.01)   | 27.30<br>(5.26)   | 27.30<br>(5.27)   | 36.00<br>(6.04)   | 30.00<br>(5.52)   | 17.00<br>(4.18)   | 7.00<br>(2.72)    | 21.40<br>(4.54) <sup>c</sup> |
| Soybean (6 rows) + Sorghum (2 rows) | 6.30<br>(2.61)    | 10.30<br>(3.28)   | 21.30<br>(4.66)   | 22.70<br>(4.79)   | 26.00<br>(5.14)   | 24.70<br>(5.01)   | 15.00<br>(3.93)   | 5.30<br>(2.41)    | 16.50<br>(3.98) <sup>c</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 2.30<br>(1.67)    | 7.30<br>(2.79)    | 9.30<br>(3.13)    | 9.30<br>(3.10)    | 11.30<br>(3.40)   | 16.00<br>(4.05)   | 5.30<br>(2.33)    | 2.70<br>(1.76)    | 7.90<br>(2.78) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 11.30<br>(3.43)   | 16.00<br>(4.05)   | 24.30<br>(4.98)   | 23.70<br>(4.91)   | 34.00<br>(5.87)   | 30.70<br>(5.57)   | 16.00<br>(4.04)   | 5.30<br>(2.40)    | 20.20<br>(4.41) <sup>c</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 4.70<br>(2.27)    | 9.00<br>(3.07)    | 12.00<br>(3.52)   | 11.70<br>(3.47)   | 15.00<br>(3.93)   | 20.70<br>(4.58)   | 17.70<br>(4.25)   | 3.30<br>(1.90)    | 11.80<br>(3.38) <sup>b</sup> |
| Soybean alone (6 rows)              | 12.00<br>(3.52)   | 17.70<br>(4.21)   | 25.30<br>(5.07)   | 26.70<br>(5.20)   | 36.00<br>(6.03)   | 30.70<br>(5.58)   | 14.30<br>(3.83)   | 5.70<br>(2.48)    | 21.00<br>(4.49) <sup>c</sup> |
| Mean                                | 2.76 <sup>b</sup> | 3.50 <sup>c</sup> | 4.36 <sup>d</sup> | 4.39 <sup>d</sup> | 5.01 <sup>e</sup> | 5.01 <sup>e</sup> | 3.63 <sup>c</sup> | 2.22 <sup>a</sup> | 3.86                         |

TREATMENT      DAYS  
SE (d)      0.085  
CD      0.179

\* Mean of 3 replications  
DAS : Days after sowing  
Figures in parenthesis are transformed values.

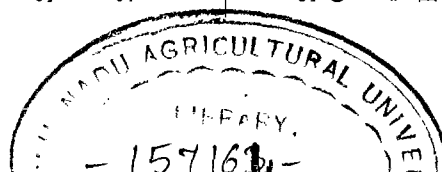


Table. 39. Effect of intercropping system on the incidence on *Spodoptera litura* of soybean \*

| Location : Avinashi                 |  | Nos. / 10 Plants |                 |                 |                 |                 |                 |                |                              |
|-------------------------------------|--|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|----------------|------------------------------|
| Treatments                          |  | DAS              |                 |                 |                 |                 |                 |                |                              |
|                                     |  | 25               | 32              | 39              | 46              | 53              | 60              | 67             | Mean                         |
| Soybean (6 rows) + maize (2 rows)   |  | 7.50<br>(2.82)   | 9.93<br>(3.23)  | 13.47<br>(3.73) | 16.80<br>(4.15) | 17.96<br>(4.30) | 6.63<br>(2.67)  | 1.83<br>(1.52) | 10.52<br>(3.20) <sup>d</sup> |
| Soybean (6 rows) + bhendi (2 rows)  |  | 10.86<br>(3.26)  | 13.33<br>(3.72) | 15.46<br>(3.99) | 17.70<br>(4.25) | 16.16<br>(4.08) | 6.13<br>(2.56)  | 1.33<br>(1.34) | 10.59<br>(3.20) <sup>d</sup> |
| Soybean (6 rows) + sorghum (2 rows) |  | 7.20<br>(2.77)   | 11.26<br>(3.43) | 11.80<br>(3.50) | 15.36<br>(3.97) | 14.93<br>(3.92) | 5.20<br>(2.37)  | 1.33<br>(1.35) | 9.58<br>(3.05) <sup>c</sup>  |
| Soybean (6 rows) + maize (4 rows)   |  | 2.90<br>(1.84)   | 5.13<br>(2.36)  | 7.56<br>(2.83)  | 9.66<br>(3.18)  | 7.60<br>(2.84)  | 3.83<br>(2.08)  | 1.06<br>(1.25) | 5.39<br>(2.34) <sup>a</sup>  |
| Soybean (6 rows) + bhendi (4 rows)  |  | 4.93<br>(2.32)   | 7.16<br>(2.76)  | 9.48<br>(3.14)  | 14.60<br>(3.47) | 12.80<br>(3.50) | 6.40<br>(2.59)  | 1.40<br>(1.37) | 8.12<br>(2.94) <sup>b</sup>  |
| Soybean (6 rows) + sorghum (4 rows) |  | 4.60<br>(2.25)   | 7.16<br>(2.76)  | 9.40<br>(3.14)  | 11.60<br>(3.47) | 11.80<br>(3.50) | 6.40<br>(2.59)  | 1.40<br>(1.37) | 7.52<br>(2.74) <sup>b</sup>  |
| Soybean alone (6 rows)              |  | 9.06<br>(3.09)   | 11.06<br>(3.40) | 15.00<br>(3.93) | 18.83<br>(4.39) | 20.93<br>(4.62) | 10.13<br>(3.25) | 3.16<br>(1.89) | 12.60<br>(3.51) <sup>e</sup> |
| Mean                                |  | 6.72<br>(2.64)   | 9.17<br>(3.08)  | 11.90<br>(3.49) | 14.55<br>(3.85) | 14.51<br>(2.58) | 6.32<br>(2.56)  | 1.62<br>(1.45) | 9.26<br>(2.98)               |

Treatment

SE(d) 0.059

CD 0.118

\* Mean of 3 replications, DAS : Days After Sowing, Figures in parenthesis are  $\sqrt{x+0.5}$  transformed values.

Table. 40. Effect of intercropping system on the incidence on *Spodoptera litura* of soybean \*

| Location : Bhavani                  |  | Nos/ 10 Plants |                |                  |                 |                 |                             |                |                               |
|-------------------------------------|--|----------------|----------------|------------------|-----------------|-----------------|-----------------------------|----------------|-------------------------------|
| Treatments                          |  | DAS            |                |                  |                 |                 |                             |                |                               |
|                                     |  | 25             | 32             | 39               | 46              | 53              | 60                          | 67             | Mean                          |
| Soybean (6 rows) + maize (2 rows)   |  | 4.33<br>(2.19) | 8.20<br>(2.93) | 8.40<br>(2.97)   | 12.26<br>(3.56) | 15.53<br>(4.00) | 9.76<br>(3.16)              | 2.56<br>(1.75) | 8.72<br>(2.94) <sup>b</sup>   |
| Soybean (6 rows) + bhendi (2 rows)  |  | 4.73<br>(2.28) | 8.80<br>(3.04) | 14.10<br>(3.80)  | 17.96<br>(4.28) | 20.86<br>(4.62) | 9.86 <sup>*</sup><br>(3.21) | 2.50<br>(1.72) | 11.26<br>(3.28) <sup>de</sup> |
| Soybean (6 rows) + sorghum (2 rows) |  | 3.90<br>(2.09) | 7.96<br>(2.90) | 10.60<br>(3.331) | 13.40<br>(3.72) | 18.66<br>(4.37) | 10.13<br>(3.25)             | 3.13<br>(1.89) | 9.68<br>(3.08) <sup>bc</sup>  |
| Soybean (6 rows) + maize (4 rows)   |  | 3.36<br>(1.96) | 5.76<br>(2.50) | 8.16<br>(2.93)   | 11.63<br>(3.47) | 13.46<br>(3.73) | 8.53<br>(3.00)              | 2.56<br>(1.75) | 7.64<br>(2.76) <sup>a</sup>   |
| Soybean (6 rows) + bhendi (4 rows)  |  | 4.00<br>(2.12) | 6.63<br>(2.67) | 9.33<br>(3.13)   | 12.46<br>(3.59) | 14.56<br>(3.87) | 9.43<br>(3.15)              | 2.33<br>(1.67) | 8.39<br>(2.88) <sup>a</sup>   |
| Soybean (6 rows) + sorghum (4 rows) |  | 4.13<br>(2.15) | 7.23<br>(2.78) | 9.96<br>(3.23)   | 14.60<br>(3.88) | 14.80<br>(3.89) | 10.53<br>(3.28)             | 2.16<br>(1.63) | 9.06<br>(2.97) <sup>b</sup>   |
| Soybean alone (6 rows)              |  | 4.53<br>(2.23) | 8.30<br>(2.96) | 16.30<br>(4.07)  | 18.96<br>(4.41) | 24.23<br>(4.98) | 10.44<br>(3.29)             | 2.66<br>(1.75) | 12.18<br>(3.38) <sup>e</sup>  |
| Mean                                |  | 4.14<br>(2.15) | 7.55<br>(2.83) | 10.96<br>(3.35)  | 14.47<br>(3.84) | 17.45<br>(4.21) | 9.81<br>(3.19)              | 2.56<br>(1.74) | 9.56<br>(3.04)                |

Treatment

SE(d) 0.075

CD 0.148

\* Mean of 3 replications, DAS : Days After Sowing, Figures in parenthesis are  $\sqrt{x+0.5}$  transformed values.

**Table 41 EFFECT OF INTERCROPPING SYSTEM ON THE OCCURRENCE OF THE Coccinellids ON SOYBEAN\***  
**LOCATION : AVINASHI**

| Treatments                          | Nos / 10 Plants   |                   |                   |                   |                   |                   |                   |                   | Mean                         |
|-------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|------------------------------|
|                                     | DAS               |                   |                   |                   |                   |                   |                   |                   |                              |
|                                     | 25                | 32                | 39                | 46                | 53                | 60                | 67                | 74                |                              |
| Soybean (6 rows) + Maize (2 rows)   | 8.70<br>(3.00)    | 10.70<br>(3.33)   | 18.00<br>(4.29)   | 24.00<br>(4.94)   | 26.70<br>(5.21)   | 14.00<br>(3.80)   | 7.70<br>(2.84)    | 2.30<br>(1.64)    | 14.00<br>(3.63) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (2 rows)  | 9.30<br>(3.12)    | 11.30<br>(3.43)   | 19.70<br>(4.48)   | 28.70<br>(6.25)   | 27.30<br>(6.54)   | 17.30<br>(5.00)   | 8.70<br>(3.57)    | 4.00<br>(2.67)    | 15.80<br>(3.88) <sup>c</sup> |
| Soybean (6 rows) + Sorghum (2 rows) | 11.70<br>(3.46)   | 13.70<br>(3.76)   | 28.70<br>(5.39)   | 38.70<br>(6.25)   | 42.30<br>(6.54)   | 24.70<br>(5.00)   | 12.30<br>(3.57)   | 6.70<br>(2.67)    | 22.30<br>(4.58) <sup>a</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 9.00<br>(3.07)    | 10.30<br>(3.33)   | 11.30<br>(4.55)   | 19.70<br>(5.45)   | 24.00<br>(5.27)   | 10.00<br>(4.05)   | 4.70<br>(2.85)    | 1.30<br>(1.77)    | 23.60<br>(4.75) <sup>a</sup> |
| Soybean (6 rows) + Bhendi (4 rows)  | 8.70<br>(3.00)    | 10.70<br>(4.01)   | 20.30<br>(5.68)   | 29.30<br>(6.35)   | 27.30<br>(6.76)   | 16.00<br>(5.17)   | 7.70<br>(3.48)    | 2.70<br>(2.79)    | 15.30<br>(3.78) <sup>c</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 13.00<br>(3.65)   | 15.70<br>(4.01)   | 32.00<br>(5.68)   | 40.00<br>(6.35)   | 45.30<br>(6.76)   | 26.30<br>(5.17)   | 11.70<br>(3.48)   | 7.30<br>(2.79)    | 23.90<br>(4.74) <sup>a</sup> |
| Soybean alone (6 rows)              | 13.00<br>(3.67)   | 16.00<br>(4.06)   | 24.70<br>(5.00)   | 38.70<br>(6.25)   | 36.70<br>(6.09)   | 20.70<br>(4.59)   | 10.00<br>(3.23)   | 4.30<br>(2.15)    | 20.50<br>(4.38) <sup>b</sup> |
| Mean                                | 3.28 <sup>c</sup> | 3.60 <sup>d</sup> | 4.69 <sup>f</sup> | 5.59 <sup>g</sup> | 5.73 <sup>g</sup> | 4.29 <sup>e</sup> | 3.03 <sup>b</sup> | 2.06 <sup>a</sup> | 4.03                         |

**TREATMENT**      **DAYS**  
SE (d)      0.084      0.091  
CD      0.168      0.179

\* Mean of 3 replications  
DAS : Days after sowing  
Figures in parenthesis are transformed values.

Table 42 : EFFECT OF INTERCROPPING SYSTEM ON THE OCCURRENCE OF THE Coccinellids ON SOYBEAN\*

## LOCATION : BHAVANI

| Treatments                          | Nos / 10 Plants              |                              |                              |                              |                              |                             |                             | Mean                          |
|-------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|-------------------------------|
|                                     | DAS                          |                              |                              |                              |                              |                             |                             |                               |
|                                     | 32                           | 39                           | 46                           | 53                           | 60                           | 67                          | 74                          |                               |
| Soybean (6 rows) + Maize (2 rows)   | 15.57<br>(4.00)              | 16.83<br>(4.16)              | 25.50<br>(5.09)              | 28.77<br>(5.39)              | 12.87<br>(3.65)              | 6.23<br>(2.56)              | 4.47<br>(2.21)              | 15.75<br>(3.87) <sup>c</sup>  |
| Soybean (6 rows) + Bhendi (2 rows)  | 9.70<br>(3.19)               | 11.43<br>(3.45)              | 20.27<br>(4.56)              | 29.27<br>(5.40)              | 13.93<br>(3.78)              | 5.40<br>(2.42)              | 4.40<br>(2.21)              | 13.49<br>(3.57) <sup>e</sup>  |
| Soybean (6 rows) + Sorghum (2 rows) | 12.53<br>(3.61)              | 14.73<br>(3.90)              | 22.07<br>(4.73)              | 27.60<br>(5.30)              | 11.73<br>(3.49)              | 6.70<br>(2.64)              | 4.40<br>(2.20)              | 14.28<br>(3.70) <sup>de</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 24.73<br>(5.01)              | 25.33<br>(5.08)              | 34.80<br>(5.93)              | 37.27<br>(6.14)              | 13.13<br>(3.68)              | 7.53<br>(2.83)              | 3.40<br>(1.97)              | 20.89<br>(4.38) <sup>a</sup>  |
| Soybean (6 rows) + Bhendi (4 rows)  | 16.73<br>(4.15)              | 9.93<br>(4.51)               | 24.20<br>(4.97)              | 26.70<br>(5.21)              | 10.17<br>(3.26)              | 7.07<br>(2.74)              | 3.13<br>(1.90)              | 15.42<br>(3.82) <sup>cd</sup> |
| Soybean (6 rows) + Sorghum (4 rows) | 20.57<br>(4.58)              | 19.07<br>(4.42)              | 24.13<br>(4.96)              | 28.33<br>(5.34)              | 10.00<br>(3.24)              | 7.03<br>(2.70)              | 3.07<br>(1.88)              | 16.03<br>(3.87) <sup>c</sup>  |
| Soybean alone (6 rows)              | 21.23<br>(4.66)              | 21.13<br>(4.65)              | 28.00<br>(5.32)              | 33.20<br>(5.80)              | 10.77<br>(3.36)              | 8.07<br>(2.92)              | 3.60<br>(2.02)              | 18.40<br>(4.18) <sup>a</sup>  |
| Mean                                | 14.30<br>(4.17) <sup>d</sup> | 18.35<br>(4.31) <sup>b</sup> | 25.57<br>(5.08) <sup>b</sup> | 30.16<br>(5.51) <sup>a</sup> | 11.80<br>(3.49) <sup>e</sup> | 6.86<br>(2.69) <sup>f</sup> | 3.78<br>(2.06) <sup>g</sup> | 16.26<br>(3.90)               |

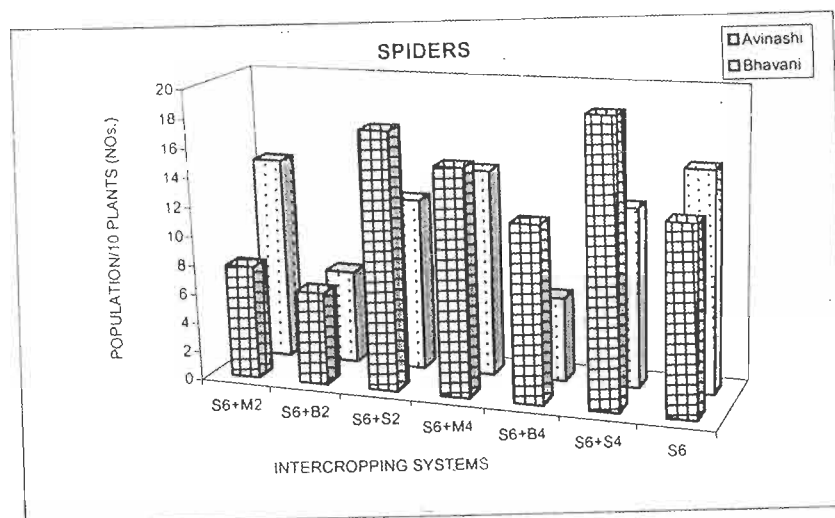
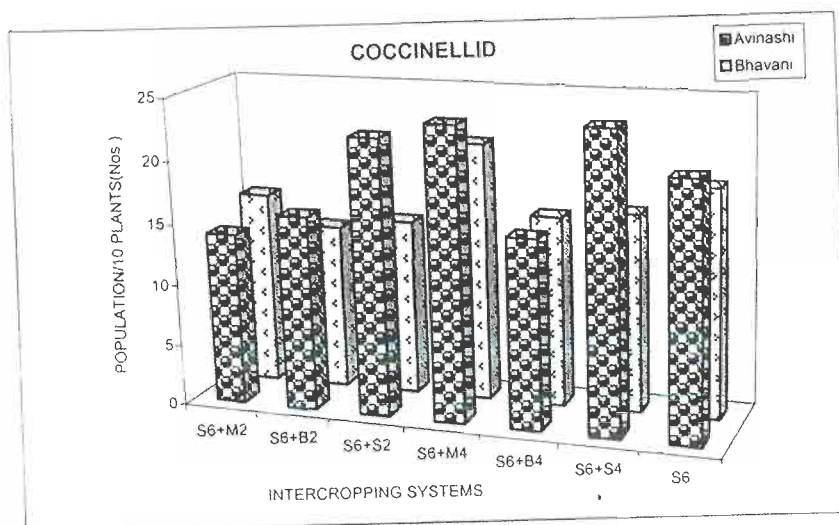
| TREATMENT | DAYS  |
|-----------|-------|
| SE (d)    | 0.169 |
| CD        | 0.209 |

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

**Fig.10. Effect of intercropping system and incidence of natural enemies (Coccinellid and Spiders)**



S6+M2-Soybean 6rows+Maize 2 rows; S6+B2-Soybean 6rows+Bhendi 2 rows;  
 S6+B2-Soybean 6rows+Bhendi 2 rows; S6+M2-Soybean 6rows+Maize 2 rows;  
 S6+B4-Soybean 6rows+Bhendi 4 rows; S6+S2-Soybean 6rows+Sorghum 2 rows;  
 S6-Soybean 6 rows only.

In both the studies the mean population of predatory coccinellids were found to be gradually increasing with the advancement of crop growth stages especially during 39-53 DAS and found to decrease at the later growth stage.

#### **4.5.3.2 Spiders**

Spiders play important role in reducing the insect pests of soybean. At Avinashi, the study revealed that the mean population was found to be significantly highest in soybean + 2 rows of sorghum (17.61) and soybean + 4 rows of sorghum (19.28) and these were on par with soybean + 4 rows of maize. (15.44) In soybean pure crop also the spider population was more (12.78) (Table 43) (Fig.10).

Study conducted at Bhavani revealed that the mean population of spiders was significantly high in pure crop of soybean (15.00) followed by soybean + 4 rows of maize (14.10) and soybean + 2 rows of maize (14.00).

In both the analyses the mean population growth was gradually increasing from 39 days to 60 days (Table 44).

### **4.5.4 EFFECT ON YIELD COMPONENTS**

#### **4.5.4.1 Pod development**

Intercropping system viz., soybean + 2 rows of sorghum and soybean + 4 rows of sorghum have recorded highest pods per plant at Avinashi and Bhavani. All other intercrop systems including pure crop of soybean had recorded equal number of pods/plant and they were on par (Table 45).

#### **4.5.4.2 Number of grains**

Significantly highest numbers of grains per plant was recorded in soybean pure crop, soybean + 2 rows of maize, soybean + 4 rows of maize, and soybean + 4 rows of bhendi followed by other intercropping system (Table 45).

Table 43 EFFECT OF INTERCROPPING SYSTEM ON THE INCIDENCE OF SPIDERS ON SOYBEAN\*

| Treatments                          | Nos./10 Plants               |                              |                              |                              |                              |                             | Mean                          |
|-------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|
|                                     | DAS                          |                              |                              |                              |                              |                             |                               |
|                                     | 39                           | 46                           | 53                           | 60                           | 67                           | 74                          |                               |
| Soybean (6 rows) + Maize (2 rows)   | 8.33<br>(2.82)               | 11.13<br>(3.42)              | 11.00<br>(3.35)              | 12.00<br>(3.53)              | 9.33<br>(3.12)               | 4.67<br>(2.26)              | 7.78<br>(2.40) <sup>d</sup>   |
| Soybean (6 rows) + Bhendi (2 rows)  | 6.33<br>(2.51)               | 7.33<br>(2.74)               | 9.33<br>(3.09)               | 6.33<br>(2.59)               | 4.33<br>(2.18)               | 4.33<br>(2.18)              | 6.33<br>(2.55) <sup>d</sup>   |
| Soybean (6 rows) + Sorghum (2 rows) | 10.33<br>(3.29)              | 13.00<br>(3.65)              | 32.00<br>(5.68)              | 26.67<br>(5.21)              | 17.67<br>(4.25)              | 6.00<br>(2.54)              | 17.61<br>(4.10) <sup>a</sup>  |
| Soybean (6 rows) + Maize (4 rows)   | 9.67<br>(3.18)               | 12.67<br>(3.61)              | 13.33<br>(3.69)              | 25.67<br>(5.08)              | 24.67<br>(4.99)              | 6.67<br>(2.65)              | 15.44<br>(3.87) <sup>ab</sup> |
| Soybean (6 rows) + Bhendi (4 rows)  | 6.33<br>(2.60)               | 7.67<br>(2.80)               | 19.00<br>(4.37)              | 23.00<br>(4.85)              | 12.67<br>(3.62)              | 3.67<br>(2.00)              | 12.06<br>(3.37) <sup>c</sup>  |
| Soybean (6 rows) + Sorghum (4 rows) | 9.67<br>(3.17)               | 17.00<br>(4.18)              | 36.67<br>(6.09)              | 28364<br>(5.40)              | 18.67<br>(4.36)              | 5.00<br>(2.30)              | 19.28<br>(4.25) <sup>a</sup>  |
| Soybean alone (6 rows)              | 7.33<br>(2.79)               | 11.33<br>(3.41)              | 16.00<br>(4.06)              | 21.33<br>(4.67)              | 14.67<br>(3.86)              | 6.00<br>(2.53)              | 12.78<br>(3.55) <sup>bc</sup> |
| MEAN                                | 11.14<br>(3.18) <sup>e</sup> | 11.48<br>(3.40) <sup>b</sup> | 19.62<br>(4.34) <sup>a</sup> | 20.52<br>(4.47) <sup>a</sup> | 14.57<br>(3.77) <sup>b</sup> | 5.19<br>(2.35) <sup>d</sup> | 13.78<br>(3.59)               |

| TREATMENT | DAYS  |
|-----------|-------|
| SE (d)    | 0.223 |
| CD        | 0.144 |

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

Table 44 EFFECT OF INTERCROPPING SYSTEM ON THE OCCURRENCE OF SPIDERS ON SOYBEAN\*

| Treatments                          | Nos / 10 Plants             |                             |                              |                              |                              |                              |                             |                             | Mean                         |
|-------------------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|------------------------------|
|                                     | DAS                         |                             |                              |                              |                              |                              |                             |                             |                              |
|                                     | 25                          | 32                          | 39                           | 46                           | 53                           | 60                           | 67                          | 74                          |                              |
| Soybean (6 rows) + Maize (2 rows)   | 4.70<br>(2.70)              | 11.00<br>(3.38)             | 17.70<br>(4.26)              | 22.30<br>(4.77)              | 26.70<br>(5.21)              | 17.30<br>(4.22)              | 9.00<br>(3.07)              | 3.00<br>(1.85)              | 14.00<br>(3.63) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (2 rows)  | 2.70<br>(1.76)              | 4.30<br>(2.18)              | 7.70<br>(2.85)               | 10.00<br>(3.23)              | 12.30<br>(3.57)              | 9.00<br>(3.07)               | 3.00<br>(1.86)              | 2.00<br>(1.55)              | 6.40<br>(2.51) <sup>d</sup>  |
| Soybean (6 rows) + Sorghum (2 rows) | 6.00<br>(2.52)              | 8.70<br>(3.00)              | 14.30<br>(3.84)              | 18.70<br>(4.37)              | 20.30<br>(4.56)              | 14.30<br>(3.85)              | 9.00<br>(3.05)              | 2.70<br>(1.76)              | 11.80<br>(3.37) <sup>b</sup> |
| Soybean (6 rows) + Maize (4 rows)   | 4.70<br>(2.26)              | 11.30<br>(3.43)             | 19.30<br>(4.43)              | 22.00<br>(4.73)              | 29.30<br>(5.45)              | 16.30<br>(4.10)              | 6.70<br>(2.63)              | 3.30<br>(1.95)              | 14.10<br>(3.62) <sup>b</sup> |
| Soybean (6 rows) + Bhendi (4 rows)  | 2.30<br>(1.67)              | 4.00<br>(2.08)              | 7.30<br>(2.75)               | 8.00<br>(2.87)               | 12.00<br>(3.52)              | 6.30<br>(2.60)               | 3.30<br>(1.95)              | 1.30<br>(1.34)              | 5.75<br>(2.45) <sup>d</sup>  |
| Soybean (6 rows) + Sorghum (4 rows) | 6.30<br>(2.61)              | 9.30<br>(3.13)              | 12.70<br>(3.61)              | 21.30<br>(4.66)              | 22.00<br>(4.74)              | 15.00<br>(3.93)              | 7.30<br>(2.77)              | 3.70<br>(2.03)              | 12.20<br>(3.43) <sup>b</sup> |
| Soybean alone (6 rows)              | 9.00<br>(3.07)              | 12.70<br>(3.62)             | 16.00<br>(4.05)              | 22.70<br>(4.81)              | 28.00<br>(5.33)              | 15.70<br>(4.01)              | 11.30<br>(3.43)             | 4.30<br>(2.18)              | 15.00<br>(3.81) <sup>a</sup> |
| Mean                                | 5.10<br>(2.31) <sup>b</sup> | 8.80<br>(2.97) <sup>d</sup> | 13.60<br>(3.68) <sup>e</sup> | 17.90<br>(4.21) <sup>f</sup> | 21.50<br>(4.63) <sup>g</sup> | 13.40<br>(3.68) <sup>e</sup> | 7.10<br>(2.68) <sup>c</sup> | 2.90<br>(1.81) <sup>a</sup> | 11.30<br>(3.25)              |

| TREATMENT | DAYS  |
|-----------|-------|
| SE (d)    | 0.086 |
| CD        | 0.092 |

\* Mean of 3 replications

DAS : Days after sowing

Figures in parenthesis are transformed values.

#### 4.5.4.3 Yield per ha<sup>-1</sup>

Calculated yield per hectare at Avinashi showed significantly highest yield (1843 kg) per ha in pure crop of soybean and soybean + 4 rows of maize (1831 kg) per ha. This was followed by other intercropped system which were at par. At Bhavani, soybean + 2 rows of maize, (1845 kg) per ha, 4 rows of maize (1802 kg) per ha and soybean pure crop (1909 kg) recorded the highest yield per hectare. This is followed by soybean + 4 rows of sorghum (Table 45).

### 4.6. FIELD EFFICACY OF DIFFERENT INSECTICIDES ON INSECT PESTS OF SOYBEAN

#### 4.6.1. Sucking pests

##### 4.6.1.1. Leaf hopper - *Empoasca fabae*

Field trails were laid out to study the effect of commonly available insecticides against the soybean insect pests prevalent during February'95 at TNAU and Udumalpet on soybean var. Co.1.

Significant reduction in the mortality of leaf hoppers population over control was observed in all the treatments. But, methyl-o-demeton 0.05 per cent and monocrotophos 0.05 per cent were found to be highly superior in reducing the population than other treatments and were effective upto 14<sup>th</sup> day after first spraying. Endosulfan 0.07 per cent and phosphomidon 0.04 per cent were next best insecticides in reducing the leaf hoppers population. The same efficacy was also noticed during second spraying where in methyl-o-demeton and monocrotophos were found to be superior insecticides in reducing the leaf hoppers population than other treatments (Table 46).

In the field experiment at TNAU, Coimbatore the per cent reduction was worked out from the data gathered. Leaf hopper population at 14<sup>th</sup> day after treatment indicated that application of methyl-o-demeton 0.05 per cent, endosulfan 0.07 per cent and monocrotophos 0.05 per cent were significantly superior in

Table 45. Effect of intercropping system on yield components and yield per hectare

| Treatments                          | No. of Pods/ Plants |                   | No. of Grains/ Plant |                   | Yield kg/ha <sup>-1</sup> |                      |
|-------------------------------------|---------------------|-------------------|----------------------|-------------------|---------------------------|----------------------|
|                                     | Avinashi            | Bhavani           | Avinashi             | Bhavani           | Avinashi                  | Bhavani              |
| Soybean (6 rows) + maize (2 rows)   | 68.3 <sup>b</sup>   | 52.0 <sup>c</sup> | 89.8 <sup>a</sup>    | 90.7 <sup>a</sup> | 1798.60 <sup>b</sup>      | 1845.40 <sup>a</sup> |
| Soybean (6 rows) + bhendi ( 2 rows) | 67.6 <sup>b</sup>   | 52.7 <sup>c</sup> | 68.0 <sup>b</sup>    | 74.7 <sup>b</sup> | 1504.20 <sup>c</sup>      | 1348.80 <sup>e</sup> |
| Soybean (6 rows) + sorghum (2 rows) | 80.2 <sup>a</sup>   | 79.2 <sup>a</sup> | 67.2 <sup>b</sup>    | 68.3 <sup>c</sup> | 1632.40 <sup>c</sup>      | 1505.00 <sup>d</sup> |
| Soybean (6 rows) + maize (4 rows)   | 71.4 <sup>b</sup>   | 54.6 <sup>c</sup> | 92.3 <sup>a</sup>    | 89.4 <sup>a</sup> | 1830.67 <sup>a</sup>      | 1802.00 <sup>a</sup> |
| Soybean (6 rows) + bhendi (4 rows)  | 71.8 <sup>b</sup>   | 53.4 <sup>c</sup> | 89.3 <sup>a</sup>    | 74.0 <sup>d</sup> | 1601.60 <sup>d</sup>      | 1620.00 <sup>c</sup> |
| Soybean (6 rows) + sorghum (4 rows) | 81.3 <sup>a</sup>   | 76.3 <sup>a</sup> | 66.6 <sup>b</sup>    | 68.6 <sup>c</sup> | 1763.80 <sup>b</sup>      | 1686.80 <sup>b</sup> |
| Soybean alone (6 rows)              | 72.8 <sup>b</sup>   | 62.3 <sup>b</sup> | 92.3 <sup>a</sup>    | 89.1 <sup>a</sup> | 1843.47 <sup>a</sup>      | 1909.20 <sup>a</sup> |

\* Mean of three replications.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Table 46. Field efficacy of insecticides against management of insect pests of soybean leafhopper – *Empoasca fabae*

Location : Udumalpet

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                 |                                |                                 |                                 |                                 |                       |  | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|---------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|-----------------------|--|-------------|
|                  |         |               | Ist Spraying                           |                                 |                                | IInd Spraying                   |                                 |                                 |                       |  |             |
|                  |         |               | DAS                                    |                                 |                                | DAS                             |                                 |                                 |                       |  |             |
|                  |         |               | 1                                      | 7                               | 14                             | 1                               | 7                               | 14                              | 14                    |  |             |
| Quinolphos       | 25 EC   | 0.04          | 64.32<br>(53.36) <sup>cd</sup>         | 58.62<br>(49.97) <sup>b</sup>   | 50.35<br>(45.20) <sup>cd</sup> | 63.96<br>(53.13) <sup>bcd</sup> | 58.70<br>(50.02) <sup>cd</sup>  | 47.87<br>(43.77) <sup>cd</sup>  | 1633.33 <sup>d</sup>  |  |             |
| Sevinflo         | 45 AF   | 0.07          | 57.46<br>(49.31) <sup>de</sup>         | 51.60<br>(49.92) <sup>bcd</sup> | 40.53<br>(39.53) <sup>c</sup>  | 62.02<br>(52.01) <sup>cd</sup>  | 46.14<br>(42.78) <sup>c</sup>   | 46.56<br>(43.03) <sup>cd</sup>  | 1172.00 <sup>c</sup>  |  |             |
| Endosulfan       | 35 EC   | 0.07          | 75.22<br>(60.26) <sup>ab</sup>         | 68.38<br>(55.82) <sup>a</sup>   | 58.65<br>(50.01) <sup>ab</sup> | 70.27<br>(57.03) <sup>b</sup>   | 65.46<br>(54.03) <sup>ab</sup>  | 60.70<br>(51.13) <sup>ab</sup>  | 2021.00 <sup>ab</sup> |  |             |
| Phoslone         | 35 EC   | 0.05          | 51.20<br>(45.68) <sup>e</sup>          | 45.38<br>(42.62) <sup>d</sup>   | 43.66<br>(41.35) <sup>de</sup> | 61.93<br>(51.92) <sup>cd</sup>  | 49.76<br>(44.86) <sup>de</sup>  | 46.49<br>(42.98) <sup>cd</sup>  | 1243.63 <sup>c</sup>  |  |             |
| Phosphomidon     | 86 EC   | 0.04          | 72.50<br>(58.42) <sup>bc</sup>         | 66.89<br>(54.88) <sup>b</sup>   | 56.04<br>(48.47) <sup>bc</sup> | 69.68<br>(56.69) <sup>cd</sup>  | 60.59<br>(52.49) <sup>abc</sup> | 54.71<br>(47.72) <sup>bc</sup>  | 1484.66 <sup>d</sup>  |  |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 83.34<br>(65.96) <sup>a</sup>          | 72.56<br>(58.45) <sup>a</sup>   | 64.23<br>(53.29) <sup>a</sup>  | 79.41<br>(63.04) <sup>a</sup>   | 72.59<br>(58.44) <sup>a</sup>   | 63.64<br>(52.93) <sup>a</sup>   | 1931.00 <sup>bc</sup> |  |             |
| Dimethoate       | 30 EC   | 0.03          | 71.68<br>(57.88) <sup>bc</sup>         | 54.53<br>(47.61) <sup>bc</sup>  | 46.97<br>(43.25) <sup>de</sup> | 63.53<br>(52.85) <sup>bcd</sup> | 62.66<br>(52.37) <sup>abc</sup> | 52.62<br>(46.51) <sup>bcd</sup> | 2070.00 <sup>ab</sup> |  |             |
| Monocrotophos    | 36 WSC  | 0.05          | 75.35<br>(60.30) <sup>ab</sup>         | 71.36<br>(57.69) <sup>a</sup>   | 66.81<br>(54.81) <sup>a</sup>  | 77.25<br>(61.54) <sup>a</sup>   | 71.85<br>(58.10) <sup>ab</sup>  | 62.91<br>(51.26) <sup>ab</sup>  | 2132.33 <sup>a</sup>  |  |             |
| Fenubucarb       | 50 EC   | 0.05          | 50.96<br>(45.57) <sup>c</sup>          | 47.99<br>(43.84) <sup>cd</sup>  | 41.59<br>(40.15) <sup>e</sup>  | 58.13<br>(49.69) <sup>d</sup>   | 51.52<br>(45.87) <sup>de</sup>  | 44.16<br>(41.63) <sup>d</sup>   | 1287.00 <sup>e</sup>  |  |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 69.08<br>(56.37) <sup>bc</sup>         | 55.65<br>(48.27) <sup>bc</sup>  | 49.98<br>(44.93) <sup>cd</sup> | 69.66<br>(56.06) <sup>bc</sup>  | 62.09<br>(52.02) <sup>bc</sup>  | 49.75<br>(44.85) <sup>cd</sup>  | 1843.33 <sup>c</sup>  |  |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

reducing the leafhopper population. After the second spraying also, the efficacy of the above insecticides persisted upto 14<sup>th</sup> DAT as evidenced by reduction in the population. This was followed by dimethoate 0.03 per cent. (Table 47).

#### 4.6.1.2 White fly - *Bemisia tabaci*

Significant differences were recorded in the per cent reduction of the whitefly population over the untreated control. Among the different insecticides tried methyl-o-demeton 0.05 per cent and dimethoate 0.03 per cent, and phosphomidon 0.04 per cent significantly reduced the population upto 14 DAT followed by monocrotophos 0.05 per cent, chlorpyriphos 0.05 per cent and endosulfan 0.07 per cent. After the second spraying, it was found that dimethoate 0.03 per cent, methyl-o-demeton 0.05 per cent, and phosphomidon 0.04 per cent were able to reduce the population significantly, followed by endosulfan 0.07 per cent monocrotophos 0.05 per cent and chlorphosphos 0.05 per cent (Table 48).

During February 1995 at TNAU, Coimbatore the per cent mortality of whitefly population was significantly higher by the application of endosulfan 0.07 per cent, methyl-o-demeton 0.05 per cent, monocrotophos 0.05 per cent and chlorpyriphos 0.05 per cent followed by quinolphos 0.04 per cent. The efficacy of these insecticides persisted upto 14 DAT. The similar effect was also seen even during second spraying (Table 49).

#### 4.6.1.3 Aphid – *Aphis craccivora*

The aphid attack was noticed at Udumalpet during February 1995. Different insecticides were evaluated against this pest and the results are furnished in the Table 50.

Table 47. Field efficacy of insecticides in the management of soybean\* leafhopper – *Empoasca fabae*

Location : TNAU, Coimbatore

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                 |                               |                                |                               |                      |  | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|--------------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|----------------------|--|-------------|
|                  |         |               | Ist Spraying                           |                                |                                 | IInd Spraying                 |                                |                               |                      |  |             |
|                  |         |               | DAS                                    |                                |                                 | DAS                           |                                |                               |                      |  |             |
|                  |         |               | 1                                      | 7                              | 14                              | 1                             | 7                              | 14                            | 14                   |  |             |
| Quinolphos       | 25 EC   | 0.04          | 69.54<br>(56.57) <sup>bc</sup>         | 59.39<br>(50.46) <sup>bc</sup> | 53.40<br>(46.91) <sup>cde</sup> | 71.42<br>(57.83) <sup>b</sup> | 57.59<br>(49.37) <sup>cd</sup> | 49.48<br>(44.71) <sup>b</sup> | 1787.33 <sup>d</sup> |  |             |
| Sevinflo         | 45 AF   | 0.07          | 58.33<br>(49.79) <sup>d</sup>          | 51.41<br>(45.81) <sup>c</sup>  | 47.91<br>(43.80) <sup>de</sup>  | 63.66<br>(52.99) <sup>b</sup> | 58.38<br>(49.83) <sup>bc</sup> | 50.88<br>(45.51) <sup>b</sup> | 1432.33 <sup>f</sup> |  |             |
| Endosulfan       | 35 EC   | 0.07          | 81.34<br>(64.62) <sup>a</sup>          | 73.93<br>(59.54) <sup>a</sup>  | 69.40<br>(56.46) <sup>a</sup>   | 82.89<br>(65.65) <sup>a</sup> | 72.10<br>(58.15) <sup>a</sup>  | 68.74<br>(56.01) <sup>a</sup> | 2042.33 <sup>b</sup> |  |             |
| Phosalone        | 35 EC   | 0.05          | 58.60<br>(49.98) <sup>d</sup>          | 51.39<br>(45.80) <sup>c</sup>  | 48.28<br>(44.01) <sup>de</sup>  | 64.77<br>(53.67) <sup>b</sup> | 51.87<br>(46.08) <sup>c</sup>  | 40.60<br>(39.15) <sup>c</sup> | 1481.00 <sup>e</sup> |  |             |
| Phosphomidon     | 86 EC   | 0.04          | 67.63<br>(55.32) <sup>bc</sup>         | 61.94<br>(51.95) <sup>bc</sup> | 55.25<br>(48.02) <sup>cd</sup>  | 65.38<br>(53.96) <sup>b</sup> | 61.90<br>(51.95) <sup>b</sup>  | 48.30<br>(44.02) <sup>b</sup> | 1480.00 <sup>e</sup> |  |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 80.56<br>(63.87) <sup>a</sup>          | 74.43<br>(59.67) <sup>a</sup>  | 66.94<br>(54.92) <sup>a</sup>   | 82.38<br>(65.28) <sup>a</sup> | 72.30<br>(58.27) <sup>a</sup>  | 67.05<br>(54.98) <sup>a</sup> | 1984.33 <sup>c</sup> |  |             |
| Dimethoate       | 30 EC   | 0.03          | 70.20<br>(56.94) <sup>bc</sup>         | 66.86<br>(54.93) <sup>ab</sup> | 57.86<br>(49.56) <sup>bc</sup>  | 67.30<br>(55.21) <sup>b</sup> | 62.44<br>(52.24) <sup>b</sup>  | 52.55<br>(46.46) <sup>b</sup> | 2031.67 <sup>b</sup> |  |             |
| Monocrotophos    | 36 WSC  | 0.05          | 81.36<br>(64.56) <sup>a</sup>          | 74.75<br>(59.84) <sup>a</sup>  | 69.36<br>(56.41) <sup>a</sup>   | 85.41<br>(67.59) <sup>a</sup> | 76.10<br>(60.74) <sup>a</sup>  | 68.26<br>(55.75) <sup>a</sup> | 2129.00 <sup>a</sup> |  |             |
| Fenubucarb       | 50 EC   | 0.05          | 64.01<br>(53.16) <sup>cd</sup>         | 52.92<br>(46.68) <sup>c</sup>  | 46.08<br>(42.75) <sup>e</sup>   | 63.44<br>(52.81) <sup>b</sup> | 54.73<br>(47.72) <sup>c</sup>  | 42.15<br>(40.45) <sup>c</sup> | 1302.67 <sup>g</sup> |  |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 74.06<br>(54.49) <sup>b</sup>          | 69.12<br>(56.26) <sup>ab</sup> | 64.01<br>(53.17) <sup>ab</sup>  | 81.10<br>(64.26) <sup>a</sup> | 56.79<br>(48.90) <sup>bc</sup> | 50.38<br>(45.22) <sup>b</sup> | 1793.33 <sup>d</sup> |  |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

**Table 48. Field efficacy of insecticides in the management of soybean\* whitefly – *Bemisia tabaci***

**Location : Udumalpet**

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                |                                 |                                |                                 | Yield Kg/ha           |
|------------------|---------|---------------|----------------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|-----------------------|
|                  |         |               | Ist Spraying                           |                                |                                | IInd Spraying                   |                                |                                 |                       |
|                  |         |               | DAS                                    |                                |                                | DAS                             |                                |                                 |                       |
|                  |         |               | 1                                      | 7                              | 14                             | 1                               | 7                              | 14                              |                       |
| Quinolphos       | 25 EC   | 0.04          | 62.46<br>(52.23) <sup>c</sup>          | 57.76<br>(49.48) <sup>c</sup>  | 45.72<br>(42.54) <sup>b</sup>  | 68.81<br>(56.11) <sup>bc</sup>  | 64.07<br>(53.21) <sup>ab</sup> | 61.63<br>(51.74) <sup>a-d</sup> | 1633.33 <sup>d</sup>  |
| Sevinflo         | 45 AF   | 0.07          | 65.23<br>(58.91) <sup>bc</sup>         | 58.07<br>(49.60) <sup>c</sup>  | 48.60<br>(44.19) <sup>b</sup>  | 50.78<br>(45.44) <sup>d</sup>   | 50.90<br>(45.53) <sup>cd</sup> | 54.26<br>(47.45) <sup>cd</sup>  | 1172.00 <sup>c</sup>  |
| Endosulfan       | 35 EC   | 0.07          | 75.63<br>(60.72) <sup>ab</sup>         | 65.16<br>(53.96) <sup>bc</sup> | 55.00<br>(47.87) <sup>b</sup>  | 67.51<br>(55.26) <sup>c</sup>   | 51.16<br>(45.68) <sup>cd</sup> | 64.66<br>(53.53) <sup>abc</sup> | 2021.00 <sup>ab</sup> |
| Phosalone        | 35 EC   | 0.05          | 59.64<br>(50.56) <sup>c</sup>          | 58.58<br>(49.97) <sup>c</sup>  | 53.63<br>(47.10) <sup>b</sup>  | 53.61<br>(47.17) <sup>d</sup>   | 50.64<br>(45.36) <sup>cd</sup> | 60.01<br>(50.78) <sup>bcd</sup> | 1243.63 <sup>c</sup>  |
| Phosphomidon     | 86 EC   | 0.04          | 82.61<br>(65.41) <sup>a</sup>          | 79.25<br>(63.08) <sup>a</sup>  | 66.20<br>(54.49) <sup>a</sup>  | 81.46<br>(64.64) <sup>a</sup>   | 69.06<br>(56.26) <sup>ab</sup> | 71.18<br>(57.60) <sup>ab</sup>  | 1484.66 <sup>d</sup>  |
| Methyl-o-demeton | 25 EC   | 0.05          | 85.60<br>(67.73) <sup>a</sup>          | 81.02<br>(64.35) <sup>a</sup>  | 69.34<br>(56.38) <sup>a</sup>  | 78.00<br>(62.18) <sup>ab</sup>  | 66.26<br>(54.50) <sup>ab</sup> | 69.19<br>(56.34) <sup>ab</sup>  | 1931.00 <sup>bc</sup> |
| Dimethoate       | 30 EC   | 0.03          | 81.56<br>(64.92) <sup>a</sup>          | 77.60<br>(61.83) <sup>a</sup>  | 65.90<br>(54.35) <sup>a</sup>  | 77.92<br>(62.03) <sup>ab</sup>  | 72.50<br>(58.44) <sup>a</sup>  | 73.86<br>(59.28) <sup>a</sup>   | 2070.00 <sup>ab</sup> |
| Monocrotophos    | 36 WSC  | 0.05          | 75.46<br>(60.33) <sup>ab</sup>         | 74.86<br>(59.96) <sup>ab</sup> | 63.64<br>(52.92) <sup>ab</sup> | 73.71<br>(59.26) <sup>ab</sup>  | 65.70<br>(54.19) <sup>ab</sup> | 65.50<br>(54.15) <sup>abc</sup> | 2132.33 <sup>a</sup>  |
| Fenubucarb       | 50 EC   | 0.05          | 66.42<br>(54.60) <sup>bc</sup>         | 62.45<br>(52.21) <sup>c</sup>  | 49.41<br>(42.66) <sup>b</sup>  | 54.61<br>(47.66) <sup>d</sup>   | 42.17<br>(40.49) <sup>d</sup>  | 48.73<br>(44.27) <sup>d</sup>   | 1287.00 <sup>e</sup>  |
| Chlorpyrifos     | 20 EC   | 0.05          | 75.45<br>(60.40) <sup>ab</sup>         | 75.52<br>(60.38) <sup>ab</sup> | 66.86<br>(54.99) <sup>a</sup>  | 72.56<br>(58.43) <sup>abc</sup> | 65.91<br>(54.36) <sup>ab</sup> | 69.26<br>(56.28) <sup>ab</sup>  | 1843.33 <sup>c</sup>  |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Table 49. Field efficacy of insecticides in the management of soybean\* whitefly – *Bemisia tabaci*

Location : TNAU, Coimbatore

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                |                                |                                |                                |                      |   |    | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|----------------------|---|----|-------------|
|                  |         |               | Ist Spraying                           |                                |                                | IInd Spraying                  |                                |                                |                      |   |    |             |
|                  |         |               | DAS                                    |                                |                                | DAS                            |                                |                                |                      |   |    |             |
|                  |         |               | 1                                      | 7                              | 14                             | 1                              | 7                              | 14                             | 1                    | 7 | 14 |             |
| Quinolphos       | 25 EC   | 0.04          | 72.86<br>(58.62) <sup>b</sup>          | 65.89<br>(54.26) <sup>ab</sup> | 58.32<br>(49.82) <sup>ab</sup> | 69.41<br>(56.48) <sup>b</sup>  | 57.65<br>(49.43) <sup>bc</sup> | 45.23<br>(42.26) <sup>bc</sup> | 1787.33 <sup>d</sup> |   |    |             |
| Sevinflo         | 45 AF   | 0.07          | 58.50<br>(49.94) <sup>c</sup>          | 54.22<br>(47.45) <sup>b</sup>  | 48.59<br>(44.17) <sup>b</sup>  | 61.21<br>(51.81) <sup>bc</sup> | 50.09<br>(45.05) <sup>c</sup>  | 41.90<br>(40.33) <sup>c</sup>  | 1432.33 <sup>f</sup> |   |    |             |
| Endosulfan       | 35 EC   | 0.07          | 84.25<br>(66.75) <sup>a</sup>          | 77.30<br>(61.65) <sup>a</sup>  | 67.38<br>(55.25) <sup>a</sup>  | 87.36<br>(69.22) <sup>a</sup>  | 76.68<br>(61.18) <sup>a</sup>  | 73.14<br>(58.86) <sup>a</sup>  | 2042.33 <sup>b</sup> |   |    |             |
| Phosalone        | 35 EC   | 0.05          | 57.07<br>(49.08) <sup>c</sup>          | 54.21<br>(47.42) <sup>b</sup>  | 48.39<br>(44.07) <sup>b</sup>  | 64.92<br>(53.71) <sup>bc</sup> | 60.95<br>(51.33) <sup>b</sup>  | 51.85<br>(46.06) <sup>bc</sup> | 1481.00 <sup>e</sup> |   |    |             |
| Phosphomidon     | 86 EC   | 0.04          | 65.81<br>(65.45) <sup>bc</sup>         | 60.74<br>(51.23) <sup>b</sup>  | 50.91<br>(45.48) <sup>b</sup>  | 64.16<br>(53.25) <sup>bc</sup> | 55.92<br>(48.41) <sup>bc</sup> | 45.30<br>(42.27) <sup>bc</sup> | 1480.00 <sup>e</sup> |   |    |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 88.56<br>(70.24) <sup>a</sup>          | 78.35<br>(62.47) <sup>a</sup>  | 69.82<br>(56.69) <sup>a</sup>  | 88.07<br>(69.81) <sup>a</sup>  | 77.99<br>(62.04) <sup>a</sup>  | 71.02<br>(57.47) <sup>a</sup>  | 1484.33 <sup>c</sup> |   |    |             |
| Dimethoate       | 30 EC   | 0.03          | 65.68<br>(54.20) <sup>bc</sup>         | 52.45<br>(46.41) <sup>b</sup>  | 49.84<br>(44.91) <sup>b</sup>  | 65.11<br>(53.86) <sup>bc</sup> | 57.08<br>(49.12) <sup>bc</sup> | 53.00<br>(46.27) <sup>b</sup>  | 2031.67 <sup>b</sup> |   |    |             |
| Monocrotophos    | 36 WSC  | 0.05          | 84.41<br>(66.82) <sup>a</sup>          | 77.67<br>(61.82) <sup>a</sup>  | 67.89<br>(55.48) <sup>a</sup>  | 88.58<br>(70.27) <sup>a</sup>  | 78.94<br>(62.70) <sup>a</sup>  | 72.22<br>(58.24) <sup>a</sup>  | 2129.00 <sup>a</sup> |   |    |             |
| Fenubucarb       | 50 EC   | 0.05          | 58.78<br>(50.16) <sup>c</sup>          | 50.58<br>(45.36) <sup>b</sup>  | 47.71<br>(43.66) <sup>b</sup>  | 59.51<br>(50.50) <sup>c</sup>  | 58.46<br>(49.91) <sup>bc</sup> | 49.13<br>(44.49) <sup>bc</sup> | 1302.67 <sup>g</sup> |   |    |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 84.84<br>(67.16) <sup>a</sup>          | 78.50<br>(62.83) <sup>a</sup>  | 65.58<br>(55.94) <sup>a</sup>  | 84.32<br>(66.86) <sup>a</sup>  | 75.97<br>(60.72) <sup>a</sup>  | 69.79<br>(56.67) <sup>a</sup>  | 1793.33 <sup>d</sup> |   |    |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

**Table 50. Field efficacy of insecticides in the management of soybean\* aphid -- *Aphis craccivora***

**Location : TNAU, Coimbatore**

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                               |                                |                               |                                |                                |                      |   | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|-------------------------------|--------------------------------|-------------------------------|--------------------------------|--------------------------------|----------------------|---|-------------|
|                  |         |               | Ist Spraying                           |                               |                                |                               | IInd Spraying                  |                                |                      |   |             |
|                  |         |               | DAS                                    |                               |                                |                               | DAS                            |                                |                      |   |             |
|                  |         |               | 1                                      | 7                             | 14                             | 1                             | 7                              | 14                             | 1                    | 7 |             |
| Quinolphos       | 25 EC   | 0.04          | 60.87<br>(51.28) <sup>b</sup>          | 59.17<br>(50.29) <sup>c</sup> | 57.06<br>(49.06) <sup>d</sup>  | 60.70<br>(51.24) <sup>c</sup> | 62.39<br>(52.22) <sup>cd</sup> | 51.66<br>(45.77) <sup>bc</sup> | 1787.33 <sup>d</sup> |   |             |
| Sevinflo         | 45 AF   | 0.07          | 58.85<br>(50.14) <sup>b</sup>          | 56.42<br>(48.70) <sup>c</sup> | 55.48<br>(48.18) <sup>d</sup>  | 62.28<br>(52.15) <sup>c</sup> | 61.59<br>(51.73) <sup>cd</sup> | 47.87<br>(43.77) <sup>bc</sup> | 1432.33 <sup>f</sup> |   |             |
| Endosulfan       | 35 EC   | 0.07          | 84.69<br>(67.01) <sup>a</sup>          | 80.11<br>(63.53) <sup>a</sup> | 75.58<br>(60.43) <sup>ab</sup> | 89.60<br>(71.19) <sup>a</sup> | 73.72<br>(59.17) <sup>ab</sup> | 69.94<br>(56.79) <sup>a</sup>  | 2042.33 <sup>b</sup> |   |             |
| Phosalone        | 35 EC   | 0.05          | 61.07<br>(51.42) <sup>b</sup>          | 59.89<br>(50.37) <sup>c</sup> | 60.92<br>(51.31) <sup>cd</sup> | 63.12<br>(52.61) <sup>c</sup> | 56.89<br>(48.70) <sup>d</sup>  | 50.27<br>(45.17) <sup>bc</sup> | 1481.00 <sup>e</sup> |   |             |
| Phosphomidon     | 86 EC   | 0.04          | 57.62<br>(49.40) <sup>b</sup>          | 53.18<br>(46.83) <sup>c</sup> | 57.65<br>(49.46) <sup>d</sup>  | 57.64<br>(49.45) <sup>c</sup> | 56.27<br>(48.60) <sup>d</sup>  | 45.45<br>(42.39) <sup>c</sup>  | 1480.00 <sup>e</sup> |   |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 79.42<br>(63.09) <sup>a</sup>          | 70.91<br>(57.41) <sup>b</sup> | 69.20<br>(56.31) <sup>bc</sup> | 76.89<br>(70.12) <sup>a</sup> | 67.38<br>(55.22) <sup>bc</sup> | 61.18<br>(51.55) <sup>b</sup>  | 1984.33 <sup>c</sup> |   |             |
| Dimethoate       | 30 EC   | 0.03          | 83.72<br>(66.24) <sup>a</sup>          | 78.29<br>(62.25) <sup>a</sup> | 78.11<br>(62.11) <sup>a</sup>  | 88.40<br>(71.09) <sup>a</sup> | 75.77<br>(60.54) <sup>a</sup>  | 68.88<br>(56.12) <sup>a</sup>  | 2031.67 <sup>b</sup> |   |             |
| Monocrotophos    | 36 WSC  | 0.05          | 61.81<br>(51.55) <sup>b</sup>          | 59.49<br>(50.50) <sup>c</sup> | 56.00<br>(48.51) <sup>d</sup>  | 65.78<br>(54.20) <sup>c</sup> | 62.44<br>(52.82) <sup>cd</sup> | 52.64<br>(46.52) <sup>bc</sup> | 2129.00 <sup>e</sup> |   |             |
| Fenubucarb       | 50 EC   | 0.05          | 55.33<br>(48.07) <sup>b</sup>          | 54.82<br>(47.44) <sup>c</sup> | 55.02<br>(47.92) <sup>d</sup>  | 60.60<br>(51.14) <sup>c</sup> | 56.77<br>(48.89) <sup>d</sup>  | 50.00<br>(45.01) <sup>bc</sup> | 1302.67 <sup>g</sup> |   |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 62.42<br>(52.28) <sup>b</sup>          | 60.61<br>(51.14) <sup>c</sup> | 59.84<br>(50.68) <sup>d</sup>  | 60.92<br>(51.42) <sup>c</sup> | 64.46<br>(53.44) <sup>cd</sup> | 54.03<br>(47.32) <sup>bc</sup> | 1793.33 <sup>d</sup> |   |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage r transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Dimethoate 0.03 per cent and endosulfan 0.07 per cent were found to be highly effective in reducing the population upto 14<sup>th</sup> DAT after first spraying. The aphid population was significantly reduced by dimethoate 0.03 per cent and endosulfan 0.07 per cent upto 14<sup>th</sup> DAT followed by methyl-o-demeton 0.05 per cent during second spraying.

#### 4.6.2 DEFOLIATORS

##### 4.6.2.1 Leafminer - *Aproaerema modicella*

The evaluation of different insecticides at Udumalpet during February 1995 showed significant effect of endosulfan 0.07 per cent, monocrotophos 0.05 per cent, methyl-o-demeton 0.05 per cent and dimethoate 0.03 per cent in reducing the mean leaf damage of leaf miner upto 14<sup>th</sup> DAT. But, after the second spraying, only endosulfan 0.07 per cent and monocrotophos 0.05 per cent had significant effect in reducing the mean leaf damages upto 14<sup>th</sup> DAT. This was followed by methyl-o-demeton 0.05 per cent and dimethoate 0.03 per cent (Table 51).

Field experiment was conducted at TNAU, Coimbatore during February'95 to evaluate the efficacy of different insecticides on leafminer *A.modicella*. The plots treated with endosulfan 0.07 per cent and monocrotophos 0.05 per cent recorded significant reduction in the per cent leaf damage upto 14<sup>th</sup> DAT. The same effect was observed upto 14<sup>th</sup> DAT also during second spraying. This was followed by dimethoate 0.03 per cent in both the sprayings (Table 52).

##### 4.6.2.2 *Helicoverpa armigera*

Significant reduction in the mortality of the insect was noticed in all the treatments over untreated control. But, endosulfan 0.07 per cent and monocrotophos were found to cause more significant reduction in the population than other treatments. Monocrotophos 0.04 per cent was equally effective upto 14<sup>th</sup> DAT after first and second spraying. This was followed by chlorpyrifos

**Table 51 : Field efficacy of insecticides against management of leafminer - *Aproaerema modicella* \* of soybean\***  
**Location : Udumalpet**

| Chemical             | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                               |                                |                               |                              |                              |                       |   | Yield Kg/ha |
|----------------------|---------|---------------|----------------------------------------|-------------------------------|--------------------------------|-------------------------------|------------------------------|------------------------------|-----------------------|---|-------------|
|                      |         |               | Ist Spraying                           |                               |                                | IInd Spraying                 |                              |                              |                       |   |             |
|                      |         |               | DAS                                    |                               |                                | DAS                           |                              |                              |                       |   |             |
|                      |         |               | 1                                      | 7                             | 14                             | 1                             | 7                            | 14                           | 1                     | 7 |             |
| Quinolphos           | 25 EC   | 0.04          | 20.97<br>(4.62) <sup>c</sup>           | 22.60<br>(4.78) <sup>c</sup>  | 25.26<br>(5.03) <sup>d</sup>   | 15.43<br>(3.98) <sup>c</sup>  | 19.53<br>(4.46) <sup>b</sup> | 14.66<br>(3.88) <sup>d</sup> | 1633.33 <sup>d</sup>  |   |             |
| Sevinflo             | 45 AF   | 0.07          | 19.43<br>(4.42) <sup>bc</sup>          | 22.60<br>(4.79) <sup>c</sup>  | 25.73<br>(5.11) <sup>d</sup>   | 15.26<br>(3.97) <sup>c</sup>  | 21.73<br>(4.71) <sup>b</sup> | 14.89<br>(3.92) <sup>d</sup> | 1172.00 <sup>e</sup>  |   |             |
| Endosulfan           | 35 EC   | 0.07          | 9.13<br>(3.10) <sup>a</sup>            | 5.53<br>(2.45) <sup>a</sup>   | 3.93<br>(2.10) <sup>a</sup>    | 8.66<br>(3.02) <sup>a</sup>   | 6.83<br>(2.70) <sup>a</sup>  | 4.30<br>(2.18) <sup>a</sup>  | 2021.33 <sup>ab</sup> |   |             |
| Phosalone            | 35 EC   | 0.05          | 17.10<br>(4.18) <sup>bc</sup>          | 21.86<br>(4.72) <sup>bc</sup> | 23.40<br>(4.88) <sup>d</sup>   | 14.06<br>(3.81) <sup>bc</sup> | 21.46<br>(4.67) <sup>b</sup> | 14.90<br>(3.91) <sup>d</sup> | 1243.33 <sup>c</sup>  |   |             |
| Phosphomidon 86 EC   |         | 0.04          | 17.86<br>(4.27) <sup>bc</sup>          | 17.40<br>(4.22) <sup>b</sup>  | 20.06<br>(4.70) <sup>bc</sup>  | 16.06<br>(4.06) <sup>c</sup>  | 22.40<br>(4.77) <sup>b</sup> | 14.60<br>(3.88) <sup>d</sup> | 1484.66 <sup>d</sup>  |   |             |
| Methyl-o-demeton     | 25 EC   | 0.05          | 15.20<br>(3.96) <sup>b</sup>           | 6.90<br>(2.33) <sup>a</sup>   | 4.06<br>(2.13) <sup>a</sup>    | 16.23<br>(4.08) <sup>c</sup>  | 18.36<br>(4.33) <sup>b</sup> | 14.13<br>(3.81) <sup>b</sup> | 1931.00 <sup>bc</sup> |   |             |
| Dimethoate           | 30 EC   | 0.03          | 10.53<br>(3.82) <sup>a</sup>           | 7.10<br>(2.75) <sup>a</sup>   | 3.73<br>(2.05) <sup>a</sup>    | 12.56<br>(3.61) <sup>b</sup>  | 9.96<br>(3.23) <sup>a</sup>  | 15.06<br>(3.46) <sup>a</sup> | 2070.00 <sup>ab</sup> |   |             |
| Monocrotophos 36 WSC |         | 0.05          | 8.96<br>(3.07) <sup>a</sup>            | 6.30<br>(2.61) <sup>a</sup>   | 3.73<br>(2.05) <sup>a</sup>    | 8.93<br>(3.67) <sup>a</sup>   | 8.13<br>(2.93) <sup>a</sup>  | 5.20<br>(2.94) <sup>a</sup>  | 2132.33 <sup>a</sup>  |   |             |
| Fenubucarb           | 50 EC   | 0.05          | 19.13<br>(4.43) <sup>bc</sup>          | 23.36<br>(4.87) <sup>c</sup>  | 20.16<br>(4.53) <sup>b</sup>   | 15.93<br>(4.05) <sup>c</sup>  | 19.80<br>(4.49) <sup>b</sup> | 15.30<br>(3.97) <sup>c</sup> | 1287.00 <sup>c</sup>  |   |             |
| Chlorpyrifos         | 20 EC   | 0.05          | 18.30<br>(4.33) <sup>bc</sup>          | 24.73<br>(5.01) <sup>c</sup>  | 23.20<br>(4.86) <sup>bcd</sup> | 16.10<br>(4.07) <sup>c</sup>  | 18.80<br>(4.37) <sup>b</sup> | 10.86<br>(3.37) <sup>c</sup> | 1843.33 <sup>c</sup>  |   |             |
| Untreated Control    |         |               | 26.67<br>(5.19) <sup>d</sup>           | 34.06<br>(5.87) <sup>d</sup>  | 37.46<br>(6.16) <sup>c</sup>   | 21.26<br>(4.66) <sup>d</sup>  | 31.60<br>(5.66) <sup>c</sup> | 33.15<br>(5.79) <sup>c</sup> | 1124.33 <sup>c</sup>  |   |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Table S2 : Field efficacy of insecticides in the management of leafminer - *Aproaerema modicella* \* on soybean\*

| Location : TNAU   |         |               |                                        |                               |                              |                              |                                |                               |                      |   |    |             |
|-------------------|---------|---------------|----------------------------------------|-------------------------------|------------------------------|------------------------------|--------------------------------|-------------------------------|----------------------|---|----|-------------|
| Chemical          | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                               |                              |                              |                                |                               |                      |   |    | Yield Kg/ha |
|                   |         |               | Ist Spraying                           |                               |                              | IInd Spraying                |                                |                               |                      |   |    |             |
|                   |         |               | DAS                                    |                               |                              | DAS                          |                                |                               |                      |   |    |             |
|                   |         |               | 1                                      | 7                             | 14                           | 1                            | 7                              | 14                            | 1                    | 7 | 14 |             |
| Quinolphos        | 25 EC   | 0.04          | 16.97<br>(4.17) <sup>cd</sup>          | 17.56<br>(4.24) <sup>cd</sup> | 12.27<br>(3.56) <sup>c</sup> | 11.59<br>(3.46) <sup>c</sup> | 16.60<br>(4.13) <sup>c</sup>   | 15.60<br>(4.01) <sup>cd</sup> | 1787.33 <sup>d</sup> |   |    |             |
| Sevinflo          | 45 AF   | 0.07          | 17.80<br>(4.27) <sup>d</sup>           | 20.67<br>(4.58) <sup>d</sup>  | 19.67<br>(4.48) <sup>d</sup> | 12.26<br>(3.57) <sup>c</sup> | 21.00<br>(4.63) <sup>de</sup>  | 18.93<br>(4.41) <sup>e</sup>  | 1432.33 <sup>f</sup> |   |    |             |
| Endosulfan        | 35 EC   | 0.07          | 7.53<br>(2.83) <sup>a</sup>            | 5.80<br>(2.51) <sup>a</sup>   | 4.78<br>(2.29) <sup>a</sup>  | 5.46<br>(2.43) <sup>a</sup>  | 5.26<br>(2.39) <sup>a</sup>    | 4.73<br>(2.28) <sup>a</sup>   | 2042.33 <sup>b</sup> |   |    |             |
| Phosclone         | 35 EC   | 0.05          | 16.90<br>(4.17) <sup>cd</sup>          | 20.38<br>(4.55) <sup>d</sup>  | 19.07<br>(4.42) <sup>d</sup> | 13.80<br>(3.77) <sup>c</sup> | 17.53<br>(4.24) <sup>cd</sup>  | 12.93<br>(3.66) <sup>b</sup>  | 1481.00 <sup>e</sup> |   |    |             |
| Phosphomidon      | 86 EC   | 0.04          | 18.00<br>(4.30) <sup>d</sup>           | 20.86<br>(4.67) <sup>d</sup>  | 20.25<br>(4.55) <sup>d</sup> | 13.40<br>(3.72) <sup>c</sup> | 19.16<br>(4.43) <sup>cde</sup> | 16.80<br>(4.16) <sup>de</sup> | 1480.00 <sup>e</sup> |   |    |             |
| Methyl-o-demeton  | 25 EC   | 0.05          | 14.67<br>(3.86) <sup>dc</sup>          | 14.97<br>(3.92) <sup>bc</sup> | 13.56<br>(3.74) <sup>c</sup> | 15.33<br>(3.97) <sup>c</sup> | 21.53<br>(4.68) <sup>e</sup>   | 14.07<br>(3.81) <sup>bc</sup> | 1984.33 <sup>c</sup> |   |    |             |
| Dimethoate        | 30 EC   | 0.03          | 14.00<br>(3.80) <sup>b</sup>           | 11.67<br>(3.48) <sup>b</sup>  | 8.23<br>(2.94) <sup>b</sup>  | 8.60<br>(2.99) <sup>b</sup>  | 8.80<br>(3.03) <sup>d</sup>    | 12.01<br>(3.55) <sup>b</sup>  | 2031.67 <sup>b</sup> |   |    |             |
| Monocrotophos     | 36 WSC  | 0.05          | 7.10<br>(2.74) <sup>a</sup>            | 5.83<br>(2.51) <sup>a</sup>   | 4.10<br>(2.14) <sup>a</sup>  | 6.00<br>(2.53) <sup>ab</sup> | 5.40<br>(2.42) <sup>a</sup>    | 4.93<br>(2.32) <sup>a</sup>   | 2129.00 <sup>a</sup> |   |    |             |
| Fenubucarb        | 50 EC   | 0.05          | 18.57<br>(4.36) <sup>d</sup>           | 16.98<br>(4.18) <sup>cd</sup> | 13.06<br>(3.75) <sup>c</sup> | 14.20<br>(3.82) <sup>c</sup> | 18.40<br>(4.34) <sup>cde</sup> | 16.80<br>(4.16) <sup>de</sup> | 1302.67g             |   |    |             |
| Chlorpyrifhos     | 20 EC   | 0.05          | 15.67<br>(4.01) <sup>bed</sup>         | 16.80<br>(4.15) <sup>cd</sup> | 31.60<br>(5.65) <sup>c</sup> | 14.80<br>(3.90) <sup>c</sup> | 20.53<br>(4.58) <sup>de</sup>  | 17.33<br>(4.22) <sup>de</sup> | 1793.33 <sup>d</sup> |   |    |             |
| Untreated Control |         |               | 23.96<br>(4.94)                        | 28.13<br>(5.34) <sup>e</sup>  | 31.60<br>(5.65) <sup>e</sup> | 21.67<br>(4.69) <sup>d</sup> | 33.80<br>(5.84) <sup>f</sup>   | 36.95<br>(6.11) <sup>f</sup>  |                      |   |    |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

0.05 per cent and quinalphos 0.04 per cent (Table 53).

#### 4.6.2.3 *Spodoptera litura*

In the field experiment conducted at Udumalpet during February 1995, among the different insecticides evaluated the per cent mortality was found to be significantly superior in chlorpyrifos 0.05 per cent, monocrotophos 0.05 per cent and endosulfan 0.07 per cent upto 14 DAT in both first and second sprayings. This was followed by dimethoate 0.03 per cent (Table 54).

#### 4.6.2.4. Pod sucking bug - *Nezara viridula*

The efficacy of different chemicals were evaluated against pod sucking bug. It was observed that monocrotophos 0.05 per cent, and endosulfan 0.07 per cent were able to reduce the population significantly upto 14<sup>th</sup> DAT than other insecticides tried during first spraying. This was followed by methyl-o-demeton 0.05 per cent quinalphos and dimethoate 0.03 per cent. At 14<sup>th</sup> DAT during second spraying also the efficacies of the above mentioned insecticides were found to reduce the population significantly when compared to other insecticides (Table 55). At TNAU, Coimbatore endosulfan 0.07 per cent, monocrotophos 0.05 per cent and methyl-o-demeton 0.05 per cent had recorded significantly highest per cent mortality upto 14<sup>th</sup> DAT. After second spraying the same insecticides significantly reduced the population upto 14<sup>th</sup> DAT (Table 56).

### 4.6.3 YIELD COMPONENT

#### 4.6.3.1 Yield per ha<sup>-1</sup>

The efficacy of different insecticides in reducing the insect pest population was very significant which was reflected in the yield of the plants treated with these insecticides at TNAU, Coimbatore and Udumalpet. Higher yield per ha<sup>-1</sup> was recorded in the plots treated with monocrotophos 0.05 per cent followed by

Table 53. Field efficacy of insecticides against management of insect pests of soybean\* - *Helicoverpa armigera*

Location : TNAU

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                |                                 |                                 |                                 |                      |  | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|----------------------|--|-------------|
|                  |         |               | Ist Spraying                           |                                |                                | IInd Spraying                   |                                 |                                 |                      |  |             |
|                  |         |               | DAS                                    |                                |                                | DAS                             |                                 |                                 |                      |  |             |
|                  |         |               | 1                                      | 7                              | 14                             | 1                               | 7                               | 14                              | 14                   |  |             |
| Quinolphos       | 25 EC   | 0.04          | 75.81<br>(60.62) <sup>b</sup>          | 69.36<br>(56.40) <sup>ab</sup> | 66.07<br>(54.41) <sup>b</sup>  | 71.51<br>(57.87) <sup>bc</sup>  | 71.77<br>(57.91) <sup>cd</sup>  | 68.14<br>(55.66) <sup>abc</sup> | 1787.33 <sup>d</sup> |  |             |
| Sevinflo         | 45 AF   | 0.07          | 58.13<br>(49.72) <sup>d</sup>          | 53.33<br>(49.92) <sup>cd</sup> | 59.20<br>(50.32) <sup>bc</sup> | 65.55<br>(54.09) <sup>bcd</sup> | 69.44<br>(56.46) <sup>cd</sup>  | 59.63<br>(50.56) <sup>d</sup>   | 1432.33 <sup>f</sup> |  |             |
| Endosulfan       | 35 EC   | 0.07          | 86.13<br>(68.32) <sup>a</sup>          | 75.00<br>(60.07) <sup>a</sup>  | 75.21<br>(60.16) <sup>a</sup>  | 83.16<br>(65.87) <sup>a</sup>   | 81.51<br>(64.57) <sup>a</sup>   | 75.23<br>(60.17) <sup>a</sup>   | 2042.33 <sup>b</sup> |  |             |
| Phosalone        | 35 EC   | 0.05          | 61.65<br>(51.75) <sup>d</sup>          | 48.14<br>(43.93) <sup>d</sup>  | 56.88<br>(48.89) <sup>bc</sup> | 61.68<br>(51.76) <sup>cd</sup>  | 66.48<br>(54.69) <sup>de</sup>  | 64.82<br>(53.62) <sup>bcd</sup> | 1481.00 <sup>e</sup> |  |             |
| Phosphomidon     | 86 EC   | 0.04          | 63.89<br>(53.09) <sup>cd</sup>         | 51.91<br>(46.09) <sup>cd</sup> | 57.56<br>(49.40) <sup>bc</sup> | 60.26<br>(50.95) <sup>d</sup>   | 65.77<br>(54.22) <sup>def</sup> | 58.99<br>(50.18) <sup>d</sup>   | 1480.00 <sup>e</sup> |  |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 70.07<br>(56.84) <sup>bc</sup>         | 63.05<br>(52.57) <sup>bc</sup> | 61.27<br>(51.57) <sup>bc</sup> | 64.60<br>(53.54) <sup>bcd</sup> | 60.33<br>(51.01) <sup>ef</sup>  | 62.52<br>(52.29) <sup>cd</sup>  | 1984.33 <sup>c</sup> |  |             |
| Dimethoate       | 30 EC   | 0.03          | 69.87<br>(56.81) <sup>bc</sup>         | 56.39<br>(48.69) <sup>cd</sup> | 61.90<br>(51.91) <sup>bc</sup> | 58.88<br>(50.16) <sup>d</sup>   | 58.33<br>(49.22) <sup>f</sup>   | 57.55<br>(49.37) <sup>d</sup>   | 2031.67 <sup>b</sup> |  |             |
| Monocrotophos    | 36 WSC  | 0.05          | 85.36<br>(67.60) <sup>a</sup>          | 76.66<br>(61.14) <sup>a</sup>  | 76.75<br>(61.17) <sup>a</sup>  | 84.27<br>(66.69) <sup>a</sup>   | 79.96<br>(63.41) <sup>a</sup>   | 74.40<br>(59.61) <sup>a</sup>   | 2129.00 <sup>a</sup> |  |             |
| Fenubucarb       | 50 EC   | 0.05          | 64.01<br>(53.16) <sup>cd</sup>         | 58.09<br>(49.68) <sup>cd</sup> | 54.18<br>(47.40) <sup>c</sup>  | 65.65<br>(54.12) <sup>bcd</sup> | 64.98<br>(53.72) <sup>def</sup> | 56.97<br>(49.02) <sup>d</sup>   | 1302.67 <sup>g</sup> |  |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 76.98<br>(61.38) <sup>b</sup>          | 70.83<br>(57.48) <sup>ab</sup> | 64.50<br>(53.43) <sup>b</sup>  | 74.25<br>(59.55) <sup>b</sup>   | 74.86<br>(59.92) <sup>bc</sup>  | 70.42<br>(57.09) <sup>ab</sup>  | 1793.33 <sup>d</sup> |  |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage r transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Table 54: FIELD EFFICACY OF INSECTICIDES AGAINST MANAGEMENT OF Spodoptera litura\* OF SOYBEAN\*

| Chemical-         | Conc. % | Dosage tested | Mortality Reduction (%) |                      |                    |                      |                     |                     | YIELD<br>Kg/ha |
|-------------------|---------|---------------|-------------------------|----------------------|--------------------|----------------------|---------------------|---------------------|----------------|
|                   |         |               | Ist Spraying            |                      |                    | IInd Spraying        |                     |                     |                |
|                   |         |               | DAS                     |                      |                    | DAS                  |                     |                     |                |
|                   |         |               | 1                       | 7                    | 14                 | 1                    | 7                   | 14                  |                |
| Quinolphos        | 25 EC   | 0.04          | 66.33<br>(54.53) de     | 63.60<br>(52.91) d   | 55.30<br>(48.05) b | 66.33<br>(54.54) bcd | 57.60<br>(49.37) d  | 45.80<br>(42.59) bc | 1787.33d       |
| Sevinflo          | 45 AF   | 0.07          | 64.23<br>(54.47) de     | 60.23<br>(50.91) bc  | 41.23<br>(39.95) c | 64.23<br>(53.25) cd  | 50.66<br>(45.38) d  | 42.03<br>(40.41) cd | 1432.33f       |
| Endosulfan        | 35 EC   | 0.07          | 80.33<br>(63.67) a      | 78.93<br>(62.67) a   | 70.96<br>(57.39) a | 80.33<br>(63.67) a   | 72.88<br>(58.60) a  | 68.56<br>(55.90) a  | 2042.33b       |
| Phosalone         | 35 EC   | 0.05          | 63.20<br>(55.67) bc     | 55.60<br>(48.21) cde | 44.60<br>(41.89) c | 68.20<br>(55.67) bc  | 45.36<br>(42.33) e  | 47.72<br>(40.23) cd | 1481.00e       |
| Phosphomidon      | 86 EC   | 0.04          | 61.90<br>(51.88) f      | 53.00<br>(46.72) dc  | 46.26<br>(42.83) c | 61.90<br>(57.89) e   | 56.13<br>(48.52) bc | 36.67<br>(37.26) c  | 1480.00e       |
| Methyl-o-demeton  | 25 EC   | 0.05          | 63.76<br>(52.99) ef     | 54.06<br>(47.33) de  | 39.90<br>(39.16) c | 63.76<br>(52.99) de  | 51.56<br>(45.90) cd | 42.80<br>(40.85) cd | 1984.33c       |
| Dimethoate        | 30 EC   | 0.03          | 69.70<br>(56.60) b      | 57.63<br>(49.41) cd  | 43.00<br>(40.97) c | 69.70<br>(56.60) b   | 60.73<br>(51.19) b  | 49.80<br>(44.88) b  | 2031.67b       |
| Monocrotophos     | 36 WSC  | 0.05          | 79.4<br>(63.06) a       | 76.66<br>(61.12) a   | 69.26<br>(56.33) a | 79.43<br>(63.05) a   | 70.83<br>(57.33) a  | 67.23<br>(55.08) a  | 2129.00a       |
| Fenubucarb        | 50 EC   | 0.05          | 62.03<br>(51.96) f      | 51.40<br>(45.80) c   | 38.16<br>(38.15) c | 62.03<br>(51.96) e   | 51.83<br>(46.05)    | 38.73<br>(38.48) de | 1302.67g       |
| Chlorpyrifos      | 20 EC   | 0.05          | 79.76<br>(63.27) a      | 74.47<br>(60.35) a   | 67.66<br>(58.35) a | 79.76<br>(63.27) a   | 69.07<br>(56.20) a  | 65.13<br>(53.82) a  | 1793.33d       |
| Untreated Control |         |               |                         |                      |                    |                      |                     |                     |                |

\* Mean of three replications.

Figures in parenthesis are angular transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

**Table 55. Field efficacy of insecticides against management of insect pests of soybean\* pod sucking bug – *Nezara viridula***  
**Location : Udumalpet**

| Chemical          | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                |                                |                                |                                |                       |    | Yield Kg/ha |
|-------------------|---------|---------------|----------------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|-----------------------|----|-------------|
|                   |         |               | Ist Spraying                           |                                |                                | IInd Spraying                  |                                |                                |                       |    |             |
|                   |         |               | DAS                                    |                                |                                | DAS                            |                                |                                |                       |    |             |
|                   |         |               | 1                                      | 7                              | 14                             | 1                              | 7                              | 14                             | 1                     | 14 |             |
| Quinolphos        | 25 EC   | 0.04          | 74.05<br>(59.39) <sup>b</sup>          | 76.05<br>(60.72) <sup>ab</sup> | 70.13<br>(56.87) <sup>b</sup>  | 65.97<br>(54.37) <sup>c</sup>  | 61.16<br>(57.47) <sup>bc</sup> | 67.00<br>(54.95) <sup>bc</sup> | 1633.33 <sup>d</sup>  |    |             |
| Sevinflo          | 45 AF   | 0.07          | 56.00<br>(48.44) <sup>c</sup>          | 53.61<br>(47.07) <sup>cd</sup> | 54.81<br>(47.77) <sup>c</sup>  | 49.15<br>(44.51) <sup>ef</sup> | 53.33<br>(46.91) <sup>d</sup>  | 51.14<br>(45.65) <sup>d</sup>  | 1172.00 <sup>c</sup>  |    |             |
| Endosulfan        | 35 EC   | 0.07          | 87.21<br>(69.42) <sup>a</sup>          | 80.43<br>(63.79) <sup>ab</sup> | 78.30<br>(62.26) <sup>a</sup>  | 86.80<br>(68.71) <sup>a</sup>  | 74.27<br>(59.82) <sup>a</sup>  | 74.20<br>(59.50) <sup>a</sup>  | 2021.00 <sup>ab</sup> |    |             |
| Phoslone          | 35 EC   | 0.05          | 57.81<br>(49.57) <sup>e</sup>          | 54.49<br>(47.58) <sup>cd</sup> | 54.71<br>(47.71) <sup>c</sup>  | 53.42<br>(46.97) <sup>ef</sup> | 45.08<br>(42.17) <sup>e</sup>  | 46.61<br>(43.05) <sup>d</sup>  | 1243.63 <sup>e</sup>  |    |             |
| Phosphomidon      | 86 EC   | 0.04          | 63.72<br>(52.98) <sup>cde</sup>        | 62.12<br>(52.06) <sup>c</sup>  | 55.12<br>(47.94) <sup>c</sup>  | 55.02<br>(51.76) <sup>cd</sup> | 51.83<br>(46.05) <sup>de</sup> | 62.33<br>(52.15) <sup>c</sup>  | 1484.66 <sup>d</sup>  |    |             |
| Methyl-o-demeton  | 25 EC   | 0.05          | 72.34<br>(58.27) <sup>bc</sup>         | 73.03<br>(58.73) <sup>b</sup>  | 69.37<br>(56.41) <sup>b</sup>  | 61.68<br>(59.47) <sup>b</sup>  | 60.77<br>(51.22) <sup>c</sup>  | 74.32<br>(59.59) <sup>a</sup>  | 1931.00 <sup>bc</sup> |    |             |
| Dimethoate        | 30 EC   | 0.03          | 73.26<br>(58.87) <sup>b</sup>          | 75.07<br>(60.11) <sup>ab</sup> | 73.36<br>(58.95) <sup>ab</sup> | 74.12<br>(43.88) <sup>f</sup>  | 67.63<br>(55.32) <sup>b</sup>  | 69.52<br>(56.52) <sup>ab</sup> | 2070.00 <sup>ab</sup> |    |             |
| Monocrotophos     | 36 WSC  | 0.05          | 84.73<br>(67.00) <sup>a</sup>          | 80.55<br>(63.93) <sup>a</sup>  | 78.67<br>(62.50) <sup>a</sup>  | 86.30<br>(68.29) <sup>a</sup>  | 74.09<br>(59.58) <sup>a</sup>  | 75.33<br>(60.22) <sup>a</sup>  | 2132.33 <sup>a</sup>  |    |             |
| Fenubucarb        | 50 EC   | 0.05          | 60.11<br>(50.84) <sup>de</sup>         | 51.34<br>(45.78) <sup>d</sup>  | 48.15<br>(43.94) <sup>d</sup>  | 48.05<br>(43.88) <sup>f</sup>  | 46.26<br>(42.85) <sup>e</sup>  | 53.00<br>(46.72) <sup>d</sup>  | 1287.00 <sup>e</sup>  |    |             |
| Chlorpyrifos      | 20 EC   | 0.05          | 67.22<br>(55.08) <sup>bed</sup>        | 54.39<br>(47.41) <sup>cd</sup> | 56.47<br>(48.74) <sup>c</sup>  | 56.25<br>(48.59) <sup>de</sup> | 62.08<br>(51.99) <sup>bc</sup> | 64.51<br>(53.46) <sup>bc</sup> | 1843.33 <sup>c</sup>  |    |             |
| Untreated Control |         |               |                                        |                                |                                |                                |                                |                                |                       |    |             |

\* Mean of three replications.

Figures in parenthesis are arcsin percentage transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

Table 56. Field efficacy of insecticides against management of insect pests of soybean\* pod sucking bug – *Nezara viridula*

Location : TNAU

| Chemical         | Conc. % | Dosage tested | Per cent mortality (%) after treatment |                                |                                |                               |                                |                                |                      |   |    | Yield Kg/ha |
|------------------|---------|---------------|----------------------------------------|--------------------------------|--------------------------------|-------------------------------|--------------------------------|--------------------------------|----------------------|---|----|-------------|
|                  |         |               | Ist Spraying                           |                                |                                | IInd Spraying                 |                                |                                |                      |   |    |             |
|                  |         |               | DAS                                    |                                |                                | DAS                           |                                |                                |                      |   |    |             |
|                  |         |               | 1                                      | 7                              | 14                             | 1                             | 7                              | 14                             | 1                    | 7 | 14 |             |
| Quinolphos       | 25 EC   | 0.04          | 65.97<br>(54.37) <sup>c</sup>          | 61.16<br>(51.47) <sup>bc</sup> | 67.00<br>(54.95) <sup>bc</sup> | 67.53<br>(55.26) <sup>c</sup> | 61.41<br>(51.61) <sup>c</sup>  | 64.21<br>(53.28) <sup>b</sup>  | 1787.33 <sup>d</sup> |   |    |             |
| Sevinflo         | 45 AF   | 0.07          | 49.15<br>(44.51) <sup>ef</sup>         | 53.33<br>(46.91) <sup>d</sup>  | 51.43<br>(45.65) <sup>d</sup>  | 45.22<br>(42.25) <sup>d</sup> | 44.13<br>(41.62) <sup>e</sup>  | 54.03<br>(47.32) <sup>c</sup>  | 1432.33 <sup>f</sup> |   |    |             |
| Endosulfan       | 35 EC   | 0.07          | 86.81<br>(68.71) <sup>a</sup>          | 74.72<br>(59.82) <sup>a</sup>  | 74.20<br>(59.51) <sup>a</sup>  | 86.75<br>(68.69) <sup>a</sup> | 84.97<br>(67.20) <sup>a</sup>  | 76.23<br>(60.93) <sup>a</sup>  | 2042.33 <sup>b</sup> |   |    |             |
| Phosalone        | 35 EC   | 0.05          | 53.43<br>(46.97) <sup>ef</sup>         | 45.08<br>(42.18) <sup>c</sup>  | 46.61<br>(43.06) <sup>d</sup>  | 44.99<br>(42.12) <sup>d</sup> | 50.71<br>(45.41) <sup>d</sup>  | 48.56<br>(44.12) <sup>c</sup>  | 1481.00 <sup>e</sup> |   |    |             |
| Phosphomidon     | 86 EC   | 0.04          | 55.03<br>(47.92) <sup>def</sup>        | 51.83<br>(46.05) <sup>de</sup> | 62.33<br>(52.15) <sup>c</sup>  | 65.42<br>(54.01) <sup>c</sup> | 63.37<br>(52.75) <sup>c</sup>  | 53.26<br>(46.87) <sup>c</sup>  | 1480.00 <sup>e</sup> |   |    |             |
| Methyl-o-demeton | 25 EC   | 0.05          | 84.69<br>(66.56) <sup>a</sup>          | 76.77<br>(60.92) <sup>a</sup>  | 74.33<br>(59.59) <sup>a</sup>  | 85.41<br>(67.58) <sup>a</sup> | 84.10<br>(66.57) <sup>a</sup>  | 74.01<br>(59.35) <sup>a</sup>  | 1484.33 <sup>c</sup> |   |    |             |
| Dimethoate       | 30 EC   | 0.03          | 74.12<br>(59.47) <sup>b</sup>          | 67.63<br>(55.32) <sup>b</sup>  | 64.51<br>(53.46) <sup>bc</sup> | 66.90<br>(54.89) <sup>c</sup> | 70.07<br>(56.87) <sup>b</sup>  | 64.53<br>(53.48) <sup>b</sup>  | 2031.67 <sup>b</sup> |   |    |             |
| Monocrotophos    | 36 WSC  | 0.05          | 86.30<br>(68.29) <sup>a</sup>          | 74.09<br>(59.58) <sup>a</sup>  | 75.33<br>(60.22) <sup>a</sup>  | 86.20<br>(68.23) <sup>a</sup> | 85.96<br>(67.99) <sup>a</sup>  | 76.57<br>(61.08) <sup>a</sup>  | 2129.00 <sup>a</sup> |   |    |             |
| Fenubucarb       | 50 EC   | 0.05          | 48.06<br>(43.88) <sup>b</sup>          | 46.26<br>(42.85) <sup>c</sup>  | 53.00<br>(46.72) <sup>d</sup>  | 46.33<br>(42.89) <sup>d</sup> | 49.55<br>(44.74) <sup>de</sup> | 54.70<br>(47.70) <sup>c</sup>  | 1302.67 <sup>e</sup> |   |    |             |
| Chlorpyrifos     | 20 EC   | 0.05          | 56.25<br>(48.59) <sup>de</sup>         | 62.08<br>(51.99) <sup>bc</sup> | 69.56<br>(56.52) <sup>ab</sup> | 73.29<br>(58.88) <sup>b</sup> | 74.05<br>(59.38) <sup>b</sup>  | 69.85<br>(56.72) <sup>ab</sup> | 1793.33 <sup>d</sup> |   |    |             |

\* Mean of three replications.

Figures in parenthesis are angular transformed values.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

endosulfan 0.07 per cent and dimethoate 0.03 per cent (Table 57).

Likewise at Udumalpet significant differences in yield were observed in between treatments and the untreated control. Significantly high yields were obtained where insects pests were controlled by two sprayings with endosulfan 0.07 per cent, monocrotophos 0.05 per cent and dimethoate 0.03 per cent followed by chlorpyriphos 0.05 per cent and methyl-o-demeton 0,05 per cent (Table 57).

#### 4.6.4 COST BENEFIT RATIO

Different insecticides were tried for the management of insect pests of soybean. Each insecticide had its own efficacy in minimising the insect pest population resulting a net return of monetary benefits. Two methods detailed elsewhere were used to compare the cost benefit ratio.

An Udumalpet the maximum return of Rs.19,190.70 per ha<sup>-1</sup> was obtained in monocrotophos 0.05 per cent sprayed plot followed by dimethoate 0.03 per cent (Rs.18,630.00) and endosulfan 0.07 per cent (Rs. 18,189.00) applications against pests. In other insecticides tried plots the return was in the range of Rs.10,548.00 to Rs.17,379.00. The cost of treatment also ranged from Rs.470.00 to 690.00 in all the insecticides treated plots. Experiment conducted at TNAU, Coimbatore, revealed that maximum return was obtained by monocrotophos 0.05 per cent (Rs.19161.00) spray followed by endosulfan 0.07 per cent (Rs.18,380.97) spray application.

The cost benefit ratio estimated through method I, for Udumalpet experiment, revealed that monocrotophos application brought the highest cost benefit ratio of 1:2.168 followed by dimethoate 0.03 per cent (1:2.123). But, in the II method, endosulfan application showed the highest cost benefit of 1:14.285 followed by dimethoate 0.03 per cent (1:13.010).

Table 57. Field efficacy of different insecticides and yield per hectare\*

| Chemical         | Con. % | Dosage tested | Yield kg/ha <sup>-1</sup> |                       |
|------------------|--------|---------------|---------------------------|-----------------------|
|                  |        |               | TNAU                      | Udumalpet             |
| Quinolphos       | 25 EC  | 0.04          | 1787.33 <sup>d</sup>      | 1633.33 <sup>d</sup>  |
| Sevinflo         | 45 AF  | 0.07          | 1432.33 <sup>f</sup>      | 1172.00 <sup>c</sup>  |
| Endosulfan       | 35 EC  | 0.07          | 2042.33 <sup>b</sup>      | 2021.00 <sup>ab</sup> |
| Phosalone        | 35 EC  | 0.05          | 1481.00 <sup>e</sup>      | 1243.63 <sup>e</sup>  |
| Phosphomidon     | 86 EC  | 0.04          | 1480.00 <sup>e</sup>      | 1484.66 <sup>d</sup>  |
| Methyl-o-demeton | 25 EC  | 0.05          | 1984.33 <sup>c</sup>      | 1931.00 <sup>bc</sup> |
| Dimethoate       | 30 EC  | 0.03          | 2031.67 <sup>b</sup>      | 2070.00 <sup>ab</sup> |
| Monocrotophos    | 36 WSC | 0.05          | 2129.00 <sup>a</sup>      | 2132.33 <sup>a</sup>  |
| Fenubucarb       | 50 EC  | 0.05          | 1362.67 <sup>g</sup>      | 1287.00 <sup>e</sup>  |
| Chlorpyrifos     | 20EC   | 0.05          | 1793.33 <sup>d</sup>      | 1843.33 <sup>c</sup>  |

\* Mean of three replications.

In a column, means followed by common letter are not significantly different at the 5% (P = 0.05) level by DMRT.

At TNAU the estimation by method I, revealed that the best cost benefit ratio was in monocrotophos 0.05 per cent (1:2.165) application followed endosulfan 0.07 per cent (1:2.112). By method II at TNAU, endosulfan 0.07 per cent application gave the highest cost benefit ratio of 1:17.585 followed by monocrotophos 0.05 per cent. (1:15.075) Table 58.

#### 4.7 FIELD EFFICACY OF DIFFERENT BIO-CONTROL AGENTS AND INSECTICIDES ON THE INSECT PESTS OF SOYBEAN

A field experiment was conducted at Aliyarnagar of Pollachi taluk to study the efficacy of different bio-control agents like HaNPV (*Helicoverpa* NPV), SINPV (*Spodoptera* NPV), *B.t.* (var. *kurstaki*) and release of *Trichogramma chilonis*, and *Chrysoperla carnea* along with insecticide like endosulfan and NPV mixtures. The plot size was 100 m<sup>2</sup> each and sowing was taken up during July '95. These bio-control agents were evaluated mainly against the soybean defoliators like *Spodoptera litura* and *Helicoverpa armigera*.

In a field experiment conducted at Aliyarnagar during July 1995 the field efficacy of three sprayings with HaNPV, SI NPV, *B.t.* and three field releases of egg parasitoid *T.chilonis* and predators *C. carnea* were evaluated on the defoliator pests like *H.armigera*, *S.litura*, and leafminer *A.modicella*. The results are furnished in Table 59.

##### 4.7.1 *Helicoverpa armigera*

Significant differences were observed on 7<sup>th</sup> DAT between the bio control agents treated plots and untreated control plots. Significant effect in reducing the populations (1.66) was observed at 7<sup>th</sup> DAT in the plots treated with *B.t.* (0.5 kg/ha) + endosulfan 0.07 per cent spray, followed by *B.t.* (1.0 kg/ha) alone, HaNPV + endosulfan 0.07 per cent, *B.t.* (0.5 kg/ha) + NPV mixtures and these were on par with endosulfan 0.07 per cent spraying alone.

Table 58. Yield on hectare basis and cost benefit ratio of different insecticides

| Treatment              | Soybean seed yield kg/ha |         |           | Returns/ha @ Rs.9/kg (Rs.) |          | Cot of treat-ment (Rs.) | Cost Benefit Ratio |             |             |      |
|------------------------|--------------------------|---------|-----------|----------------------------|----------|-------------------------|--------------------|-------------|-------------|------|
|                        | Udumalpet                |         | TNAU      | Udumalpet                  |          |                         | TNAU               | Udumalpet   |             | TNAU |
|                        | Udumalpet                | TNAU    | Udumalpet | TNAU                       | Method I |                         | Method II          | Method I    | Method II   |      |
| Quinalphos 25EC        | 1633.30                  | 1787.33 | 14699.70  | 16085.97                   | 620.00   | 1:1.661(6)              | 1:5.201(6)         | 1:1.817(6)  | 1:9.628(6)  |      |
| Sevinflo 45AF          | 1372.00                  | 1432.30 | 10548.00  | 12890.70                   | 520.00   | 1:1.205(10)             | 1:1.678(8)         | 1:1.473(9)  | 1:5.180(9)  |      |
| Endosulfan 35EC        | 2021.00                  | 2042.33 | 18189.00  | 18380.97                   | 470.00   | 1:2.091(3)              | 1:14.285(1)        | 1:2.112(2)  | 1:17.585(1) |      |
| Phosalone 35EC         | 1343.00                  | 1481.00 | 11192.40  | 13329.00                   | 520.00   | 1:1.279(9)              | 1:1.176(9)         | 1:1.523(7)  | 1:6.178(7)  |      |
| Phosphomidon 86 EC     | 1484.60                  | 1486.00 | 13361.40  | 13374.00                   | 690.00   | 1:1.498(7)              | 1:2.733(7)         | 1:1.499(8)  | 1:4.722(8)  |      |
| Methyl-o-demeton 25 EC | 1731.00                  | 1984.33 | 17379.00  | 17858.97                   | 530.00   | 1:1.984(4)              | 1:1.139(4)         | 1:2.038(4)  | 1:14.609(4) |      |
| Dimethoate 30 EC       | 2070.00                  | 2031.67 | 18630.00  | 18285.00                   | 550.00   | 1:2.123(2)              | 1:13.010(2)        | 1:2.082(3)  | 1:14.842(3) |      |
| Monocrotophos 36 WSC   | 2132.00                  | 2129.00 | 19190.70  | 19161.00                   | 620.00   | 1:2.168(1)              | 1:12.859(3)        | 1:2.165(1)  | 1:15.075(2) |      |
| Fenubucarb 50 EC       | 1287.00                  | 1302.67 | 11583.00  | 11724.03                   | 520.00   | 1:1.323(8)              | 1:0.207(10)        | 1:1.339(10) | 1:3.092(10) |      |
| Chlorpyrifos 20EC      | 1843.30                  | 1793.33 | 16589.70  | 16139.97                   | 490.00   | 1:1.902(5)              | 1:10.438(5)        | 1:1.851(5)  | 1:12.290(5) |      |
| Untreated control      | 1275.00                  | 1124.00 | 11475.00  | 10116.00                   |          |                         |                    |             |             |      |

Method I : (Heinrichs *et al.*, 1981)C:B =  $\frac{\text{Value of treated crop} - \text{Value of untreated crop}}{\text{Cost of protection to treated crop}}$ 

Method II : (Akila Selvaraj and Sundara Babu, 1994)

C:B =  $\frac{\text{Treatment yield (kg/ha)} \times \text{Value of soybean seed (Rs./kg)}}{\text{Basic cost of cultivation} + \text{Cost of Protection}}$

Table 59. Efficacy of Biocontrol agents, (virus, *B.t* and insecticide) combinations on the larval population of *Helicoverpa armigera* on soybean \*(after three rounds of application)

| Sl.No. | Treatments                                   | Precount<br>population | Larval population / 10 plants |                               |                              | % pod<br>damage               | Yield kg / ha.         |
|--------|----------------------------------------------|------------------------|-------------------------------|-------------------------------|------------------------------|-------------------------------|------------------------|
|        |                                              |                        | I Spraying<br>7 DAT           | II Spraying<br>7 DAT          | III Spraying<br>7 DAT        |                               |                        |
| 1.     | <i>Trichogramma</i> sp. (releases)           | 10.66                  | 9.66<br>(0.97) <sup>de</sup>  | 7.66<br>(0.88) <sup>cd</sup>  | 4.66<br>(0.67) <sup>b</sup>  | 11.86<br>(1.06) <sup>d</sup>  | 1575.00 <sup>bc</sup>  |
| 2.     | <i>Chrysoperla</i> sp.                       | 11.33                  | 9.00<br>(0.94) <sup>de</sup>  | 6.66<br>(0.82) <sup>bcd</sup> | 2.66<br>(0.43) <sup>ab</sup> | 10.07<br>(0.99) <sup>cd</sup> | 1399.42 <sup>cde</sup> |
| 3.     | Ha.NPV                                       | 9.33                   | 6.66<br>(0.82) <sup>bcd</sup> | 5.00<br>(0.69) <sup>abc</sup> | 1.66<br>(0.23) <sup>a</sup>  | 5.48<br>(0.74) <sup>abc</sup> | 1740.60 <sup>abc</sup> |
| 4.     | SLNPV                                        | 10.33                  | 9.00<br>(0.91) <sup>cde</sup> | 7.00<br>(0.83) <sup>bcd</sup> | 4.33<br>(0.63) <sup>b</sup>  | 10.07<br>(1.00) <sup>cd</sup> | 1325.00 <sup>de</sup>  |
| 5.     | <i>B.thuringiensis</i> ( <i>B.t</i> )        | 11.00                  | 3.66<br>(0.52) <sup>b</sup>   | 3.00<br>(0.47) <sup>a</sup>   | 1.66<br>(0.23) <sup>a</sup>  | 3.22<br>(0.47) <sup>a</sup>   | 2003.50 <sup>ab</sup>  |
| 6.     | HaNPV + Endosulfan 0.07%                     | 8.33                   | 3.33<br>(0.52) <sup>b</sup>   | 2.33<br>(0.37) <sup>a</sup>   | 2.33<br>(0.36) <sup>a</sup>  | 3.28<br>(0.49) <sup>a</sup>   | 2032.4 <sup>a</sup>    |
| 7.     | SINPV + Endosulfan 0.07%                     | 10.00                  | 9.66<br>(0.96) <sup>de</sup>  | 9.00<br>(0.94) <sup>cd</sup>  | 5.33<br>(0.72) <sup>bc</sup> | 9.93<br>(0.99) <sup>d</sup>   | 1127.60 <sup>ef</sup>  |
| 8.     | <i>B.t</i> (0.5kg)/ha + Endosulfan 0.07%     | 11.66                  | 1.66<br>(0.21) <sup>a</sup>   | 2.66<br>(0.41) <sup>a</sup>   | 3.66<br>(0.56) <sup>a</sup>  | 2.89<br>(0.44) <sup>a</sup>   | 2013.60 <sup>a</sup>   |
| 9.     | <i>B.t</i> (0.5kg/ha) dose + NPV<br>mixtures | 12.00                  | 4.00<br>(0.56) <sup>b</sup>   | 3.02<br>(0.47) <sup>a</sup>   | 2.33<br>(0.36) <sup>a</sup>  | 4.92<br>(0.67) <sup>c</sup>   | 1826.50 <sup>ab</sup>  |
| 10.    | Endosulfan 0.07 %                            | 13.00                  | 4.33<br>(0.62) <sup>bc</sup>  | 3.30<br>(0.52) <sup>ab</sup>  | 2.00<br>(0.30) <sup>a</sup>  | 5.59<br>(0.79) <sup>ab</sup>  | 1803.30 <sup>ab</sup>  |
| 11.    | Farmer's practice                            | 11.00                  | 7.66<br>(0.88) <sup>cde</sup> | 7.33<br>(0.86) <sup>bcd</sup> | 3.66<br>(0.56) <sup>ab</sup> | 10.85<br>(1.03) <sup>cd</sup> | 1635.50 <sup>abc</sup> |
| 12.    | Untreated                                    | 14.66                  | 15.00<br>(1.17) <sup>e</sup>  | 13.33<br>(1.10) <sup>d</sup>  | 11.00<br>(1.04) <sup>c</sup> | 12.10<br>(1.04) <sup>cd</sup> | 1144.90 <sup>f</sup>   |

\* Mean of three replication

Figures in parenthesis are transformed values

In a column, means followed by common letter are not significantly different at 5% (p=0.05%) level by DMRT

Significant reductions in the mean population were recorded on 7 DAT in the plots treated with *B.t.* (0.5 kg) + endosulfan, 0.07 per cent, *B.t.* (0.5 kg) + NPV mixture and HaNPV + endosulfan 0.07 per cent during second spraying which were significantly superior. Endosulfan 0.07 per cent spraying alone also had equal effect and on par with these effective treatments. Highest mean populations were observed in the plots where in parasitoid and predators were released (Table 59).

Similarly, the effectiveness of these bio-control agents were observed after the third spraying (7 DAT). Significant lowest mean populations were observed in the plots treated with *B.t.* (1.0 kg) endosulfan 0.07 per cent alone, *B.t.* (0.5kg) + endosulfan 0.07 per cent, *B.t.*(0.5 kg/ha) + NPV mixtures, HaNPV + endosulfan 0.07 per cent and HaNPV alone. The insecticides used in the farmers field were also found to be effective in reducing the larval population.

#### 4.7.1.1. Effect on per cent pod damage

*H.armigera* populations were prevalent from early stages of crop causing heavy defoliation but their damages to pods were severe at the later stages of the plant growth. The effect of the different bio-control agents was noticed in the reduction of per cent pod damage. The plots treated with *B.t.* (1.0 kg), HaNPV + endosulfan 0.07 per cent, *B.t.* (0.5 Kg) + endosulfan 0.07 per cent recorded significantly lowest per cent pod damage which were on par with the plots treated with Ha NPV alone and followed by endosulfan 0.07 per cent alone (Table 59).

#### 4.7.2 *Spodoptera litura*

The different bio control agents had significant difference in reducing the *S.litura* population over the untreated control. Significantly lowest population

(2.33 to 4.0) was recorded in the plots treated with *B.t.* (1.0 kg), *B.t.* (0.5 kg) + endosulfan 0.07 per cent, SINPV alone and endosulfan 0.07 per cent alone. Equal effect was noticed in the plots treated with SINPV + endosulfan 0.07 per cent also.

Similarly after the second spraying significant reduction in mean population was recorded in the plots treated with *B.t.* (1.0 kg), SINPV + endosulfan 0.07 per cent and SINPV and these effects were on par with the plots treated with endosulfan 0.07 per cent alone.

After the third spraying of SINPV + endosulfan 0.07 per cent, *B.t.* 0.5 kg + endosulfan 0.07 per cent, *B.t.* (1.0 kg) and SINPV alone, recorded significant reduction in the mean population, which were on par with endosulfan 0.07 per cent alone (Table 60).

#### 4.7.3 EFFECT ON YIELD

The bio-control agents by reducing the population of pests and per cent pod damage had significant effect on the yield per hectare.

Highest mean yield (2032.4 kg) per ha was recorded in the plots treated with HaNPV + endosulfan 0.07 per cent and plots treated with *B.t.* (0.5 kg) + endosulfan 0.07 per cent (2013.6 kg). *B.t.* (1.0 kg) (2003.5 kg), *B.t.* (0.5 kg) + NPV mixture (1826.5 kg) and endosulfan 0.07 per cent (1803.30 kg) alone had also recorded equally the mean yield per ha. The HaNPV spraying alone and farmer's practice had yielded 1740.60 and 1633.50 kg respectively and they were on par with each other. (Tables 59 & 60).

#### 4.7.4. EVALUATION OF DIFFERENT COMPONENTS OF BIO CONTROL AGENTS AND INSECTICIDAL TREATMENTS

Field experiment was conducted in a plot of 120m<sup>2</sup> with five components of biocontrol agents experimented in seven treatment with the untreated check. In

**Table 60. Efficacy of Biocontrol agents, virus, *B.t* and insecticide combinations on the larval population of *Spodoptera litura* on soybean\* (after three rounds of application)**

| S.No. | Treatments                                   | Precount population | Larval population / 10 plants |                              |                               | Yield kg / ha.         |
|-------|----------------------------------------------|---------------------|-------------------------------|------------------------------|-------------------------------|------------------------|
|       |                                              |                     | I Spraying<br>7 DAT           | II Spraying<br>7 DAT         | III Spraying<br>7 DAT         |                        |
| 1.    | <i>Trichogramma</i> sp.                      | 13.66               | 9.66<br>(0.98) <sup>cd</sup>  | 10.00<br>(0.98) <sup>c</sup> | 11.33<br>(1.03) <sup>cd</sup> | 1575.00 <sup>bc</sup>  |
| 2.    | <i>Chrysoperla</i> sp.                       | 15.00               | 8.00<br>(0.98) <sup>cd</sup>  | 4.00<br>(0.54) <sup>ab</sup> | 5.33<br>(0.73) <sup>ab</sup>  | 1399.42 <sup>cde</sup> |
| 3.    | Ha.NPV                                       | 14.00               | 12.00<br>(1.08) <sup>d</sup>  | 11.66<br>(1.06) <sup>c</sup> | 11.33<br>(1.03) <sup>cd</sup> | 1740.60 <sup>abc</sup> |
| 4.    | SL. NPV                                      | 15.33               | 2.33<br>(0.34) <sup>a</sup>   | 2.33<br>(0.34) <sup>a</sup>  | 2.66<br>(0.42) <sup>a</sup>   | 1325.00 <sup>de</sup>  |
| 5.    | <i>B. thuringiensis</i> ( <i>B.t</i> )       | 13.66               | 3.33<br>(0.42) <sup>a</sup>   | 2.66<br>(0.42) <sup>a</sup>  | 2.33<br>(0.36) <sup>a</sup>   | 2003.50 <sup>ab</sup>  |
| 6.    | HaNPV + Endosulfan 0.07%                     | 13.66               | 10.66<br>(1.02) <sup>cd</sup> | 11.33<br>(1.05) <sup>c</sup> | 10.33<br>(1.01) <sup>cd</sup> | 2032.40 <sup>a</sup>   |
| 7.    | SINPV + Endosulfan 0.07%                     | 14.00               | 4.66<br>(0.66) <sup>ab</sup>  | 3.00<br>(0.43) <sup>a</sup>  | 1.66<br>(0.22) <sup>a</sup>   | 1227.60 <sup>ef</sup>  |
| 8.    | <i>B.t.</i> (0.5 kg / ha) + Endosulfan 0.07% | 12.66               | 3.33<br>(0.52) <sup>a</sup>   | 7.00<br>(0.84) <sup>bc</sup> | 3.00<br>(0.41) <sup>a</sup>   | 2013.60 <sup>a</sup>   |
| 9.    | <i>B.t.</i> (0.5 kg / ha) + NPV mixtures     | 14.33               | 7.00<br>(0.83) <sup>bc</sup>  | 7.00<br>(0.84) <sup>bc</sup> | 7.66<br>(0.88) <sup>cd</sup>  | 1826.50 <sup>ab</sup>  |
| 10.   | Endosulfan 0.07 %                            | 14.00               | 4.00<br>(0.59) <sup>a</sup>   | 4.33<br>(0.63) <sup>ab</sup> | 3.66<br>(0.54) <sup>ab</sup>  | 1803.31 <sup>ab</sup>  |
| 11.   | Farmer's practice                            | 15.33               | 9.33<br>(0.96) <sup>cd</sup>  | 10.00<br>(0.98) <sup>c</sup> | 12.33<br>(1.09) <sup>d</sup>  | 1633.50 <sup>abc</sup> |
| 12.   | Untreated                                    | 16.66               | 21.33<br>(1.32) <sup>e</sup>  | 26.00<br>(1.39) <sup>d</sup> | 29.66<br>(1.47) <sup>e</sup>  | 1144.90 <sup>f</sup>   |

\*Mean of three replication Figures in parenthesis are transformed values in a column, means followed by common letter are not significantly different at 5% (p=0.05%) level by DMRT

each treatment (from 1-6) one component was deleted and tried with four replications.

#### 4.7.4.1. *Helicoverpa armigera*

The data on efficacies of the different components on *H.armigera* were furnished in Table 61. The reduction in the mean populations at 33 DAS was significant in the treatments where three releases of *T.chilonis* were made and they were all on par with each other. The population was high in the plots where *T. chilonis* has not been released including untreated control.

The efficacy of different treatments with less one components had significantly reduced the population over untreated control. On 52 DAS lowest mean larval population was recorded where, *T.chilonis* and *C.carnea* were released when compared to untreated control and as well in the plots where *C.carnea* was not released.

Significantly lesser populations was recorded on 67 DAS in the plots treated with *B.t* as a component in the treatment. Highest mean populations was observed in untreated control and as well in the plots where *B.t.* has not been used as a component

The treatments with the applications of NPV + endosulfan 0.07 per cent had significantly reduced the mean population than untreated control and also higher population was observed in the plots where no treatment with NPV + endosulfan 0.07 per cent during 74 DAS was effected .

#### 4.7.4.3. Yield

The treatment containing all the components (T1) had recorded highest yield (2016.00kg/ha) followed by TC/*B.t.*/NPV/Endo(T2)(1912.5) and TC/CC/*B.t.*/Endo (T4) (1903.2) where *C.carnea* release and NPV components had

Table.61 Efficacy of Biocontrol agents, virus, *B.thuringiensis* and insecticide combination against the pests of soybean\* -  
*Helicoverpa armigera*

| S.No. | Treatment               | Precount<br>population<br>Mean | Larval Population / 10 plants |                              |                              |                               | % Pod<br>damage    | Yield<br>kg / ha.    |
|-------|-------------------------|--------------------------------|-------------------------------|------------------------------|------------------------------|-------------------------------|--------------------|----------------------|
|       |                         |                                | 33 DAS                        | 52 DAS                       | 67 DAS                       | 74 DAS                        |                    |                      |
| 1.    | T.C./C.C./B.t. NPV-Endo | 7.66                           | 3.66<br>(0.56) <sup>a</sup>   | 4.66<br>(0.66) <sup>a</sup>  | 3.00<br>(0.47) <sup>a</sup>  | 1.33<br>(0.12) <sup>a</sup>   | 4.74 <sup>a</sup>  | 2016.0 <sup>a</sup>  |
| 2.    | TC/B.t-NPV-Endo         | 11.00                          | 4.66<br>(0.67) <sup>ab</sup>  | 11.33<br>(1.05) <sup>b</sup> | 4.00<br>(0.60) <sup>a</sup>  | 2.33<br>(0.36) <sup>ab</sup>  | 7.47 <sup>ab</sup> | 1912.5 <sup>b</sup>  |
| 3.    | TC/C.C./NPV-Endo        | 11.33                          | 5.33<br>(0.73) <sup>ab</sup>  | 5.00<br>(0.66) <sup>a</sup>  | 10.33<br>(1.01) <sup>b</sup> | 3.33<br>(0.52) <sup>b</sup>   | 8.01 <sup>ab</sup> | 1870.5 <sup>bc</sup> |
| 4.    | TC/C.C./B.t-Endo        | 11.33                          | 6.33<br>(0.80) <sup>abc</sup> | 4.33<br>(0.63) <sup>a</sup>  | 3.66<br>(0.56) <sup>a</sup>  | 6.33<br>(0.80) <sup>cc</sup>  | 4.02 <sup>a</sup>  | 1903.2 <sup>b</sup>  |
| 5.    | TC/C.C./B.t-NPV         | 10.66                          | 5.00<br>(0.69) <sup>ab</sup>  | 5.33<br>(0.69) <sup>a</sup>  | 4.33<br>(0.62) <sup>a</sup>  | 11.33<br>(1.05) <sup>cd</sup> | 7.78 <sup>ab</sup> | 1581.5 <sup>c</sup>  |
| 6.    | C.C/B.t-NPV-Endo        | 12.66                          | 10.33<br>(1.01) <sup>cd</sup> | 4.66<br>(0.61) <sup>a</sup>  | 5.00<br>(0.69) <sup>a</sup>  | 11.66<br>(1.06) <sup>cd</sup> | 4.88 <sup>a</sup>  | 1485.0 <sup>d</sup>  |
| 7.    | Untreated               | 13.33                          | 13.00<br>(1.11) <sup>d</sup>  | 16.00<br>(1.19) <sup>b</sup> | 16.33<br>(1.22) <sup>b</sup> | 16.33<br>(1.21) <sup>d</sup>  | 13.41 <sup>c</sup> | 1185.2 <sup>e</sup>  |
|       | Mean                    | 11.33                          | 6.91                          | 7.33                         | 6.70                         | 7.52                          | 10.41              | 1707.0               |

Figures in parenthesis are transformed values.

\*mean of three replication Figures in parenthesis are transformed values in a column, means followed by common letter are not significantly different at 5% (p=0.05%) level by DMRT

TC- *Trichogramma chilonis*; CC-*Chrysoperla carnea*, B.t.- *Bacillus thuringiensis*, NPV- Nuclear Polyhedrosis Virus, Endo-Endosulfan.

been deleted respectively. The treatment TC/CC/NPV/Endo (T3) without *B.t* component had recorded a yield of (1870.5 kg) per ha which was on par with TC/CC/*B.t*/NPV (T5) (1581.5 kg) per ha (Table 61).

#### **4.7.5. COST BENEFIT RATIO**

##### **4.7.5.1. The usage of bio-control agents**

Different parameters like total cost of bio-control agents, cost of labour for the different applications were worked out and additional income over the untreated control was worked out and presented in Table 62.

Individual ranking has been indicated in the Table 62. Highest cost benefit was noticed in egg parasitoid released plots (1:9.68) followed by endosulfan 0.07 per cent treated plots. Even though the application of *B.t* (1.0 kg) was found to be effective in reducing *Helicoverpa* sp and *Spodoptera* sp., it's cost benefit ratio was low due to its higher cost (Rs.3000/ha<sup>-1</sup>). The efficacy of endosulfan 0.07 per cent alone (1:7.09) brought economic returns followed by HaNPV + endosulfan 0.07 per cent (1:6.74) treatment. In farmers practice three different chemicals were used as spraying four times but the treatment cost was very high and cost benefit ratio was 1:2.41 (8th rank).

##### **4.7.5.2 The usage of different Bio-control agent components**

Economics had been derived out of the total income and additional income compared with untreated control. All the treatments were indicating same cost benefit ratio which were not effective for consideration since they were all below 1:3.00 ratio (Table 63).

Table 62. Effect of different biocontrol agents, virus, *B.t.* and insecticides on the pests of soybean and their cost benefit ratio

| Sl. No. | Treatments                                                                         | Application rate/ha <sup>-1</sup> | Total cost / ha <sup>-1</sup> | Labour cost / ha <sup>-1</sup> (Rs.) | Total cost / ha <sup>-1</sup> (Rs.) | Yield kg/ha <sup>-1</sup> | Total income Rs./ha <sup>-1</sup> | Addl. income over control (Rs.) | C.B. ratio / Rank |
|---------|------------------------------------------------------------------------------------|-----------------------------------|-------------------------------|--------------------------------------|-------------------------------------|---------------------------|-----------------------------------|---------------------------------|-------------------|
| 1       | <i>Trichogramma</i> sp. release                                                    | 6.00 cc                           | 288.00                        | 45.00                                | 333.00                              | 1575.00                   | 11812.00                          | 3225.25                         | 1:9.68 (1)        |
| 2.      | <i>Chrysoperla</i> sp. release(Grubs)                                              | 50000 Nos.                        | 750.00                        | 45.00                                | 845.00                              | 1399.42                   | 10495.50                          | 1908.75                         | 1:2.26 (9)        |
| 3.      | HaNPV                                                                              | 250 LE                            | 745.00                        | 180.00                               | 825.00                              | 1740.60                   | 13054.50                          | 4467.75                         | 1:5.41 (5)        |
| 4.      | SI NPV                                                                             | 1000 g                            | 3000.00                       | 180.00                               | 3100.00                             | 1325.00                   | 9937.50                           | 1350.75                         | 1: 6.64 (4)       |
| 5.      | <i>B.t</i>                                                                         | 250 LE/ 1000 ml                   | 807.00                        | 180.00                               | 987.00                              | 2003.50                   | 15026.25                          | 6439.50                         | 1:2.08 (10)       |
| 6.      | HaNPV + Endosulfan 0.07%                                                           | 250 LE/ 1000 ml.                  | 807.00                        | 180.00                               | 987.00                              | 2032.40                   | 15243.00                          | 6656.25                         | 1:6.74 (3)        |
| 7.      | SINPV + Endosulfan 0.07%                                                           | 250 LE/ 1000 ml                   | 807.00                        | 180.00                               | 987.00                              | 1227.60                   | 9207.00                           | 620.25                          | 1:0.51 (11)       |
| 8.      | <i>Bacillus thuringiensis</i> 0.5 kg/ha + Endosulfan 0.07%                         | 500 g 1000 ml                     | 1758.00                       | 180.00                               | 1938.00                             | 2013.60                   | 15102.00                          | 6515.25                         | 1:3.23 (6)        |
| 9.      | <i>B.t.</i> 0.5 kg/ha + 1/2 mixture of NPV                                         | 500 g                             | 1875.00                       | 160.00                               | 2055.00                             | 1826.50                   | 13689.75                          | 5103.00                         | 1:2.79 (7)        |
| 10.     | Endosulfan 0.07 %                                                                  | 1000 ml                           | 516.00                        | 180.00                               | 696.00                              | 1803.3                    | 13524.75                          | 4938.75                         | 1:7.09 (2)        |
| 11.     | Farmer's practice chlorpyrifos - 1 spray Quinalphos - 2 spray Dimethoate - 1 spray | 500 ml 1000 ml 500 ml             | 1280.00                       | 240.00                               | 1520.00                             | 1633.50                   | 12751.10                          | 3664.50                         | 1:2.41 (8)        |
| 12.     | Control                                                                            | -                                 | -                             | -                                    | -                                   | 1144.90                   | 8586.75                           | -                               | -                 |

## 4.8. YIELD LOSS ASSESSMENT

### 4.8.1. Yield loss due to seasonal incidence of key pests

#### 4.8.1.1. Leaf hopper - *Empoasca fabae*

Studies were conducted on yield loss due to leaf hoppers in February, July and September seasons during 1995-96 and 1998-99. The mean differences under protected and unprotected condition at 41 DAS were -4.78, -1.19 and -3.75 during February, July and September respectively. Similarly, the mean differences in the population observed on 62 DAS were -1.15, -2.23 and -2.10 during February, July and September respectively. Significant increase in seed yield due to the protection with methyl demeton 0.05 per cent was also recorded as 293.34, 270.00 and 190.00 kg per ha with 16.66, 16.43 and 11.51 per cent as avoidable yield loss were recorded during February, July and September respectively (Table 64) (Fig. 11).

#### 4.8.1.2. Leaf miner - *Aproaerema modicella*

Spraying of monocrotophos 0.05 per cent on 38 DAS and 53 DAS had reduced the leaf damage caused by leaf miner during February, July and September. Significant difference in reduction in per cent leaf damages were recorded upto -19.00, -25.35 and -27.40 on 41 DAS and -20.00, -23.30 and -21.10 on 62 DAS during February, July and September respectively. Significant increase in seed yield was recorded upto 299.98, 303.14 and 276.67 kg per ha with 27.52, 21.02 and 22.49 per cent of avoidable loss recorded during February, July and September respectively (Table 65) (Fig. 12).

#### 4.8.1.3 *Helicoverpa armigera*

The effect of sprayings of endosulfan 0.07 per cent on 38 and 53 DAS revealed significant differences in reduction of larval population upto 2.95 and 2.92 on 41 DAS and 1.86 and 1.81 on 62 DAS during July and September respectively. Significant seed yield increases were recorded upto 240.00 and 343.33 kg per hectare with 16.07 and 24.12 per cent avoidable loss during July

Table 63: Effect of different Biocontrol agents and insecticides packages and their cost benefit ratio

| S.No. | Treatments          | Total Cost/ha <sup>-1</sup><br>Rs. | Yield/Kg/ha | Total income | Additional income | C:B ratio |
|-------|---------------------|------------------------------------|-------------|--------------|-------------------|-----------|
| 1.    | TC/CC/B.t./NPV/Endo | 6466.00                            | 2016.0      | 15120.0      | 6231.00           | 1:0.96    |
| 2.    | TC/B.t./NPV/Endo    | 5621.00                            | 1912.5      | 14343.75     | 5454.75           | 1:0.97    |
| 3.    | TC/CC/NPV/Endo      | 3286.00                            | 1870.5      | 14028.75     | 5139.75           | 1:1.56    |
| 4.    | TC/CC/B.t./Endo     | 5641.00                            | 1903.2      | 14274.00     | 5385.00           | 1:0.95    |
| 5.    | TC/CC/B.t./NPV      | 5770.00                            | 1581.5      | 11861.25     | 2972.25           | 1:0.51    |
| 6.    | CC/B.t./NPV/Endo    | 6133.00                            | 1485.0      | 11137.50     | 2248.50           | 1:0.37    |
| 7     | Untreated           |                                    | 1185.2      | 8889.00      |                   |           |

TC- *Trichogramma chilonis*; CC-*Chrysoperla carnea*, B.t.- *Bacillus thuringiensis*, NPV- Nuclear Polyhedrosis Virus, Endo-Endosulfan.

Table 64. Population and yield loss due to soybean leaf hoppers – *Empoasca fabae*

| Season / Crop stage | Mean population  |                    | Mean difference (Nos.) | Yield loss |       | SE   | 't'     |
|---------------------|------------------|--------------------|------------------------|------------|-------|------|---------|
|                     | Protected (Nos.) | Unprotected (Nos.) |                        | (Kg)       | %     |      |         |
| February            |                  |                    |                        |            |       |      |         |
| 41 DAS              | 0.98             | 5.76               | -4.78                  |            |       | 0.30 | 15.78** |
| 62 DAS              | 0.88             | 2.03               | -1.15                  |            |       | 0.20 | 5.86**  |
| Yield g/plant       | 6.16             | 5.28               | 0.88                   |            |       | 0.38 |         |
| Yield kg/ha         | (2053.33)        | (1759.99)          |                        | 293.34     | 16.66 |      | 5.37**  |
| July                |                  |                    |                        |            |       |      |         |
| 41 DAS              | 0.41             | 1.60               | -1.19                  |            |       | 0.24 | 4.90**  |
| 62 DAS              | 1.09             | 3.32               | -2.23                  |            |       | 1.16 | 1.88**  |
| Yield g/plant       | 5.74             | 5.02               | 1.11                   |            |       | 0.24 |         |
| Yield kg/ha         | (1913.33)        | (1643.33)          |                        | 270.00     | 16.43 |      | 19.87** |
| September           |                  |                    |                        |            |       |      |         |
| 41 DAS              | 0.88             | 4.63               | -3.75                  |            |       | 1.09 | 11.47** |
| 62 DAS              | 1.02             | 3.12               | -2.10                  |            |       | 0.73 | 30.02** |
| Yield g/plant       | 5.52             | 4.95               | 0.59                   |            |       | 0.26 | 9.43**  |
| Yield kg/ha         | (1839.98)        | (1649.98)          |                        | 190.00     | 11.51 |      |         |

Protection : Spraying with methyl-o-demeton 0.05% on 38 and 53 DAS

P\* = (0.05)

P\*\* = (0.01)

Figures in parenthesis are calculated yield in kg per hectare.

Fig. 11. Linear regression on yield loss and injury level of *Empoasca fabae*

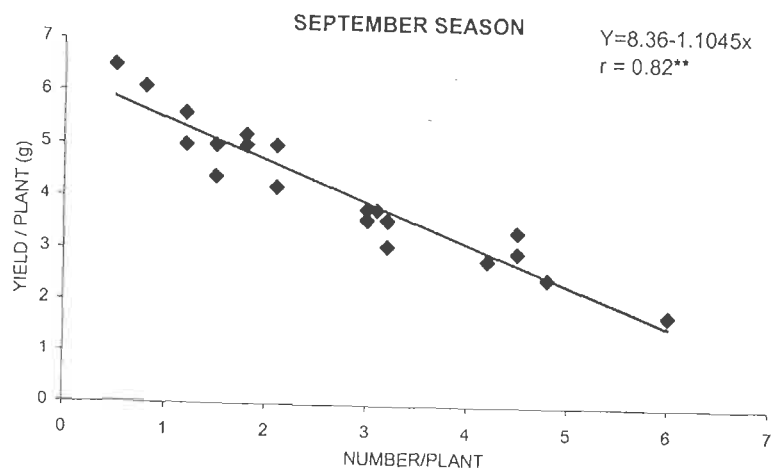
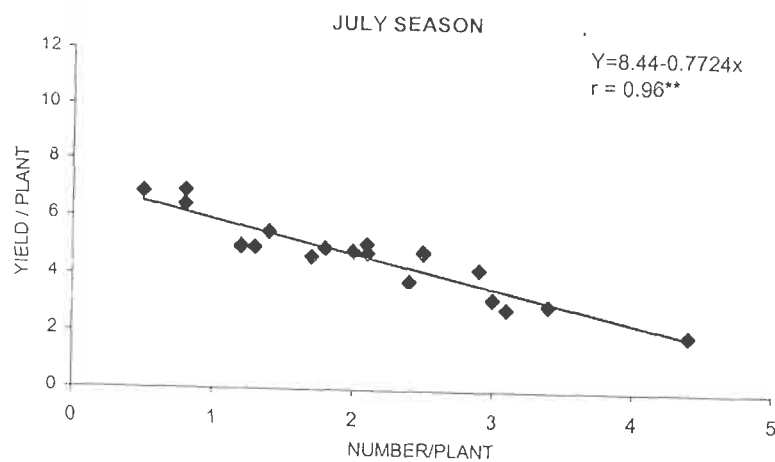
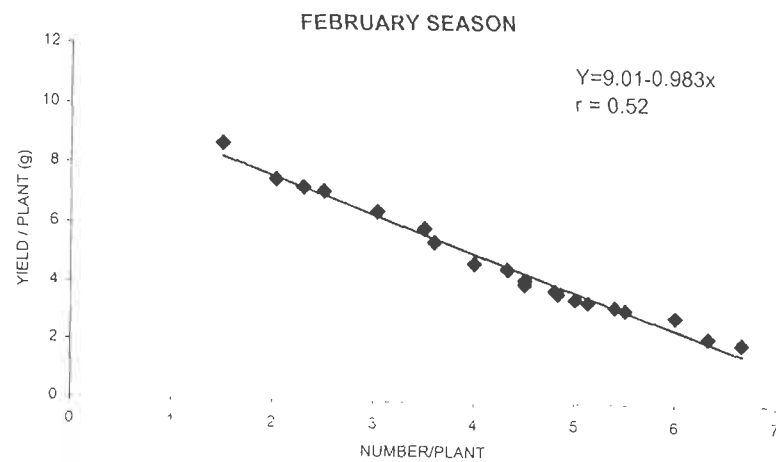


Table 65. Population and yield loss due to soybean leaf miner – *Aproaereme modicella*

| Season / Crop stage | Per cent leaf damage (%) |                    | Mean difference (Nos.) | Yield loss |       | SE    | 't'     |
|---------------------|--------------------------|--------------------|------------------------|------------|-------|-------|---------|
|                     | Protected (Nos.)         | Unprotected (Nos.) |                        | (Kg)       | %     |       |         |
| February            |                          |                    |                        |            |       |       |         |
| 41 DAS              | 8.60                     | 27.60              | -19.00                 |            |       | 0.994 | 20.75** |
| 62 DAS              | 12.40                    | 32.40              | -20.00                 |            |       | 1.343 | 14.87** |
| Yield g/plant       | 4.17                     | 3.27               | 0.90                   |            |       | 0.215 | 14.36** |
| Yield kg/ha         | (1389.98)                | (1090.00)          |                        | 299.98     | 27.52 |       | 5.37**  |
| July                |                          |                    |                        |            |       |       |         |
| 41 DAS              | 9.25                     | 34.60              | -25.35                 |            |       | 1.224 | 20.70** |
| 62 DAS              | 9.90                     | 33.20              | -23.30                 |            |       | 1.169 | 18.79** |
| Yield g/plant       | 5.24                     | 4.33               | 0.91                   |            |       | 0.245 | 19.87** |
| Yield kg/ha         | (1746.47)                | (1443.33)          |                        | 303.14     | 21.02 |       |         |
| September           |                          |                    |                        |            |       |       |         |
| 41 DAS              | 8.80                     | 36.20              | -27.40                 |            |       | 1.099 | 11.48** |
| 62 DAS              | 10.20                    | 31.30              | -21.10                 |            |       | 0.732 | 30.03** |
| Yield g/plant       | 4.52                     | 3.69               | 0.83                   |            |       | 0.262 | 9.43**  |
| Yield kg/ha         | (1506.66)                | (1229.99)          |                        | 276.67     | 22.49 |       |         |

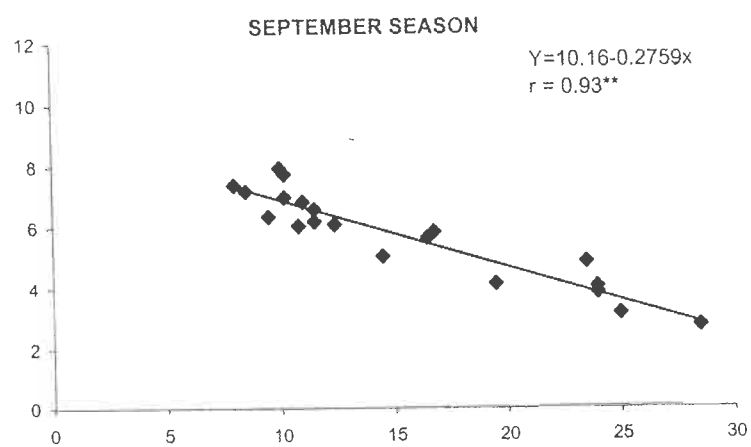
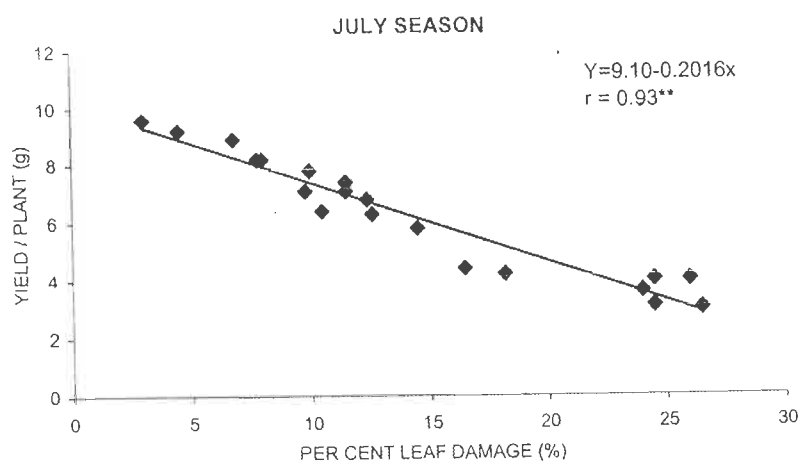
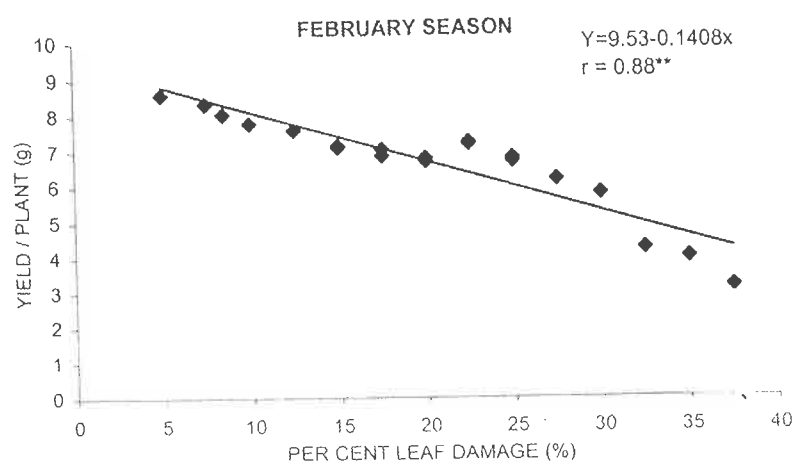
Protection : Spraying with monocrotophos 0.05% on 38 and 53 DAS

P\* = (0.05)

P\*\* = (0.01)

Figures in parenthesis are calculated yield in kg per hectare.

**Fig. 12. Linear regression on yield loss and injury level of *Aproaerema modicella***



and September respectively. (Table 66)(Fig.13).

#### **4.8.2. STUDIES ON YIELD LOSS ASSESSMENT IN SOYBEAN DUE TO LEAF MINER *Aproaerema modicella***

Different insect pests of soybean cause damage to leaves, stem, flowers and developing pods. All the damages caused by the insect pests result in heavy loss of the seed yield in soybean. An attempt was made to estimate the yield loss in soybean var. Col due to the infestation of leaf miner *A.modicella* which was prevalent in all the three seasons of soybean cultivation.

The yield loss assessment for the leaf miner was estimated in pot culture experiment using laboratory reared larvae of the pest and as well in open condition in the field experiment. Mathematical model like Mitscherlich's and logistic models were used for the estimation of yield loss. Yield loss and the rate of yield loss due to the different larval population and different leaf damage levels were predicted.

##### **4.8.2.1. Predicted yield loss and rate of yield loss at different levels of leaf miner larvae**

The yield loss recorded was minimum (0.390 g/plant) with 3.46 per cent of yield loss, when one larva was introduced. As the population increased, the yield showed decreasing trend and the yield loss was increasing correspondingly. The yield loss was 3.960 g per plant at maximum number of larvae (10) resulting in 35.17 per cent of yield loss. The predicted yield loss estimated was between 0.174 g per plant to 1.778 at minimum (1) and maximum (10) numbers of larvae respectively.

The rate of yield loss was estimated from the Mitcherlich's curve. The rate of yield loss was 0.127 g/plant when one larva was introduced and showed a maximum rate of yield loss of 1.270 g/plant at 10 larvae (Table 67 and Fig.14).

Table 66. Population and yield loss due to *Helicoverpa armigera*

| Season / Crop stage | Mean population  |                    | Mean difference (Nos.) | Yield loss |       | SE    | 't'     |
|---------------------|------------------|--------------------|------------------------|------------|-------|-------|---------|
|                     | Protected (Nos.) | Unprotected (Nos.) |                        | (Kg)       | %     |       |         |
| July                |                  |                    |                        |            |       |       |         |
| 41 DAS              | 0.95             | 3.90               | -2.95                  |            |       | 0.251 | 13.72** |
| 62 DAS              | 1.29             | 3.15               | -1.86                  |            |       | 0.205 | 8.69**  |
| Yield g/plant       | 5.20             | 4.48               | 0.72                   |            |       | 0.170 | 15.81** |
| Yield kg/ha         | (1733.33)        | (1493.33)          |                        | 240.00     | 16.07 |       |         |
| September           |                  |                    |                        |            |       |       |         |
| 41 DAS              | 0.95             | 3.87               | -2.92                  |            |       | 0.251 | 13.72** |
| 62 DAS              | 1.29             | 3.18               | -1.81                  |            |       | 0.205 | 8.67**  |
| Yield g/plant       | 5.30             | 4.27               | 1.03                   |            |       | 0.165 | 15.81** |
| Yield kg/ha         | (1766.66)        | (1423.33)          |                        | 343.33     | 24.12 |       |         |

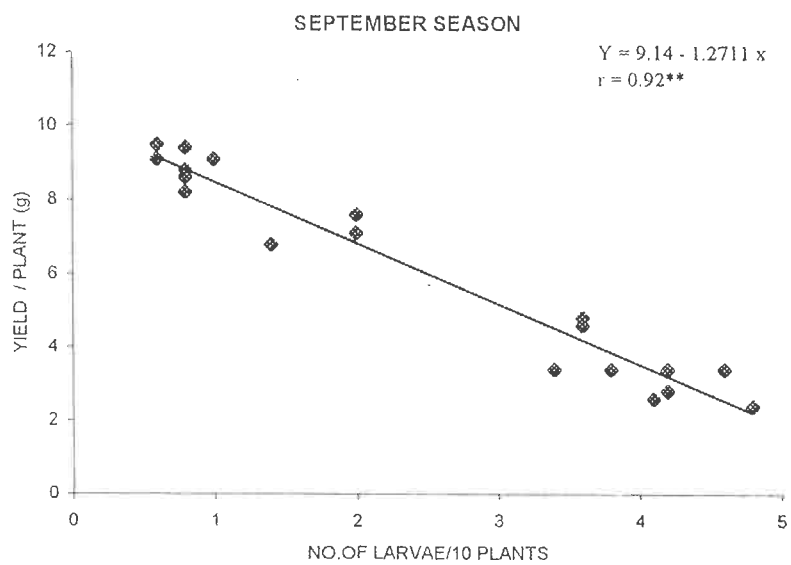
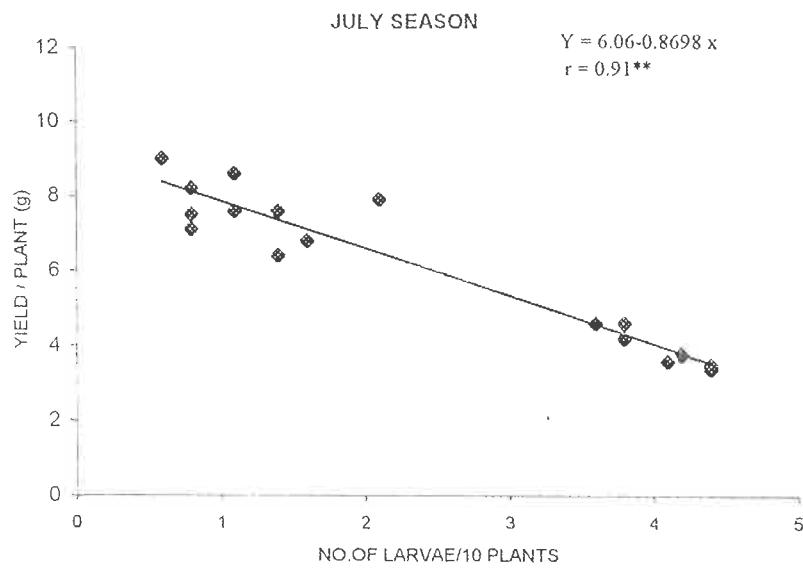
Protection : Spraying with endosulfan 0.07% on 38 and 53 DAS

P\* = (0.05)

P\*\* = (0.01)

Figures in parenthesis are calculated yield in kg per hectare.

Fig. 13. Linear regression of yield loss and injury level of *Helicoverpa armigera*



#### 4.8.2.2. Predicted yield loss and rate of yield loss at different damage levels of leaf miner *A.modicella*

Under field conditions, when the damage of the plant was at five per cent level, the yield loss estimated was 0.82 g per plant (8.07 per cent). As the damage level increased the yield also increased. An yield loss of. 3.76 g per plant (37.01 per cent) was obtained at 50 per cent leaf damage. The predicted yield loss of 3.79 g/plant (37.30 per cent) was estimated at 50 per cent damage. The rate of yield loss due to leaf damage was estimated from logistic curve by using the formula. The rate of yield loss of 0.0322 g/plant was estimated at five per cent damage and the maximum rate of yield loss of 0.1006 g/plant was estimated at 50 per cent leaf damage (Table 68 and Fig.14).

### 4.9. ASSESSMENT OF ECONOMIC INJURY LEVEL (EIL) FOR KEY PESTS OF SOYBEAN USING STATIC MODEL

#### 4.9.1. Leafminer - *A. modicella*

Significant negative relationships were observed between larval populations and seed yield through linear model (Annexure 2) for February, July and September seasons. Through linear equations EIL worked out were 2.68, 1.59 and 1.24 larvae per plant during February, July and September seasons respectively. (Table 69).

#### 4.9.2. *Helicoverpa armigera*

Three forms of equations viz., linear, log linear, and quadratic were fitted for *H. armigera* infestation and yield for February, July and September seasons under field conditions to quantify the relationship between the pest infestation and yield. Significant negative relationship were known to exist between infestation of larvae and seed yield in all the three seasons through the linear (L), log linear (LL) and quadratic equation (Q). The EIL worked out through linear model

**Table 67. Predicted yield loss at different levels of leafminer -*Aproaerema modicella* populations**

| Number of<br>leafminer<br>larvae | Yield<br>obtained<br>g/plant | Yield loss g/plant |           | percentage          |                 | Rate of yield<br>loss g/plant |
|----------------------------------|------------------------------|--------------------|-----------|---------------------|-----------------|-------------------------------|
|                                  |                              | obtained           | predicted | Expected<br>yield % | Yield<br>loss % |                               |
| 1.                               | 10.87                        | 0.390              | 0.174     | 96.54               | 3.46            | 0.127                         |
| 2.                               | 10.40                        | 0.860              | 0.347     | 92.36               | 7.64            | 0.254                         |
| 3.                               | 9.94                         | 1.320              | 0.521     | 88.28               | 11.72           | 0.381                         |
| 4.                               | 9.60                         | 1.660              | 0.695     | 85.25               | 14.75           | 0.508                         |
| 5.                               | 9.30                         | 1.960              | 0.869     | 82.59               | 17.41           | 0.635                         |
| 6.                               | 9.06                         | 2.200              | 1.043     | 80.46               | 19.54           | 0.762                         |
| 7.                               | 8.52                         | 2.740              | 1.217     | 75.66               | 25.34           | 0.958                         |
| 8.                               | 8.18                         | 3.080              | 1.390     | 72.64               | 27.36           | 1.016                         |
| 9.                               | 7.68                         | 3.580              | 1.600     | 68.21               | 31.79           | 1.143                         |
| 10.                              | 7.30                         | 3.960              | 1.778     | 64.81               | 35.17           | 1.270                         |
| Control                          | 11.26                        |                    |           |                     |                 |                               |

$$Y^e = 3.698 (1 - 0.9512e^{-0.0375 x})$$

Fig.14. Predicted yield loss/predicted rate of yield loss due to leafminer, *Aproaerema modicella*

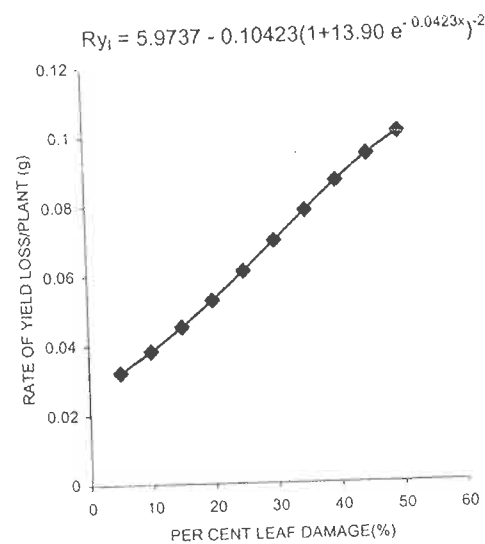
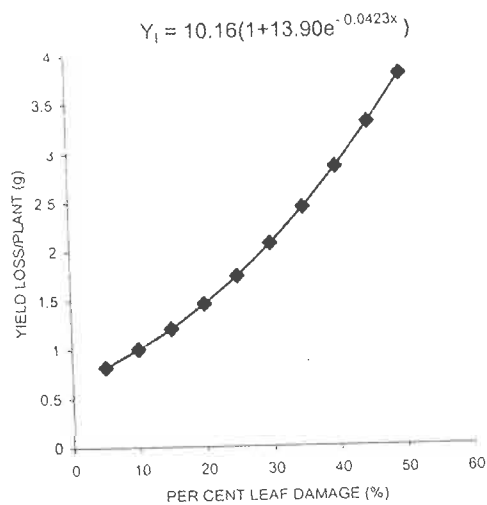
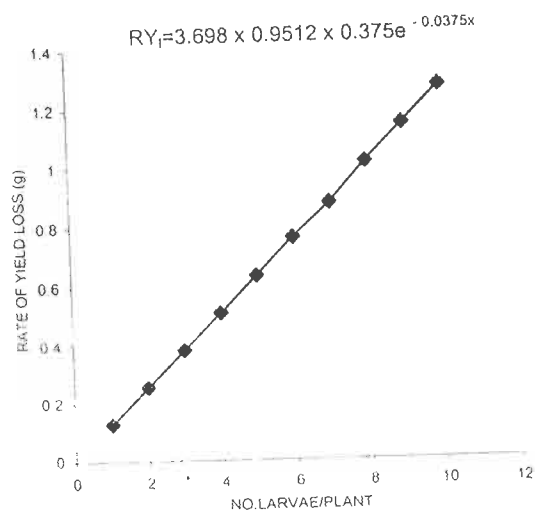
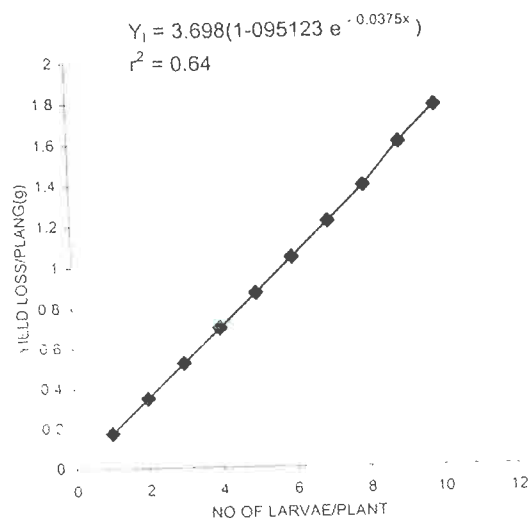


**Table 68** Predicted yield loss at different per cent leaf damage levels of leafminer  
*Aproaerema modicella* under uncaged condition in the field.

September 1998

Var : Co.1

| Damage (%) | Yield obtained<br>g/plant | Yield loss                        | Rate of yield loss<br>(RYL) g/plant |
|------------|---------------------------|-----------------------------------|-------------------------------------|
|            |                           | <u>g/plant</u><br>Predicted (Y/L) |                                     |
| 5          | 9.60                      | 0.82                              | 0.0322                              |
| 10         | 9.20                      | 1.00                              | 0.0383                              |
| 15         | 8.60                      | 1.21                              | 0.0452                              |
| 20         | 8.36                      | 1.46                              | 0.0528                              |
| 25         | 8.10                      | 1.74                              | 0.0611                              |
| 30         | 8.06                      | 2.07                              | 0.0697                              |
| 35         | 7.80                      | 2.44                              | 0.0784                              |
| 40         | 7.46                      | 2.85                              | 0.0868                              |
| 45         | 7.20                      | 3.30                              | 0.0944                              |
| 50         | 6.40                      | 3.79                              | 0.1006                              |
| Control    | 10.16                     |                                   |                                     |

$$YL = 10.16 (1 + 13.90 \cdot 0.0423x)$$

$$RYL = 5.9737 - 0.10423(1 + 13.90 - 0.0423X)^{-2}$$

(Annexure 3) were 2.50 and 2.70 larvae per ten plants during July and September respectively. The regression equations fitted with  $R^2$  values ranged from 0.91\*\* to 0.92\*\* (Table 69).

#### **4.9.3. Whitefly - *Bemisia tabaci***

The EIL obtained through linear equation (Annexure 4) were 0.52, 0.66 and 0.51 number per three leaves during February, July, and September seasons respectively (Table 69).

Table 69. Economic injury level assessment of key pests of soybean

| Name of the Pest            | Season    | Yield loss equation | r <sup>2</sup> | EIL                               |
|-----------------------------|-----------|---------------------|----------------|-----------------------------------|
| <i>Aproaerema modicella</i> | February  | Y=9.53 – 0.1408x    | 0.88**         | 2.68 / Plant (or) 26.80/10 plants |
|                             | July      | Y=9.10 – 0.2016x    | 0.93**         | 1.59/Plant (or) 15.90/10 plants   |
|                             | September | Y=10.16 – 0.2759x   | 0.95**         | 1.24/Plant (or) 12.40/10 plants   |
| <i>Helicoverpa armigera</i> | July      | Y=6.06 – 0.8698x    | 0.91**         | 0.25/Plant (or) 2.50/10 plants    |
|                             | September | Y=9.14 – 1.2711x    | 0.92**         | 0.27/Plant (or) 2.70/10 plants    |
| <i>Empoasca fabae</i>       | February  | Y=9.01 – 1.0983x    | 0.95**         | 0.52/Plant                        |
|                             | July      | Y=8.44 – 0.7724x    | 0.96**         | 0.66/Plant                        |
|                             | September | Y=8.36 – 1.1045x    | 0.82**         | 0.51/Plant                        |

\* = Significant at 0.05 level

\*\* = Significant at 0.01 level

## **DISCUSSION**

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## 5. DISCUSSION

### 5.1. Seasonal abundance of insect pests of soybean

Soybean is grown as monoculture in various parts of the world in association or in rotation with corn, cotton, rice, sugarcane and tobacco. The number of species associated with the crop is assumed to be a function of the area under cultivation in a given region and the functional characteristics of niches in soybean systems that are related to various plant parts (Strong, 1979).

Helm *et al.* (1980) described the geographical distribution of the potato leafhopper *Empoasca fabae* which is generally distributed throughout eastern half of the United States. It is most abundant at elevations below 1000m and in relatively humid regions receiving 75-100 mm of rainfall monthly, during growing season. The present study revealed that the leafhopper incidences were noticed during February, July, September months. Peak incidences were observed at 48 to 55 DAS during July and from 27 to 38 DAS during September. The incidences were low during February when compared to other months. Significant differences were observed between locations. Singh and Singh (1991) reported that leafhopper, *Apheliona maculosa* appeared on soybean in the first week of August and remained active up to third week of September, 1988 having maximum nymphal and adult populations in middle August. Earlier studies indicated that populations generally would peak between mid July and early August during the middle of the soybean growing season, with adults present on plants until maturity and harvest (Ogunlana and Pedigo, 1974).

Similarly soybean whitefly, *Bemisia tabaci* was also observed throughout the year in all the three seasons viz., February, July and September. It was observed that the peak incidences were observed during 69 to 76 DAS during February and July and at 48 DAS during September. *Bemisia tabaci* has a

widespread distribution throughout the tropical and subtropical regions of all continents. Bhattacharjee (1990) reported that the *B. tabaci* on soybean is a serious pest, found practically throughout the year in India. In kharif, from June to September when both temperature and humidity were high, maximum activity of *B. tabaci* was noticed in early stage of the crop, whereas other whitefly species like *B. argentifolli* and *T. abutilonea* were peaked in early September and late September on soybean during 1993 and 1994. (McPherson and Lambert, 1995). Lambert *et al.* (1997) found that trap captures of whitefly were very low in June during 1993 and 1994, rose steadily and peaked in mid to late September.

Everywhere soybean is grown and aphids form a community. Aphids are either colonizers of soybean fields (or) they are transient members of soybean community, colony forming aphids are actual (or) potential pests of soybean. (Irwin, 1980). *Aphis craccivora* is one of the major aphid species in soybean, groundnut and pulse crops. In the present study, aphid populations were observed in all the three seasons but lowest population was recorded during September and highest incidence were noticed during July. Peak incidence was seen between 48 and 69 DAS in all the three seasons. Similar results were reported by Bhakhetia and Sidhu (1976) and the peak period of aphid infestation was observed in July - September during Kharif season. However, in Madhya Pradesh, the bean aphid (*A. craccivora*) on soybean was predominantly present from middle December to first week of January, 1989 (Singh and Singh, 1995). June month was found to be appropriate for taking control measures since aphids were abundant during May - June on soybean. (Wang *et al.*, 1996).

The leafminer *A. modicella* was the serious defoliator on soybean which was prevalent throughout the three seasons viz., February, July and September in the present study. Highest per cent leaf damage was recorded during February and there were no significant differences between locations. The incidences were

noticed even from 27 DAS onwards but in all three seasons, the peak incidences were observed between 41 to 62 DAS. In MadhyaPradesh, the soybean leaf miner appeared regularly both in *Kharif* (June - October) and *Rabi* (November - April) seasons (Gujarati *et al.*, 1973). Kothai (1974) reported severe outbreak of the leafminer in the month of September. The leaf miner was found to be a problem towards the end of rainy season ( September - October) especially in drought (or) low rainfall years. (Amin, 1983). Kempraj (1992) found that highest incidence of leafminer was observed when soybean was sown during second and third weeks of August 1984, second and third weeks of October 1987 and also during first week of June and of August, 1988. Soybean leafminer was found throughout the year and the highest incidences were observed from September to November (Muthiah, 1995).

On soybean, seasonal activity of defoliators, *Heliothis* Spp. was very conspicuous and varied according to the seasons, and climate prevailed. In the present investigation on the seasonal incidence of *H. armigera* on soybean was very prominent during July and September and negligible incidences were observed during February. Peak incidences were noticed at 48 DAS during July and 62 DAS during September season. Jayaraj *et al.* (1990) reported that *H. armigera* was found to feed and breed on 181 species of host plants including soybean and cotton was the most favoured host plant. Oviposition of moths usually started in early June with the onset of premonsoon showers. *Heliothis* was more abundant in dry than in irrigated soybean (Fellard and Pitre 1991). Contrary to the present results, the peak population was actually found during February to March (Dubey *et al.*, 1993).

The present study on the seasonal incidence of *S. litura* on soybean revealed that the pest was seen during February and September seasons, the peak incidence was noticed at 48 DAS during February and between 41 and 48 DAS

during September seasons. A sudden peak incidence of *S.litura* incidence was observed during last week of June and last week of August and increased activities were noticed during October 1989.(Misra and Sontakke 1992). However, rainfall could be a deciding factor for occurrence of *S.litura*.

The green stink bug is highly polyphagous, attacking both monocot and dicot. Atleast 40 species of stink bugs were found to occur worldwide on soybean. The present study revealed that this pod sucking bug was prevalent during February, July and September seasons. Peak incidences were observed during 69 DAS in all these seasons indicating its abundance from pod initiation to pod formation stages. Soybean became attractive primarily after flowering and pod set, due to succulence of the green pods, although a few individuals were found in the crop throughout the year. The peak incidence of pod sucking bug *N.viridula* on soybean was noticed in early November. (McPherson *et al* 1979). Soybean was attractive in late July and August, after the migration of bugs from vegetables, leguminous crops during April to June. (Todd and Herzog, 1980). Similarly Ragsdale *et al.* (1981) reported the abundance of *N. viridula* on soybean during July to August. The adults and nymphs of *N.viridula* were frequently observed during vegetative stages of soybean development (Stam *et al.*, 1987).

## 5.2 Monitoring soybean insect pests

This strategy of using pheromones in traps for monitoring *H.armigera* of soybean in the fields is meant for detection, surveillance and prediction purposes. The results obtained in the present study revealed that the correlation between the pheromone trap catches and the larval population in the field was highly positive ( $r=0.96^{**}$  and  $0.78^{**}$ ) during July at TNAU, Coimbatore and Aliyarnagar respectively and ( $r=0.70^{**}$  and  $0.78^{**}$ ) during September at Avinashi and Bhavani respectively. It was also found that the emergence of moth activity was noticed from 20 to 34 DAS and its peak activity was observed during 48 to

60 DAS during July and the peak activity was seen at 41 to 55 DAS during September. The correlation between trap collection of moths and larval population in the field was highly significant.

Herbert *et al.* (1991) also observed highest *H.zea* population during August to September on soybean and pheromone traps provided timely reduction of moths in the fields. Sinha and Jain (1992) found that the moth catches of *H.armigera* in pheromone traps were found to be positively correlated with larval counts in the fields. But, Dubey *et al.* (1993) reported that its peak activity was noticed during February and March in soybean crop. Sex pheromone traps were very useful in monitoring and for the management of *H. armigera* population (Prasad, 1996).

In monitoring study of *S.litura* on soybean, there were significant correlations between moth catches in pheromone traps and the larval population in the field. The correlation was highly significant during February ( $r=0.51^*$  and  $0.60^*$ ) at Udumalpet and TNAU, Coimbatore respectively and during September ( $r=0.68^*$  and  $0.56^*$ ) at Avinashi and Bhavani respectively. Lawrence *et al.* (1990) described the uses of pheromone traps for *Spodoptera* sp. in Africa and Asia. In a pheromone trap study, a sudden peak activity of *S.litura* was noticed during first week of October, 1989 (Misra and Sontakke, 1992). Sushil Kumar and Patel (1995) noticed maximum activity of *S.litura* was noticed during 40<sup>th</sup> standard week in groundnut crop.

In soybean IPM, the real contribution of sex pheromone traps of *H.armigera* and *S. litura* are meant for not only monitoring purpose but also for the purpose of lure and kill in early stages by mass trapping of pests in soybean cropping system.

### 5.3.1. Correlation between weather parameters and incidence of soybean insect pests

In respect of leafhopper, significant multiple regressions were obtained for the population prevalent at TNAU whereas it was not significant at Aliyarnagar. Though the result was significant at TNAU, Coimbatore, there was negative influence of maximum temperature ( $r = -0.023$ ), minimum temperature ( $r = -0.093$ ), GDD ( $r = -0.356$ ) and PTU ( $r = -0.297$ ) to leafhopper. This might be due to the optimum weather prevailed at Coimbatore due its geographical position which had a mean altitude of 426.72m (MSL). At Aliyarnagar, minimum temperature ( $r = -0.682^{**}$ ), GDD ( $r = -0.590^{*}$ ) and PTU ( $r = -0.581^{*}$ ) had significant negative influences on leafhopper populations. A season with high humidity and high precipitation is favourable to more leafhopper populations but dry weather and high temperature, when prevailed over a week, caused drastic reduction in the leafhopper populations as reported by DeLong (1938).

With regard to whitefly population, there was significant positive correlation with rainfall ( $r = 0.613^{*}$ ) and negative influence with maximum temperature ( $-0.696^{**}$ ), GDD ( $-0.743^{**}$ ) and PTU ( $r = -0.571^{*}$ ) at TNAU, Coimbatore whereas only minimum temperature ( $r = -0.643^{**}$ ) could influence a significant negative effect on the whitefly population at Aliyarnagar. But Bhattacharjee (1990) reported that both high temperature and humidity favoured the higher incidence of the whitefly population during June to September on soybean.

With reference to the leafminer, at Aliyarnagar, maximum temperature ( $r = -0.534^{*}$ ), minimum temperature ( $r = -0.691^{**}$ ) and PTU ( $r = -0.529^{**}$ ) had exhibited significantly negative influence on the leafminer population whereas at Coimbatore, all the parameters showed negative influences except morning ( $r = 0.356$ ) and evening RH ( $r = 0.157$ ) and maximum temperature ( $r = 0.137$ ). These results are in conformity with the findings of Jena and Kuila (1997) who reported

that leafminer infested groundnut plants were negatively correlated with maximum temperature and minimum temperature but positively correlated with rainfall and relative humidity.

In the present investigation, the multiple regression analyses revealed that the accumulated GDD and PTU exhibited greater role on the incidence of leafminer of soybean. Significant negative influence of minimum temperature, PTU rainfall and evening RH was observed with the incidence of leafminer on soybean. Although, none of the correlations were significant and the multiple correlation was found to be significant due to multiple linearity among the weather parameters. In accordance to the present investigation, Reddy (1968) stated that drought conditions characterised by bright sunshine and occasional rains induced the multiplication of leafminer population. Lewin *et al.* (1979) observed that temperature was also positively correlated with leafminer incidence. The epidemic form of occurrence of soybean leafminer during 1971 in Maharashtra was observed due to high temperature accompanied by little rainfall, bright sunshine and prevalence of dry weather following continuous rains from June to the first week of September (Gujarati *et al.*, 1973).

In India, the leafminer is often a problem towards the end of the rainy season (September and October) especially in drought (or) low rainfall seasons (Amin 1983). But however, Kempraj (1992) reported the significant positive association of morning relative humidity, rainfall and wind velocity and negative association with the evening relative humidity with leafminer incidence on soybean. Minimum temperature exerted a negative influence on the pest and maximum temperature, relative humidity and rainfall showed positive influence.

In respect of *H. armigera*, only GDD and PTU had negative influence on the larval population since the leaf growth in soybean mostly depended upon

accumulated GDD and PTU. Hence, with increasing foliage, the damage caused by *H.armigera* was on the negative side in the present study.

The GDD ( $r = -0.574^*$ ) and PTU ( $r = -0.576^*$ ) had significant influence over *H.armigera* population at TNAU, Coimbatore. But at Aliyarnagar, the correlation among weather factors and *H.armigera* population was not significant. Yadava and Lal (1988) found that maximum and minimum temperatures and relative humidity had significant positive correlations with *Heliothis* incidence on Chickpea. *H. armigera* incidence on pigeonpea was influenced by overall effect of weather parameters to the tune of 63.65 per cent and individual factor had no influence as reported by Jayaraj *et al.* (1990). Joginder singh and Sidhu (1990) reported that high temperature coupled with low RH (or) lower temperature coupled with higher RH proved detrimental for *Heliothis* development and multiplication under Punjab condition.

In the present study, multiple regression analyses showed that maximum temperature ( $r = -0.567^*$  and  $-0.653^{**}$ ), minimum temperature ( $r = -0.688^{**}$  and  $-0.028$ ), GDD, ( $r = -0.681^{**}$  and  $-0.767^{**}$ ) and PTU ( $r = -0.695^*$  and  $-0.584$ ) had significant negative influences over the predatory populations of spider at Aliyarnagar and at TNAU, Coimbatore respectively but rainfall showed significant positive effect ( $r = 0.151$  and  $0.583^*$ ) on the spider population in these two locations.

Similarly, the regression analyses showed that maximum temperature ( $r = -0.369$  and  $-0.666^{**}$ ), minimum temperature ( $r = -0.631^*$  and  $-0.112$ ), GDD, ( $r = -0.564$  and  $-0.738^{**}$ ) and PTU ( $r = -0.580^*$  and  $-0.475$ ) had significant negative influences over the predatory populations of coccinellid at Aliyarnagar and at TNAU, Coimbatore respectively but rainfall showed significant positive effect ( $r = 0.164$  and  $0.542^*$ ) on the coccinellid population at Aliyarnagar and TNAU, Coimbatore.

### 5.3.2. Effect of leaf temperature and humidity on incidence of sucking pests and defoliators

Soybean leaf temperature recorded from 27 DAS had positive significant relationship with leafhopper population recorded at 7 days after. Similar sequential post effect was also observed upto 47 DAS. The results indicated that the leaf temperature recorded at a particular point of crop growth stage, influenced the leafhopper population 3-7 days later. This indicated that leaf temperature had positive role on the physiology of the leaf tissues and cells, thereby enhanced the sap flow, being the source of food of the leafhopper population. Same trend was also observed for whitefly population. But, there was an interesting feature noticed that the leaf temperature observed from 47 DAS had no relationship with subsequent whitefly population.

Jayapaul *et al.* (1995) reported that soil application of coir increased the relative leaf water content but decreased leaf temperature. The study on the dynamics of Leaf Surface Wetness (LSW) in sorghum showed characteristic relation to resistance to shootfly, *Atherigona soccata* (Rondani) egg eclosion (Nwaze *et al.*, 1992).

The red pumpkin beetles, *Rhaphidopalpa foveicollis* (Lucas.) were found mainly on the upper leaf surface at low light intensity and mainly in the lowersurface from about 10 hrs when light intensity was 10046 lux and the temperature of the leaf surface exceeded 33.85°C. The migration of beetles in the reverse direction occurred when light intensity was 10054 lux on both leaf surface and leaf temperature at 33.71°C (Singh *et al.*, 1984). Banerjee (1980) reported the leaf temperature and light penetration into the bushes appeared to be major factors regulating the mite *Oligonychus coffeae* (Niethner) population in coffee plants.

In the present study, at later growth stages of soybean plant, where more branches and leaves appeared and there was no correlation between whitefly population and leaf temperature probably due to poor light interception (or) penetration and leaf temperature developed there upon might not have been conducive for the development of egg or adults.

It was also found that the soybean leaf temperature recorded at 27 DAS had a positive relationship with leafhopper population developed at 3-7 days later. This result indicated that soybean plant at early stages of the crop close to the irrigated fields where light interception and development of leaf surface wetness were more and favoured oviposition by leafhopper on the leaf surface and its further development. The leaf temperature recorded during 37 DAS had significant correlation with the leafminer population prevailed at 40 DAS. Yeargan *et al.* (1994) found that early moisture stress at vegetative stage of soybean crop might exacerbate the *Empoasca* sp population on soybean yield. Wang *et al.* (1994) rightly pointed out that plant canopy cover and leaf canopy emissivities of soybean due to effect of soil water content directly play important role in the leaf surface wetness and leaf temperature. This was well supported by the findings of Jeyapaul *et al.* (1995) that soil application of coir pith increased relative leaf water content which decreased leaf temperature.

Regarding the defoliators, a correlation existed at 50 DAS between leafminer population (*A. modicella*) with leaf temperature recorded at 47 DAS and thereafter correlation was not significant. Shanower *et al.* (1993) reported that high rainfall was the key factor regulating leafminer population indicating the relationship of leaf surface wetness and the night leaf temperature developed due to rainfall, would have favoured egg laying.

The data on the leaf humidity was also compared with sucking pests and defoliators. With respect to sucking pests there was an indication that decreasing leaf relative humidity influenced the leafhopper as well as whitefly population. The leaf humidity effect was prevalent during the later stage *viz.*, 57 and 67 DAS, had significant effect on the population at 60 and 70 DAS respectively, whereas the leaf humidity at 37 and 47 DAS had significant influence over the whitefly population at 40 and 50 DAS respectively and the same had no influence over the population at later stage of the crop.

With reference to defoliators, the present study revealed that the leaf humidity prevalent during 47 DAS had significant correlation with the leafminer population during 50 DAS and leaf humidity in the later stages of crop had no influence over the leafminer population. The leaf humidity in general is controlled by soil moisture stress, as evidenced in a report indicating that soil moisture stress had influence on the pest load. (Jeyapaul *et al.*, 1995).

In future, there are possibilities to explore the details of the change in the leaf temperature and leaf humidity due to macro climatical factors and the incidence of pests of soybean.

## **5.4 CULTURAL METHOD OF CONTROL**

### **5.4.1 Effect of spacing on the incidence of insect pests of soybean**

Cultural practices such as selection of cultivators, planting date and row spacing are known to influence some soybean insect population (Buschman *et al.*, 1981). The present study revealed a significant influence of spacing on the different insect pests of soybean. Mixed responses on sucking pest populations were noticed in different locations of Coimbatore district. Neither closer spacing nor wider spacing had any significant influence on the leafhopper (*E.fabae*) populations at one location (Avinashi) whereas in other (Udumalpet),

widerspacing (45 x 10 cm) had significant effect in reducing the population level. Mayse (1978) reported that in a conventional wider row spacing and low density plant population cultivation of soybean was associated with high population of the potato leafhopper *E.fabae*. Lam and Pedigo (1998) reported that the leafhopper *E.fabae* was one of the predominant insect pests in soybean and no significant differences were detected between population of leafhopper and narrow versus wider spacing treatments.

Similarly the different spacing levels had little impact on the whitefly population at Udumalpet but it was found that in one location (Avinashi) the whitefly population was significantly low in the plots where wider spacing was adopted. But, Satishkumar and Bhattacharya (1989) found that the highest population of *B.tabaci* was recorded in plots having 30 cm row to row distance and a gradual decrease in overall whitefly population was observed as row to row spacing was increased from 45 cm to 75 cm which was in confirmity with the results obtained at Udumalpet. Thus, row spacing in soybean had an impact on the high (or) low density populations of like leafhopper and whiteflies in soybean.

Significant effect of spacing on the leaf damage caused by the leafminer was observed at two locations. Wider spacing (45 x 10 cm) had greater significant influence in reducing the leaf damage of the leafminer. Logiswaran and Mohanasundaram (1985) reported that significantly lesser incidence of leafminer *A.modicella* in closer spacing viz., 20 x 10 cm and 15 x 10 cm than normal spacing of 30 x 10 cm of groundnut. The possible reason might be that wider spacing with uneven coverage of leaves would not have been preferred by the leafminer to lay their eggs and thus resulting in less population.

The present results also indicated that closer spacing (30 X 10cm) recorded significantly less population of *H.armigera* than wider spacing (45 X 10 cm). Larval populations consistently peaked at the medium pod stage (R4 - R5) and the

populations in open canopied (wider space) fields were consistently higher than in closer canopied fields (Stinner *et al.*, 1980). Whereas Buschman *et al.* (1981) recorded that *Heliothis* larvae were as high as  $3.74/\text{m}^2$  during blooming stage of soybean and the populations of *Heliothis* larvae were nearly equal in narrow and wider row planting. Closed canopies (narrow row spacing) inhibited moth flight (or) obscure visual cues of flowers and thereby prevented oviposition (or) a favourable microclimate in the closed canopy favoured pathogens, and predators thereby decreased the chances of larval survival as reported by Terry *et al.* (1987). The present finding is in confirmity with that of Anderson and Yeargan (1998) wherein the early planting in narrow rows was found to be the most effective cultural method of preventing outbreak of *H. zea* on soybean.

The effect of spacing on the *S. litura* in the present study indicated that the population was significantly lesser in wider spacing and heavy population was noticed in closer spacing. Higher populations of defoliators like *Diacarsia* Sp., *S. litura* and *Pulsia* sp. per ten metre length were observed in the plots having row to row spacing of 30 cm than in 45, 60 and 75 cm row spacing during various stages of soybean crop.

The apparent reason might probably be due to even coverage of leaves of soybean in the closer spacing (30 cm), which would have attracted these defoliators for egg laying. Satish Kumar and Bhattacharya (1989) reported that in closer spacing (30cm) higher population of *S. litura* (27.7 larvae per ten meter) was observed which decreased as the row to row distance was increased from 45 to 75cm. In the present investigation it was observed there was no significant difference in the mean population of green stink bugs, *N. viridula* in the different spacing levels at Udumalpet. Buschman *et al.* (1984) reported that in the factorial analysis between the main effects of planting date and row spacing on the stink bug populations were not significant. But at Avinashi the study indicated that

widerspacing recorded lesser incidence of the stink bug population. This is in confirmity to the results reported by Lam and Pedigo (1998) that the southern stink bugs were more in narrow row soybean than in wider-row soybean fields.

#### **5.4.2. Effect of spacing on natural enemies of pests of soybean**

Predator complex associated with pests of soybean appears to be of prime importance in preventing insect species attaining key pest status (Turnipseed and Kogen, 1976).

The results of the present study showed that the closer spacing (30 X 10 cm) in soybean had significant effect on the abundance of the predatory population but they were low in wider spacing. Earlier scientists reported that predators like coccinellids, spiders, *Nabis* Spp. and *Orius* Spp. in soybean were more abundant in all three narrow row spacing systems than in conventionally planted fields (open canopy) (Ferguson *et al.*, 1984). Anderson and Yeargan (1998) reported that abundance of the most common predator groups was substantially affected by close canopy and the predators consumed 70 per cent of *H. zea* eggs, exposed in the soybean field. Mayse (1978) demonstrated that narrow spacing and high density planting of soybean were favourable for the population growth of Nabids. Sprenkel *et al.* (1979) reported that *Nabis* Spp densities were greater in closed dense soybean canopies than in open, sparse canopies because prey were more abundant and microhabitat conditions were more favourable. Bechinski and Pedigo (1981) found damsel fly, bugs and spiders accounting for 90 per cent of the foliage inhabitat in soybean.

#### **5.4.3 Effect of fertiliser ( $P_2O_5$ ) on the incidence of insect pests of soybean:**

Present study on the effect of phosphorous fertiliser application on different insect pests of soybean revealed that leafhopper (*E. fabae*) and whitefly (*B.tabaci*)

populations were effectively minimised by the application of 80 kg  $P_2O_5$  basal with 20 kg  $P_2O_5$  as top dressing either as two split doses (at 30 & 40 DAS) or with three split doses (at 30,40 and 50 DAS). Purushothaman *et al.* (1994) reported that soil application of 60 kg  $P_2O_5$  per ha as basal, combined with foliar application of 20 kg  $P_2O_5$  per ha in three equal splits on 30,40 and 50 days after sowing could be recommended as improved phosphorus fertilising technique for irrigated soybean.

Rajmohan *et al.* (1974) investigated the additive effect of 'N' fertilisation when coupled with widerspacing to induce luxuriant growth and to facilitate congregation of nymphal population of leafhopper on sunflower. But, Aganon (1989) reported fertilisers had no significant effect on soybean leafhopper and whiteflies populations.

In case of soybean defoliators *H. armigera*, leafminer *A.modicella* and *S. litura*, the present study revealed that a basal application of 80 kg  $P_2O_5$  recorded low mean population of *A.modicella* and leafminer population was increased with the increased levels of phosphorous applications.

No significant differences in *H.armigera* population were noticed in all the fertiliser applied plots except the plot where 80 kg  $P_2O_5$  + 20 kg  $P_2O_5$  were applied in three split doses at 30,40 and 50 DAS. This result also indicated that the more the  $P_2O_5$  level, higher the *H.armigera* population. In case of *S.litura*, lesser incidences were observed in the plots treated with 80 kg  $P_2O_5$  alone followed by 60 kg  $P_2O_5$  + two splits of 20 kg  $P_2O_5$  at 30 and 40 DAS and higher incidences were observed in the plots where no  $P_2O_5$  was applied.

These findings are in confirmity with the results of Funderberk *et al.* (1991) who found that population density of velvet bean caterpillar (*Anticarsia* Sp.) of soybean increased as the phosphorous level increased.

In the present study, more population of stinkbug was recorded in the soybean plants where more  $P_2O_5$  as basal and as topdressing was applied which is in conformity with the findings of Funderburk *et al.* (1991) who observed that the mean densities of *N. viridula* were significantly greater at higher levels of 'P'. In the present study, significantly higher population of predators were observed in the plots which received 80 kg  $P_2O_5$  applied as basal + 20 kg  $P_2O_5$  applied either in two (or) three splits on 30 and 40 DAS or 30, 40 and 50 DAS respectively.

Funderburk *et al.* (1994) earlier observed that high phosphorous application favoured dense population of nymphs of *Nabis* sp. *Hoplistoscelis* Sp., *Geocoris* Sp. and spiders. In the present study it was observed that higher levels of  $P_2O_5$  were able to favour the multiplication and development of natural enemies population like *M. sexmaculatus* and spiders. Lam and Pedigo (1998) recorded common natural enemies of soybean like damsel bugs (*Nabis* spp.) and insidious flower bugs [*Orius insidiosus* (Say)] but found no significant differences among natural enemies in the tested combinations of row spacing and tillage practices.

#### 5.4.4. Effect of spacing and $P_2O_5$ application on soybean oil content

Significantly higher oil content was recorded in the grains when planted in widerspacing and application of  $P_2O_5$  @ 80 kg as basal and 20 kg as topdressing in two and three split doses. The per cent of oil content was in the increasing trend when the  $P_2O_5$  level was also increased. These findings are in conformity with the results of Goswami *et al.* (1991) who recorded maximum oil content at 60 kg  $P_2O_5$  per hectare and with 80 kg  $P_2O_5$  as reported by Bisht and Chandal (1996) and stated that the oil content increased significantly with increase in phosphate levels since phosphorous was known to be directly responsible for oil and albumin synthesis.

In contrary to this, Jadhava *et al.* (1994) observed that the protein content was decreased with increasing the plant density (closer spacing) but oil content and yield were increased in soybean, but Dwivedi and Bapat (1998) reported that seed yield, protein, and oil content of soybean were significantly increased with application of sulphur upto 50 kg/ha and  $P_2O_5$ .

#### 5.4.5. Effect of spacing and fertiliser on yield component and yield

In the present study, maximum number of pods and grains per plant were recorded in wider spacing resulting maximum yield at Udumalpet and Avinashi. Weber *et al.* (1966) reported that yield was decreased at higher plant densities (closer spacing) due to greater competition and the seed yield would have been maximised with wider plant spacing. This is in conformity with the present results.

Higher yield of seed grain was obtained at Udumalpet and Avinashi locations where 80 kg  $P_2O_5$  and 20 kg  $P_2O_5$  were applied as top dressing in two (or) three split doses at 30 and 40 DAS or 30, 40 and 50 DAS respectively. This result is in conformity with the finding of Buttery (1969) wherein more number of flowers plus pods observed when fertilizer level was increased in soybean. Pooled analysis indicated that grain yield, number of pods, and number of grains were increased significantly with increasing levels of phosphorous in soybean (Abbas *et al.*, 1994). Purushothaman *et al.* (1994) also indicated that the application of 60 kg  $P_2O_5$  per ha through foliage in three equal splits on 30, 40 and 50 DAS recorded significantly higher grain yield in irrigated soybean.

Similar response was observed with  $P_2O_5$  application in soybean with increased seed yield, plant height, number of pods, grains and oil content by Thimmegowda and Devakumar (1996) and Taware *et al.* (1997). The extra  $P_2O_5$  applied was needed for the soybean plant to produce more flowers and pods to compensate the seed yield loss caused by sucking and defoliating insects.

#### 5.4.6. Effect of intercropping on the incidence of insect pests of soybean

Changes in cropping practices directly affect the dynamics of soybean arthropod associations. Alterations in cropping pattern contribute to fluctuations in pest status and the relative dominance of species in the community (Kogen and Turnipseed, 1987).

The results of the intercropping system study undertaken in the present investigation revealed that mean incidence of leafhopper, *E.fabae* was significantly lower in the soybean intercropped with two or four rows of maize which is in accordance with the results of Altieri *et al.* (1978) who reported less damage caused by *Empoasca* sp. on beans when intercropped with maize. The presence of Coriander in soybean suppressed the population of *E. fabae* on soybean (Rodenhouse *et al.*, 1992). Tonhasca (1994) also confirmed that *E. fabae* was more abundant in mono culture soybean plants and less in strip intercropping of maize and sorghum. Hence, the present study results confirmed that intercropping soybean with 2 or 4 rows of maize resulted an impact on the population of *E. fabae*.

Similarly in the present study, the mean population of *B. tabaci* was less in soybean when intercropped with 2 (or) 4 rows of bhendi. However, Satishkumar and Bhattacharya (1986) reported that soybean as mono culture and soybean intercropped with maize and blackgram significantly had higher population of *B.tabaci*. Singh *et al.* (1990) found that the whitefly population (*B.tabaci*) was found to be numerically more in pure soybean than in intercropped soybean with sorghum.

In the present study the lowest per cent leaf damage caused by leafminer and less larval population of *H.armigera* were recorded in the soybean when intercropped with 2 (or) 4 rows of maize and with 4 rows of sorghum.

Among the different intercropped systems tried by Kempraj (1992) that the incidence of leafminer was lowest in soybean + cumbu followed by soybean + sorghum and soybean + maize. Groundnut crop intercropped at 3:1 or 4:1 ratio with cowpea, cumbu, sorghum and blackgram had significantly less incidence of leafminer on groundnut (Fletcher, 1914, Murali Baskaran *et al.*, 1993, Muthiah, 1995).

Bhatnagar and Davies (1981) demonstrated that the number of *Heliothis* larvae and per cent damage were greater in pigeonpea / sorghum intercropping than in sole crop. Whereas, in the present study it was observed that the mean population of *H. armigera* was significantly low in soybean intercropped with 4 rows of maize (or) 2 or 4 rows of sorghum.

In the present study, lesser population of *S.litura* was recorded in the soybean intercropped with 2 or 4 rows of maize, 2 or 4 rows of sorghum and 4 rows of bhendi which in confirmity with the study on the intercropping of soybean with blackgram and maize wherein the population of *S. litura* was considerably low when soybean was intercropped with maize (Satish Kumar and Bhattacharya 1989).

In the present study, higher population of coccinellid, *M. sexmaculatus* and spiders were recorded in soybean when intercropped with 2 (or) 4 rows of maize (or) 6 rows of pure crop soybean or 2 (or) 4 rows of sorghum. These are in confirmity with the results of Tonhasca (1994) and Wang and Feng (1998) who had reported the abundance of natural enemies of soybean in stripped intercropping system than in monoculture of soybean or corn or maize.

Duffield and Reddy (1997) studied the distribution and movement of predators of *H. armigera* on pigeonpea intercropped with soybean and reported that Coccinellidae, Neuroptera, Anthocoridae and Aeneae were prominent predators recorded in the intercropping system with sorghum, and coccinellids were dominated by *M. sexmaculatus* accounting for over 95%, Neuroptera were dominated by *Chrysopa* spp., and Hemiptera by *Orius* spp. for over 90% and Aeneae showed two peaks in pigeonpea. Krishna and Rajkhekar (1997) pointed out that the maize and soybean system recorded in lower values of the relative crowding coefficient (K), resulting lower competition between sole and intercrops. Intercropping system showed higher water use and water use efficiency than sole soybean. The competitive ratio (CR) and relative crowding coefficient (RCC) values remained 1 and sorghum showed higher competitiveness with soybean than *Cajanus cajan* (Prasad *et al.*, 1998). These reasons may substantiate for lower incidence in soybean with millets as intercrop.

Hence, raising an intercrop of 2 (or) 4 rows of maize, 2 (or) 3 rows of bhendi would be of much benefit and advantageous in reducing the soybean pest population and providing an environment or a microclimate for the development of natural enemies of pests of soybean.

### 5.5. Chemical control

Conventional chemical insecticides have generally provided effective and economic suppression of soybean insects that exceeded economic injury level. The present study on the insecticidal control indicated that methyl-o-demeton 0.05 per cent and monocrotophos 0.05 per cent were found to be highly superior in reducing the leafhopper population in different locations, whereas chlorpyrifos 0.05 per cent and endosulfan 0.07 per cent were also found to be significantly effective in reducing the leafhopper population at TNAU, Coimbatore. The

superior efficacy of monocrotophos is in conformity with the results of Singh and Singh (1994) in reducing both nymphs and adults of leafhopper, *Apheliona maculosa* Dist. on soybean.

In the present study, methyl-o-demeton 0.05 per cent, dimethoate 0.03 per cent and phosphamidon 0.04 per cent were found to be effective in reducing the population of whitefly, *B. tabaci* followed by monocrotophos 0.05 per cent, chlorpyrifos 0.05 per cent and endosulfan 0.07 per cent at Udumalpet whereas at TNAU, Coimbatore, monocrotophos 0.05 per cent, methyl-o-demeton 0.05 per cent and endosulfan 0.07 per cent were found to be effective against whiteflies. Latha *et al.* (1993) found that spraying with monocrotophos 0.05 per cent on 31 and 51 DAS was most effective against whiteflies on soybean.

The present evaluation of insecticides against aphids revealed that dimethoate 0.03 per cent and endosulfan 0.07 per cent were found to be highly effective in reducing the population of aphids. Qu *et al.* (1989) reported that the application of dimethoate at 20 g a.i./ha and fenvalerate 3 g a.i./ha at seedling stage and diflubenzuron at 20 g a.i./ha at flowering and podding stage effectively controlled *A. glycines* on soybean.

The present study to identify effective chemicals for the management of the leafminer (*A.modicella*) revealed that monocrotophos 0.05, endosulfan 0.07 and dimethoate 0.03 per cent were found to be very effective in reducing per cent leaf damage caused by the leafminer. Earlier studies also revealed that monocrotophos was found to be effective against leafminer (Khan and Raodea, 1979; Muthiah, 1995 and Umesh and Naik, 1996). Whereas Geh and Tim (1975), Abdul Kareem and Subramanian (1976) and Jena and Kuila, (1997) reported that endosulfan was found to be effective against leafminer *A. modicella* which confirms the results of the present investigation.

In the present investigation, endosulfan 0.07 per cent and monocrotophos 0.05 per cent had brought significant effect in reducing the population of *H. armigera*. The efficacy of endosulfan in controlling the larvae of *H. armigera* is in conformity with the results of Rajmohan and Ramakrishnan (1976) and Srinivas (1987).

In the present investigation, chlorpyriphos 0.05, monocrotophos 0.05 and endosulfan 0.07 per cent were found to be very effective in reducing the population of *S. litura* in soybean. Masuda *et al.* (1981) reported that chlorpyriphos was also effective against for control of *S. litura* on soybean crop.

In the present study, monocrotophos 0.05, endosulfan 0.07 and dimethoate 0.03 per cent were found to reduce the population of stinkbug *N. viridula* significantly. The controlled application of endosulfan at 525g a.i/ha was very effective against *N. viridula* on soybean as reported by Gazzoni (1998). Komari *et al.* (1995) reported that stink bugs feeding on soybean susceptible to insecticides viz., fenthion, fenitrothion and phenthoate.

### 5.5.1 Cost benefit analysis

Norgaard (1976) indicated that the cost of pest management included the cost of acquiring information and making decisions, cost of carrying out cultural practices and applying inputs alongwith cost of pest control inputs. The resultant profit (yields) therefore is a function of these efforts plus the other inputs of cultivation.

In the present study, two methods were used for working out the cost benefit ratio. In method I, the yield was assumed to be due to all functions involved in crop production efforts including the one for crop protection. In this

method the proportion of total value of returns to the total cost investment was calculated. This gave the highest return of 2.168 in monocrotophos followed by dimethoate (2.123) and endosulfan (2.091) at Udumalpet. Dimethoate (2.060), methyl-o-demeton (1.983) and chlorpyriphos (1.902) were the other insecticides whose cost benefit ratios were also effective and considerable.

Similarly, the cost benefit ratio for the insecticides tried against soybean pest at TNAU, Coimbatore, monocrotophos recorded highest return (2.165) followed in the order endosulfan (2.112) > dimethoate (2.082) > methyl-o-demeton (2.035) > chlorpyriphos (1.851).

The cost benefit arrived in the method I precisely gave information on, how much money a farmer can expect for the every rupee invested in managing the insect pests. In this method, the basic cost of cultivation was taken into consideration. Ramasubramaniam (1996) reported that by using botanicals high return of 1:1.89 was obtained in managing the rice black bug *Scotinophora coarctata* (Fab) following the same method.

The second method proposed by Heinrich's *et al.* (1981) assumed the extra yield over control to be solely due to plant protection. In this method the proportion of the value of the difference in the treatment and control yield to the cost of plant protection was worked out and cost benefit ratio was obtained. Highest cost benefit ratio was obtained with endosulfan 1:14.285 and 1:17.585 at Udumalpet and TNAU, Coimbatore, respectively. Monocrotophos although was found to be highly effective recorded a benefit ratio of 1:12.859 (3<sup>rd</sup>) at Udumalpet and 1:15.075 (2<sup>nd</sup>) at TNAU, Coimbatore while dimethoate had as 1:13.010 (2<sup>nd</sup>) and 1:14.842 (3<sup>rd</sup>) at Udumalpet and TNAU, Coimbatore respectively.

Singh and Singh (1991) reported that the cost benefit ratio was the highest in the case of phosphamidon (1:10.88) followed by chlorpyriphos (1:8.40) in the

management of soybean leafhopper, *Apheliona maculosa* Dist. Similarly Jena and Kuila (1997) indicated that endosulfan spraying brought out a cost benefit ratio of 1:4.7 in managing leafminer in groundnut. Using the same method it was reported that the cost-benefit ratios were ranging from 17.42 to 30.40 among insecticides and from 8.00 to 21.74 for the botanicals in the management of rice black bug (Ramasubramanian, 1996).

It may be concluded that the pest management inputs do not contribute for extra yield but mitigate possible yield loss due to pests. Hence, any extra yield realised through pest management is the resultant output due to crop husbandry efforts. Therefore, a realistic cost-benefit ratio estimate should be based on all inputs on cultivation rather than working out ratio using the extra yield value and cost of protection.

### **5.6 Biological control in the management of key pests of soybean**

Among the different bio - control agents tried individually (or) along with insecticides, the results revealed that three sprayings of NPV of *H. armigera* at 250 LE + endosulfan 0.07 per cent and *B.thuringiensis* (0.50 kg /ha) + endosulfan 0.07 per cent were able to significantly reduce the larval population of *H. armigera* and increase the yield and the per cent pod damage caused by *H. armigera* was also significantly less in the plots treated with the above mentioned effective treatments.

It was evident from the results that individual treatments of *B.thuringiensis* (1.0 kg/ha) and endosulfan 0.07 per cent were also effective in reducing the larval population and per cent pod damage but they were on par with the best *B.t* (0.5 kg/ha) + endosulfan 0.07 per cent treatment. Dubey *et al.* (1998) reported less soybean pod damage in triazophos and Bioasp (*B.t.* formulation) sprayed plots. However, the cost benefit analysis revealed that the release of *T.chilonis*

parasitoid ranked first (1:9.68) followed by endosulfan 0.07 per cent alone (1 : 7.09) and HaNPV + endosulfan 0.07% (1: 6.74).

Rabindra and Jayaraj (1985) found the application of NPV at 250 LE/ha followed by endosulfan 262 g a.i. / ha 5 days later, reduced the *H. armigera* population and pod damage on chickpea. Application of NPV 250 LE/ha + endosulfan 0.07 per cent had better control of *H. armigera* than virus application alone (Vijayakumar, 1980 and Santharam *et al.*, 1981).

In the present study on the evaluation of bio-control agents and its combination with insecticides revealed that *B. thuringiensis* (1kg/ha) alone, *S. litura* NPV (SINPV) alone, SL NPV + endosulfan 0.07 per cent and B.t (0.5kg/ha) + endosulfan 0.07 per cent had expressed their significant ability to reduce the larval population of *S. litura* on soybean. But, significantly higher yields were obtained in B.t (1kg/ha), B.t (0.5kg/ha) + endosulfan 0.07 per cent whereas the SINPV alone and in combination with endosulfan 0.07 per cent spraying had not recorded higher yields.

The efficacy of SINPV in reducing the larval population and leaf damage was reported in India by Jayaraj *et al.*, (1980). Dhandapani and Sundara Babu (1995) found that two rounds of application of NPV at 250 LE/ha at ten days interval with adjuvant crudesugar at 2.5 kg/ha were significantly superior in reducing the larval population of *S. litura* with increased yield in groundnut.

Studies conducted on the effectiveness of *B.t* + NPV mixtures against *S. litura* and *H. armigera* indicated that they were not as effective as individual application of *B.t*, NPV, endosulfan 0.07 per cent spray on soybean. This is in confirmity with the findings of Santharam *et al.* (1993) that a combination of *B.t* + NPV had not reduced the larval population of *H. armigera* and also its damage on pods in chickpea.

## Cost Benefit Ratio

The cost benefit ratio for *B.t* for full dose (1 kg/ha) was 1:2.08 when compared to that of *B.t* (0.5 kg/ha) + endosulfan 0.07 per cent 1:3.23 and *B.t* (0.5kg/ha) + NPV mixture 1:2.79. Endosulfan 0.07 per cent when combined with HaNPV and applied the cost benefit ratio was 1:6.74 but endosulfan 0.07 per cent spray alone, brought out cost benefit ratio of 1:7.09. Kalayanasundaram *et al.* (1994) opined that the combined use of biocontrol agents along with insecticides was a successful proposition against *S.litura* and *H.armigera* in groundnut which brought highest cost benefit ratio of 1:3.61. Considering the cost benefit analysis in the present study, endosulfan 0.07 per cent + HaNPV 250 LE/ha is a choice candidate for effective management of *H.armigera* in soybean.

The results obtained on the performance of combination of different biocontrol agents revealed that reduction of *H.armigera* population was significant when all the biocontrol treatments were used as a single component. It was evident that the release of *T. chilonis* and *C. carnea* dose had greater impact in reducing the early instars larval population of *H.armigera*. The presence of the *B.t* in the component was very conspicuous in the reduction of larvae at the middle stages of the plant growth. Above all, at the later stages of the crop spraying of NPV + endosulfan was also significantly effective to control the third (or) fourth instars of residual population of *H. armigera*.

Hence, the present investigation on the efficacy of combination of biopesticides and endosulfan is in agreement with the findings of earlier workers Kalyanasundaram *et al.* (1994) and Butter *et al.* (1995) on groundnut and cotton, respectively.

## 5.7. Yield loss assessment

### 5.7.1 Yield loss assessment due to key pests

The present study on the yield loss assessment due to the varying levels of leafhopper population in different seasons brought about reduction in population due to the insecticidal protective treatment given to the soybean plants which resulted in increased yield. The results indicated that soybean plants protected with methyl-o-demeton 0.05 per cent at 38 and 53 DAS against leafhopper (*E.fabae*) gave an increased yield of 293.34, 270.00 and 190.00 kg per hectare with the corresponding increased percentage of 16.66, 16.43 and 11.51 during February, July and September seasons respectively compared to untreated check. In earlier studies, the soybean crop treated with monocrotophos 0.036 per cent carried significantly less number of leafhopper population than untreated one and an avoidable loss ranging from 21.46 to 35.37 per cent in grain yield over untreated plant was recorded by Singh *et al.* (1991). Yeargan *et al.*, (1994) attributed that increased infestation of leafhopper at vegetative stage resulted in significant reduction in plant height, number of pods in soybean.

In the case of soybean leafminer (*A.modicella*) incidence, when the plants were protected with monocrotophos 0.05 per cent at 38 and 53 DAS, resulted in increased yield of 299.98, 303.14 and 276.67 kg per hectare with the corresponding increased percentage of 27.52, 21.02 and 22.49 in February, July and September seasons, respectively. Logiswaran and Mohanasundaram (1985) reported the pod yield loss of 50 per cent due to *A. modicella* on groundnut. Two applications of quinolphos and endsulfan produced an increased pod yield of 89.8 per cent over untreated check due to control of *A. modicella* on groundnut. (Jena and Kuila 1997).

Yield loss due to *H.armigera* was also assessed and the results indicated that an increased yield of 240.0 and 343.33 kg per hectare were obtained due to

the protection given to soybean plant with endosulfan 0.07 per cent spraying at 38 and 53 DAS respectively. This had resulted in an increased per cent yield of 16.07 and 24.12 in July and September seasons respectively. Gangrade *et al.* (1977) reported at Jabalpur, Madhya Pradesh that *H. armigera* consumed both leaves and pods and resulted in removal of two-thirds of leaves from blooming stages with 56.6 to 60.0 per cent yield loss. McPherson and Moss (1989) reported that the natural population of *H. zea* @ 27.6 larvae/0.915 m row consumed the pods and seeds of soybean and reduced the grain to an extent of 1301 kg per ha over control.

### 5.7.2. Prediction of yield loss and rate of yield loss

In the present investigation on the yield loss assessment made in a pot culture study revealed that the yield was in decreasing trend as the population increased. It was estimated that the yield loss of 3.960 g per plant was recorded when ten larvae of leafminer were introduced per plant. By using the mathematical model like 'Mitscherlich's and logistic curve, the rate of yield loss was estimated as 0.127 g per plant when one larva or 1.27g per plant when ten larvae were introduced per plant.

The results of the experiment on assessment of yield loss due to the leafminer population indicated that yield was declined for every unit increase in population of pest. The quantum of loss increased with an increase in the pest population. The rate of loss, quantified for every unit increment was, however, not equal at each stage of increment. A decreasing trend was observed. The damage caused by this pest in the early stages of soybean crop was very detrimental to the yield. The linear trend of yield loss for every additional larvae might be due to the leaf damage caused by these larvae by mining and competitive sharing of food by these larvae in a single plant.

Kalyanasundaram and Sellamal Murugesan (1989) estimated the yield loss due to *A. modicella* on soybean and found that significant yield reduction to an extent of      and      per cent when two larvae were infested at 30 and 45 DAS and also to an extent of 40 and 60 per cent when 10 larvae were introduced at 30 and 40 DAS respectively. In the present study, the regression of yield of leafminer infestation indicated that yield was reduced by 0.463 and 0.716 g per plant for every larva per plant when introduced at 30 and 45 DAS respectively. The present study showed that with one larva, plant suffered little loss but with 10 larvae, the loss was 35.16 per cent.

Under uncaged condition in the field, for every additional per cent damage, the yield loss observed was nominal and the trend was increasing for every increment of five per cent leaf damage. At a maximum of five per cent leaf damage, the yield loss observed was 8.07 per cent with a maximum of 37.01 yield loss recorded at 50 per cent leaf damage. The rate of increase of yield loss was estimated as 0.032 g per plant for a minimum of five per cent damage and a maximum of 0.1006 g per plant at 50 per cent leaf damage. In a similar study Kalyanasundaram and Sellammal Murugesan (1989) reported that for every one per cent increase in damaged leaves, the yield reduction was 0.0467g/plant at 30 DAS and 0.1226 g/plant at 45 DAS on soybean.

## 5.8 Economic Injury Levels (EIL)

### 5.8.1 Economic injury level of key pests of soybean

In the present study, the EIL for *H. armigera* was calculated by fitting three types of equations viz., linear, loglinear and quadratic. Gain threshold (GT) per plant and yield reduction due to the insect pest damage were the components used for the calculation of EIL. It was observed that the effect of yield loss due to *H.armigera* was exhibited in a linear form and the linear equation was taken as best fit. In this case, the  $R^2$  value was highly significant 0.91\*\* and 0.92\*\* for

July and September seasons, respectively. The results also indicated that the EIL was fixed as 0.25 and 0.27 larva/plant for July and September seasons (or) EIL may be fixed in the range of 2.50 to 3.00 larvae per ten plants of soybean in respective seasons.

Bolde *et al.* (1975) observed that 61.6 per cent of the total weight of soybean pods was consumed by the 6th instar of *H.zea*. One *H.zea* larva damaged an average of 8.2 soybean pods and 7 per cent seeds (Smith and Bass, 1972). Fehr *et al.* (1977) demonstrated that defoliation by soybean pests imposed on at reproductive stages between  $R_2$  and  $R_5$  had a substantial effect on yield.

To establish injury-yield loss relationships, it is essential to accurately quantify the injury imposed over time and space (Hammond and Pedigo, 1982; Ostlie and Pedigo, 1985). In the present study, the yield loss relationship was established by taking into account the per cent yield reduction which was quantified for calculating the gain threshold per plant (Annexure 2). There is possibility of the reasons beyond defoliation. It was well explained that a significant linear relationship existed between light interception (following defoliation) and corresponding soybean yield loss by Higley (1992). This concept may also be applicable for determining the relationship between insect injury and yield loss. It was reported that high levels of defoliation resulted in reduced light interception which in turn led to reduced yield and detailed study was done to relate the defoliation - light interception hypothesis on soybean by Haile *et al.*, (1998). Hence, it is felt that further studies on the relationship between the defoliation and light interception can be taken to highlight the actual yield loss and to fix an accurate EIL for *H.armigera* on soybean.

In the same way, the linearity of the yield loss effect was also seen for the leafminer *A. modicella* on soybean. In all the three seasons the linearity  $R^2$

values were 0.83, 0.93 and 0.95 and the EIL were 2.68, 1.59 and 1.24 larvae per plant for February, July and September seasons, respectively.

Biotic stressors such as defoliators could cause a significant injury to soybean at reproductive stage  $R_2$  to  $R_5$  but less injury after  $R_5$  or at vegetative stages (Fehr *et al.*, 1977). Haile *et al.* (1998) indicated the significant contribution of moisture towards soybean tolerance to defoliation even when a defoliation level of as high as 75 per cent was imposed. Two mechanisms for compensation of defoliation in soybean may occur *viz.*, the compensatory leaf growth from the main stem and delayed leaf senescence. Rapid recovery in leaf area was caused by compensatory leaf growth. Soybean yield was reported to be a function of canopy apparent photosynthesis during reproductive stages proceeding seed enlargement (Wells *et al.*, 1982).

Considering these above facts, the variation in EIL for soybean leafminer *A. modicella* was due to February, July and September seasons. The EIL was fixed as one or two leafminer larvae per soybean plant at 30 DAS and the per cent yield loss was more at 45 DAS where the EIL may be modified due to yield compensatory behaviour of the plant.

The injury caused by the leafhopper, *E. fabae* at early growing stage (or) vegetative stage had great impact on yield reduction.

Ogunlana and Pedigo (1974) showed that an intense potato leafhopper *E. fabae* population on soybean was capable of causing noticeable damage to pubescent soybean. In all the three seasons the linearity  $R^2$  values were significant as 0.95\*\*, 0.96\*\* and 0.82\*\*. The EIL for leafhopper infestation was fixed as 1, 9 and 18 at V1, R4 and R7 respectively. There was a straight line relationship between soybean development stage and leafhopper incidence. The present study revealed that EIL of leafhopper was fixed at 0.52, 0.66 and 0.51 per plant for

February, July and September seasons, respectively. Detailed further study on the injury level caused at different development stages of soybean would throw more light on EIL against leafhopper of soybean.

The injury equivalency system for primary leaf mass consuming pests of soybean to incorporate consumption differences among three size classes of larvae of the three lepidopteran pests and estimating size class difference from a pest population within the same species based on differential consumption potential, current prediction on future crop injury induced management of soybean injury guilds may be considered for future research not only for soybean and but also for other crops as opined by Hutchins and Funderburk (1996).

## SUMMARY

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## SUMMARY

### Seasonal occurrence

- \* Survey at farmer's field on insect pests of soybean crop in and around Coimbatore revealed that sucking pests like leafhoppers (*E. fabae*) were prevalent in between 27 to 55 DAS during February, July and August seasons. Maximum incidences were observed during July. Whiteflies *B. tabaci* was also noticed in all the three seasons and population increased from 27 DAS upto 76 DAS. The incidence of aphids, *A. craccivora* was more during July season and peak incidence was observed in between 48 to 62 DAS in all the three seasons.
- \* Among the defoliators, the leafminer *A. modicella* was more abundant during July season even though it was noticed during all the three seasons and peak incidences were noticed during 41 to 62 DAS. *H. armigera*, the incidence was observed during July and September. Maximum incidences were noticed during July season and from 48 DAS to 62 DAS.
- \* *S. litura* was observed during February and September but it was negligible during July season. Peak incidences were observed in between 41 to 48 DAS.
- \* The pod sucking bugs were prevalent in all the three seasons during 69 to 72 DAS causing heavy damage to pods.

### Monitoring

- \* The pheromone trap catches of *H. armigera* and *S. litura* were correlated with larval population in the field and significant correlations were observed. The peak trap collections were noticed during 48 to 60 DAS during July and between 41 to 55 DAS during September season.

### Weather correlation

- \* The weather parameters had influences at different locations. Minimum temperature, GDD, PTU and rainfall showed negative influence over leafhopper population. Likewise, maximum temperature, minimum temperature, GDD and PTU had negative influence on whitefly and leafminer populations and rainfall had positive correlation with whitefly population alone. GDD and PTU alone had significant negative influences over *H. armigera* population.
- \* Maximum and minimum temperature, GDD and PTU had significant negative influence over predators like coccinellid and spiders. Rainfall showed positive influence over spider population.

### Microclimate

- \* Leaf temperature and leaf humidity played a role in the development of insect pests population of soybean. Leaf temperature prevalent during 27 DAS to 37 DAS had significant correlation with leafhopper population but the same had no influence at later stage of the plant growth. Similar effect was also observed for whitefly population.
- \* The leaf temperature at 47 DAS had significant correlation with the leafminer population and no correlation existed in the later stage of the plant growth.
- \* The leaf humidity prevalent during 37 DAS alone, 37 and 47 DAS and 47 DAS alone had influenced leafhopper, whitefly, and leafminer populations , respectively.

## MANAGEMENT

### Cultural Methods : Effect of spacing

- \* Soybean planted in 45 x 10 cm (wider spacing) significantly reduced the insect pests population like leafhopper (*E. fabae*), whitefly (*B. tabaci*), *S. litura* population, *N. viridula* and per cent leaf damage of leafminer (*A. modicilla*). Whereas the soybean planted in 30 x 10 cm (closer spacing) had significant effect in reducing the population of *H. armigera*.
- \* Different spacing levels had no influence over the per cent pod damage caused by *H. armigera*.
- \* Percentage of grain affected by pod sucking bugs was higher in closer spacing than in wider spacing.
- \* Maximum number of predatory population (coccinellid and spiders) was observed in plants sown in closer spaced plants.
- \* Yield components like number of pods, number of grains per plant were more influenced by the wider spacing than closer spacing.
- \* Soybean crop raised in wider spacing recorded significantly higher yield than other spacing levels.

### Effect of Fertiliser

- \* Experiments were conducted to study the effect of phosphorous fertiliser application on the incidence of insect pests revealed that the sucking pests like leafhopper and whiteflies could be effectively minimised by the application of 80 kg  $P_2O_5$  as basal with the top dressing either in two (or) three split doses at 20 kg  $P_2O_5$  at 30, 40 DAS or 30,40 and 50 DAS respectively.

- \* In order to effectively manage the soybean defoliators, it was observed that 80 kg  $P_2O_5$  as basal application was essential to reduce the per cent leaf damage of leafminer (*A. modicella*).
- \* There were significant differences between mean population of *H. armigera* in the treated plot over control and the higher  $P_2O_5$  plots. Incidences of *S. litura* and pod sucking bugs increased with the increased rate of  $P_2O_5$  application.
- \* The yield components like number of pods, grains per plant, per cent pod damage and per hectare yield were found to increase at the increased rate of  $P_2O_5$  application in order to compensate the plant vigour lost due to insect damage and also to make the plants to produce more seed yield.
- \* It was also observed that higher levels of  $P_2O_5$  were able to favour the multiplication and development of natural enemies population like coccinellid (*M. sexmaculatus*) and spiders in soybean ecosystem.
- \* Higher per cent oil content was recorded in wider spacing (45 x10 cm) and higher  $P_2O_5$  applied plots.

#### **Effect of intercropping on the incidence of insect pest of soybean**

- \* Among the different intercropping systems tried, soybean intercropped with 2 or 4 rows of maize and 2 or 4 rows of sorghum, had significant influence in reducing the populations of leafhopper, leafminer, *H. armigera* and *S. litura*. Whereas *B. tabaci* population was reduced in the soybean intercropped with 2 or 4 rows of bhendi.
- \* Maximum numbers of coccinellid and spiders were observed in soybean intercropped with 2 or 4 rows of sorghum, 4 rows of maize and also in pure crop of soybean.

- \* Higher yields were obtained in pure crop and soybean intercropped with 2 or 4 rows of maize, 2 or 4 rows of sorghum and 4 rows of bhendi.

### Chemical control

- \* Field evaluation of different insecticides revealed that sucking pests like leafhopper whiteflies could be effectively managed by the two rounds of application with any one of the insecticides like methyl-o-demeton 0.05 per cent, monocrotophos 0.05 per cent, endosulfan 0.07 per cent, Dimethoate 0.03 per cent.
- \* Soybean defoliators like leafminer (*A. modicela*) *H. armigera* and *S. litura* could be effectively managed by the application of two rounds of the insecticides like endosulfan 0.07 per cent (or) monocrotophos 0.05 per cent (or) chlorpyrifos 0.05 per cent.
- \* The population of sucking bugs (*N. viridula*) could be effectively reduced by the application of two rounds with endosulfan 0.07 per cent (or) monocrotophos 0.05 per cent.
- \* Maximum return in terms of rupees was obtained by the applications of monocrotophos 0.05 per cent, followed by endosulfan 0.07 per cent and dimethoate 0.03 per cent.

**Biological control**

- \* Present investigation revealed that two rounds application of *B.t.* alone or *B.t.* at half the recommended dosage along with endosulfan 0.07 per cent and as well HaNPV combined with endosulfan 0.07 per cent could effectively reduce the population of defoliators viz., *H. armigera* and *S. litura*.
- \* Significant higher yields were recorded in the plots where HaNPV + endosulfan 0.07 per cent, *B.t.* + endosulfan 0.07 per cent, *B.t.* alone and endosulfan 0.07 per cent alone were applied to manage effectively these defoliators.
- \* High cost benefit ratio was noticed in the parasite released plots and plot sprayed with endosulfan alone.
- \* In another experiment use of different components of biocontrol agents were applied as a single treatment and revealed that the key pests like *H.armigera* was effectively managed by the use of different packages like three releases of egg parasite, *T. chilonis*, three releases of predators *C. carnea*, followed by two application of *B.t.* and HaNPV + endosulfan 0.07 per cent.

**Yield loss assessment**

- \* The young soybean crops were protected against the leafhopper by the application of two rounds of spraying with methyl-o-demeton 0.05 per cent and an increased yield of 293.34, 270.00 and 190.00 kg per hectare over untreated was recorded in February, July and September seasons, respectively.
- \* Soybean crop protected with the two sprayings with monocrotophos 0.05 per cent at 38 and 53 DAS significantly reduced the leaf damage by the leafminer. An increase of 299.98, 303.14 and 276.67 kg per hectare in the seed yield over untreated were recorded during February, July and September, respectively.

The avoidable loss recorded was 27.52, 21.02 and 22.49 per cent in the three seasons, respectively.

- \* Soybean plants protected with insecticides like endosulfan 0.07 per cent at 38 and 53 DAS against *H. armigera* recorded significant increased yield of 240.0 to 343.3 kg per hectare over untreated with an avoidable loss of 16.07 and 24.12 per cent during July and September seasons, respectively.

#### **Mathematical Model : Yield loss and rate of yield loss**

- \* In pot culture experiment, it was found that a yield loss of 0.390 g per plant yield loss was observed due to introduction of one larvae per plant, maximum yield loss of 3.96 g per plant was observed when ten number of larvae were introduced.
- \* The rate of yield loss was estimated by a mathematical model using Mitcherlich's curve and found that the rate of yield loss was 0.127 g/plant due to one leafminer larvae or 1.270 g/plant for 10 larvae.
- \* In the field experiments (uncaged) different per cent leaf damages were assessed at the interval of five per cent level and found that yield loss estimated was 0.82 g/plant at five per cent leaf damage. At the maximum of 50 per cent leaf damage, the yield loss was 3.79 g/plant. By using logistic curve the rate of yield loss was estimated at five per cent leaf damage as 0.0322 g/plant and maximum of 0.1006 g/plant at 50 per cent leaf damage.

#### **Economic Injury Levels (EIL)**

- \* Different static models were used to estimate the relationship of larval populations and seed yield to fix EIL for different key pests of soybean. It was observed that among all the models, the linear regression model was found to be the best fit.

- \* Through linear equation, the EIL for the leafminer (*A. modicella*) was worked out as 2.68, 1.59 and 1.24 larvae per plant during February, July and September seasons, respectively.
- \* The EIL worked out through linear model for *H. armigera* was 2.50 and 2.70 numbers per ten plants during July and September, respectively.
- \* The EIL for the leafhopper (*E. fabae*) through linear equation was fixed as 0.52, 0.66 and 0.51 numbers per plant during February, July and September seasons, respectively.

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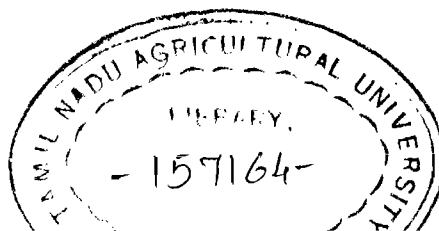
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\* Originals not seen.

## **ANNEXURES**

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## ANNEXURE – I

Data on weather parameters from observatory at Agricultural Research  
Station at Aliyar

| Month / Date | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|--------------|-------------|---------|-------------------|---------|------------------|
|              | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| JUNE – 1995  |             |         |                   |         |                  |
| 1            | 23.0        | 34.0    | 76                | 51      | -                |
| 2            | 26.0        | 34.0    | 92                | 56      | -                |
| 3            | 23.5        | 35.0    | 92                | 50      | -                |
| 4            | 24.0        | 34.5    | 87                | 61      | -                |
| 5            | 24.0        | 34.0    | 92                | 56      | -                |
| 6            | 27.5        | 37.0    | 89                | 45      | -                |
| 7            | 24.0        | 34.0    | 74                | 51      | -                |
| 8            | 25.5        | 35.0    | 96                | 53      | -                |
| 9            | 25.0        | 34.5    | 92                | 43      | -                |
| 10           | 24.0        | 29.0    | 96                | 78      | 3.2              |
| 11           | 25.0        | 30.0    | 92                | 65      | 6.6              |
| 12           | 24.0        | 29.0    | 88                | 92      | -                |
| 13           | 24.0        | 29.0    | 88                | 92      | 4.4              |
| 14           | 25.0        | 29.5    | 92                | 82      | 11.6             |
| 15           | 25.0        | 29.5    | 84                | 75      | 3.0              |
| 16           | 25.0        | 30.0    | 92                | 68      | -                |
| 17           | 25.5        | 32.0    | 88                | 61      | -                |
| 18           | 25.0        | 34.0    | 88                | 62      | -                |
| 19           | 25.0        | 33.5    | 92                | 59      | -                |
| 20           | 25.0        | 32.0    | 88                | 73      | -                |
| 21           | 24.5        | 33.0    | 88                | 64      | -                |
| 22           | 24.5        | 34.0    | 88                | 54      | -                |
| 23           | 25.0        | 29.0    | 92                | 78      | 1.2              |
| 24           | 25.0        | 34.0    | 92                | 56      | 10.0             |
| 25           | 24.0        | 33.5    | 88                | 54      | -                |
| 26           | 25.5        | 30.0    | 88                | 78      | -                |
| 27           | 25.5        | 32.0    | 98                | 67      | -                |
| 28           | 24.0        | 34.0    | 92                | 46      | 1.8              |
| 29           | 23.0        | 30.5    | 63                | 65      | 1.0              |
| 30           | 23.5        | 31.0    | 80                | 70      | -                |

| Month / Date       | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|--------------------|-------------|---------|-------------------|---------|------------------|
|                    | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| <b>JULY – 1995</b> |             |         |                   |         |                  |
| 1                  | 23.5        | 28.5    | 84                | 71      | 5.8              |
| 2                  | 23.0        | 30.0    | 87                | 65      | 3.2              |
| 3                  | 22.5        | 34.5    | 66                | 71      | 2.8              |
| 4                  | 23.0        | 32.0    | 84                | 67      | -                |
| 5                  | 24.0        | 34.0    | 79                | 56      | -                |
| 6                  | 24.5        | 33.5    | 81                | 54      | -                |
| 7                  | 24.0        | 30.0    | 92                | 72      | 2.4              |
| 8                  | 24.0        | 30.0    | 84                | 78      | -                |
| 9                  | 23.0        | 30.0    | 84                | 72      | 2.0              |
| 10                 | 22.5        | 29.5    | 70                | 65      | 3.2              |
| 11                 | 22.0        | 27.0    | 66                | 77      | 9.0              |
| 12                 | 22.5        | 30.5    | 80                | 68      | 11.4             |
| 13                 | 26.5        | 31.5    | 96                | 55      | 2.0              |
| 14                 | 23.0        | 29.5    | 70                | 65      | -                |
| 15                 | 24.0        | 33.5    | 88                | 48      | -                |
| 16                 | 23.5        | 29.5    | 84                | 62      | -                |
| 17                 | 23.0        | 30.5    | 96                | 60      | 25.0             |
| 18                 | 23.0        | 30.0    | 91                | 72      | 3.6              |
| 19                 | 24.0        | 30.5    | 92                | 62      | 2.2              |
| 20                 | 23.5        | 32.5    | 67                | 58      | -                |
| 21                 | 25.0        | 32.0    | 70                | 56      | -                |
| 22                 | 25.0        | 32.0    | 92                | 55      | -                |
| 23                 | 24.0        | 30.0    | 92                | 72      | -                |
| 24                 | 23.5        | 32.0    | 96                | 67      | 4.8              |
| 25                 | 24.5        | 32.0    | 96                | 64      | -                |
| 26                 | 26.0        | 33.0    | 92                | 62      | -                |
| 27                 | 24.5        | 30.5    | 88                | 68      | -                |
| 28                 | 24.0        | 32.0    | 84                | 64      | -                |
| 29                 | 21.5        | 30.5    | 87                | 65      | -                |
| 30                 | 23.0        | 32.0    | 96                | 67      | 11.4             |
| 31                 | 23.0        | 30.0    | 88                | 65      | 0.9              |

| Month / Date             | Temperature |         | Relative Humidity |         | Rainfall |
|--------------------------|-------------|---------|-------------------|---------|----------|
|                          | Minimum     | Maximum | 0722 hr           | 1422 hr | (mm)     |
| <b>AUGUST<br/>- 1995</b> |             |         |                   |         |          |
| 1                        | 23.0        | 30.0    | 84                | 72      | -        |
| 2                        | 23.5        | 31.5    | 88                | 55      | -        |
| 3                        | 22.5        | 29.0    | 83                | 78      | -        |
| 4                        | 24.0        | 32.5    | 92                | 64      | -        |
| 5                        | 23.0        | 33.0    | 84                | 48      | -        |
| 6                        | 24.0        | 33.0    | 84                | 48      | -        |
| 7                        | 23.0        | 34.0    | 88                | 59      | -        |
| 8                        | 24.0        | 33.0    | 84                | 46      | -        |
| 9                        | 24.0        | 30.0    | 92                | 53      | -        |
| 10                       | 22.5        | 29.5    | 87                | 68      | -        |
| 11                       | 25.0        | 32.5    | 92                | 37      | 12.0     |
| 12                       | 22.5        | 30.0    | 84                | 59      | -        |
| 13                       | 22.5        | 32.0    | 80                | 44      | -        |
| 14                       | 23.0        | 32.0    | 76                | 58      | -        |
| 15                       | 23.0        | 33.0    | 73                | 56      | -        |
| 16                       | 22.5        | 34.0    | 73                | 36      | -        |
| 17                       | 23.0        | 32.5    | 88                | 49      | -        |
| 18                       | 23.0        | 33.0    | 80                | 54      | -        |
| 19                       | 23.5        | 32.0    | 88                | 61      | -        |
| 20                       | 23.5        | 31.00   | 84                | 64      | -        |
| 21                       | 23.5        | 30.5    | 84                | 59      | -        |
| 22                       | 24.0        | 32.0    | 92                | 61      | 1.2      |
| 23                       | 24.0        | 28.0    | 92                | 77      | -        |
| 24                       | 23.5        | 29.0    | 96                | 71      | 15.6     |
| 25                       | 23.0        | 28.5    | 91                | 64      | 3.0      |
| 26                       | 23.5        | 28.0    | 86                | 70      | 2.2      |
| 27                       | 23.0        | 29.0    | 86                | 58      | 5.6      |
| 28                       | 24.0        | 29.0    | 92                | 64      | 2.0      |
| 29                       | 24.0        | 30.0    | 96                | 59      | 4.0      |
| 30                       | 24.0        | 29.5    | 96                | 65      | 4.2      |
| 31                       | 24.5        | 30.5    | 80                | 62      | 10.0     |

| Month / Date        | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|---------------------|-------------|---------|-------------------|---------|------------------|
|                     | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| SEPTEMBER<br>– 1995 |             |         |                   |         |                  |
| 1                   | 23.5        | 30.0    | 80                | 65      | 8.6              |
| 2                   | 23.0        | 29.0    | 86                | 64      | 7.4              |
| 3                   | 24.0        | 32.0    | 92                | 61      | -                |
| 4                   | 23.0        | 30.5    | 84                | 62      | 1.0              |
| 5                   | 24.0        | 31.0    | 88                | 67      | 1.6              |
| 6                   | 24.0        | 29.5    | 84                | 68      | 3.6              |
| 7                   | 23.0        | 30.0    | 86                | 65      | -                |
| 8                   | 24.0        | 32.0    | 88                | 61      | -                |
| 9                   | 24.0        | 31.0    | 92                | 64      | -                |
| 10                  | 23.0        | 30.5    | 91                | 68      | -                |
| 11                  | 23.5        | 32.0    | 96                | 55      | -                |
| 12                  | 20.5        | 32.5    | 83                | 55      | -                |
| 13                  | 22.0        | 34.0    | 74                | 54      | -                |
| 14                  | 23.0        | 35.0    | 86                | 45      | -                |
| 15                  | 23.0        | 34.0    | 84                | 46      | -                |
| 16                  | 24.0        | 34.5    | 86                | 46      | -                |
| 17                  | 23.0        | 33.5    | 84                | 54      | 1.4              |
| 18                  | 23.0        | 32.0    | 84                | 52      | -                |
| 19                  | 21.5        | 32.5    | 76                | 52      | -                |
| 20                  | 22.5        | 32.0    | 76                | 61      | -                |
| 21                  | 23.5        | 32.0    | 80                | 55      | -                |
| 22                  | 22.5        | 32.5    | 76                | 52      | -                |
| 23                  | 23.5        | 32.0    | 76                | 64      | -                |

**Data on Weather parameters from observatory at TNAU, Coimbatore**

| Month / Date       | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|--------------------|-------------|---------|-------------------|---------|------------------|
|                    | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| <b>JUNE – 1995</b> |             |         |                   |         |                  |
| 1                  | 22.5        | 34.0    | 84                | 55      | -                |
| 2                  | 24.5        | 34.0    | 77                | 49      | -                |
| 3                  | 23.6        | 34.0    | 79                | 47      | -                |
| 4                  | 23.6        | 34.0    | 85                | 55      | -                |
| 5                  | 24.5        | 34.5    | 81                | 47      | -                |
| 6                  | 23.0        | 34.5    | 84                | 55      | -                |
| 7                  | 23.0        | 34.0    | 73                | 49      | -                |
| 8                  | 25.2        | 33.5    | 74                | 59      | -                |
| 9                  | 24.0        | 30.0    | 84                | 68      | 2.5              |
| 10                 | 24.0        | 28.5    | 84                | 58      | 2.5              |
| 11                 | 22.8        | 31.0    | 66                | 58      | 2.0              |
| 12                 | 24.0        | 31.0    | 72                | 61      | -                |
| 13                 | 22.6        | 31.6    | 85                | 60      | -                |
| 14                 | 22.0        | 31.5    | 75                | 44      | -                |
| 15                 | 22.5        | 32.6    | 76                | 50      | -                |
| 16                 | 22.4        | 32.0    | 84                | 61      | -                |
| 17                 | 22.8        | 32.5    | 88                | 58      | -                |
| 18                 | 23.0        | 32.0    | 85                | 54      | -                |
| 19                 | 23.5        | 33.5    | 82                | 52      | -                |
| 20                 | 24.0        | 32.0    | 68                | 63      | -                |
| 21                 | 23.0        | 30.5    | 78                | 57      | -                |
| 22                 | 22.4        | 32.0    | 88                | 53      | -                |
| 23                 | 22.4        | 32.7    | 80                | 64      | -                |
| 24                 | 22.4        | 32.5    | 81                | 54      | -                |
| 25                 | 23.0        | 33.0    | 79                | 55      | -                |
| 26                 | 24.0        | 32.0    | 81                | 54      | -                |
| 27                 | 23.4        | 32.0    | 79                | 50      | 1.0              |
| 28                 | 23.4        | 32.0    | 74                | 72      | -                |
| 29                 | 24.0        | 31.0    | 77                | 69      | -                |
| 30                 | 24.5        | 31.5    | 74                | 78      | -                |

| Month / Date       | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|--------------------|-------------|---------|-------------------|---------|------------------|
|                    | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| <b>JULY – 1995</b> |             |         |                   |         |                  |
| 1                  | 24.5        | 29.5    | 65                | 60      | 1.5              |
| 2                  | 24.0        | 31.5    | 62                | 55      | -                |
| 3                  | 22.4        | 31.5    | 80                | 44      | 1.2              |
| 4                  | 21.5        | 33.0    | 79                | 49      |                  |
| 5                  | 21.5        | 34.0    | 85                | 60      |                  |
| 6                  | 23.0        | 33.0    | 79                | 60      |                  |
| 7                  | 23.0        | 33.0    | 80                | 60      | 2.0              |
| 8                  | 21.7        | 32.5    | 81                | 49      |                  |
| 9                  | 23.2        | 33.0    | 83                | 60      |                  |
| 10                 | 23.0        | 31.5    | 76                | 84      |                  |
| 11                 | 22.5        | 29.6    | 69                | 72      | 5.0              |
| 12                 | 22.5        | 28.8    | 69                | 53      | 5.0              |
| 13                 | 23.5        | 30.2    | 75                | 53      |                  |
| 14                 | 24.0        | 31.0    | 82                | 50      |                  |
| 15                 | 22.3        | 31.0    | 88                | 51      | 2.5              |
| 16                 | 23.8        | 32.0    | 79                | 60      |                  |
| 17                 | 21.5        | 30.0    | 80                | 64      | 11.0             |
| 18                 | 22.5        | 29.5    | 75                | 75      | 6.0              |
| 19                 | 24.0        | 29.0    | 66                | 62      | -                |
| 20                 | 23.5        | 29.0    | 73                | 57      |                  |
| 21                 | 23.5        | 30.0    | 71                | 49      | -                |
| 22                 | 23.5        | 30.6    | 77                | 66      |                  |
| 23                 | 22.5        | 31.5    | 91                | 88      |                  |
| 24                 | 22.0        | 28.5    | 91                | 67      | 2.0              |
| 25                 | 22.0        | 31.5    | 91                | 65      | 0.5              |
| 26                 | 20.8        | 31.0    | 86                | 66      | 3.0              |
| 27                 | 23.0        | 32.0    | 88                | 54      |                  |
| 28                 | 22.5        | 32.0    | 91                | 66      |                  |
| 29                 | 21.8        | 31.0    | 91                | 60      |                  |
| 30                 | 23.0        | 31.0    | 90                | 56      |                  |
| 31                 | 22.8        | 31.5    | 78                | 53      |                  |

| Month / Date             | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|--------------------------|-------------|---------|-------------------|---------|------------------|
|                          | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| <b>AUGUST –<br/>1995</b> |             |         |                   |         |                  |
| 1                        | 21.0        | 33.0    | 74                | 57      | -                |
| 2                        | 24.0        | 32.0    | 72                | 48      | -                |
| 3                        | 21.6        | 31.0    | 78                | 45      | -                |
| 4                        | 21.6        | 32.0    | 83                | 45      | -                |
| 5                        | 22.7        | 32.5    | 83                | 70      | -                |
| 6                        | 22.6        | 31.5    | 85                | 55      | 4.8              |
| 7                        | 23.0        | 33.0    | 91                | 51      | 24.8             |
| 8                        | 23.5        | 30.5    | 73                | 55      | -                |
| 9                        | 23.8        | 30.0    | 76                | 55      | -                |
| 10                       | 21.5        | 31.0    | 86                | 53      | -                |
| 11                       | 23.4        | 33.0    | 90                | 61      | 0.8              |
| 12                       | 23.0        | 32.0    | 88                | 52      | -                |
| 13                       | 22.6        | 34.0    | 79                | 57      | -                |
| 14                       | 22.0        | 33.0    | 76                | 69      | -                |
| 15                       | 22.0        | 32.0    | 89                | 46      | -                |
| 16                       | 21.7        | 30.0    | 83                | 51      | -                |
| 17                       | 22.0        | 33.5    | 86                | 65      | -                |
| 18                       | 22.4        | 31.0    | 83                | 61      | -                |
| 19                       | 22.0        | 32.0    | 86                | 69      | -                |
| 20                       | 23.0        | 32.5    | 83                | 65      | -                |
| 21                       | 24.0        | 32.0    | 88                | 59      | -                |
| 22                       | 23.0        | 33.0    | 90                | 69      | 1.4              |
| 23                       | 23.4        | 32.0    | 88                | 59      | -                |
| 24                       | 23.0        | 32.5    | 90                | 56      | 3.0              |
| 25                       | 22.0        | 32.5    | 90                | 46      | -                |
| 26                       | 23.4        | 33.0    | 88                | 59      | 0.4              |
| 27                       | 22.8        | 31.0    | 91                | 55      | 0.4              |
| 28                       | 22.5        | 30.5    | 88                | 68      | -                |
| 29                       | 23.8        | 29.5    | 71                | 79      | -                |
| 30                       | 23.0        | 29.5    | 70                | 78      | 1.2              |
| 31                       | 22.3        | 28.0    | 74                | 65      | 12.0             |

| Month / Date                | Temperature |         | Relative Humidity |         | Rainfall<br>(mm) |
|-----------------------------|-------------|---------|-------------------|---------|------------------|
|                             | Minimum     | Maximum | 0722 hr           | 1422 hr |                  |
| <b>SEPTEMBER<br/>- 1995</b> |             |         |                   |         |                  |
| 1                           | 23.4        | 28.4    | 82                | 63      | 1.0              |
| 2                           | 23.5        | 29.0    | 71                | 53      | 0.3              |
| 3                           | 23.2        | 30.5    | 75                | 65      | 1.0              |
| 4                           | 24.5        | 30.2    | 71                | 50      | -                |
| 5                           | 23.5        | 31.5    | 70                | 45      | -                |
| 6                           | 21.0        | 32.0    | 78                | 57      | -                |
| 7                           | 21.8        | 30.5    | 83                | 48      | -                |
| 8                           | 21.4        | 33.5    | 86                | 45      | -                |
| 9                           | 21.0        | 32.5    | 81                | 61      | -                |
| 10                          | 22.3        | 32.5    | 88                | 48      | 4.0              |
| 11                          | 22.5        | 32.5    | 83                | 80      | -                |
| 12                          | 20.5        | 30.5    | 83                | 46      | 4.2              |
| 13                          | 20.0        | 30.5    | 81                | 45      | -                |
| 14                          | 20.6        | 33.5    | 81                | 45      | -                |
| 15                          | 23.5        | 32.5    | 71                | 48      | -                |
| 16                          | 23.4        | 32.0    | 88                | 51      | -                |
| 17                          | 24.0        | 32.5    | 84                | 55      | -                |
| 18                          | 23.0        | 32.5    | 82                | 43      | -                |
| 19                          | 21.0        | 33.0    | 75                | 34      | -                |
| 20                          | 21.6        | 33.5    | 80                | 43      | -                |
| 21                          | 24.0        | 33.5    | 88                | 87      | -                |
| 22                          | 23.0        | 31.0    | 91                | 63      | 9.5              |
| 23                          | 21.4        | 30.7    | 86                | 55      | -                |
| 24                          | 21.0        | 31.0    | 88                | 51      | -                |
| 25                          | 21.4        | 31.6    | 89                | 55      | -                |
| 26                          | 21.0        | 31.6    | 83                | 49      | -                |
| 27                          | 21.8        | 32.5    | 85                | 36      | -                |
| 28                          | 20.8        | 33.6    | 89                | 50      | -                |
| 29                          | 20.0        | 33.0    | 89                | 47      | -                |
| 30                          | 21.0        | 33.0    | 83                | 60      | -                |



## ANNEXURE II

### EIL ASSESSMENT FOR LEAF HOPPER

|                         |            |                                                                                                          |
|-------------------------|------------|----------------------------------------------------------------------------------------------------------|
| LEAF HOPPER             | :          | <i>Empoasca fabae</i>                                                                                    |
| a) Season               | :          | February                                                                                                 |
| Linear equation         | :          | <b><math>Y=9.01-1.0983x</math></b>                                                                       |
| Gain Threshold (GT)     | :          | Cost of Protection (Rs./ha)                                                                              |
|                         | =          | $\frac{\text{Cost of Produce Rs./Quintol}}{\text{Yield/Plant}}$                                          |
|                         | GT =       | $\frac{1100}{900} = 1.22$                                                                                |
|                         | GT/Plant = | $\frac{1.22 \times 100}{3,33,333} = 0.37$                                                                |
| Yield Loss / Plant (Yl) | =          | Yield/Plant* x Loss in (%) due leaf hopper                                                               |
| Loss in (%)             | =          | <b><math>Y=9.01-1.0983x = 12.19 \%</math></b>                                                            |
|                         |            | $\frac{5.99 \times 12.19}{100} = 0.706$                                                                  |
|                         | EIL =      | $\frac{\text{GT/Plant}}{\text{Yl}} = \frac{0.37}{0.706} = 0.52/\text{Plant (or)} 5.20/10 \text{ Plants}$ |

\*(Yield obtained : 1996 kg/ha)

b) Season : July

Linear equation :  $Y=8.44-0.7724x$

$$GT = \frac{1100}{900} = 1.22$$

$$GT/Plant = 0.37$$

$$\text{Yield Loss (YL)} = Y=8.44- 0.7724 = 9.15 \%$$

$$YL = \frac{6.126 \times 9.15}{100} = 0.56$$

$$EIL = \frac{GT/Plant}{YL} = \frac{0.37}{0.56} = 0.66/Plant \text{ (or)} \\ 6.60/10 \text{ Plants}$$

(Yield obtained : 2042 kg/ha)

c) Season : September

Linear equation :  $Y=8.36-1.1045x$

$$GT = \frac{1100}{900} = 1.22$$

$$GT/Plant = 0.37$$

$$\text{Plant yield reduction} = 8.36 - 1.045 x = 12.50 \%$$

$$\text{Yield Loss (YL)} = \frac{5.79 \times 12.50}{100} = 0.724$$

$$EIL = \frac{0.37}{0.724} = 0.51/Plant \text{ (or)} \\ 5.11/10 \text{ Plants}$$

(Yield obtained : 1930 kg/ha)

## ANNEXURE III

### EIL ASSESSMENT FOR *Helicoverpa armigera*

|                                       |   |                                                                                           |
|---------------------------------------|---|-------------------------------------------------------------------------------------------|
| a) Season                             | : | July                                                                                      |
| Linear equation                       | : | $Y=6.06 - 0.8698x$                                                                        |
| Gain Threshold (GT)                   | = | $\frac{\text{Cost of Protection (Rs./ha)}}{\text{Cost of Produce (Rs./Quintol)}}$         |
| GT                                    | = | $\frac{700}{900} = 0.777$                                                                 |
| GT/Plant                              | = | $\frac{0.777 \times 100 \times 1000}{3,33,333} = 0.233$                                   |
| Yield Loss / Plant (Yl)<br>H.armigera | = | Yield/Plant* x Percent yield loss due to                                                  |
| Percent yield reduction               | = | $6.06 - 0.8698 = 14.35 \%$                                                                |
| Yield Loss (YL)                       | = | $\frac{6.522 \times 14.35}{100} = 0.935$                                                  |
| EIL                                   | = | $\frac{\text{GT/Plant } 0.233}{\text{Yl } 0.935} = 0.249 \text{ (or)}$                    |
| 0.25/Plant                            |   | 2.50/10 Plants                                                                            |
| *(Yield obtained : 2174 Kg/ha)        |   |                                                                                           |
| b) Season                             | : | September                                                                                 |
| Linear equation                       | : | $Y=9.14 - 1.2711x$                                                                        |
| GT                                    | = | $\frac{700}{900} = 0.777$                                                                 |
| GT/Plant                              | = | 0.233                                                                                     |
| Percent yield reduction               | = | $9.14 - 1.2711 = 13.91 \%$                                                                |
| Yield Loss (YL)                       | = | $\frac{6.096 \times 13.91}{100} = 0.847$                                                  |
| EIL                                   | = | $\frac{\text{GT/Plant } 0.233}{\text{Yl } 0.847} = 0.275 \text{ (or) } 0.27/\text{Plant}$ |
|                                       |   | 2.70/10 Plants                                                                            |
| *(Yield obtained : 2032 Kg/ha)        |   |                                                                                           |

## ANNEXURE IV

### EIL ASSESSMENT FOR LEAFMINER *Aproaerema modicella*

a) Season : February

Linear equation :  $Y = 9.53 - 0.1408x$

$$GT = \frac{760}{900} = 0.844$$

$$GT/Plant = \frac{0.844 \times 100 \times 1000}{3,33,333} = 0.253$$

Yield Loss / Plant (YL) = Yield/Plant\* x Percent yield reduction due to H.armigera

$$= \frac{6.387 \times 1.477}{100} = 0.943$$

$$EIL = \frac{GT/Plant}{YL} = \frac{0.253}{0.943} = 2.683 \text{ (or) } 2.7/Plant$$

27.0/10 Plants

\*(Yield obtained : 2128.9 Kg/ha)

b) Season : July

Linear equation :  $Y = 9.10 - 0.2016x$

$$GT/Plant = 0.253$$

$$\text{Percent yield reduction} = 9.10 - 0.2016 = 2.215\%$$

$$\text{Yield Loss (YL)} = \frac{7.215 \times 2.215}{100} = 0.159$$

$$EIL = \frac{GT/Plant}{YL} = \frac{0.253}{0.159} = 1.59/Plant \text{ (or) } 15.90/10 Plants$$

\*(Yield obtained : 2404 Kg/ha)

c) Season : September

Linear equation :  $Y = 10.16 - 0.2759x$

GT/Plant = 0.253

Yield reduction =  $10.16 - 0.2759 = 2.715\%$

Yield Loss (YL) =  $\frac{7.252 \times 2.715}{100} = 0.204$

EIL =  $\frac{\text{GT/Plant}}{\text{YL}} = \frac{0.253}{0.204} = 1.240/\text{Plant (or)}$   
12.40/10 Plants

\*(Yield obtained : 2417.3 Kg/ha)

## ANNEXURE V

| Stage No.                  | Abbreviated Stage Title | Description                                                                                                                                                      |
|----------------------------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VE                         | Emergence               | Cotyledons above the soil surface.                                                                                                                               |
| VC                         | Cotyledon               | Unifoliate leaves unrolled sufficiently so the leaf edges are not touching.                                                                                      |
| VI                         | First node              | Fully developed leaves or unifoliate nodes.                                                                                                                      |
| V2                         | Second node             | Fully developed trifoliate leaf at node above the unifoliate nodes.                                                                                              |
| V3                         | Third node              | Three nodes on the main stem with fully developed leaves beginning with the unifoliate nodes; n can be any number beginning with one for VI, first node stage    |
| <b>Reproductive Stages</b> |                         |                                                                                                                                                                  |
| R1                         | Beginning bloom         | One open flower at any node on the main stem.                                                                                                                    |
| R2                         | Full bloom              | Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf.                                                                      |
| R3                         | Beginning pod           | Pod 5 mm (3/16 in) long at one of the four uppermost nodes on the main stem with a fully developed leaf.                                                         |
| R4                         | Full pod                | Pod 2 cm (3/4 in) long at one of the four upper most nodes on the main stem with fully developed leaf.                                                           |
| R5                         | Beginning maturity      | Seed 3 mm (1/8 in) long in a pod at one of the uppermost nodes on the main stem with a fully developed leaf.                                                     |
| R6                         | Full seed               | Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed leaf.                           |
| R7                         | Beginning maturity      | One normal pod on the main stem that has reached its mature pod colour.                                                                                          |
| R8                         | Full maturity           | 95% of the pods that have reached their mature pod colour: 5 to 10 days of drying weather are required after R8 before the soybeans have less than 15% moisture. |

(From Fehr, W.R., C.E. Calvines, D.T. Burmood and J.S. Pennington, 1971. Stage of development descriptions for soybean *Glycine max* (L.) Merrill. **Crop Sci.**, 11:929-931.)