STUDIES ON INCIDENCE AND MANAGEMENT OF DEFOLIATOR PESTS OF SOYBEAN

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
degree of

Master of Science (Agriculture)
in
Agricultural Entomology

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FEBRUARY, 2008

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1. INTRODUCTION

Soybean [*Glycine max* (L.) Mirrill] is an unique crop with high nutritional value, providing 40 per cent protein and 20 per cent edible oil besides minerals and vitamins. It is playing an important role in augmenting both the production of edible oil and protein simultaneously under the circumstances in which the shortage of these commodities being experienced by India. It also supports many industries, soybean oil is used as raw material in manufacturing antibiotics, paints, varnishes, adhesives, lubricants etc. Soybean meal is used as protein supplement in human diet, cattle and poultry feed (Alexander, 1974).

Soybean is globally grown over an area of 91.40 m.ha with a production of 20.40 mt with a productivity of 2233 kg per ha (Anon., 2004). In India soybean is grown over an area of 7.2 million ha with a production of 5.5 million tonnes and productivity of 763 kg per ha which is much below the average productivity of world *i.e.,* 2233 kg/ha (Anon., 2004).

The major soybean producing States are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh and Gujarat. In Karnataka, soybean is grown over an area of 1.59 lakh ha with a production of 0.96 lakh tonnes and the productivity of 639 kg per ha (Anon., 2004). Karnataka ranks fourth in area and production next to Madhya Pradesh, Maharashtra and Rajasthan. Belgaum, Dharwad, Bidar, Bagalkot and Haveri are the major soybean growing districts of Karnataka.

The luxuriant crop growth, soft and succulent foliage attracts many insects and provides unlimited source of food, space and shelter. About 380 species of insects have been reported on soybean crop from many parts of the world. During the introduction of soybean in India in the early seventies, only about a dozen minor insect pests were recorded, while in 1997 this number has swelled to an alarming figure 270, besides 1 mite, 2 millipedes, 10 vertebrates and 1 snail (Singh, 1999). About 65 insect species have been reported to attack soybean from cotyledon to harvesting stage from Karnataka (Rai *et al*., 1973; Adimani, 1976; Thippaiah, 1997). Among these, leaf miner *Aproaerema modicella* Deventer and stem fly *Melanagromyza sojae* Zehnter are known to cause 100 per cent damage resulting in reduction of yield by 20 to 30 per cent (Singh and Singh, 1990). The defoliators [*Spodoptera litura* (fab), *Thysanoplusia orichalcea* (Fab), *Spilarctia obliqua* (Walk)] and *Helicoverpa armigera* (Hubner) are feeding on foliage, flower and pods causing significant yield loss (Singh and Singh, 1990).

Thysanoplusia orichalcea (Fab) damages the crop from August to September during *kharif* and March to May during *rabi* season. The infestation can result into 30 per cent undeveloped pods and about 50 per cent yield loss. In case of heavy attack, the caterpillars are also found to feed on flowers and pods (Anon., 2007).

The sucking pests viz. *Bemisia tabaci* (Genn) and *Thrips palmi* (Karny) cause economic damage. (Singh and Singh, 1990). Insect pest complex in soybean cause yield loss up to 24% in Himachal Pradesh.

The Bihar hiary caterpillar, *Spilarctia obliqua* (Walk) is a voracious feeder which feeds gregariously on soybean leaves in early instars. In case of severe infestation, the entire crop is damaged badly thus causing 40% defoliation of leaf area.

The tobacco caterpillar, *Spodoptera litura* (fab) is a serious and regular pest in Madhya Pradesh. It damages soybean from mid August to October in *kharif* and from November to March in *rabi* (Anon., 2007). Incidence of *S. litura* was observed in all the soybean growing parts of north Karnataka and was confined to *kharif* season. After damaging the leaves, they also start feeding on young parts, consequently damaging 30 to 50 per cent of the pods (Anon., 2007). Higher population was noticed in Dharwad and Belgaum districts. The pest was active in grand growth stage of the crop (Patil, 2002).

To avoid losses caused by these defoliator pests, various control measures were attempted; earlier more importance was given to chemical control measures, which were found effective. Further, scheduled application of chemicals and sub-optimal doses without regard to the pest density and damage potential, were practiced. Dusts and granules were applied to the soil in bulk quantity which disturbed and polluted soil ecology (Singh *et al.,* 2000). Indiscriminate use of chemicals led to the problems like pest out break, development of resistance by pest species to insecticides, elimination of natural enemies, risk to human and animal health besides environmental pollution. Integrated pest management (IPM) is perceived as the only alternative to combat these problems (Rao *et al.,* 1999).

Integrated pest management comprises biological method, cultural method and also use of biorationals which are major components. Among these, use of resistant varieties, fungal pathogens, NPV, plant and animal origin insecticides are gaining more importance in recent years. Hence, the present investigation on management of defoliator pests of soybean was undertaken with the following objectives.

1. To study the seasonal incidence of defoliator pests of soybean.

2. To study the relative susceptibility of soybean varieties to defoliator pests.

3. To evaluate the efficacy of biorationals against defoliator pests of soybean.

2. REVIEW OF LITERATURE

The reviews pertaining to the objectives envisaged in the previous chapter are presented below.

2.1 Seasonal incidence of defoliator pests of soybean

Approximately 380 different species of insects have been collected from soybean crop from many parts of the world according to Luckmann (1971). A total of 267 insect species were collected from soybean fields in Arkansas (Tugwell *et al.,* 1973). Fletcher (1922) is the earliest worker to report the incidence of nine species of insects occurring on soybean from India. Ramakrishna Ayyar (1963) reported two insects of soybean crop from south India. Rawat *et al.,* (1969) recorded over two dozen different species of arthropod pests of soybean from Madhya Pradesh, India. Saxena (1972) observed 32 insect pests and two non insect pests of soybean in Madhya Pradesh. Singh (1973) reported 56 insect pests and a mite on soybean crop from Pantnagar, Uttar Pradesh.

Rai *et al.,* (1973) recorded 24 insect species feeding on soybean in Karnataka and mentioned that, among them maximum damage was done by the larvae of *Lamprosoma indicate* F, *Stomopteryx subsecivella* Zeller, *Diacrisia oblique* Walker and Gelechid shoot borer. About 85 species of insects belonging to six different orders of insects and a mite on soybean have been reported from Madhya Pradesh by Gangrade (1974) Adimani(1974) recorded 59 insect species belonging to six orders occurring around Dharwad on soybean in Karnataka.

Singh *et al.,* (1988) reported a higher population of larvae of a species of the noctuid genus Rivula was recorded on D.S.76-1-29 and P.K.472 (18.4-19.8 larvae/ 10 plants) than on M.A.C.S.75 and J.S.76-259 (4.8-5.0 larvae/10 plants) than those sown on 8 and 22 July. P.K.472 and Bragg sown on 25 June, however, gave maximum grain yield compared with the remaining cultivars and dates of sowing.Cultivars sown on 25 June had higher larval populations of Rivula sp. (20.5 larvae/10 plants)

A 3-year survey (1981-83) of soyabean insect pests was conducted in the newly-expanded acreage in south-eastern Texas. The major lepidopterous defoliators were *Anticarsia gemmatalis, Pseudoplusia includens [Chrysodeixis includens], Trichoplusia ni, Plathypena scabra* and *Heliothis zea [Helicoverpa zea]. A. gemmatalis* occurred at a maximum average density of 19.4 larvae/10 sweeps for all fields sampled in 1982. Minor lepidopterous defoliators included *Loxostege sp., Colias eurytheme, Spodoptera ornithogalli, S. exigua* and *Elasmopalpus lignosellus.* The area-wise average percentage defoliation from all pests exceeded 40 only during 1982 (late in the season). This coincided with an outbreak of *A. gemmatalis*. As reported by Drees and Rice (1990)

Sontakke and Patro (1991) reported the incidence and injuriousness of about 20 insect pests in western orissa.

Field studies were carried out during 1988-89 in Chiplima, Orissa, India, and the *kharif* crop of soybeans suffered greater damage by insect pests than the *rabi* crop. Lowest pest incidence and greatest yields were recorded with early sowings (20 June-5 July and 1-15 November) in both seasons. Three need-based applications of monocrotophos in *kharif* and 2 in *rabi* gave satisfactory control of all the pests, resulting in increased grain yield of 11.2 and 3.1 q/ha, respectively., compared with the control as reported by Sontakke and Mishra (1994)

Field studies conducted in Himachal Pradesh, India, during 1993 showed that delaying the sowing date of soybeans resulted the decrease in yields. The maximum yield (3.69 tonnes/ha) was obtained by sowing on 28 May and the lowest yield (1.45 tonnes/ha) was obtained by sowing on June 25. Insect pests were more abundant when soybeans were sown earlier in the year as reported by Chandel and Gupta (1995).

Forty-seven insect species were recorded as leaf feeders on soybean in Nanjing, China (Cui *et al.,* 1995). Among these the most important species were *Lamprosema indicate* Fab and *Spodoptera litura*(fab.)

Occurrences of 34 different species of insects have been observed during *kharif* and summer. Among them *Aproaerema modicella, Liriomyza trifolii, Melanagromyza sojae, Thysanoplusia orichalcia, Monolepta sp* and *Helicoverpa armigera* were considered as major insect pests on the crop Venkataravanappa (1996).

Gai-JunYi and Cui-ZhangLin (1997) reported that data from field surveys of soybean leaf-feeding insects (LFI) and screening for sources of resistance of soybeans to LFI carried out in Nanjing during 1983-94. Defoliating insect's viz. *Lamprosema indicata [Omiodes indicata], Ascotis selenaria, Prodenia litura [Spodoptera litura], Plusia agnata [Chrysodeixis agnata], Cifuna locuples, Ilattia octo [Amyna octo], Bomolocha tristalis [Hypena tristalis], Hypena taenialoides, Mocis undata* and *Clanis bilineata* were collected. The time period from August 10 to September 20 was suitable for screening under natural insect infestation in Nanjing.

Thippaiah (1997) noticed 34 species of insects on soybean during *kharif* season and 25 species during summer season, in Bangalore, Karnataka.

The population dynamics of soybean pests and their natural enemies in 3 medium cycle cultivars were surveyed weekly from July to October 1995 in Tocantins State, Brazil using the plant-shaking method. *Anticarsia gemmatalis, Hedylepta indicata [Omiodes indicata]* and *Chrysodeixis includens* occurred in decreasing order of abundance. *Cerotoma sp*. was the most abundant defoliator beetle found during the extension of cultural development cycle, with population peaks observed close to the reproductive stage. Among the natural enemies collected, *Cicloneda sanguinea*, *Geocoris sp*. and *Lebia sp*. were the most abundant, as reported by Didonet *et al.,* (1998).

Chaturvedi *et al.,* (1998) reported that during *kharif* of 1995, 17 insect and one mite species were recorded infesting soybean variety JS 72-44 (Gaurav) sown on 15 July 1995 in Sehore, Madhya Pradesh, India. Of these, two damaged the stems, 10 defoliated the plants, five sucked the cell sap and one damaged the roots at different growth stages of the crop, starting just after the emergence of the cotyledons.

The population density of some insects associated with soybean was estimated in a field experiment in India in *kharif* 1985 by following simple random sampling and two-stage sampling techniques at three stages of plant growth, 60-64, 86-89 and 98-99 days after sowing, using the ground cloth sampling method. Population densities of *Spilosoma obliqua* Walker and *Spodoptera litura* (Fab.) during the crop growth period were maximum around the second half of October. However, density of *Plusia orichalcea* (Fab.) was higher during the later part of September or early October. Significant correlations were observed between population densities of some insect species as reported by Vinod Kumar *et al.,* (1998).

Populations of *Biloba subsecivella* (*Bilobata subsecivella*), *Chrysodeixis acuta*, *Spodoptera litura* and *Spilosoma obliqua* (*Spilarctia obliqua*) were low in early-sown (22 June and 2 July) soybeans. Incidence of these pests was high in crops sown between 12 July and 1 August (Mandal *et al*., 1998).

Field experiments were conducted during the rainy seasons of 1994, 1995 and 1996 to determine the insects associated with soybean and their pest status in Northern Nigeria. A total of 82 insect species belonging to seven orders and 32 families were recorded on the crop. Coleoptera and Hemiptera were the numerically dominant orders, constituting 31.5 and 30.2% of the total species, respectively. Majority of the insect pests was of no economic importance. *Ootheca mutabilis*, *O. bifrons* and *Pyrgomorpha vignaudi* were the major pests during the vegetative phase of growth causing extensive defoliation as reported by Adamu *et al.,* (1999).

Adamu *et al.,* (1999) reported the effects of sowing date (three dates, each two weeks apart, starting in mid-July in 1994 and 1995) and intra-row spacing (4.2 and 8.4 cm) on the level of pest infestation and insect damage to soybean cultivars Samsoy 2 and TGX 536-02D were investigated in Samaru Zaria, Nigeria. *Ootheca mutabilis* and *Pygomorpha vignaudi* were the major defoliators during the vegetative phase. The highest percentage defoliations (13.9% at 2 weeks after planting (WAP) and 15.1% at 4 WAP, during 1994 and 1995, respectively) were below the economic threshold level of 30%. In general, sowing dates and spacing did not significantly affect percentage defoliation. The highest seed yields were recorded from the earliest sowing dates in both years.

Three hundred species of insect pests infesting soybean were reported by Singh *et al.,* (2000). Of which blue beetle, grey semi looper, green semi looper and stem fly were major insect pests in Madhya Pradesh.

Pests and natural enemies were surveyed in fields of 11 soybean cultivars, planted in strips of 40x8 m (320 m^2) in a 3520 m^2 area, in Acre, Brazil. An area of 80 m^2 in each strip received no insecticide. Four samplings were made each week in each strip (two samplings were made on each controlled and uncontrolled areas). The most abundant insect pest was *Cerotoma tingomarianus,* which caused heavy defoliation in uncontrolled areas. The main predators were *Lebia concinna*, *Callida [Calleida] sp*. and *Tropiconabis [Nabis] sp* as reported by Thomazini (2001).

The studies on date of sowing carried out at Dharwad also revealed the incidence of *S. litura* with late sown ground nut crop (Patil, 1995), and same thing was reported on soybean (Patil, 2002).

Patil (2002) reported that soybean was attacked by 48 phytophagous species, among these the seedling borers, *Melangromyza sojae* Zehnter, *Obereopsis brevis* Swed, leaf eating caterpillar, *Spodoptera litura* Fab and pod borer, *Cydia ptychora* Meyrick were key pests during *kharif*. Whereas, leaf miner, *Aproaerema modicella* Deventer, white fly, *Bemisia tabaci* Genn and leaf hopper, *Amrasca biguttula biguttula* Ishida were major during summer.

Experiment was carried out at the experimental station of the University of the Tocantins in Gurupi, Brazil to determine the population fluctuation of soyabean pests and their natural enemies. Among defoliating caterpillars, *Anticarsia gemmatalis* and *Chrysodeixis includens* were the most abundant. Among the defoliating beetle complexes, *Cerotoma arcuata* was the most abundant, with population peaks near the reproductive stage. Among the natural enemies, the spiders, *Geocoris sp., Lebia sp*. (Coleoptera: Carabidae) and *Callidae sp*. were the most abundant as reported by Didonet *et al.,* (2003).

Sastawa *et al.,* (2004) reported that the number of insect defoliators and pod sucking bugs were significantly higher in soybean sown on 31 July in 2001 and on 28 August in 2002. Grain yields were higher in early sown soybean in 2001 compared to 2002.

The surface grasshopper, *Chrotogonus sp* (Orthoptera ; Acrididae). It is a pest of soybean crop in Madhya Pradesh (Gangrade, 1974 ; Anon.., 1992)

The green tobacco grasshopper, *Attractomorpha crenulata* Fabricius (Orthoptera : Acrididae). It has been reported on soybean from Madhya Pradesh (Saxena, 1972), Uttar Pradesh (Singh, 1973; Garg, 1985), Karnataka (Rai *et al.,* 1973; Adimani, 1976).

The cotton grasshopper, *Cyrtacanthacris ranacea* Linnaeus (Orthoptera : Acrididae). Gangrade (1974) reported this insect on soybean in Madhya Pradesh, India. The tree cricket *Oecanthus indicus* Saussure (Orthoptera ; Oecanthidae). According to Hori (1927) *Oecanthus langicanda* Mats occurs as soybean pest in Japan. The Bihar hairy caterpillar, *Spilosoma obliqua* Walk (Lepidoptera ; Acrtiidae).

Fletcher (1922) observed it on soybean, field bean, cowpea, cereals, fiber crops, pulses, oilseeds, vegetables and ornamental plants in India. It has been reported on soybean from Madhya Pradesh (Rawat *et al.,* 1969 ; Saxena, 1972 ; Singh and Singh, 1990a), Karnataka (Rai *et al.,* 1973 ; Adimani, 1976), Uttar Pradesh (Singh, 1973) and also by Saha and Sahria (1983) and Garg (1985).

The gram caterpillar, *Helicoverpa armigera* Hubner (Lepidoptera ; Noctuidae). It is known as a pest of soybean in Pantnagar (Singh, 1973), Karnataka (Rai *et al.,* 1973) and Madhya pradesh (Gangrade, 1974 ; Singh and Singh, 1990). The tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera ; Noctuidae)

It has been reported on soybean by Rai *et al.,* (1973) and Adimani (1976) from Karnataka, Gangrade (1974) reported its incidence on soybean from September to February in Madhya Pradesh. It has also been reported as most abundant and injurious insect to soybean (Mundhe, 1980 ; Anon., 1991 ; 1992).

The green semilooper, *Plusia orichalcea* Fabricius. (Lepidoptera ; Noctuidae).

Singh (1973) reported it on soybean from Panthnagar, Gangrade (1974) stated that all instars of this insect feed on the soybean leaves from margin in Madhya Pradesh also reported as injurious pest of soybean in Karnataka (Adimani, 1976 ; Anon., 1991).

The castor semilooper, *Achoea janata* Linn. (Lepidoptera ; Noctuidae). This insect was found to feed on soybean leaves in Madhya Pradesh (Saxena, 1972), Maharastra (Mundhe, 1980) and Karnataka (Adimani, 1976).

The white spotted flea beetle, *Monolepta signata* oliv (Coleoptera : Chrysomelidae). Rai *et al.,* (1973) and Adimani (1976) observed this insect damaging soybean leaves in Karnataka. The grey weevil, *Myllocerus undecimpustulatus* Faust (Coleoptera : Curculionidae). This grey weevil was noticed as a pest of soybean in Uttar Pradesh (Singh, 1973), Madhya Pradesh (Gangrade, 1974) and Karnataka (Rai *et al.,* 1973; Adimani, 1976), According to Peswani (1971) adults feed on the leaf and tender parts in Delhi, India.

The grey weevil, *Myllocerus discolor* Bohem. (Coleoptera ; Curculionidae). According to Singh (1973), adults feed on soybean leaves in Pantnagar. It has reported on soybean from Karnataka (Rai *et al.,* 1973 ; Adimani, 1976 ; Anon., 1991 ; 1992). The field bean weevil, *Episomus lacerta* Fabricius. (Coleoptera ; Curculionidae).

The weevil was found feeding on soybean leaves in Karnataka (Rai *et al.,* 1973 ; Adimani, 1976). The greasy green caterpillar, *Lamprosema indicate* Fabricius (Lepidoptera : Pyralidae). It has been recorded on soybean crop in Madhya Pradesh (Kapoor *et al.,* 1972), Karnataka (Rai *et al.,* 1973 ; Adimani, 1976), Uttar Pradesh (Garg, 1985). The groundnut leaf miner, *Aproerema modicella* (Deventer) (Lepidoptera : Gelechiidae).

The leaf miner appeared in an epidemic form on soybean causing up to 100 per cent damage in Madhya Pradesh (Gangrade, 1972 ; Singh and Singh, 1990), Maharastra (Mundhe, 1980 ; Shetgar and Thombre, 1984), Himachal Pradesh (Bharadwaj and Bhalla, 1976) and in Karnataka (Rai *et al.,* 1973 ; Adimani, 1976 ; Ramani, 1979; Anon., 1991 ; 1992).

Serpentine leaf miner, *Liriomyza trifolia* Burgers (Diptera ; Agromyzidae). The leaf miner was found to cause serpentine like mines with a hood on leaves of soybean (Anon., 1993; Viraktmath *et al.,* 1993).

2.2 Relative susceptibility of soybean varieties to defoliator pests

Hag *et al.,* (1984) they noticed good tolerance capacities at both flowering and pod stages in Caribe VCF-1 (BP-2) and F-76-8827 soybean cultivars against *Spodoptera litura*.

Soybean cultivars *viz.,* PL-209837 and FC 3152 were reported to posses non-preference and antibiosis characters of host plant resistance against *S. litura* (Gary *et al.,* 1985).

Singh *et al*., (1989) they observed fewer larvae of *Rivula sp* on JS-80-21 than other varieties tested.

Ramani (1979) he used the percentage of leaf lets damaged as a yard stick in evaluating soybean varieties and reported soya-1 as resistant variety to *Aproaerema modicella*

Eighteen soybean varieties tested by Shetgar and Thombre (1984) were equally preferred by *Aproaerema modicella* at 30 and 75 days after sowing. However, the pest incidence was lower on varieties MACS-36 and AMSS-25 than on control variety (Bragg) at 60 days after sowing.

Shrivastava *et al.,* (1988) they reported that, out of 40 cultivars screened for resistance, JS-73-32, JS-78-41, JS-71-5, JS-74-46 and JS-52 were relatively less susceptible to *Aproaerema modicella* than other cultivars.

Research on soybean varieties resistant to insect pests in Indonesia is described. Some breeding lines and varieties have been found to be relatively resistant to *Spodoptera litura* and *Riptortus linearis*. The varieties Manalagi, Kerinci, Tidar and Gallunggung showed potential for use in breeding programmes as reported by Suharsono (1992)

Behera *et al.,* (1990) rated JS-72-44, MACS-125 and MACS-56 varieties as the least susceptible to soybean leaf miner *Aproaerema modicella.*

At Bangalore, India, MACS-329, JS-SH-1310, DS-68-75, MACS-346, KHSB-2, JS-87-28, NRC-3 and other ten cultivars were reported to be susceptible to leaf miner *Aproaerema modicella* (Anon., 1991).

The observations of Ganapathy *et al.,* (1991) they indicated that JS-2, Monetta and MACS-13 were found to be the most resistant lines to *Aproaerema modicella*. JS-2 consistently recorded less leaf miner damage, larval population and higher grain yield.

Kalyanasundaram and Sundarababu (1993) they screened 150 accessions for resistance to *Aproaerema modicella*. Among these, 25 accessions showed 10 per cent of leaf damage compared to 50.8 per cent in the control. PL227687, Nimsoy, PL507, JS-75-1 and EC 18678 accessions exhibited low fecundity, high larval mortality, prolonged larval and pupal periods and production of more males and low leaf damage.

According to Anon., (1985) MACS -94, MACS-176, MACS-127 and S-83-P were free from stem fly infestation. Himso-1509 and Himso – 352 had 0.33 larvae per meter row at Sehore, Madhya Pradesh.

PK-628 was found to be resistant to stem fly, nematode and yellow mosaic virus, among 190 soybean germplasm evaluated by Kundu and Misra (1985) and they also recorded 19 germplasm with 20 per cent stem tunneling.

The screening trails conducted at Panthanagar, Parbhani, Sehore and Ranchi revealed that four lines *viz.,* MACS-94, MACS-176, MACS-127 and S-83-P were free from the infestation of Bihar hairy caterpillar and six lines *viz.,* Himso-558A, Himso-1509, MACS-94, MACS-176, JS-79-295 and PK-327 showed multiple resistance against stem fly (Anon., 1986).

MACS-125 and MACS-32 varieties of soybean with less than 20 per cent stem tunneling of stem fly were reported to be least susceptible to stem fly from Sehore, India. At Delhi, MACS-125 with13.17 per cent stem tunneling was reported to be resistant and KB-34 with 43.80 per cent stem tunneling was reported to be susceptible to stem fly (Anon., 1987).

According to Shrivastava and Shrivastava (1987), none of the varieties among 40 soybean varieties was completely resistant to agromyzid, *M. phaseoli* but, per cent plant damage was lower in JS-73-32. The maximum per cent plant damage was recorded in JS-78-78 and JS-78-67. least stem tunneling was recorded in JS-72-185 and maximum in Ankur.

DS-76-129, PK-472, MACS-78 and JS-76-259 cultivars did not differ significantly with regard to infestation by *M. sojae* (Singh *et al.,* 1988)

Bragg (73.36%) and NRC-3 (33.20%) were reported to be low and moderately resistant to stem fly at Delhi and Sehore respectively. At Bangalore, India, out of 17 cultivars MACS-329, JS-SH-1310, DS-68-75, MACS-346 and KHSB-2 were reported to be moderately resistant to stem fly (Anon., 1991).

DS-22 and MACS-212 were relatively resistant to agromyzid fly, among the tested 40 varieties and germplasm of soybean (Kundu and Srivastava, 1991). MACS-346, JS-SH-1310 and DS-86-75 were found to be highly resistant to stem fly at Delhi where as at Bangalore KB-92 was resistant to stem fly (Anon., 1992).

Wang *et al.,* (1992) they reported that the logarithm of the number of agromyzid maggots was positively related to the diameter ratio of the pith to the stem and negatively to the ratio of xylem width of stem diameter.

It was reported from Indore that, JS (SH)-78-41, JS-89-43, MACS-366 and KB-111 varieties as highly resistant and MAUS-2 as resistant and PUSA -40 and NRC-3 as moderately resistant to stem fly (Anon., 1992).

PUSA-40, NRC-10, NRC-11, JS-SH-78-41 and Bragg varieties had less pod damage compared to other varieties and the pod damage varied from 0.31 to 1.29 per cent (Anon., 1992). Odulaja and Nokoe (1993) reported that a maximin-minimax approach considered percentage yield loss and actual yield potential of the varieties. The method seeks to minimize percentage yield loss while maximizing yield potential.

Screening of 16 soybean (*Glycine max*) genotypes was carried out on the basis of number of plants/plant parts cut down by larvae of *Obereopsis brevis*, leaf area damaged by defoliators, stem tunnelling by larvae of *Melanagromyza sojae*, and grain yield. Accordingly, cultivars JS 335, NRC 2, Punjab 1 and genotypes DS 396, L 129 and Soja Savana were found to be tolerant to overall insect damage. Genotype TGX 855-53D was less damaged by defoliators and TGX 342-536D and TGX 814-54D were less damaged by *M. sojae* and *O. brevis* as reported by Sharma (1995)

Bhattacharya and Ram (1995) studied inheritance and the biochemical basis of resistance to *Spilosoma obliqua* [*Spilarctia obliqua*] in four interspecific crosses between 4 susceptible cultivars of *Glycine max* and resistant *G. soja*. Data from the F1, F2 and F3 generations indicated that resistance was controlled by one incompletely dominant gene. Chemical analysis for phenolic acids (benzoic acid, coumaric acid, tannic acid, 3, 4 dicaffeoyl-quinic acids, caffeic acid, p-chloromercurobenzoic acid and chlorogen acid) did not show any clearcut relationship between resistance to *S. obliqua* and these phenolics.

Sharma (1996) studied two procedures for grouping genotypes: the All-India Co-ordinated Research Project on Soybean (AICRPS) method and a novel 'maximin-minimax' approach were compared for their effectiveness. Sixteen soybean (*Glycine max*) genotypes were grouped into different categories of insect resistance using data from field experiments conducted in India during the rainy seasons of 1993 and 1994. According to the AICRPS method, which takes into account only the extent of injury or insect population (not the yield), Punjab-1 and TGx814-54D were rated as resistant to *Melanagromyza sojae*. This method places marginally less resistant genotypes into other categories, even if they are not significantly different from the resistant ones. However, this procedure helps in the identification of source resistant to particular insect species. On the other hand, the 'maximin-minimax' approach involves a vital yield component and the entire insect-pest complex, to classify the genotypes into resistant groups. It is possible to identify genotypes with resistance/tolerance to a location-specific pest complex and good yield potential. Using this approach, cultivars JS 335 and NRC-2 and a germplasm line L-129 have been found to be tolerant to insect damage.

During 1983, 1989-90 and 1992-94, 20 soybean genotypes were selected out of 6724 germplasm accessions screened for high resistance to leaf-feeding insects. Eight genotypes were resistant to bean pyralids [*Omiodes indicata*], 6 genotypes were resistant to mugwort looper [*Ascotis selenaria*] and cotton worm [*Spodoptera litura*], and 6 genotypes were resistant to all three pests as reported by Cui *et al.,* (1997) Lourencao *et al .,* (1997) they studied the performance of soybean cultivars and lines belonging to two maturity groups (110-125 and 140-160 days of cycle) in two experiments under field conditions in Sao Paulo, Brazil, in relation defoliators (predominantly *Anticarsia gemmatalis*). The criterion used to estimate the defoliation was the PAFC (percentage of eaten leaf area). Among genotypes of the early maturity group (IAC 100, IAC 17, IAC Holambra Stuart-2, IAS 5 and IAC 83-311) no difference in resistance to the defoliators was observed. The genotypes showing longer cycles (145-160 days) comprised eleven lines of the soybean breeding program and three cultivars (IAC 14, IAC 8 and IAC PL-1). In this group significant differences among the treatments in relation to defoliators were observed: line IAC 78-2318, with multiple insect resistance, confirmed this characteristic while cultivar IAC PL-1 was the most defoliated, showing high susceptibility. When yield was considered, most of the breeding lines showed good performance, giving higher yields than the three cultivars.

Field studies conducted in Ohio and Illinois for insect resistance using the Mexican bean beetle (*Epilachna varivestis*) and the potato leafhopper (*Empoasca fabae*) (in Illinois alone). Although a few lines (PI 567.751C, PI 567.765D, PI 567.770C, PI 567.452, and PI 567.685) had potentially useable levels of resistance, none had resistance levels similar to the earlier described lines PI 171.451, PI 229.358, and PI 227.687 as reported by Hammond *et al.,* (1998)

The relative susceptibility of the promising soybean cultivars NRC-12, JS 71-05, PK-564, NRC-7, JS-335, PUSA-16 and NRC-8 was studied in a field experiment conducted during the *kharif* season of 1996-97 in Madhya Pradesh, India. NRC-12 was tolerant to the infestation of blue beetle (*Cneorane sp*.), gram caterpillar (*Helicoverpa armigera*), leaf miner (*Bilobata subsecivella*), whitefly (*Bemisia tabaci*) and jassid (*Amrasca sp*.). NRC-7 recorded tolerance against grey weevil (*Myllocerus maculosus* [*Myllocerus undecimpustulatus*]), green semilooper (*Plusia orichalcea* [*Thysanoplusia orichalcea*]), girdle beetle, jassid, leaf miner and whitefly. JS 71-05 was tolerant to green semilooper, girdle beetle, jassid and stemfly. PUSA-16 was tolerant to jassid as reported by Gaur and Deshpande (1998)

Originating as F7-derived selections from the cross Hobbit 87 x HC83-123-9, these soybean germplasm lines (PI604463 and PI604464, respectively) were released jointly in 1998 because of their high levels of resistance to Mexican bean beetle (*Epilachna varivestis*) as reported by Cooper and Hammond (1999)

Kenty *et al.,* (2001) they reported that soybean (*Glycine max*) germplasm line DMK93-9048, an F3-derived line from the cross D86-3429 x Braxton, was developed jointly by the USDA-ARS and the Mississippi Agricultural and Forestry Experiment Station, Stoneville, Mississippi, USA, and released in April 1999 for its high resistance to foliar feeding by the soybean looper (*Pseudoplusia includens* [*Chrysodeixis includens*]).

Spilosoma obliqua [*Spilarctia obliqua*] (Lepidoptera; Arctiidae), a polyphagous insect that often causes serious economic damage to several crops, particularly soybean (*Glycine max*). One wild accession *G. soja* is found to be resistant to this insect. An attempt was made to determine the relationship of the pubescence tip sharpness, length and density with resistance to *Spilosoma obliqua* with the help of 'Scanning Electron Microscopy (SEM)', and common compound microscope in the interspecific crosses between *G. max* (cultivars Bragg, Ankur and PK 472) and *G. soja* was reported by Bhattacharya and Ram (2001)

Field evaluation of 14 soybean cultivars for their major insect pests was carried out in *kharif* 1998-99 at Parbhani. All the cultivars varied in leaf damage from 29.0 to 52.0% and number of leaf miner (*Aproaerema modicella*) from 3.18 to 5.13 larvae plant^{-1}. The highest incidence of leaf miner was recorded in MAUS-20 (5.13 larvae plant^{-1}) and the lowest leaf damage in NRC-37 (3.18 larvae plant^{-1}). Stem length tunneled due to stem fly (*Melanagromyza sojae*) varied from 5.87 to 14.07%. The highest stem length tunneling was recorded in JS (SH)-9246 (14.07%) and the lowest in NRC-37 (5.86%). Girdle beetle (*Obereopsis brevis*) infestation varied from 9.62 to 18.75%. Infestation was maximum in RSC-3 (18.79%) and minimum in NRC-37 (9.62%) as reported by Salunke *et al.,* (2002).

Garewal *et al.,* (2003) they evaluated ten genotypes of soybeans (early maturing, NRC-18, NRC-25, NRC-33, JS 71-05 and NRC-7; medium maturing JS-335, L-129 and

MACS-450; and late maturing Bragg and JS 80-21) in *kharif* 2000 in Madhya Pradesh, India for resistance to green semi-loopers (*Chrysodeixis acuta* and *Diachrysia orichalcea* [*Thysanoplusia orichalcea*]), blue beetle (*Cneorane spp.*), Stem fly (*Melanagromyza sojae*), jassids and caterpillar (*Spodoptera litura*). JS 71-05 was highly resistant and NRC-25 was resistant to green semiloopers. JS 71-05 and NRC-33 were highly resistant, and NRC-18 and NRC-7 were resistant to tobacco caterpillar. JS 335 and JS 80-21, and line 129 were highly resistant to stem fly. None of the genotypes were resistant to girdle beetle. NRC-18, JS 335, JS 71-05 and JS 80-21 were highly resistant to jassids.

DT98-2448 (PI 614894), a soybean (*Glycine max*) germplasm selected from the F5 plants of the cross D88-5684 x DP 3589, was released in July 2000 in the USA to provide resistance to defoliating insects and improve the agronomic performance of soybeans in southeastern USA as reported by Abel and Tyler (2003)

Miranda *et al.,* (2003) they reported that the breeding line IAC 93-345(IAC-23) was selected from the cross BR-6 XIAC 83-23 through single seed descent method (SSD) to increase insect resistance. IAC-23 productivity, large stability and resistance levels to leaf and pod feeders insects is similar to that observed for IAC-17, and superior to that of IAS-5. The cultivar IAC-23 is then recommended for cultivation in the State of Sao Paulo and in similar environmental conditions.

The breeding line IAC 93-3335 (IAC-24) was selected from the cross IAC 80-1177 x IAC 83-288 through single seed descent method (SSD) by the IAC breeding program to increase insect resistance. This cultivar has in its background two important genotypes: PI 229358 e PI 227687 (USDA germplasm), as sources of resistance to insect. The Dunnet test indicated that the difference was significant when compared with IAC-15. Among the lines, IAC-24 showed the lowest defoliation by caterpillars, and presented low pod damage similar to IAC-100 soybean cultivar. So, the new cultivar is resistant to insect damage, has good yield, and should be recommended for cultivation in State of Sao Paulo and similar environments as reported by Miranda *et al.,* (2003)

Komatsu *et al.,* (2004) they reported that the common cutworm (*Spodoptera litura*) is a menace to soybean production in southwestern Japan. Soybean germplasms were evaluated for resistance to common cutworm to develop resistant cultivars and have found a cultivar named 'Himeshirazu', which is distinguished by its high level of resistance.

Wu-YeChun *et al.,* (2004) they carried out field experiments in 2000 and 2001, 51 soybean entries were evaluated for their resistance to the natural populations of leaf-feeding insects (LFIs) by visually estimating per cent defoliation Five genotypes were identified as LFI-resistant, Wujiang Qingdou 3, PI227687, Mianyang Baimaodou, Tongshan Bopi Huangdoujia and Gantai-2-2, and another 5 as LFI-susceptible, Shandong Dadou, Daqingrang Heidou, Aiganhuang, Shangqiu 7602 and Wan82-178..

The resistance of 46 soybean genotypes against major insect pests, *i.e.* stem fly (*Melanagromyza sojae*), girdle beetle (*Obereopsis brevis*), pod borer (*Cydia ptychora* [*Leguminivora ptychora*]), and white fly (*Bemisia tabaci*), and non filling of pods was evaluated in Tikamgarh, Madhya Pradesh, India, during the *kharif* seasons of 1995-99. Based on mean pest incidence, MACS-13, JS-84-200, JS-86-24, JS-81-1610 and JS-78-41 (14.3-15.7% damaged stem length) were resistant to stem fly. Resistance to girdle beetle was observed in JS-86-22, JS-81-1564, JS-81-303, JS-81-1504, JS-81-1619, JS-86-23, JS-84-1, JS-81-1608, JS-77-81, JS-72-44, JS-81-1625, JS-80-21 and JS-84-200 (1-5.7% stem tunnelling). JS-77-81, PK-472, JS-86-24, JS-81-335, JS-87-59, JS-76-205, JS-86-26 and JS-86-23 (3.5-4.9% pod damage) were resistant to pod borer. The genotypes which exhibited multiple resistance includes JS-84-200 (against stem fly, girdle beetle and non-filling of pods), JS-86-23 (against girdle beetle, pod borer and non-filling of pods), JS-86-24 (against stem fly and pod borer), JS-86-22 (against girdle beetle and non filling of pods), JS-81-1504 (against girdle beetle and white fly), JS-81-335 (against pod borer and non-filling of pods), and JS-77-81 (against girdle beetle and pod borer) as reported by Gupta *et al.,* (2004).

2.3 Efficacy of biorationals on defoliator pests of soybean

2.3.1 Insect pathogens

Seven weekly application of dust formulation @ 5.6 X 10^{13} conidia/ 0.4 ha gave significant control of *T.ni* on spring and fall cabbage as measured by larval mortality and damage at harvest (Bell, 1981).

Field application of *N.rileyi* conidial suspension to neonate larvae in Taiwan was found to be as effective as carbofuran in controlling *H. armigera* in maize (Tang and Hou, 1998).

Kulkarni (1999) reported that *N. rileyi* (1.2 X 10^{12} conidia/l) significantly reduced the *S. litura* larvae in soybean at 7 and 14 DAS. Patil (2000) reported that the soil application of *N. rileyi* in groundnut was found less effective in controlling *S. litura* as compared to foliar spray alone with population reduction of 36.2 and 42.36 per cent, respectively.

Hegde (2001) showed that *N. rileyi* (2 X 10^{8} conidia/l) proved its superiority over untreated control upto 75 DAS. The lower dosage (1 X 10^{8} conidia/l) was less effective compared to SLNPV and Bt. How ever a high dose (2 X 10^{8} conidia/l) of the fungus proved to be better than Bt and SLNPV in lowering the population of *S. litura*.

Kulkarni and lingappa (2002) reported that treatment effect due to *N. rileyi* became visible at 7 DAS and its superiority was more evident at 14 DAS. The pathogen inflicted significantly higher reduction of *Spodoptera* larvae at higher concentration (1.2×10^{12} conidia/l) at 14 DAS, than in SLNPV and Bt and performed at par in lowering per cent leaf let damage. Pod and grain damage in soybean by lepidopteron pod borer at higher dose was on par with Bt. Grain yield did not vary between NPV and *N. rileyi* treated plot but Bt treatment caused higher yield.

Ingle *et al.,* (2004) reported severe infestation by *N. rileyi* was observed in *Diachrysia orichalcea [Thysanoplusia orichalcea]* on soybean, and in *Helicoverpa armigera* and *Spodoptera litura* on green gram. Lower incidence of *N. rileyi* was evident in *Spilosoma obliqua [Spilarctia obliqua]* on soybean. Approximately 22.2 *D. orichalcea*, 8.4 *Spodoptera litura* and 2.4 *Spilosoma obliqua* dead larvae per meter row length infected by *N. rileyi* were recorded.

2.3.2 Nuclear polyhedrosis virus

Survey conducted during 1995-96 in Indonesia, the prevalence of infection by NPV on *S. litura* ranged from 1 to >40 per cent (Wahyuni *et al.,* 1997). In India, epizootic of NPV in *S. litura* larvae was reported in two daincha (*Sesbania bispinola* L.) fields at Madurai (TN) (Dhandapani *et al.,* 1982).

Santharam and Balasubramanium (1980) reported that application of SLNPV @125 and 250 LE per ha gave 62.78 and 86.39 per cent reduction of *S. litura* larvae after 7 days, respectively.

Ramakrishnan *et al.,* (1981) opined that the effect of NPV against *S. litura* was equal to test in insecticide based on three years trial conducted in Andra Pradesh. Application of SLNPV as water dispersible powder or unformulated virus at 250LE per ha at 10 days interval was as effective as test insecticide in reducing the *S. litura* larval population and fruit damage on chillies (Dandapani and Jayraj, 1989). Application of NPV at 250 LE with the adjuvant of crude sugar at 2.5 kg per ha at 10 days interval significantly reduced the larval population of *S. litura* on groundnut.

2.3.3 Botanicals

Aqueous extracts of botanicals like NSKE, *Vitex negundo* L, *Argemone mexicana* L, and *Annona squamosa* L, were evaluated in field against *S. litura* in groundnut ecosystem at Dharwad, Karnataka. NSKE and *Allium sativum* L, have shown good ovicidal property compared to others. Adverse effect on the hatchability of eggs of *S. litura* may due to the presence of leucodin and anonine alkaloids in *A. squamosa* (Patil, 2000).

Sayed (1983) observed the effect of various concentrations of ground seeds of neem on egg and larvae of *S. litura* in the laboratory. A study carried out using leaf extracts of *V. negundo* resulted in 100 per cent mortality of third instar larvae of *S. litura* at 500 ppm concentration (Bai and Kandaswamy, 1985). The extracts of *Ipomea carna* and *V. negundo* were most effective particularly at higher concentrations after 48 h of treatment (More *et al.,* 1989).

Feeding of 1 and 5 mg azadirachtin to *S. litura* had no effect on moulting. At higher doses (10.25 to 50 mg), a large number of insects showed juvenilizing effect manifested in the formation of larval and pupal intermediaries. Studies on the effect of azadirachtin rich fraction on *S. litura* revealed that Ne-pet-et possesses strong antifeedant action of *S. litura*. Due to exposure of interracial content through opening formed in the abdominal region and larval pupil intermediaries were observed in vemdin, Nem-75, Nemedin treatments. Adult malformation was observed in Ne-pet-et and nemedin (Jayarajan *et al.,* 1990).

Six per cent crude extract of *Calotropis gigantia* Ait, *Azadirachta indica A. juss* and *Pongemia pinnata* L caused 75,72 and 63 per cent mortality of *Aproaerema modicella*, respectively, after exposure for 96 h (Sahayaraj and Pautraj, 1998).

Laboratory and field experiments have shown that neem based insecticides, azadirachtin (Koul, 1985, Rao and Subramanian, 1987) and Margocide Ck (Anon., 1990), reduced *S. litura* growth and its damage on foliage of groundnut resulting in higher pod yields. Plant extracts from *V. negundo* and *Stachytarpheta uticifolia* (Salish) Sims were also found to cause mortality of the third instar larvae of *S. litura* in castor (Bai and Kandaswamy, 1985).

Aqueous extracts of different plant species were tried on first instar larvae of *S. litura*. It was found that most of the extracts exhibited varying degree of toxicity to first instar larvae, whereas, they were least toxic to third instar larvae. NSKE, *V. negundo* and *A. squamosa* extracts caused mortality of 87.20, 55.2 and 52.10 per cent respectively 72 h after treatment (Patil, 2000).

According to Joshi *et al*., (1984) neem seed kernel suspension of 0.5, 0.75 and 1.0 per cent protected tobacco plants from *S. litura* for seven days.

The ethanol extracts of *Tribulus terrestis* and methanol extracts of neem seed kernel resulted in morphological deformities (Gujar and Mehotra, 1983, Gunashekaran and Chellaiah, 1985). The repellency of neem seed kernel suspension (Joshi and Sitaramaih, 1979) and neem oil to *S. litura* has been proved.

The results indicated that leaf and seed extracts of neem and the seed extract of Karanja at 15% concentration were highly detrimental and offered 78.55, 88.96 and 66.41 per cent protection respectively. Protection provided by extracts of *A. squamosa*, *Adathoda vasica Ness*, *Datura suavealens* were 26.51, 6.98 and 16.35 per cent, respectively (Koshiya and Ghelani, 1990).

Extracts of *V. negundo, A. mexicana*, *Adathoda vasica Ness* possessed considerable antifeedant property at higher concentrations (Patil, 2000)

2.3.4 Animal origin insecticides

Jansson *et al*., (1996) observed that dry powder blend formulations of emamectin benzoate were very effective in controlling *Helothis zea* Boddie, *Keiferia lycopersicella* Walsingham and *Spodoptera exigua* Hubner in tomato.

Dubnar *et al*., (1998) reported that in field, emamectin benzoate was very effective in controlling cotton boll worm *H. zea* at low use rates of 0.0075-0.015 lb ai/acre.

Sullivan *et al*., (1999) found that new insecticides *viz.,* pirate R (Pyrolle), Tracer R (Spinosyn), Proclaim R (Avermectin) and Steward R (Oxadiazine) provided adequate control of beet army worm *S. exigua*, fall army worm *Spodoptera furgiperda* Smith and soybean looper *Pseudoplusia includens* Walker in cotton.

Pan- DengMing *et al*., (2000) observed that the optimal application rate of spinosad on *H. armigera* was 30.24 – 40.32 g/ha. Spinosad was particularly effective against older larvae. Mascarenhas and Boethel (2000) found out that the diagnostic concentration (concentration that kill 90-95% of susceptible individuals) of emamectin benzoate was 5 ppm and spinosad was 60 ppm against soybean looper, *P. includens*.

Hall *et al*., (2000) observed that thiodicarb at 0.125, 0.25, 0.375 and 0.5 lb ai/acre and spinosad at 0.0012 and 0.025 lb ai/acre caused highest mortality of soybean looper (*P. includens*) larvae when fed with treated foliage of cotton.

Knight *et al*., (2000) reported that indoxacarb, methoxy fenozide and spinosad were having greater potential to control *Thysanoplusia orichalcea* in soybean. Spinosad was safe to beneficial species also.

Emamectin benzoate 5 SG @ 200 g/ha was found effective in reducing dead hearts and also fruit damage in brinjal, total yield also higher in this treatment (Prasad and Devappa 2006a). Emamectin benzoate 5 SG @ 150 and 200 g/ha was found to be effective in suppressing the larval population of the pest compared to other insecticides. These two treatments also recorded higher yield of cabbage heads per hectare (Prasad and Devappa 2006b).

Emamectin benzoate 5 SG @ 11 g ai /ha was highly effective in reducing the larval population and fruit damage as well in increasing the yield of tomato (Murugaraj *et al,* 2006). Emamectin benzoate was found effective in controlling of bollworm complex as evidenced with lower incidence of square and boll damage (Sontakke *et al,* 2007).

3. MATERIAL AND METHODS

The studies on the seasonal incidence and evaluation of insect pest management components in soybean particularly on defoliators was conducted during *kharif* 2006-07 at Main Agricultural Research station (MARS), University of Agricultural Sciences, Dharwad. It is situated in the transitional tract of Karnataka (zone 8) at $15^0 26^1$ north latitude and $75^0 07^1$ east longitude with an altitude of 678 m above the MSL and has mild tropical rainy climate. The mean annual rainfall of Dharwad is about 890 mm distributed over a period of seven to eight months (April to November) with two prominent peaks occurring in July and October. The details of material used and the methodology adopted during the course of investigation are described here under.

3.1 Seasonal incidence of defoliator pests of soybean

In order to know the seasonal incidence of defoliators infesting soybean, cultivar JS 335 was sown on 10 m × 10 m plot at Main Agricultural Research station (MARS), UAS Dharwad during *kharif* 2006 – 2007. All the recommended agronomic practices were followed to grow the crop except the measures for insect pest control. The plot was further divided into three sub plots. Observations on defoliator pests of soybean in each sub plot were taken at an interval of 15 days. Using suitable techniques for different insects as explained below.

3.1.1 Leaf eating caterpillars

Observation on larval population of leaf eating caterpillar was made at three randomly selected spots of one meter row in each treatment leaving border rows. Larval count was made by shaking the plant gently over a white cloth placed between the rows. Average number of caterpillars found per meter row was worked out.

3.1.2 Grasshoppers

Observation on grasshoppers was made at three randomly selected spots of one meter area in each treatment. Five sweeps were taken randomly at three selected spots and average number of grasshoppers per sweep was worked out.

3.2 Relative susceptibility of soybean genotypes to defoliator pests

Eleven genotypes of soybean were screened against defoliator pests. Field experiment was carried out in randomized complete block design with three replications, having the plot size of 5 m × 1.5 m area with a spacing of 30 cm × 10 cm.

Five lines of each variety were sown in each replication. All the recommended package of practices was followed in establishing the plants except the insect pests control measure. Incidence of defoliator pests were recorded only from unprotected set of entries, at flowering stage. Grain yield (kg/plot) was recorded in each genotype from both protected and unprotected plots and analyzed the data by maximin-minimax method.

The genotypes were tested together with one each of resistant and susceptible checks, percentage yield loss due to pest attack for the resistant susceptible and the varieties are obtained as,

$P_R = 100 (Z_R - Y_R) / Z_R$

$P_S = 100 (Z_S – Y_S) / Z_S$

$P_i = 100 (Z_i – Y_i) / Z_i$

Table 1: List of genotypes evaluated against defoliator pests

l No.	Entries
1.	DSb-1
2.	Bragg
3.	PK-1029
4.	JS-9305
5.	KHSb-2
6.	MRSB-342
7.	DSb 6-1
8.	Monetta
9.	MACS-450
10.	NRC-67
11.	JS-335

Where,

Y_R and Z_R – yield of the resistant check when protected and un protected respectively.

Y_S and Z_S – yield of the susceptible check when protected and un protected respectively.

Genotypes I, I = I, ………. V, are Y_i and $Z_{i.}$

$P_{R,}$ $P_{S,}$ P_i are - percentage yield loss due to pest or disease attack respectively for the resistant, susceptible and i^{th} variety.

The relative yield of each genotypes may be obtained as,

$RY_i = 100\ Y_i / Y_R$

With relative percentage yield loss given as,

$RP_i = 100\ P_i / P_R$

Maximin – minimax plot is divided into four quadrants as,

First and third quadrant – Resistant but high yielding and low yielding respectively.

Second and third quadrant – susceptible but high yielding and low yielding respectively (Odulaja and Nokoe, 1993).

3.3 Efficacy of biorationals on defoliator pests of soybean

3.3.1 Prepration of 5% Neem Seed Kernel Extract (NSKE)

50 gram of smashed seeds of neem were soaked overnight in one litre of water, squeezed through muslin cloth and the extract collected was used for spraying.

3.3.2 Preparation of 5% leaf extract of *Vitex negundo*

Fresh leaves were collected and brought to laboratory, washed thoroughly 3-4 times with tap water. After that, they were chopped into small pieces with knife. 50 gram of the chopped leaves were soaked over night in enough water, squeezed through muslin cloth and residue was smashed in mortar and pestle, again extracted and filtered through muslin cloth and volume was made up to one litre and used for spraying.

3.3.3 Preparation of monocrotophos Poison bait

Rice bran 50 kg + Jaggary 4 kg + monocrotophos 36 EC 250 ml + 8 litres of water is mixed thoroughly and dried under shade condition.

Experiment was laid out in a randomized complete block design with three replications.

JS 335 variety of soybean was used for sowing and all the recommended package of practices were followed to raise the crop. Observation on larval population of leaf eating caterpillar was made at three randomly selected spots of one meter row length in each treatment leaving border rows. Larval count was made by shaking the plant gently over a white cloth placed between rows. Yield of individual treatments were noted down after the harvesting of the crop.

Table 2: Treatment details for the evaluation of biorationals against defoliator pests of soybean

Sl. No.	Treatments	Dose
1	*Nomuraea rileyi* 2 X 10^8 conidia/l	2 gm/l
2	SlNPV 250LE/ ha	2 ml/l
3	NSKE	5%
4	*Vitex negundo* leaf extract	5 %
5	Pongamia oil	2 %
6	Monocrotophos poison bait	50 kg/ha
7	Spionosad 45 SC	0.2 ml/l
8	*Emamectin benzoate* 5 SG	0.2 g/l
9	Chlorpyriphos 20 EC	2 ml/l
10	untreated check	-

3.3.4 Statistical analysis

Yield data was converted to Kg/ha. Per cent pod damage data was subjected to arcsine transformation before the analysis. Also the population count data was transformed to $\sqrt{X + 0.5}$ values for reliable analysis.

Finally, the yield data and the transformed data were analyzed using ANOVA technique and subjected to DMRT (Duncan's Multiple Range Test).

4. RESULTS

Results of the present investigation on the incidence of defoliator pests of soybean sown during different dates, screening of varieties and evaluation of biorationals against defoliator pests of soybean are elucidated in this chapter.

4.1 Seasonal incidence

The study was conducted during *kharif* season during 2006-2007 at main research station, University of Agricultural Sciences Dharwad. During the course of study, incidence of three lepidopterans and six orthopterans were recorded as per the procedure mentioned in “Material and Methods” and presented.

4.1.1 Order : Lepidoptera

Three major lepidopteran defoliators were associated with soybean crop sown at different dates. The larvae of *Spodoptera litura* Fab. were noticed feeding at early vegetative stage of the crop. Newly hatched caterpillars had characteristic gregarious feeding behaviour. They fed on chlorophyll content of the leaves from under surface and skeletonised them. The grown up larvae fed on the leaves eating away the entire portion.

The incidence of *S. litura* was observed in crop sown during all the dates of sowing. The population of *S. litura* larvae ranged from 2.60 to 7.80 larvae per meter row length (mrl) during crop sown on 08-06-06. The population increased gradually and reached peak during 60DAS (7.80 larvae/mrl) of the crop. Similarly during crop sown on 27-06-06 population of larvae ranged from 3.50 to12.00 larvae/mrl, highest larval population was recorded during 75 DAS (12.00 larvae/mrl). Likewise in crop sown on 08-07-06 larval population ranged from 3.00 to 12.80 larvae/mrl, highest larval population was recorded during 75 DAS (12.80 larvae/mrl). The crop sown on 08-07-06 recorded higher incidence 7.68 larvae per meter row length (mrl) compared to crop sown on 08-06-06 and 27-06-06 which recorded 5.58 and 6.75 larvae per mrl, respectively. It was observed in the study that during all dates of sowing there was fall in larval population during later stages of the crop

The semilooper, *Thysanoplusi orichalcea* Fab. early instar larvae fed on leaves by scratching the green matter, grownup larvae consumed entire leaves leaving behind only the midribs and veins. This pest was noticed defoliating at vegetative stage of the crop. In this study it was found that larvae of *T. orichalcea* ranged from 2.80 to 6.50 larvae/mrl, highest larval population was reached during 60 DAS (6.50 larvae/mrl) during crop sown on 08-06-06. In crop sown 27-06-06 larval population ranged from 3.60 to 6.20 larvae/mrl, larval population reached peak during 45 DAS (6.20 larvae/mrl). In case of 08-07-06 sown crop the larval population ranged from 3.60 to 8.60 larvae/mrl, in which larval population was highest during 60 DAS (8.60 larvae/mrl). Here also early sown crop *i.e.* on 08-06-06 recorded lower incidence of semilooper (3.27 larvae per mrl). Where as, crop sown on 08-07-06 recorded the higher incidence (4.80 larvae per mrl).

The early instar larvae of *Spilarctia obliqua* Walk fed gregariously on the under surface of the leaves, later stages defoliated the crop. The larvae were found feeding on leaves in crop sown during all the dates of sowing. In this study the pest observed during 45 DAS, in which the larval population of *S. obliqua* ranged from 2.80 to 3.50 larvae/mrl during crop sown on 08-06-06. In the crop sown on 27-06-06, it was observed that the larval population ranged from 2.80 to 4.50 larvae/mrl. In the July sown crop on 08-07-06 the larval population ranged from 4.30 to 5.80 larvae/mrl. Here also the trend remained same *i.e.*, early sown crop on 08-06-06 recorded the least infestation 1.05 larvae per mrl where as crop sown during 08-07-06 recorded the maximum incidence (2.53 larvae per mrl).

4.1.2 Order : Orthoptera

Six species of short horned grasshoppers *Chrotogonus trachypterus* Blanchard, *Neorthacris nilgirensis* Uvarov, *Aiolopus thalassinus* (Fabricius), *Gastrimargus africanus*

Table 3(a): Seasonal incidence of lepidopteran pests of soybean

Sl. No.	Insect pests	Date of sowing	No of larvae / mrl							
			15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	Total	Mean
1	*Spodoptera litura*	08-06-06	3.00	2.60	6.80	7.80	7.00	6.30	33.50	5.58
		27-06-06	0.00	3.50	8.40	11.80	12.00	4.80	40.50	6.75
		08-07-06	3.00	4.30	9.10	10.60	12.80	6.30	46.10	7.68
2	*Thysanoplusia orichalcea*	08-06-06	2.80	4.50	5.80	6.50	0.00	0.00	19.60	3.27
		27-06-06	3.60	5.70	6.20	5.80	4.70	0.00	26.00	4.33
		08-07-06	3.60	5.70	6.20	8.60	4.70	0.00	28.80	4.80
3	*Spilarctia obliqua*	08-06-06	0.00	0.00	0.00	0.00	2.80	3.50	6.30	1.05
		27-06-06	0.00	0.00	2.80	3.50	4.50	2.80	13.60	2.27
		08-07-06	0.00	0.00	0.00	4.30	5.10	5.80	15.20	2.53

DAS- Days after sowing, mrl- meter row length

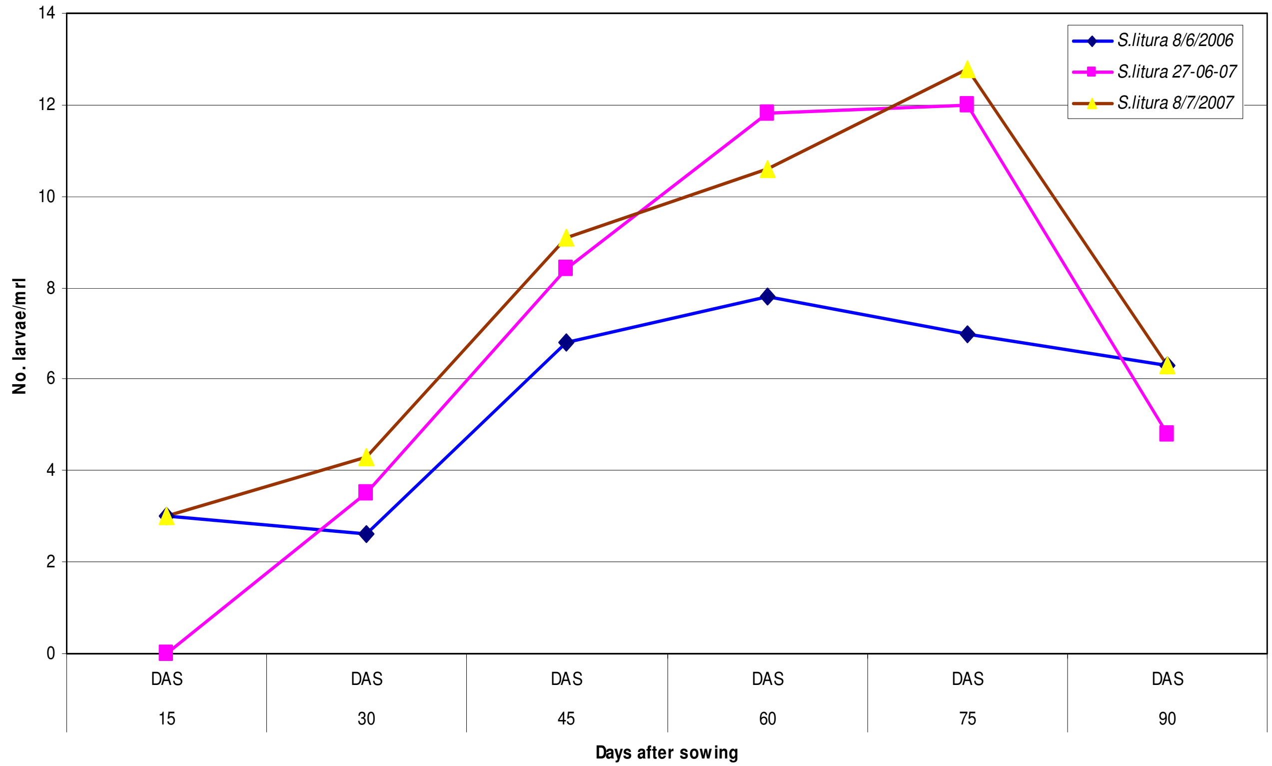

Fig. 1: Seasonal incidence of *S litura*

Fig.1: Seasonal incidence of S litura

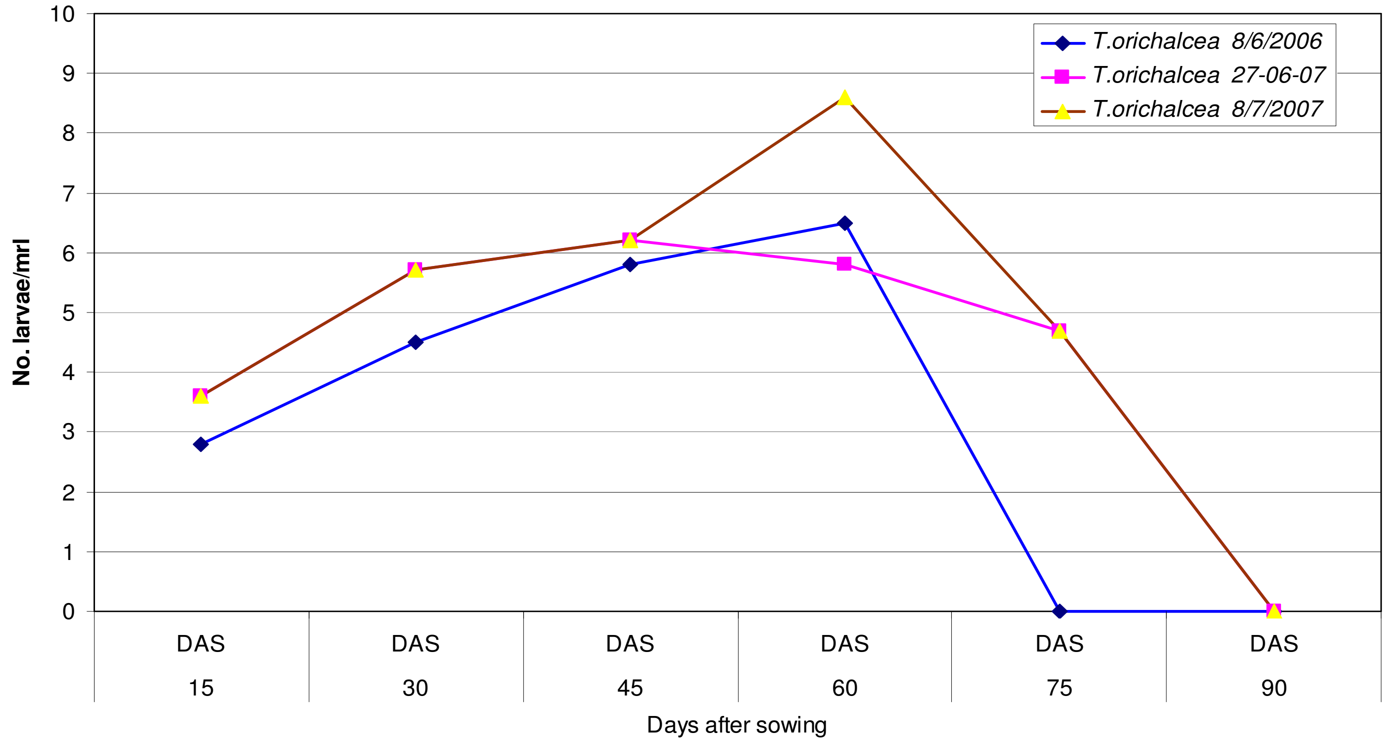

Fig. 2: Seasonal incidence of *T orichalcea*

Fig.2: Seasonal incidence of T orichalcea

Table 3 (b): Seasonal incidence of orthopteran pests of soybean

Sl. No.	Insect pests	Date of sowing	No of grasshoppers per sweep							
			15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	Total	Mean
1	*Chrotogonus tarchypterus*	08-06-06	1.90	2.80	2.90	3.10	0.00	0.00	10.70	1.78
		27-06-06	2.50	2.00	4.00	3.60	2.60	0.00	14.70	2.45
		08-07-06	3.50	3.80	2.00	3.60	2.60	0.00	15.50	2.58
2	*Cyrtacantharis tatarica*	08-06-06	0.00	1.20	1.60	2.00	0.00	0.00	4.80	0.80
		27-06-06	0.40	1.20	1.60	2.00	0.00	0.00	5.20	0.87
		08-07-06	0.80	1.60	2.60	2.00	0.00	0.00	7.00	1.17
3	*Gastrimargus africanus*	08-06-06	0.00	0.10	0.20	0.00	0.00	0.00	0.30	0.05
		27-06-06	0.00	0.20	0.20	0.00	0.00	0.00	0.40	0.07
		08-07-06	0.00	0.30	0.20	0.10	0.00	0.00	0.60	0.10
4	*Morphocaris fasciata*	08-06-06	0.00	0.10	0.10	0.00	0.00	0.00	0.20	0.03
		27-06-06	0.00	0.20	0.20	0.00	0.00	0.00	0.40	0.07
		08-07-06	0.00	0.20	0.40	0.10	0.00	0.00	0.70	0.12
5	*Aiolopus thalassinus*	08-06-06	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.02
		27-06-06	0.00	0.20	0.00	0.20	0.00	0.00	0.40	0.07
		08-07-06	0.00	0.20	0.10	0.20	0.00	0.00	0.50	0.08
6	*Neorthacris niligrensis*	08-06-06	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.02
		27-06-06	0.00	0.10	0.20	0.10	0.00	0.00	0.40	0.07
		08-07-06	0.00	0.10	0.20	0.20	0.00	0.00	0.50	0.08

DAS- Days after sowing

Table 3(c): Activity of natural enemies

Natural enemies	Date of sowing	No of larvae / mrl					Total	Mean
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS		
Coccinellids	08-06-06	0.00	0.00	7.00	5.30	0.00	12.30	2.46
	27-06-06	0.00	0.00	7.30	5.40	0.00	12.70	2.54
	08-07-06	0.00	0.00	7.35	5.45	0.00	12.80	2.56
Chrysopids	08-06-06	0.00	1.30	2.22	0.00	0.00	3.52	0.704
	27-06-06	0.00	2.00	2.80	0.00	0.00	4.80	0.96
	08-07-06	0.00	2.16	3.50	0.00	0.00	5.66	1.132
N. rileyi (mycosd larvae/mrl)	08-06-06	0.00	2.00	0.93	1.53	1.00	4.46	0.892
	27-06-06	0.00	2.20	1.60	1.58	1.20	5.38	1.076
	08-07-06	0.00	2.30	1.62	1.60	1.22	5.52	1.104

DAS- Days after sowing, mrl- meter row length

Plate1: General view of the experimental plot

Plate2: Experimental plot showing damage symptoms

Saussure, *Morphocaris fasciata* (Thumberg), *Cyrtacantharis tatarica*, were found defoliating soybean during early vegetative stage of the crop. Their incidence was sporadic in nature. However, *Chrotogonus trachypterus* was the only grasshopper species found in slightly higher number.

4.1.3 Natural enemies

Coccinellids, Chrysopids and entomopathogenic fungus *N. rileyi* were recorded during the course of investigation. Infested larvae were found on crop sown at all dates of sowing. However their incidence was more in crop sown on 08-07-06.

4.2 Screening of genotypes for resistance against defoliator pests of soybean

Eleven genotypes including the susceptible check (JS 335) were tested for relative field resistance to defoliator pests as per the methodologies explained in "Material and Methods". Among the eleven genotypes, there was no significant difference in larval population throughout the cropping season. The level of infestation was on par in all the genotypes (table 4a and 4b).

4.2.1 Per cent defoliation

Per cent defoliation in all the genotypes was found significantly superior over check except Monetta which was found to be on par with the check genotype, JS 335. Least per cent defoliation was observed in KHSb-2 (14.33 per cent) followed by DSb -1 (21.33 per cent). KHSb-2, DSb-1 and Bragg were categorized as highly resistant, PK1029, NRC-67, MACS-450 and MRSB-342 were categorized as moderately resistant, DSb-6-1 and JS-9305 were categorized as susceptible. JS 335 and Monetta are recorded as highly susceptible genotypes (table-5).

4.2.2 Per cent pod damage

Per cent pod damage reveals that least per cent pod damage was noticed in Monetta (20.75 per cent), JS-9305 (21.21 per cent), DSb –1 (26.41 per cent), PK 1029 (26.67 per cent), KHSb – 2 (27.82 per cent) which were on par with the standard check JS 335 (17.68 per cent) and maximum damage was noticed in case of DSb 6- 1 (64.33 per cent), MACS 450 (59.72 per cent), Bragg (53.72 per cent) and MRSb 342 (52.45 per cent) and they were found on par with each other. JS-335, Monetta, JS-9305 were categorized as highly resistant, DSb-1, PK1029, KHSb-2 and NRC-67 were categorized as moderately resistant and DSb 6-1 MACS-450, Bragg and MRSB-342 were categorized as highly susceptible varieties.

4.2.3 Categorization of soybean genotypes under Maximin-Minimax method

The study revealed that per cent yield loss due to insect pest complex ranged from 19.61(DSb-1) to 36.37 (NRC-67). As per the maximin-minimax method six genotypes *viz.*, JS 335, DSb–1, PK1029, JS-9305, Monetta and Bragg were rated as susceptible high yielding *i.e.* tolerant to insect pest complex and rest of the genotypes were rated as susceptible low yielding (table-7).

4.3 Management of defoliator pests of soybean using biorationals

Data recorded on the efficacy of biorationals against major defoliators pests of soybean are presented in Table 8-11. The experiment was carried out by using entamopathogenic fungus *Nomurea rileyi,* SLNPV, NSKE, *Vitex negundo* leaf extract, pongamia oil, monocrotophos poison bait and animal origin insecticides with chloropyriphos as a standard check.

Table 4(a): Field screening of soybean genotypes against defoliator pests

Sl. No.	Entries	No of *S. litura* larvae/ mrl					
		15 DAG	30 DAG	45 DAG	60 DAG	75 DAG	90 DAG
1	DSb-1	0.00 (0.71)*	3.67 [a] (2.04)	8.13[a] (2.94)	9.57 [a] (3.17)	10.83 [a] (3.37)	3.80 [a] (2.07)
2	Bragg	0.00 (0.71)	3.33 [a] (1.95)	7.93 [a] (2.90)	9.53 [a] (3.17)	10.53 [a] (3.32)	3.60 [a] (2.02)
3	PK1029	0.00 (0.71)	3.50 [a] (1.99)	8.10 [a] (2.93)	9.47 [a] (3.16)	10.57 [a] (3.33)	4.17 [a] (2.16)
4	JS-9305	0.00 (0.71)	3.60 [a] (2.02)	8.60 [a] (3.02)	9.87 [a] (3.22)	10.87 [a] (3.37)	3.83 [a] (2.08)
5	KHSb-2	0.00 (0.71)	3.40 [a] (1.97)	8.37 [a] (2.98)	9.60 [a] (3.18)	10.93 [a] (3.38)	4.20 [a] (2.17)
6	MRSB-342	0.00 (0.71)	3.20 [a] (1.92)	7.87 [a] (2.89)	9.50 [a] (3.16)	10.50 [a] (3.32)	3.53 [a] (2.01)
7	DSb-6-1	0.00 (0.71)	3.40 [a] (1.97)	7.93 [a] (2.90)	9.47 [a] (3.16)	10.57 [a] (3.33)	3.87 [a] (2.09)
8	Monetta	0.00 (0.71)	3.50 [a] (1.99)	8.43 [a] (2.99)	9.50 [a] (3.16)	10.53 [a] (3.32)	3.67 [a] (2.04)
9	MACS-450	0.00 (0.71)	3.67 [a] (2.04)	8.60 [a] (3.02)	9.83 [a] (3.21)	10.87 [a] (3.37)	3.67 [a] (2.04)
10	NRC-67	0.00 (0.71)	3.40 [a] (1.97)	7.93 [a] (2.90)	9.47 [a] (3.16)	10.53 [a] (3.32)	3.83 [a] (2.08)
11	JS-335	0.00 (0.71)	3.70 [a] (2.05)	8.60 [a] (3.02)	9.90 [a] (3.22)	11.00 [a] (3.39)	3.83 [a] (2.08)
	SEm±	-	0.10	0.04	0.02	0.02	0.05
	CD at 5%	-	0.28	0.12	0.06	0.07	0.15

*Figures in parentheses are $\sqrt{X+0.5}$ transformed values DAG- Days after germination, mrl-meter row length

Table 4(b): Field screening of soybean genotypes against defoliator pests

Sl. No.	Entries	No *T.orichalcea* of larvae/ mrl					
		15DAG	30DAG	45DAG	60DAG	75DAG	90DAG
1	DSb-1	0.00 [a] (0.71)*	1.97 [a] (1.57)	3.77 [a] (2.06)	4.90 [a] (2.32)	2.43 [a] (1.71)	0.00 (0.71)
2	Bragg	0.33 [a] (0.88)	1.87 [a] (1.54)	3.67 [a] (2.04)	5.00 [a] (2.34)	2.47 [a] (1.72)	0.00 (0.71)
3	PK1029	0.33 [a] (0.88)	2.07 [a] (1.60)	3.83 [a] (2.08)	4.97 [a] (2.34)	2.50 [a] (1.73)	0.00 (0.71)
4	JS-9305	0.00 [a] (0.71)	2.17 [a] (1.63)	4.03 [a] (2.13)	5.03 [a] (2.35)	2.53 [a] (1.74)	0.00 (0.71)
5	KHSb-2	0.00 [a] (0.71)	2.27 [a] (1.66)	4.17 [a] (2.16)	5.13 [a] (2.37)	2.43 [a] (1.71)	0.00 (0.71)
6	MRSB-342	0.33 [a] (0.88)	2.17 [a] (1.63)	3.83 [a] (2.08)	5.06 [a] (2.36)	2.57 [a] (1.75)	0.00 (0.71)
7	DSb 6-1	0.00 [a] (0.71)	2.27 [a] (1.66)	4.17 [a] (2.16)	5.13 [a] (2.37)	2.47 [a] (1.72)	0.00 (0.71)
8	Monetta	0.00 [a] (0.71)	1.98 [a] (1.58)	3.77 [a] (2.06)	5.03 [a] (2.35)	2.43 [a] (1.71)	0.00 (0.71)
9	MACS-450	0.00 [a] (0.71)	1.99 [a] (1.58)	3.77 [a] (2.06)	4.97 [a] (2.34)	2.47 [a] (1.72)	0.00 (0.71)
10	NRC-67	0.33 [a] (0.88)	2.05 [a] (1.60)	3.80 [a] (2.07)	4.90 [a] (2.32)	2.53 [a] (1.74)	0.00 (0.71)
11	JS-335	0.33 [a] (0.88)	2.37 [a] (1.69)	4.23 [a] (2.18)	5.13 [a] (2.37)	3.57 [a] (1.75)	0.00 (0.71)
	SEm±	0.12	0.05	0.04	0.04	0.04	-
	CD at 5%	0.35	0.14	0.11	0.10	0.11	-

*Figures in parentheses are √X+0.5 transformed values DAG- days after germination, mrl- meter row length

Table 5: Per cent defoliation in different soybean genotypes

Sl. No.	Entries	Per cent Defoliation	Category
1	DSb-1	21.33 [f] (27.48)*	HR
2	Bragg	28.67 [e] (32.18)	HR
3	PK1029	32.67 [de] (34.75)	MR
4	JS-9305	48.00 [b] (43.84)	S
5	KHSb-2	14.33 [g] (22.09)	HR
6	MRSB-342	41.67 [bc] (40.18)	MR
7	DSb 6-1	47.67 [b] (43.64)	S
8	Monetta	63.67 [a] (52.93)	HS
9	MACS-450	40.33 [bcd] (39.39)	MR
10	NRC-67	38.00 [cd] (37.96)	MR
11	JS-335	66.67 [a] (54.81)	HS
	SEm±	1.55	
	CD at 5%	4.47	

*Figures in parentheses are angular transformed values

HR- Highly resistant MR- Moderately resistant

S- Susceptible HS- Highly susceptible

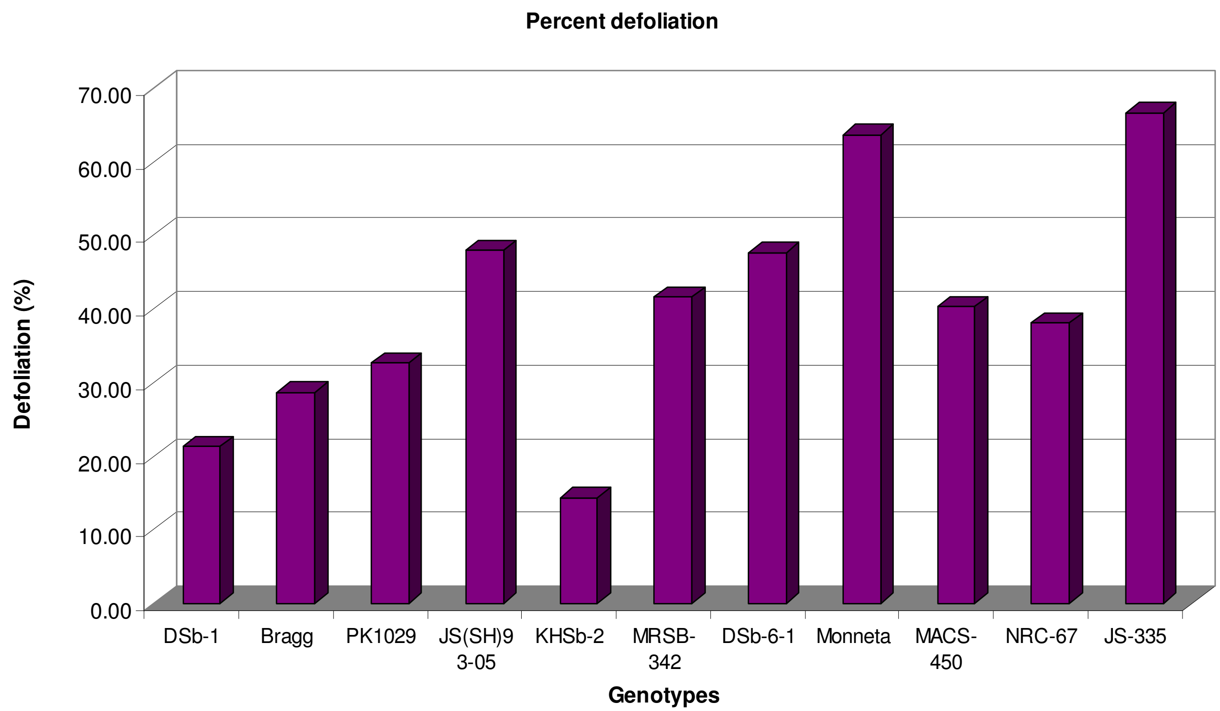

Fig. 3: Per cent defoliation in genotypes

Fig3: Percent defoliation in genotypes

Table 6: Per cent pod damage in soybean genotypes

Sl. No.	Entries	Per cent Pod damage	Category
1	DSb-1	26.41 [bc] (30.72)	MR
2	Bragg	53.72 [a] (47.12)	HS
3	PK1029	26.67 [bc] (30.79)	MR
4	JS-9305	21.21 [bc] (27.35)	HR
5	KHSb-2	27.82 [bc] (31.74)	MR
6	MRSB-342	52.45 [a] (46.39)	HS
7	DSb 6-1	64.33 [a] (53.34)	HS
8	Monetta	20.75 [bc] (26.90)	HR
9	MACS-450	59.72 [a] (50.62)	HS
10	NRC-67	29.08 [b] (32.49)	MR
11	JS-335	17.68 [c] (24.69)	HR
	SEm±	2.29	
	CD at 5%	6.58	

*Figures in parentheses are angular transformed values

HR- Highly resistant MR- Moderately resistant

S- Susceptible HS- Highly susceptible

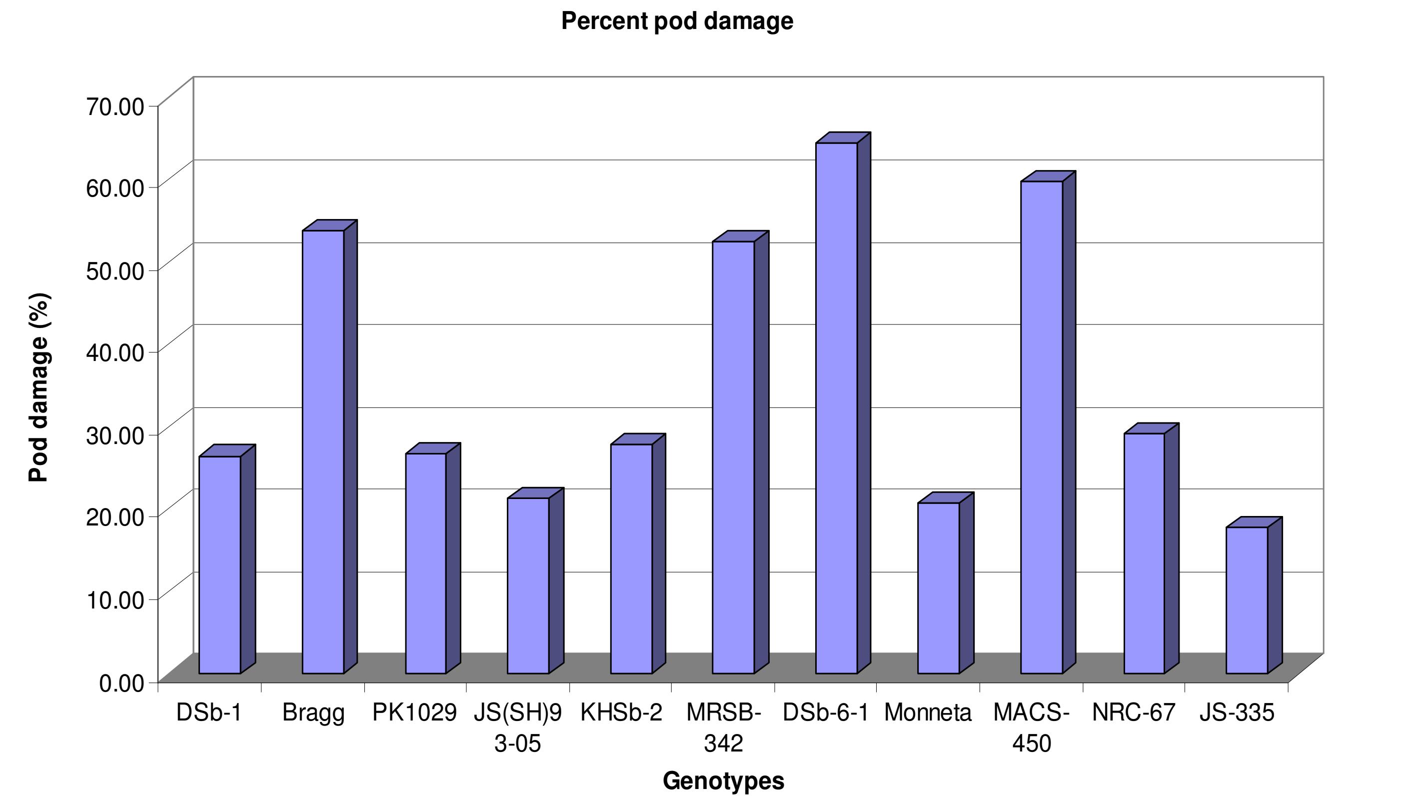

Fig. 4: Per cent pod damage in genotypes

Fig.4: Percent pod damage in genotypes

Table 7: Grain yield and yield loss in soybean genotypes

Sl. No.	Entries	Unprotected (Kg/ha)	Protected (Kg/ha)	Per cent yield loss	Per cent relative yield (RY)	Per cent relative yield loss(RP)	Category
1	DSb-1	1866.33	2321.67	19.61	99.75	53.93	S-HY
2	Bragg	1559.67	2145.00	27.29	83.36	75.03	S-HY
3	PK1029	1864.67	2300.00	18.93	99.66	52.04	S-HY
4	JS-9305	1772.67	2266.33	21.78	94.74	59.89	S-HY
5	KHSb-2	1465.00	2082.67	29.66	78.30	81.55	S-LY
6	MRSB-342	1453.33	2167.67	32.95	77.68	90.61	S-LY
7	DSb 6-1	1251.00	1879.00	33.42	66.86	91.89	S-LY
8	Monetta	1650.00	2250.00	26.67	88.19	73.32	S-HY
9	MACS-450	1245.33	1935.00	35.64	66.56	98.00	S-HY
10	NRC-67	1344.33	2112.67	36.37	71.85	100	S-LY
11	JS-335	1871.00	2429.00	22.97	100	63.17	S-HY

S-HY: Susceptible high yielding
S-LY: Susceptible low yielding

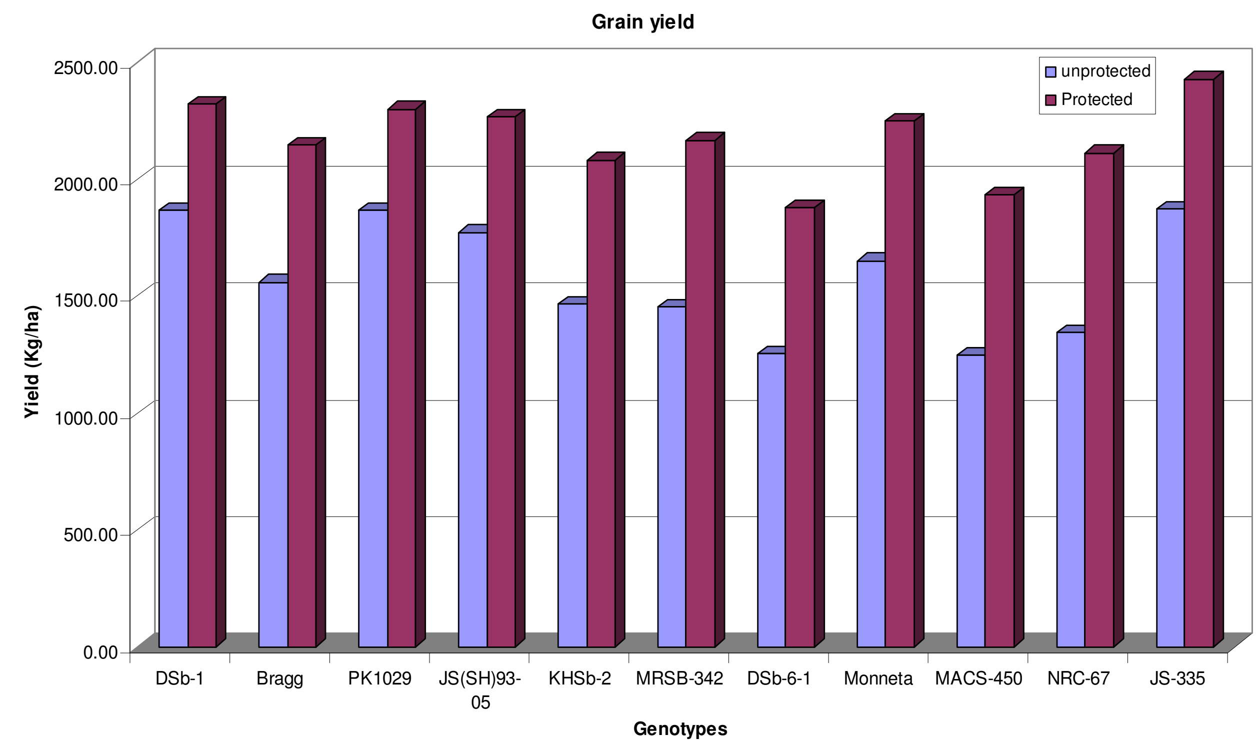

Fig. 5: Grain yield in protected and unprotected plots

Fig.5: Grain yield in protected and uprooted plots

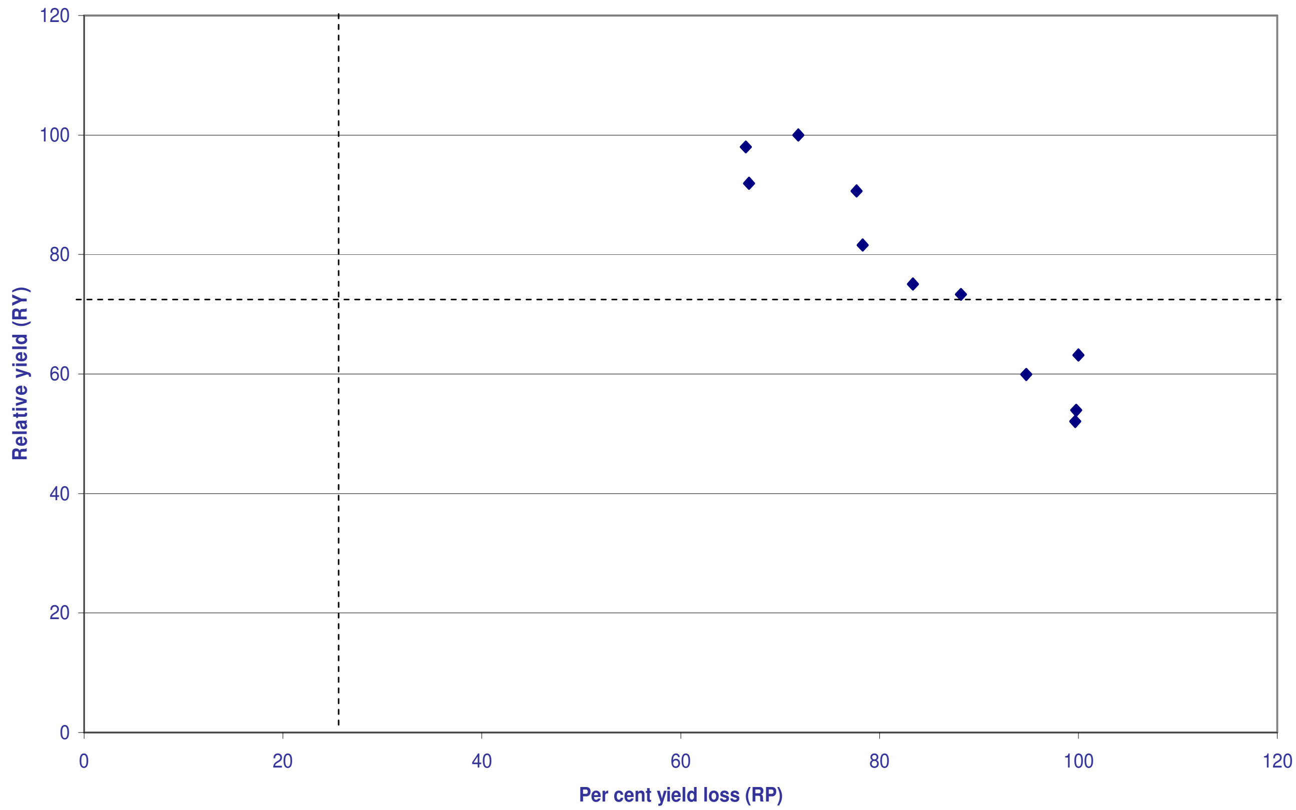

Fig. 6: Maximin-Minimax plot for 11 soybean genotypes

Fig.6: Maximum-minimax plot for 11 soybean genotypes

4.3.1 Tobacco caterpillar, *Spodoptera litura*

The data pertaining to the efficacy of biorationals on *S litura* larval population on a day before and at 3, 7 and 15 days after spraying (DAS) are given in Table 8a and 8b.

4.3.1.1 First spray

The initial larval population of *S. litura* on one day before imposing the treatment ranged from 3.51 to 3.55 larvae per mrl which were on par with each other. At three days after spray Emamectin benzoate recorded the least larval population (1.25 per mrl) which was significantly superior over the standard check chlorpyriphos (1.44 larvae per mrl). Spinosad found to be the next best treatment which recorded 1.37 larvae per mrl and was on par with the standard check. However, all the treatments were significantly superior over untreated control, whereas pongamia oil recorded highest larval population of 2.99 larvae per mrl. At seven days after spraying similar trend was noticed. At fifteen days after spraying emamectin benzoate recorded the lowest larval population (1.66 larvae per mrl) over the standard check chlorpyriphos (1.78 larvae per mrl) which is significantly superior. Untreated check recorded significantly higher population (3.75 larvae per mrl) (Table 8a).

4.3.1.2 Second spray

The data pertaining to the effects of biorationals on *S litura* larval population on a day before, 3, 7 and 15 days after spraying (DAS) during II- spray are given in Table 8b.

During second spray the larval population significantly varied among the treatments, highest larval population was recorded in untreated check where as emamectin benzoate recorded the lowest larval population.

The trend during second spray was similar as that of first spray where emamectin benzoate was significantly superior over other treatments after three, seven, and fifteen days after spraying.

4.3.2 Semilooper, *Thysanoplusia orichalcea*

The data pertaining to the effect of biorationals on *T. orichalcea* larval population on a day before and at 3, 7 and 15 DAS during first spray are given in Table 9a.

4.3.2.1 First spray

The initial larval population of *T. orichalcea* on one day before imposing the treatment ranged from 2.37 to 2.53 larvae per mrl which were on par with each other. At three days after spray emamectin Benzoate recorded the least larval population (0.36 per mrl) which was significantly superior over the standard check chlorpyriphos (0.57 larvae per mrl). Spinosad found to be the next best treatment which recorded 0.49 larvae per mrl and was on par with the standard check. However, all the treatments were significantly superior over untreated control, whereas pongamia oil recorded highest larval population of 2.15 larvae per mrl. At seven days after spraying similar trend was noticed. At fifteen days after spraying emamectin benzoate recorded the lowest larval population (0.58 larvae per mrl) over the standard check chlorpyriphos (0.91 larvae per mrl) which is significantly superior. Untreated check recorded significantly higher population (2.85 larvae per mrl).

4.3.2.2 Second spray

The data pertaining to the effects of biorationals on *T. orichalcea* larval population on a day before, 3, 7 and 15 DAS during II spray are given in Table 9b.

During second spray the larval population significantly varied among the treatments, highest larval population was recorded in untreated check where as emamectin benzoate recorded the lowest larval population. The trend during second spray was similar as that of first spray where emamectin benzoate was significantly superior over other treatments after three, seven, and fifteen days after spraying.

Table 8 (a): Efficacy of biorationals in the management of *S. litura*

Sl. No.	Treatments	Concentrations	No. of larvae/mrl during I- Spray			
			1 DBS	3 DAS	7 DAS	15 DAS
1	T1-*N.rileyi*	2×10^8 conidea/l	3.53 [a] (2.01)*	2.67 [d] (1.78)	2.09 [e] (1.61)	2.49 [e] (1.73)
2	T2- SLNPV	250 LE/ha	3.51 [a] (2.00)	2.57 [e] (1.75)	2.01 [f] (1.58)	2.35 [f] (1.69)
3	T3- NSKE	5%	3.55 [a] (2.01)	2.75 [d] (1.80)	2.25 [d] (1.66)	2.75 [d] (1.80)
4	T4-*V.negundo*	5%	3.54 [a] (2.01)	2.88 [c] (1.84)	2.56 [c] (1.75)	2.97 [c] (1.86)
5	T5- Pongamia oil	2%	3.53 [a] (2.01)	2.99 [b] (1.87)	2.76 [b] (1.81)	3.16 [b] (1.91)
6	T6- Monocrotophos poison bait	0.5%	3.54 [a] (2.01)	2.52 [e] (1.74)	1.87 [g] (1.54)	2.31 [f] (1.68)
7	T7- Spinosad 45 SC	0.02%	3.54 [a] (2.01)	1.37 [f] (1.37)	1.37 [h] (1.37)	1.76 [g] (1.50)
8	T8-Emamectin Benzoate 5 SG	0.02%	3.54 [a] (2.01)	1.25 [g] (1.32)	1.25 [i] (1.32)	1.66 [h] (1.47)
9	T9-Chlorpyriphos 20 EC	0.2%	3.53 [a] (2.01)	1.44 [f] (1.39)	1.44 [h] (1.39)	1.78 [g] (1.51)
10	T10- UTC	-	3.52 [a] (2.00)	3.53 [a] (2.01)	3.61 [a] (2.03)	3.75 [a] (2.18)
	SEm±		0.005	0.009	0.007	0.009
	CD at 5%		0.016	0.026	0.021	0.025

*Figures in parentheses are √X+0.5 transformed values DBS- Days before spraying, DAS- Days after spraying, mrl- meter row length

Table 8(b): Efficacy of biorationals in the management of *S. litura*

Sl. No.	Treatments	Concentrations	No. of larvae/mrl during II- Spray			
			1 DBS	3 DAS	7 DAS	15 DAS
1	T1-*N.rileyi*	2×10^8 conidea/l	2.49 [e] (1.73)*	1.66 [e] (1.47)	1.08 [e] (1.26)	1.48 [e] (1.41)
2	T2- SLNPV	250 LE/ha	2.35 [f] (1.69)	1.62 [e] (1.46)	1.06 [e] (1.25)	1.40 [e] (1.38)
3	T3- NSKE	5%	2.75 [d] (1.80)	2.17 [d] (1.63)	1.67 [d] (1.47)	2.17 [d] (1.63)
4	T4-*V.negundo*	5%	2.97 [c] (1.86)	2.48 [c] (1.73)	2.16 [c] (1.63)	2.66 [c] (1.78)
5	T5- Pongamia oil	2%	3.16 [b] (1.91)	2.82 [b] (1.82)	2.52 [b] (1.74)	3.02 [b] (1.88)
6	T6- Monocrotophos poison bait	0.5%	2.31 [f] (1.68)	1.50 [f] (1.42)	0.85 [f] (1.16)	1.15 [f] (1.29)
7	T7- Spinosad 45 SC	0.02%	1.76 [g] (1.50)	0.24 [h] (0.86)	0.24 [gh] (0.86)	0.45 [g] (0.98)
8	T8-Emamectin Benzoate 5 SG	0.02%	1.66 [h] (1.47)	0.20 [i] (0.83)	0.20 [h] (0.83)	0.36 [h] (0.93)
9	T9-Chlorpyriphos 20 EC	0.2%	1.78 [g] (1.51)	0.30 [g] (0.89)	0.30 [g] (0.89)	0.50 [g] (1.00)
10	T10- UTC	-	3.75 [a] (2.18)	3.81 [a] (2.19)	3.86 [a] (2.20)	3.94 [a] (2.22)
	SEm±		0.009	0.010	0.011	0.010
	CD at 5%		0.025	0.028	0.031	0.030

*Figures in parentheses are √X+0.5 transformed values DBS- Days before spraying, DAS- Days after spraying, mrl- meter row length

Table 9(a): Efficacy of biorationals in the management of *T.orichalcea*

Sl. No.	Treatments	Concentrations	No. of larvae/mrl during I- Spray			
			1 DBS	3 DAS	7 DAS	15 DAS
1	T1-*N.rileyi*	2×10^8 conidea/l	2.50 [a] (1.73)*	1.98 [c] (1.57)	1.57 [e] (1.44)	1.95 [d] (1.56)
2	T2- SLNPV	250 LE/ha	2.43 [a] (1.71)	2.03 [c] (1.59)	1.82 [c] (1.52)	2.13 [c] (1.62)
3	T3- NSKE	5%	2.37 [a] (1.69)	2.02 [c] (1.59)	1.74 [d] (1.50)	2.01 [d] (1.58)
4	T4-*V.negundo*	5%	2.37 [a] (1.69)	2.02 [c] (1.59)	1.76 [d] (1.50)	2.15 [c] (1.63)
5	T5- Pongamia oil	2%	2.50 [a] (1.73)	2.15 [b] (1.63)	1.93 [b] (1.56)	2.32 [b] (1.68)
6	T6- Monocrotophos poison bait	0.5%	2.37 [a] (1.69)	1.69 [d] (1.48)	1.38 [f] (1.37)	1.58 [e] (1.44)
7	T7- Spinosad 45 SC	0.02%	2.50 [a] (1.73)	0.49 [e] (1.00)	0.49 [h] (1.00)	0.81 [g] (1.14)
8	T8-Emamectin Benzoate 5 SG	0.02%	2.53 [a] (1.74)	0.36 [f] (0.93)	0.36 [i] (0.93)	0.58 [h] (1.04)
9	T9-Chlorpyriphos 20 EC	0.2%	2.50 [a] (1.73)	0.57 [e] (1.03)	0.57 [g] (1.03)	0.91 [f] (1.19)
10	T10- UTC	-	2.50 [a] (1.73)	2.59 [a] (1.76)	2.64 [a] (1.77)	2.85 [a] (1.83)
	SEm±		0.031	0.013	0.006	0.008
	CD at 5%		0.089	0.036	0.018	0.023

*Figures in parentheses are √X+0.5 transformed values   DBS- Days before spraying, DAS- Days after spraying, mrl- meter row length

Table 9(b): Efficacy of biorationals in the management of *T.orichalcea*

Sl. No.	Treatments	Concentrations	No. of larvae/mrl during II- Spray			
			1 DBS	3 DAS	7 DAS	15 DAS
1	T1-*N.rileyi*	2×10^8 conidea/l	1.95 [d] (1.56)*	1.37 [e] (1.37)	0.97 [e] (1.21)	1.31 [e] (1.34)
2	T2- SLNPV	250 LE/ha	2.13 [c] (1.62)	1.83 [c] (1.53)	1.44 [c] (1.39)	1.74 [c] (1.50)
3	T3- NSKE	5%	2.01 [d] (1.58)	1.69 [d] (1.48)	1.31 [d] (1.34)	1.61 [d] (1.45)
4	T4-*V.negundo*	5%	2.15 [c] (1.63)	1.88 [c] (1.54)	1.49 [c] (1.41)	1.79 [c] (1.51)
5	T5- Pongamia oil	2%	2.32 [b] (1.68)	2.12 [b] (1.62)	1.82 [b] (1.52)	2.20 [b] (1.64)
6	T6- Monocrotophos poison bait	0.5%	1.58 [c] (1.44)	0.94 [f] (1.20)	0.47 [f] (0.98)	0.77 [f] (1.13)
7	T7- Spinosad 45 SC	0.02%	0.81 [g] (1.14)	0.29 [h] (0.89)	0.29 [h] (0.89)	0.57 [h] (1.03)
8	T8-Emamectin Benzoate 5 SG	0.02%	0.58 [h] (1.04)	0.06 [i] (0.75)	0.06 [i] (0.75)	0.34 [i] (0.92)
9	T9-Chlorpyriphos 20 EC	0.2%	0.91 [f] (1.19)	0.39 [g] (0.94)	0.39 [g] (0.94)	0.67 [g] (1.08)
10	T10- UTC	-	2.85 [a] (1.83)	2.87 [a] (1.83)	2.97 [a] (1.86)	2.97 [a] (1.86)
	SEm±		0.008	0.009	0.010	0.010
	CD at 5%		0.023	0.027	0.030	0.027

*Figures in parentheses are √X+0.5 transformed values

DBS- Days before spraying, DAS- Days after spraying, mrl- meter row length

Table 10: Effect of biorationals on yield of soybean

Sl. No.	Treatments	Per cent defoliation	Per cent pod damage	Seed yield (Kg/ha)
1	T1- *N.rileyi* 2×10^8 conidea/l	43.00 [d] (40.96)*	26.99 [e] (31.29)	2135.00 [f]
2	T2- SLNPV 250 LE/ha	44.67 [d] (41.91)	27.27 [e] (31.47)	2018.33 [e]
3	T3- NSKE 5%	63.33 [c] (52.72)	28.81 [d] (32.46)	1967.67 [d]
4	T4-*V.negundo 5%*	64.67 [c] (53.51)	29.73 [c] (33.03)	1927.67 [c]
5	T5- Pongamia oil 2%	70.00 [b] (56.77)	31.03 [b] (33.84)	1882.33 [b]
6	T6- Monocrotophos poison bait	36.33 [e] (37.04)	16.73 [f] (24.14)	2195.00 [g]
7	T7- Spinosad 45 SC	32.00 [e] (34.43)	11.22 [h] (19.56)	2274.67 [i]
8	T8- Emamectin Benzoate 5 SG	26.00 [f] (30.56)	11.23 [h] (19.57)	2276.67 [i]
9	T9- Chlorpyriphos 20 EC	36.00 [e] (36.85)	13.67 [g] (21.69)	2221.33 [h]
10	T10- UTC	83.33 [a] (65.93)	42.80 [a] (40.84)	1524.33 [a]
	SEm±	0.93	0.12	3.57
	CD at 5%	2.68	0.36	10.60

* Figures in parentheses are angular transformed values

Table 11: Economics of biorationals in management of defoliator pests of soybean

Sl No	Treatments	Concentrations	Total cost of treatments (Rs.\ ha)	Yield (q/ha)	Gross returns (Rs.\ ha)	Net returns (Rs.\ ha)	Net profit (Rs.\ ha)
1	T1-*N.rileyi*	2×10^8 conidea/l	400	21.35	26687.50	7637.50	7237.50
2	T2- SLNPV	250 LE/ha	700	20.18	25225.00	6175.00	5475.00
3	T3- NSKE	5%	412.8	19.67	24587.50	5537.50	5124.70
4	T4-*V.negundo*	5%	200	19.27	24087.50	5037.50	4837.50
5	T5- Pongamia oil	2%	1200	18.82	23525.00	4475.00	3275.00
6	T6- Monocrotophos Poison bait	0.5%	553	21.95	27437.50	8387.50	7834.50
7	T7- Spinosad 45 SC	0.02%	1386	22.74	28425.00	9375.00	7989.00
8	T8-Emamectin Benzoate 5 SG	0.02%	1250	22.76	28450.00	9400.00	8150.00
9	T9-Chlorpyriphos 20 EC	0.2%	380	22.21	27762.50	8712.50	8332.50
10	T10- UTC	-		15.24	19050.00		

4.3.3 Yield parameters

The results pertaining to percent defoliation, pod damage and grain yield are presented in the Table 10.

4.3.3.1 Per cent defoliation

Least per cent defoliation was observed in case of emamectin benzoate treated plots (26.00 per cent) which was superior to the standard check chlorpyriphos 36.00 per cent. spinosad (32.00 per cent) and poison bait treated plots (36.33 per cent) also recorded least defoliation which was on par with the standard check. However, all the treatments were superior to untreated check. The highest defoliation was noticed in pongamia oil sprayed plots (70.00 per cent)

4.3.3.2 Per cent pod damage

Emamectin benzoate (11.23 per cent) and spinosad (11.22 per cent) treated plots recorded significantly least pod damage compared to other treatments which was significantly superior over the standad check, chlorpyriphos (13.67 per cent). All the treatments were found superior untreated check.

4.3.3.3 Yield (Kg/ha)

There was a significant difference in grain yield among the treatments. Highest grain yield was recorded in emamectin benzoate treated plots (2276.67 Kg/ha) and Spinosad (2274.67 Kg/ha) which were on par with chemical check. However, all the treatments found superior than untreated check.

4.3.3.4 Cost economics

Economics of biorationals in the management of defoliator pests of soybean is presented in Table 11.

The highest net profit was obtained from chlorpyriphos treated plots (Rs. 8332.50) followed by emamectin benzoate (Rs. 8150) and spinosad (Rs. 7989).

5. DISCUSSION

The results of the investigation on the seasonal incidence, resistant varieties and biorationals are necessary to formulate sound pest management strategies. Heavy dependence on chemical for the purpose of plant protection has created lot of problems. Alternate crop protection methods are gaining interest in order to have a sustainable IPM package against many insect pests in field crops.

Defoliators like *S. litura, T. orichalcea and S. obliqua* are major in soybean. Present study was carried out with objectives like seasonal incidence of defoliators, screening of varieties and management of defoliators with utilization of entomopathogens *viz, N. rileyi*, SlNPV, botanicals and animal origin insecticides which ultimately help to develop strong IPM strategies. The results obtained are discussed in the light of available literature.

5.1 Seasonal incidence

The results on the incidence of defoliators was carried out in MARS Dharwad, are discussed here under. The observation on incidence of defoliators was recorded at 15 days interval.

5.1.1 Lepidopteran defoliators

Three lepidopteran defoliators were noticed to feed on the leaves during *kharif*. The newly hatched larvae of *Spodoptera litura* Fab. fed gregariously, on the chlorophyll content of the leaves and skeletonised them. The grown up larvae defoliated the crop.

The incidence of *S. litura* was observed in crop sown during all the dates of sowing. Maximum larval population of 7.80, 12.00 and 12.80 larvae/mrl were noticed during 08-06-06, 27-06-06 and 08-07-06 dates of sowing respectively. The present observations on *S. litura* incidence are in agreement with the findings of Rai *et al*. (1973), Gangrade (1974), Adimani (1976), Satish Kumar and Bhattacharya (1989), Venkataravanappa (1996) and Thippaiah (1997).

Early sown crop during 08-06-06 recorded the lower incidence of *S. litura* (5.58 larvae/mrl) where as late sown crop during 08-07-06 recorded the higher incidence of *S. litura* (7.68 larvae/mrl). Similar observations were noticed by Sontakke and Mishra (1994) who stated that the lowest pest incidence and highest yields were recorded with early sowings (20 June-5 July and 1-15 November)

The studies on light trap catches confirm *Spodoptera* moth emergence which coincided with higher incidence of larvae on soybean (Anon. 1999). The studies on date of sowing carried out at Dharwad also revealed the incidence of *S. litura* with late sown crop of ground nut (Patil, 1995), and same thing was reported on soybean (Patil, 2002).

The green Semilooper, *Thysanoplusia orichalcea*, neonate larvae were found feeding on leaves by scratching the green matter, grownup larvae consumed entire leaves. This pest was noticed defoliating at vegetative stage of the crop. Maximum number of larvae recorded were 6.50, 6.20 and 8.60 larvae/mrl were noticed during 08-06-06, 27-06-06 and 08-07-06 dates of sowing respectively. Similar observations were made by Singh and Chhibber (1969), Saxena (1972), Bhardwaj and Bhalla (1976), Adamani (1976), Singh and Singh (1990) and Tippaiah (1997). Early sowing during 08-06-06 recorded lower incidence of semilooper (3.27 larvae per mrl). Where as, crop sown during 08-07-06 recorded the maximum incidence (4.80 larvae per mrl).

Spilarctia obliqua larvae were gregarious like *S. litura* in early instar and defoliated extensively during peak foliage stage of the crop. Higher incidence of *S. obliqua* was noticed during 08-07-06 sown crop and compared to 08-06-06 sown crop. Populations of *Biloba subsecivella* (*Bilobata subsecivella*), *Chrysodeixis acuta*, *Spodoptera litura* and *Spilosoma obliqua* (*Spilarctia obliqua*) were low in early-sown (22 June and 2 July) soybeans. Incidence of these pests was high in crops sown between 12 July and 1 August (Mandal *et al*., 1998)

Plate.3: Thysanoplusia orichalcae

Plate 4: Spilarctia obliqua

Plate5: Spodoptera litura

Plate6: Spodoptera litura damage

5.1.2 Orthopteran defoliators

Six species of short horned grasshoppers *Chrotogonus trachypterus* Blanchard, *Neorthacris nilgirensis* Uvarov, *Aiolopus thalassinus* (Fabricius), *Gastrimargus africanus* Saussure, *Morphocaris fasciata* (Thumberg), *Cyrtacantharis tatarica* recorded during crop sown at different dates. The incidence of these grasshoppers did not cause any economic damage to the crop, however among these grasshopper species *Chrotogonus trachypterus* Blanchard and *Cyrtacantharis tatarica* were found to defoliate the crop upto 75 and 60 DAG and their incidence was sporadic in nature. Reports on influence of sowing dates on grasshopper are lacking.

Similar damage to soybean by orthopterans was reported by Saxena (1972), Rai *et al.* (1973), Singh (1973), Gangrade (1974), Adimani (1976), Thippaiah (1997), Kamala (2000) and Patil (2002).

Coccinellids, Chrysopids and *N. rileyi* were recorded during crop sown at all dates of sowing the incidence was recorded more in crop sown during 08-07-06.

5.2 Soybean genotypes were screened against major defoliators and results are discussed here under

Ten varieties DSb-1, Bragg, PK1029, JS-9305, KHSb-2, MRSB- 342, DSb 6-1, Monetta, MACS-450 and NRC-67 were tested for relative field resistance to defoliators along with standard check (JS 335).

KHSb–2, DSb-1 and Bragg were identified as resistant varieties against defoliation as they recorded 14.33 per cent, 21.33 per cent and 28.67 per cent defoliation respectively. Where as, JS-335 and Monetta found to be highly susceptible for defoliators as they recorded 66.67 per cent and 63.37 per cent defoliation respectively. Similar observations were made by Garewal *et al.,* (2003) who reported that JS 71-05 was highly resistant and NRC-25 was resistant to green semiloopers. JS 71-05 and NRC-33 were highly resistant, and NRC-18 and NRC-7 were resistant to tobacco caterpillar.

The least per cent pod damage was noticed in Monetta (20.75 per cent), JS-9305 (21.21 per cent), DSb–1 (26.41 per cent), PK 1029 (26.67 per cent), KHSb-2 (27.82 per cent) which were on par with the standard check JS 335 (17.68 per cent) and maximum pod damage was noticed in case of DSb 6-1 (64.33 per cent), MACS 450 (59.72 per cent), Bragg (53.72 per cent) and MRSB 342 (52.45 per cent) and were considered to be highly susceptible to pod borer damage. Similar observation was made by Hag *et al.,* (1984) who noticed good tolerance capacities at both flowering and pod stages in Caribe VCF-1 (BP-2) and F-76-8827 soybean cultivars against *Spodoptera litura*. PUSA-40, NRC-10, NRC-11, JS-SH-78-41 and Bragg varieties had less pod damage compared to other varieties and the pod damage varied from 0.31 to 1.29 per cent (Anon., 1992).

Six genotypes namely JS 335, DSb – 1, PK 1029, JS (SH) 93-05, Monetta and Bragg were rated as susceptible high yielding i.e. tolerant to insect pest complex and rest of the varieties were rated as susceptible low yielding. Similar method was followed by Sharma (1996) who reported that 'maximin-minimax' approach involves a vital yield component and the entire insect-pest complex, to classify the genotypes into resistant groups. It was possible to identify genotypes with resistance/tolerance to a location-specific pest complex and good yield potential. Using this approach, cultivars JS 335 and NRC-2 and a germplasm line L-129 have been found to be tolerant to insect damage. Similar reports were also made by Salunke *et al*., (2002).

The varieties screened in this experiment against defoliators are new entries; hence, there is no information to compare present findings.

5.3 Data pertaining to efficacy of biorationals in the management of defoliators are discussed below

Emamectin benzoate found to be effective in controlling both *S. litura* and *T. orichalcea.* Emamectin benzoate treated plots recorded least larval population during 3, 7, and 15 days after spraying similar trend was noticed during second spray also, which was significantly superior over the standard check chlorpyriphos. Spinosad was found to be the next best treatment and it was on par with the standard check. All the treatments were found superior over untreated control during both sprays. Pongamia oil treated plots recorded highest larval population.

Least per cent defoliation was recorded in emamectin benzoate treated plots (26.00 per cent) which was significantly superior over Standard check (36.00 per cent). Spinosad and poison bait also recorded least per cent defoliation 32.00 and 36.33 per cent respectively which was on par with Standard check. Pongamia oil treated plots recorded highest per cent of defoliation (70.00)

Emamectin benzoate and spinosad recorded least per cent pod damage 11.23 and 11.22 per cent respectively which was superior over the standard check 13.67 per cent. Emamectin benzoate and spinosad even though recorded higher yields of 2276.67 and 2274.67 Kg/ ha respectively the net profit was found to be lower than the standard check due to higher cost of chemicals.

The reviews pertaining to efficacy of emamectin benzoate in soybean ecosystem are lacking, as this is a newer chemical. However, Hall *et al*. (2000) reported highest mortality of soybean looper (*P. includens*) when applied with spinosad at 0.012 and 0.025 lb ai/ acre. Knight *et al*. (2000) reported that indoxacarb, methoxy fenozide and spinosad had good potential to control soybean looper (*Thysanoplusia orichalcea*).

Emamectin benzoate were very effective in controlling *Helothis zea* Boddie, *Keiferia lycopersicella* Walsingham and *Spodoptera exigua* Hubner in tomato (Jansson *et al*., 1996).

Emamectin benzoate found effective in control of bollworm complex as evidenced with lower incidence of square and boll damage (Sontakke *et al*., 2007). Emamectin benzoate 5 SG @ 200 g/ha was found effective in reducing dead hearts and also fruit damage in brinjal, total yield also higher in this treatment (Prasad and Devappa 2006a). Emamectin benzoate 5 SG @ 150 and 200 g/ha was found to be effective in suppressing the larval population of the pest compared to other insecticides. These two treatments also recorded higher yield of cabbage heads per ha (Prasad and Devappa, 2006b).

Emamectin benzoate 5 SG @ 11 g ai /ha was highly effective in reducing the larval population and fruit damage as well in increasing the yield of tomato (Murugaraj *et al*., 2006).

6. SUMMARY AND CONCLUSIONS

The results of the investigation on the seasonal incidence, resistant varieties and biorationals are necessary to formulate sound pest management strategies. Heavy dependence on chemical for the purpose of plant protection has created lot of problems. Alternate crop protection methods are gaining interest in order to have a sustainable IPM package against many insect pests in field crops.

Defoliators like *S. litura, T. orichalcea and S. obliqua* are major in soybean. Present study was carried out with objectives like seasonal incidence of defoliators, screening of varieties and management of defoliators with utilization of entomopathogens *viz, N. rileyi*, SlNPV, botanicals and animal origin insecticides which ultimately help to develop strong IPM strategies. The results obtained are summarized in this chapter.

The incidence of *S. litura* was observed in crop sown during all the dates of sowing. Maximum larval population of 7.80, 12.00 and 12.80 larvae/mrl was noticed during 08-06-06, 27-06-06 and 08-07-06 dates of sowing respectively. Similarly semilooper larvae recorded maximum number 6.50, 6.20 and 8.60 larvae/mrl were noticed during 08-06-06, 27-06-06 and 08-07-06 dates of sowing respectively. Early sown crop recorded lower incidence of *S. litura*, *T. orichalcea* and *S. oblique* compared to that of late sown crop.

Six species of short horned grasshoppers *Chrotogonus trachypterus* Blanchard, *Neorthacris nilgirensis* Uvarov, *Aiolopus thalassinus* (Fabricius), *Gastrimargus africanus* Saussure, *Morphocaris fasciata* (Thumberg), *Cyrtacantharis tatarica* were recorded during crop sown at different dates. The incidence of these grasshoppers did not cause any economic damage to the crop, however among these grasshopper species *Chrotogonus trachypterus* Blanchard and *Cyrtacantharis tatarica* were found to defoliate the crop upto 75 and 60 DAG and their incidence was sporadic in nature.

Coccinellids, Chrysopids and *N. rileyi* were recorded during crop sown at all dates of sowing the incidence was recorded more in crop sown during 08-07-06.

KHSb–2, DSb-1 and Bragg were identified as resistant varieties against defoliation as they recorded 14.33 per cent, 21.33 per cent and 28.67 per cent defoliation respectively.

The least per cent pod damage was noticed in Monetta (20.75 per cent), JS-9305 (21.21 per cent), DSb–1 (26.41 per cent), PK 1029 (26.67 per cent), KHSb–2 (27.82 per cent) which were on par with the standard check JS 335 (17.68 per cent).

Six genotypes namely JS 335, DSb–1, PK 1029, JS-9305, Monetta and Bragg were rated as susceptible high yielding i.e. tolerant to insect pest complex and rest of the varieties were rated as susceptible low yielding.

Emamectin benzoate found to be effective in controlling both *S. litura* and *T. orichalcea*. Emamectin benzoate treated plots recorded least larval population at 3, 7, and 15 days after spraying similar trend was noticed during second spray. Emamectin benzoate was significantly superior over the standard check chlorpyriphos. Spinosad was found to be the next best treatment and it was on par with the standard check.

Least per cent defoliation was recorded in emamectin benzoate treated plots (26.00 per cent) which was significantly superior over Standard check (36.00 per cent). Spinosad and monocrotophos poison bait also recorded least per cent defoliation of 32.00 and 36.33 per cent respectively which was on par with Standard check.

Emamectin benzoate and spinosad recorded least per cent pod damage 11.23 and 11.22 per cent respectively which was superior over the standard check 13.67 per cent. Emamectin benzoate and spinosad even though recorded higher yields of 2276.67 and 2274.67 Kg/ ha respectively the net profit was found to be lower than the standard check due to higher cost of chemicals.

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STUDIES ON INCIDENCE AND MANAGEMENT OF DEFOLIATOR PESTS OF SOYBEAN

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ABSTRACT

Investigations were carried out during *kharif* 2006-07 at Main Agricultural Research station (MARS), Dharwad, on incidence, varietal screening and management of major defoliator pests. Maximum larval population of spodoptera and semilooper (7.80, 12.00 and 12.80 larvae/mrl and 6.50, 6.20 and 8.60 larvae/mrl) was noticed during 08-06-06, 27-06-06 and 08-07-06 dates of sowing respectively. Early sown crop recorded the lower incidence of *S. litura*, *T. orichalcea* and *S. oblique* compared to that of late sown crop.

Six species of short horned grasshoppers *Chrotogonus trachypterus* Blanchard, *Neorthacris nilgirensis* Uvarov, *Aiolopus thalassinus* (Fabricius), *Gastrimargus africanus* Saussure, *Morphocaris fasciata* (Thumberg), *Cyrtacantharis tatarica* recorded. Their incidence was sporadic in nature no economic injury was recorded. Coccinellids, Chrysopids and *N. rileyi* were recorded during crop sown at all dates of sowing the incidence was recorded more in crop sown during late sown crop.

KHSb–2, DSb-1 and Bragg were identified as highly resistant varieties against defoliation as they recorded 14.33 per cent, 21.33 per cent and 28.67 per cent defoliation respectively. The least per cent pod damage was noticed in Monetta (20.75%), JS (SH) 93-05 (21.21%), DSb-1 (26.41%), PK 1029 (26.67%), KHSb-2 (27.82%) which were on par with the standard check JS 335 (17.68%). Six genotypes namely JS 335, DSb-1, PK 1029, JS (SH) 93-05, Monetta and Bragg were rated as susceptible high yielding *i.e.* tolerant to insect pest complex.

Emamectin benzoate found to be effective in controlling both *S. litura* and *T. orichalcea.* Least larval population, least per cent defoliation was recorded in emamectin benzoate treated plots (26.00%) emamectin benzoate and spinosad recorded least per cent pod damage 11.23 and 11.22 per cent and higher yields of 2276.67 and 2274.67 kg per ha, respectively.