BIO ECOLOGY AND INTEGRATED PEST MANAGEMENT OF STEM FLY, *Ophiomyia phaseoli* Tryon (Diptera: Agromyzidae) ON BLACKGRAM AND GREENGRAM

Thesis submitted in part fulfilment of the requirements for the award of the Degree of

MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL ENTOMOLOGY

to the Tamil Nadu Agricultural University, Coimbatore - 641 003

By

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

CENTER FOR PLANT PROTECTION STUDIES

TAMIL NADU AGRICULTURAL UNIVERSITY

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(P. SAKTHIVEL)

ABSTRACT

BIO ECOLOGY AND INTEGRATED PEST MANAGEMENT OF STEM FLY, *Ophiomyia phaseoli* Tryon (Diptera: Agromyzidae) ON BLACKGRAM AND GREENGRAM

By

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Detailed investigations were made on the seasonal incidence, biology, natural enemies, screening of germplasm and chemical control of the stem fly on blackgram and greengram. In blackgram the stem fly damage ranged from 36.0 and 73.0 per cent in November and August, respectively and in greengram the damage was between 2.0 and 12.0 per cent, indicating that blackgram is more susceptible to stem fly than greengram. Stem fly incidence exerted a significant negative association with rainfall and rainy days, whereas the influence of other weather parameters was not significant.

The stem fly species was identified as *Ophiomyia phaseoli* based on its ovipositional site, larval feeding, pupal colour and the pupation site. The mean egg, larval and pupal periods of *O. phaseoli* on blackgram was 3.1, 7.2 and 9.4 days, respectively. The average fecundity of *O. phaseoli* was observed as 23.1 on blackgram. The Stem fly *O. phaseoli* was the only species found to attack on blackgram and greengram.

The maggots of *O. phaseoli* were parasitized by seven species of hymenopteran parasitoids, of which three are Pteromalids, (*Sphegigaster brunneicornis* Ferrier, *Syntomopus nigrus* Sureshan and Narendran, and *Halticoptera propinqua* Waterston), a Braconid, *Opius* sp., a Eurytomid, *Eurytoma* sp., an Eulopid, *Aprostoporoides curiosus* Narendran, and an Eucoilid, *Eucoilidea* sp. Among these parasitoids, *Opius* sp. was found to be predominant as there was a maximum parasitisation of 24.0 per cent followed by *S. brunneicornis* (14.0 %). Parasitism by all other species was less than 10.0 per cent. Among these parasitoids, *Aprostoporoides curiosus*, is reported for the first time in India on *O. phaseoli*. Similarly the parasitisms by *Syntomopus nigrus*, *Halticoptera propinqua*, *Opius* sp., *Eurytoma* sp., *Aprostoporoides curiosus* on stem fly are reported for the first time in Tamil Nadu.

Among 126 blackgram entries tested, only four entries *viz*., COBG 671, AC 222, COBG 672, and COBG 660 were found to be resistant against *O. phaseoli*. Among 114 greengram entries tested, only four entries viz., COGG 912, ML1256, COGG 917 and LM360 were identified as resistant source for *O. phaseoli*.

In general blackgram was found to be more susceptible to stem fly than greengram. Biochemical analysis of resistant blackgram and greengram entries showed that the phenol content ranged from 0.50 to 1.28 mg/g in different entries of blackgram, while it was 1.20 to 2.80 mg/g in resistant greengram entries. The mean tannin, PAL and reducing sugars contents of blackgram entries were 0.46 mg/g, 0.49 µ mol TCA min^{-1} g^{-1} and 1.18 mg/g respectively. Likewise in greengram the mean tannin, PAL and reducing sugars was 0.40 mg/g, 0.46 µ mol TCA min^{-1} g^{-1} and 1.18 mg/g respectively. The high phenol content in greengram was found to be responsible for offering resistance to stem fly.

The seed treatment with carbosulfan + *T. viride* (2 ml + 4g / kg of seed), dimethoate + *T. viride* (5 ml + 4g / kg of seed) and carbosulfan + carbendazim (2ml + 2g / kg of seed) were found to be very effective as it had recorded the low stem fly damage (37.25 to 43.84 %) and root rot (4.04 to 6.65 %) in blackgram. While in untreated plot the stem fly and root rot damage were 58.61 and 23.55 respectively. Similar trend was observed in greengram. Regarding soil application, phorate + carbendazim (0.5 kg a.i / ha + 2g / kg of seed) and carbofuran + carbendazim (1 kg a.i / ha + 2g / kg of seed) combination were found to be highly effective in blackgram, as it had recorded the low stem fly damage (25.08 to 28.55 %) and root rot (5.52 + 7.79 %) while in untreated plot the stemfly and root rot damage were 61.73 and 24.55 per cent respectively. Similar trend was also observed in greengram. Carbosulfan and dimethoate at all the doses tested did not inhibit the growth of *T. viride* indicating its compatibility to insecticides. The growth of *P. fluorescens* at different concentration of carbosulfan and dimethoate was low.

Based on the above findings an IPM module has been developed for the management of stem fly.

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CHAPTER I

INTRODUCTION

Pulses occupy an important position in Indian agriculture as they provide high protein content to the average Indian diet. This is one of the cheapest sources of dietary protein. India grows a variety of pulse crops under a wide range of agroclimatic conditions, contributing to 26 per cent of the global production and is recognized as a major grower of pulses in the world. Inspite of being the largest producer in the world, India has to import pulses to the tune of 2 million tonnes every year to meet its domestic requirement. This is due to the fact that pulses are required in bulk quantity as inseparable ingredients of vegetarian diet (Bhuvaneshwari, 2001). Recent estimates for the year 2003 – 04 indicated that the production of pulses in the country was 15.24 million tonnes from an area of 24.45 m.ha (Masood Ali and Shiv Kumar, 2005).

Among the pulses pigeonpea, chickpea, blackgram and greengram are the major grain legumes in India. However in Tamil Nadu state, the major pulses are pigeonpea, greengram and blackgram. Blackgram is cultivated in an area of 0.02 m.ha with an annual production of 0.75 lakh tonnes and it occupies 34.6 per cent of the total area under pulse cultivation. Greengram is cultivated over 0.01 m.ha with an annual production of 0.53 lakh tonnes and it occupies 31.4 per cent of the total area under pulse cultivation (SCR, 2004). These two crops are predominantly cultivated either as a rainfed crop or as an intercrop with cotton, maize, millets, pigeonpea, sunflower and sugarcane or as a monocrop in *Kharif* season. These crops are also grown as a short duration *Rabi* crop in rice fallow or rice - rice cropping system.

The yield of blackgram and greengram is comparatively low due to biotic and abiotic stresses. Among the biotic factors, the insect pests are of most important. The gram pod borer, *Helicoverpa armigera* Hubner, tobacco cut worm, *Spodoptera litura* Fab. spotted pod

borer, *Maruca vitrata* Geyer, blue butterfly, *Lampides boeticus* Linnaeus, aphid, *Aphis craccivora* Koch, whitefly, *Bemisia tabaci* Gennaidus, blister beetle, *Mylabris* spp. are causing considerable loss in these crops. In recent years the attack of stem fly is noticed in severe form in blackgram and greengram. It was also observed that stem fly damage is occurring along with root rot disease as pest and disease complex. The stem fly, *Ophiomyia phaseoli* Tryon (Agromyzidae: Diptera) is an important pest and is found to attack blackgram, *Vigna mungo*, greengram, *Vigna radiata*, common bean, *Phaseolus* spp., cowpea, *Vigna unguiculata*, lima bean, *Phaseolus* spp., pea, *Pisum sativum*, soybean, *Glycine max* in various parts of India (Plate 1). This pest has been variously referred as stem fly, pea stem borer, soybean stem borer and cowpea stem fly in India and as bean fly in abroad (Bindra and Singh, 1969).

Severe yield loss caused by the stem fly, *O. phaseoli* had been reported from very early years by many workers from all over the world. Rutherford (1914) reported that only 20 plants were obtained out of 600 seeds of *Vigna sinensis*. Kapoor *et al*., 1973 reported yield loss of 15.8 – 47.5 per cent in *Rabi* and upto 96 per cent in *Kharif* sown soybean in India and upto 100 per cent infestation in greengram in Malaysia (Ooi, 1973). Gangrade (1974) mentioned that a net loss of 1.1 g per plant (223 kg/ha) was in evitable even when insecticides were used.

While glancing through the literature it was found that major research programmes were carried out on stem fly in soybean, beans, peas and research on other important legumes such as blackgram and greengram is meager. As the stem fly is assumed as a major pest in Tamil Nadu on blackgram and greengram, there is an urgent need to develop IPM module with easily adoptable IPM components. In the light of the above background, the present research was programmed with the following objectives.

i. To study the seasonal incidence and biology of stem fly

ii. To record the natural enemies of stem fly

iii. To screen the available blackgram and green gram germplasm against stem fly for their relative resistance so as to identify resistant sources

iv. To unravel the biochemical basis of resistance in promising blackgram and greengram entries.

v. To study the effect of seed treatment and soil application with insecticide and fungicide on stem fly and root rot complex and

vi. To develop suitable IPM module for stem fly.

CHAPTER II

REVIEW OF LITERATURE

2.1. Stem flies attacking the genus Phaseolus

Many species of stem flies *viz*., *Agromyza destructor*, *Melanagromyza dolichostigma*, *M. Phaseoli*, *M. sojae*, *M. spencerella*, and *Ophiomyia centrosematis*. attack on Phaseolus crops and are distributed all over the world (Malloch, 1916; Agarwal and Pandey, 1961; Greathead, 1968; Ooi, 1973; Talekar, 1990; Srivastava and Sehgal, 2002; Amit Kumar and Sharma, 2003). Among them *M. phaseoli* is widely distributed in India. *M. phaseoli* had been transferred to the genus *Ophiomyia* and renamed as *Ophiomyia phaseoli* (Spencer, 1973).

2.1.1. Common names of stem fly species

According to Talekar (1990) different species of stem fly is being referred by various names in the world.

Species	Country	Common name
Ophiomyia phaseoli	India	Stem fly, pea stem fly and agromyzid fly
	Other parts of the world	Bean fly, snapbean fly, french bean fly, french bean miner, bean stem maggot, stem borer, pea stem borer, soybean miner, bean agromyza, legume root miner, pea stem borer, bean stem miner
O. centrosematis	India	Stem fly
	Other parts of the world	Bean root miner, stem fly
O. spencerella	India	Stem fly
	Other parts of the world	Bean fly
Melanagromyza sojae	India	Soybean stem fly
	Other parts of the world	Bean stem miner, soybean stem miner, soybean stem borer, soybean leaf miner, soybean fly.

2.2. Global distribution of stem fly Species

Country	*Ophiomyia phaseoli*	*Ophiomyia spencerella*	*Ophiomyia centrosematis*	*Melanagromyza sojae*
India	Singh (1982)		Singh *et al.*, (1981)	
Philippines	Otanes (1918)			IRRI (1982)
Japan	Kato (1961)		Spencer (1962)	Kato (1961)
Singapore	Mathiew (1920)			
China	Campbell (1925)		Sasakawa and Fan (1985)	
Indonesia	Van der Goot (1930)		de Meijere (1940)	Van der Goot (1930)
Mauritius	Moutia (1932)			
Burma	Ghosh (1940)			
Fiji	Lever (1946)			
Taiwan	Chen (1953)		AVRDC (1984)	AVRDC (1984)
Zimbabwe	Taylor (1958)			
Zaire, South Africa	Spencer (1959)			
Sri Lanka	Wickramasinghe and Fernando (1962)			
Australia	Jones (1965)		Spencer (1973)	Shepard *et al.*, (1983)
Egypt	Abul-Nasr and Assem (1966)			
Malaysia	Ho (1967)		Spencer (1973)	
Tanzania	Swaine (1968)	Spencer (1973)		
Israel	Avidov and Harpaz (1969)			

Pakistan	Khan and Shafique (1974)			
Hawaii	Raros (1975)			
Kenya	Khamala (1978)	Greathead (1968)		
Rwanda	Nyabyenda *et al*. (1981)	Trutmann (1986)		
Ethiopia, Mali, Nigeria, Sudan	De Lima (1983)	Spencer (1973)		
Papua New Guinea	Young (1984)			
Uganda		Greathead (1968)		
Thailand			Sasakawa (1981)	
South Korea				Kwon *et al* ., (1980)
Vietnam				Huynh (1981)
Laos				Talekar (1983)

2.3. Host range of stem fly species in different countries

2.3.1. *Ophiomyia phaseoli*

Host species	Country	Reference
Cajanus cajan (Red gram) *Dolichos lablab* (Field bean*),* *D. uniflorus,* *Glycine max* (Soybean) *Lablab niger, Phaseolus vulgaris* *Pisum arvense* *P. phaseolus* *P. sativum* (Pea)	India	Babu (1977) Singh (1982) Agarwal and Pandey (1961) Fletcher (1914) Pandey (1962) Singh and Ipe (1973)

Vigna aconitifolia *V. mungo* (Blackgram) *V. radiata* (Greengram) *V. umbellata* *V. unguiculata* (Cowpea)		
D. auxillaris *D. uniflorus,* *P. austropurpureus* *P. lathyroides* *P. panduratus* *P. vulgaris* *V. marina* *V. mungo* (Blackgram) *V. radiata* (Greengram) *V. ripens*	Australia	Jones (1965) Kleinschmidt (1970) Wilson (1958) Tryon (1894)
Crotalaria juncea (Sunhemp) *C. mucronata* *P. semierectus* *V. hosei* *V. radiata* (Greengram)	Indonesia	Van der Goot (1930)
Cyamopsis psoraloides *Mucuna derringiana* *M. pruriensis* *V. radiata* (Greengram)	Malaysia	Ho (1967) Yunus and Ho (1980) Ooi (1973)
C. cajan (Redgram) *Solanum nigrum*	Egypt	Abul-Nasr and Assem (1966)
G. max (Soybean)	China	Cheu (1944)
G. max (Soybean) *V. mungo* (Blackgram) *V. umbellata*	Kenya	Khamala (1978) Greathead (1968)

L. niger	Uganda	Greathead (1968)
Medicago sativa (Lucerne) *P. coccineus* *V. aconitifolia* *V. angularis* *V. radiata* (Greengram)	Taiwan	AVRDC (1984); Lin (1979); Chiang and Talekar (1980)
Macroptilium lathyroides *Psophocarpus tetragonolobus* *V. radiata* (Greengram) *V. unguiculata* (Cowpea)	Papau New Guinea	Young (1984) Lamb (1978)
Astragalus sinicus	Japan	Kato (1961)
Aeschynomene indica *Flemingia sp.* *Indigofera suffruticosa* *I. sumatrana*	Indonesia	Van der Goot (1930)
G. max (Soybean)	Vietnam, Philippines, Australia	Huynh (1981) IRRI (1982) Shepard *et al*. (1983)
P. vulgaris	Malaysia	Yunus and Ho (1980)

2.3.2 *Ophiomyia spencerella*

L. niger *P. lunatus* *V. mungo* (Blackgram) *V. umbellata*	Kenya, Tanzania, Uganda	Greathead (1968)
P. vulgaris *V. unguiculata*	Rwanda Nigeria	Trutmann (1986) Spencer (1973)

2.3.3 *Ophiomyia centrosematis*

C. cajan (Red gram) *Coccina indica* *P. sativum* (Pea) *Tephrosia candida*	India	ICRISAT (1976) Singh and Ipe (1973) Singh *et al* ., (1979) Sehgal (1965)
Calopogonium mucunoides *Centrosema pubescens* *G.max* (Soybean) *T. vogelli*	Malaysia Indonesia	Spencer (1973) de Meijere (1940) Talekar (1984) Kalshoven (1951)
C. mucronata *D. biflorus* *M. denticulata* *M. sativa* (Lucerne) *V. angularis* *V. mungo* (Blackgram) *V. radiata* (Greengram) *V. unguiculata* (Cowpea)	Tanzania Taiwan	Greathead (1968) Talekar and Lee (1988) AVRDC (1984) Chiang and Talekar (1980)
L. niger *P. lunatus* *P. vulgaris* *V. marina*	Uganda and Kenya Zambia Australia	Greathead (1968) EPADP (1986) Jones (1965)

2.3.4. *Melanagromyza sojae*

G. max (Soybean) *P. sativum* (Pea)	India	Singh (1982) Pandey (1962)
V. aconitifolia *C. cajan* (Redgram)		 AVRDC (1984)
C. juncea (Sunhemp) *G. max* (Soybean)	Taiwan	Chiang and Talekar (1980)

G. soja *M. denticulata* *M. sativa* (Lucerne) *V. angularis*		Lee (1962)
Astralagus sinicus *Aeschynomene indica* *Flemingia sp.* *Indigofera suffruticosa* *I. sumatrana*	Japan Indonesia	Kato (1961) Van der Goot (1930)
G. max (Soybean)	Vietnam Philippines Australia	Huynh (1981) IRRI (1982) Shepard *et al.*, (1983)
P.vulgaris	Malaysia	Yunus and Ho (1980)

2.4. Bionomics of stem fly species complex

2.4.1. *O. phaseoli*

2.4.1.1. Mating

Van der Goot (1930) reported that copulation takes place within two days after the emergence. Lall (1959) observed that mating was soon after emergence, while Agarwal and Pandey (1961) found that adults paired two to six days after emergence. Raros (1975) reported that pairs mated twice a day, once in the morning and again in the afternoon. Copulation of adults in the field last for 40 to 50 minutes with a longest duration of 2 hours and 40 minutes (Singh, 1982).

2.4.1.2. Oviposition

When the damage by *O. phaseoli* was initially recognized, it was believed that adult flies lay eggs in the stem close to the larval feeding site (Froggatt, 1898). But Jarvis (1913) and Holdaway (1925) proved that the insect lays eggs in the foliage and the

oviposition commences three to four days after the adult emergence and continues for 10-15 days (Morgan, 1938).The adults makes ovipositional punctures on the leaves and feed on saps exuding from those punctures (Ho, 1967; Abul-Nasr and Assem, 1968; Raros, 1975). About 10-11 per cent of the punctures made by the adults contained eggs (Jarvis, 1913; Davis, 1969 and Singh, 1982), while Agarwal and Pandey (1961) observed that 15 per cent of the leaf punctures contained eggs. Abul-Nasr and Assem (1968) found that oviposition was activated by sunshine and may occur at any time during the day except noon in summer. Talekar (1990) indicated that the incubation period of eggs various depending upon the temperature. An incubation period of 1.9 to 4 days was reported depending upon the temperature and RH (Raros, 1975; Burikam, 1980; Agarwal and Pandey 1961 and Singh, 1982)

2.4.1.3. Maggot

Soon after hatching the tiny maggot mined the leaf, eventually found its way to a vein and reached one side branch within one to three days. Depending upon the type and age of the plant the maggot tunnelled the stem upto ground level or completed their development in the leaf stalk or leaf axil. Before pupation the last instar maggot cut an exit hole through which the adult emerged. The larval period varied between 9 to 12 days in November - December and 6 to 7 days in June - July (Talekar, 1990).

2.4.1.4. Pupation

Grownup maggot pupated inside the tunnels, mostly in the underground portion of the stem in young plants or in the side branches or in the stem in older plants. The pupal period varied from 5 to 19 days depending upon the season (Talekar, 1990). Pupal period is also influenced by the temperature. On cowpea the pupal period of the insect lasted between 185 to 212 hours with an average of 199 hours at 30 $\pm$ 2^{o}C and 70% RH (Singh, 1982).

2.4.1.5. Adult

The adults were active throughout the day avoiding direct sunlight at noon and flies emerged through the cracks in the stem. The females fed on the sap oozing from the punctures made on the leaves with the ovipositor. The longevity of adult female varied between 8 to 22 days and it was 11 days for male. The total developmental period varied from two and half to four weeks in summer and upto 12 weeks in winter (Davis 1969; Singh, 1982 and Talekar, 1990).

2.4.1.6. Number of generations

A maximum of 14 generations per year was observed by Van der Goot (1930) in Java on snap bean. On soybean 8 to 9 generations were noted between July and April in India (Agarwal and Pandey, 1961 and Pandey, 1962). Eleven to twelve generations were also reported on soybean and french bean (Abul-Nasr and Assem, 1968). Yasuda (1982) and Okinda (1979) reported 11 generations per year on french bean.

2.4.2. Bionomics of *O. spencerella and O. centrosematis*

	O. spencerella	***O. cenrosematis***	**Reference**
Site of oviposition	Oviposits in the hypocotyl at ground level	Oviposits in the stem and hypocotyl region	Greathead (1968) Talekar and Lee (1988)
Nature of larval feeding characters	Larvae mine into the stem and pupate in healthy tissue and construct "Special Window" for emergence of adult	Larvae mine into the stem and pupate beneath the epidermis --	Greathead (1968)
Pupation	Pupate in the root shoot junction as that of *O. phaseoli*	Pupates in the tap root region	Greathead (1968) Talekar and Lee (1988)
Adult	No feeding punctures in the foliage	Make feeding punctures	Spencer (1973) Talekar and Lee (1988)
Total life period (days)	28 to 37	30	Greathead (1968)

2.5 Host Plant Resistance

Biochemical and morphological characteristics are known to contribute to plant resistance to insect pests (Norris and Kogan, 1980). The later have effects through their physical interference with the mechanisms of host selection, feeding, ingestion, digestion, mating and oviposition. Chiang and Norris (1983) reported that during early plant growing stages, bean fly infestation seems to be influenced especially by the trichome density, leaf area, leaf moisture content, stem diameter, leaf dry weight and stem moisture content in older/later stages. Balboa (1972) observed that toughness of stem adversely affected the mining of stems by the larva of *O. phaseoli*. Lin (1979) and Talekar (1980) reported that non-inference was due to presence of low quality of attractant, higher quantity of anti feedants and higher degree of pubescence. Chiang and Talekar (1980) reported that among 6775 soybean and 3713 mungbean accessions, only 4 soybean accessions were highly resistant and 3 mungbean accessions were moderately resistant to all 3 species of stem fly, *O. phaseoli*, *O. centrosematis* and *O. spencerella*

Chiang and Norris (1983) mentioned that the length of internodes of susceptible varieties was atleast twice as that of the resistant ones. Chiang and Norris (1984) reported that purple pigments in the stem epidermis of wild soybean contain specific traits for resistance to beanfly *O. centrosematis*. Kundu and Misra (1983) reported that among 190 soybean germplasm 19 were found to be resistant to bean fly, *O. phaseoli.* According to Amit Kumar and Sharma (2003) among 25 vegetable pea germplasm only 4 entries showed least infestation (0-5%). Gupta *et al*. (2004) identified only four soybean genotypes as resistant to stem fly, when 46 soybean genotypes were listed and one genotype JS-86-24 exhibited multiple resistance against stem fly and pod borer.

2.6. Parasitoids of stem fly species

The parasitoids of different species of stem fly recorded in various parts of the world is summarized below.

2.6.1. *Ophiomyia phaseoli*

Parasitoid	Stage of attack	Host plant	Location	Reference
Tetrastichus sp. Eulophidae : Hymenoptera	-	Soybean	India	Gangrade (1974)
Opius phaseoli Fischer Braconidae : Hymenoptera	Larva	Cowpea, Garden pea	India	Singh (1982)
Polycystus sp. Pteromalidae : Hymenoptera	-	Snapbean	India	Babu (1977)
Sphegigaster sp. Cynipidae : Hymenoptera *Eucoilidea* sp. *Eurytoma* sp. Eurytomidae: Hymenoptera	Larva -	Blackgram Cowpea, Garden pea	India	Singh (1982)
Chrysomotomyia douglasi Girault Eulophidae : Hymenoptera	-	Cowpea	Australia	Kleinschmidt (1970)

Hemiptarsenus sp.	-	Cowpea	Philippines	Litsinger (1987)
O. liogaster Szepliget Braconidae : Hymenoptera	Larva	Snapbean	Zimbabwe	Taylor (1958)
O. importatus Fischer	Larva	Snapbean	Hawaii	Raros (1975)
Opius sp.	Larva	Soybean	Taiwan	Chu and Chou (1965)
Biosteres sp.	Larva	Cowpea	Thailand	Burikam (1980)
Callitula yasudi Yasuda Pteromalidae : Hymenoptera	-	Snapbean	Japan	Yasuda (1982)
Callitula sp.	-	Snapbean	Ethiopia	Negasi (1986)
Cryptoprymna sp.	-	Soybean	Taiwan	Chu and Chou (1965)
Halticoptera sp.	-	Snapbean, cowpea	Egypt	Abul-Nasr and Assem (1968)
Norbanus sp.	-	Snapbean	East Africa	Greathead (1968)
Sphegigaster sp.	Larva	Soybean	Taiwan	Chu and Chou (1965)
S. hamvgurivara *Syntomopus* sp.	Larva	Snapbean	Japan	Yasuda (1982)
S. agromyzae (Dodd)	Larva	Cowpea	Australia	Kleinschmidt (1970)
Cynipoide sp. Cynipidae : Hymenoptera	-	Snapbean	Java	Van der Goot (1930)
Eucoilidea sp.	Larva	Soybean	Taiwan	Chu and Chou (1965)

Eupelmus urozomus Dalman Eupelmidae : Hymenoptera	-	Snapbean Cowpea	Egypt	Abul-Nasr and Assem (1968)
E. larvicola Girault Eurytomidae : Hymenoptera	-	Cowpea	Australia	Kleinschmidt (1970)
Plutarchia sp.	Larva	Mungbean Cowpea	Malaysia Thailand	Ooi (1973) Burikam (1980)
Menismonella shakespearei Girault Chalcididae : Hymenoptera	-	Cowpea	Australia	Kleinschmidt (1970)

2.6.2. *Ophiomyia spencerella*

Eucoilidea sp. Cynipidae : Hymenoptera *O. phaseoli* Fischer Braconidae :Hymenoptera	Larva	Snapbean	East Africa	Greathead (1968)

2.6.3. *Ophiomyia centrosematis*

Cryptorymna sp. Pteromalidae : Hymenoptera *Halticoptera* sp. Pteromalidae : Hymenoptera *Sphegigaster* sp. Pteromalidae : Hymenoptera	Larva	Soybean	Taiwan	Chu and Chou (1965)
Eucoilidea sp. Cynipidae : Hymenoptera	Larva	Snapbean	East Africa	Greathead (1968)`
Eurytoma sp. Eurytomidae : Hymenoptera	-	Soybean	Taiwan	Chu and Chou (1965)
O. phaseoli Fischer Braconidae : Hymenoptera	Larva	Snapbean	East Africa	Greathead (1968)

2.6.4. *Melanagromyza sojae*

Afrostilba sp. Cynipidae : Hymenoptera	-	Mungbean	India	Singh (1982)
Eucoilidea sp.	Larva	Soybean	India	Gangrade (1974)
O. phaseoli Fischer Braconidae : Hymenoptera	Larva	Mungbean	India	Singh (1982)

Sphegigaster sp. Pteromalidae : Hymenoptera *Tetrastichus* sp. Eulophidae : Hymenoptera	-	Soybean	India	Gangrade (1974)
Gronotoma sp. Cynipidae : Hymenoptera *Bracon* sp. Braconidae : Hymenoptera	pupa	Soybean	China	Cheu (1944)
Cryptoprymna sp. *Halticoptera* sp. Pteromalidae : Hymenoptera	-	Soybean	Taiwan	Chu and Chou (1965)
Eurytoma sp. Eurytomidae : Hymenoptera *Euderus* sp. Eulophidae : Hymenoptera	- Larva	Soybean	Java	Van der Goot (1930)

2.7. Integrated pest management for stem fly

2.7.1 Cultural control

Sl.No.	Practice	Nature of protection	References
i.	Earthing up	Encourage the growth of fresh roots above damaged portion	Otanes (1918) Austin (1926) Moutia (1944)
ii.	Mulching with rice straw	Reduce the infestation	Ruhendi (1979) Ampofo (1993)
iii.	Intercropping with maize	Reduce infestation	Van der Goot (1930)
iv.	Fertilizer application	Does not reduce the pest infestation but enhance the plant tolerance	Moutia (1944)
v.	Trap crop and crop rotation	Reduce the damage	Froggat, 1922 Wallace, 1939 Lefevre, 1944 Moutia, 1942 Tryon, 1925

2.7.2 Insecticidal control

2.7.2.1. Seed treatment

Sl.No.	Practice	Nature of protection	Reference
a.	Wet dressing with cyclodiene compounds (aldrin, endrin, dieldrin)	Very effective	Walker, 1960; Wickramasinghe and Fernando, 1962
b.	Seed treatment with phorate alone	Very effective	Bindra and Singh (1969)
c.	Seed treatment with phorate and disyston	Effective protection	Jotwani and Butani (1977); Abo-El Ghar and Maksoud (1960); Vyas and Saxena (1977)
d.	Seed treatment with carbofuran 2% and 4%	Increase in yield upto 11% in *Phaseolus aureus* and 95 per cent in *P. mungo*	Saxena *et al. (*1975); Vyas and Saxena (1977); Sinha *et al.* (1993)

e.	Seed treatment with chlorpyriphos, dimethoate and monocrotophos @ 10ml / kg of seed	Effective control upto 28 DAS	Chander and Singh (1991)
f.	Seed treatment with carbosulfan 5, 6 and 7 per cent	Highly effective in reducing the no. of mines / plant, percentage of infested plants.	Mote and Shah (1983)
g.	Seed treatment with carbosulfan and monocrotophos	Effective in reducing the stem fly incidence	Ramdoss and Sivaprakasam (1993)
h.	Seed coating with dimethoate on blackgram	Most economically viable treatment with highest cost benefit ratio of 1: 229:70	Pisal *et al.* (1999)
i.	Seed treatment with chlorpyriphos 20 EC @ 8 ml/ kg seed	Highly effective against stem fly	Dodia *et al.* (2005)

2.7.2.2 Soil application

i	Soil application of disulfoton and phorate granules in soybean and asparagus bean	Highly effective	Chiang (1971) Verma and Pant (1975)
ii	Dusts of aldrin and BHC mixed into soil before peas were sown	Significant reduction on stem fly damage	Singh (1970); Singh *et al. (*1974); Kapoor *et al.* (1973)
iii	Soil application of cyolane, disulfoton, cytrolane and phorate (1.5 kg a.i/ha) in mungbean	Highly effective	Pablo and Pangga (1971), Naresh and Thakur (1972), Bindra and Singh(1969)
iv	Carbaryl and thiodemeton granules @ 1 kg a.i/ha	Proved most effective	Saxena (1972)
v	Monocrotophos (0.75 kg a.i./ha) applied twice in blackgram	Offered protection upto one month	Kapoor *et al.* (1973)

vi	Soil application with phorate, disulfoton, aldicarb or carbofuran granules @ 1.0 kg a.i/ha	Highly effective in soybean, greengram and cowpea	Bhattacharjee (1976) Srivastava and Singh (1976); Chaudhary *et al.* (1981)
vii	Aldicarb 10 g (2.0kg a.i. / ha) mixed with soil around root zone	Highly effective	Jotwani and Butani (1977)
viii	Application of carbofuran (3%) or phorate 10 G @ 1 kg a.i. / ha	Proved quite effective	Sharma *et al.* (1981); Brar *et al.* (1993) Krishnamoorthy and Tewari (1987); Kundu and Mishra (1983)
ix	Thimet 10g + captan (10 kg ha^{-1} + 3 g^{-1} kg)	Most effective in reducing plant mortality and increasing yield	Harpal and Singh (2001)
x	Soil application of lindane @ 0.5 kg a.i./ha	Effective in controlling pea stem fly	Sharma *et al.* (2003)

2.8.2.3 Foliar application

a	Spray with nicotine sulphate and white oil at different concentration	Gave adequate protection	Morgan (1938); Caldwell (1939); Hassan (1947)
b	Spray with organochlorine insecticides	Successful protection	Hely (1945) Moutia (1945) Smith (1945) Saunders (1968) El-Kifl *et al.* (1973) EI-Nahal and Assem (1970)
c	Diazinon 0.05 % or 0.02 % spray	Effective protection	Braithwaite (1957) and Hua (1967)
d	Dimethoate (0.03 %) spray at three, seven and fourteen DAG	Ensured bean fly free navy beans	Passlow (1969)

e	Foliar treatment with nuvacron (0.04 %), dimethoate (0.04 %) and endosulfan (0.05 %)	Recorded nil damage by the stem fly on soybean	Kapoor *et al.* (1973) Saxena (1972) Jotwani and Butani (1977)
f	Foliar spray with triazophos (0.04 %) for four times at weekly intervals	Highest yield was obtained	Sudarwohadi and Eveleens, (1974)
g	Foliar spray of endosulfan (0.7 kg a.i/ha) at 15 and 25 DAS	Effective in reducing *O. phaseoli*	Krishnamoorthy and Tewari (1987)
h	Foliar application of monocrotophos (0.04%) after 30 DAS	Effective in reducing the incidence of *O. phaseoli*	Srivastava and Sehgal (2002)
i	Foliar application of of chlorpyriphos	Successfully controlled the *O. phaseoli* in blackgram	Pisal *et al*. (1999)

CHAPTER III

MATERIALS AND METHODS

Research methodology followed for the study of seasonal incidence, biology, host plant resistance and management practices for *O. phaseoli* is presented below.

3.1. Seasonal incidence

Seasonal incidence of stem fly, *O. phaseoli* was studied at the Department of Pulses, Tamil Nadu Agricultural University, Coimbatore, in Blackgram (variety CO 5) and green gram (variety CO 6). Eight monthly sowings for each crop was taken up in an area of 40 m^2 starting from August 2005 to March 2006. These crops were raised by following the recommended agronomic practices except plant protection measures. Observation on the stem fly incidence was made at 15 days after sowing by collecting 50 plants at random per plot. The stem fly damage (%) was worked out by recording the total number of healthy and affected plants using the following formula,

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

3.2. Influence of weather parameters

The data on weather parameters such as maximum temperature (°C), minimum temperature (°C), morning Relative Humidity (%), evening Relative Humidity (%), wind speed (KMPH), total rainfall (mm) and number of rainy days during the crop period were obtained from the Department of Agricultural Meteorology, Tamil Nadu Agricultural University. The incidence of stem fly recorded in the seasonal incidence study was correlated with all the above parameters by using the incidence of stem fly as dependent variable (Y) and each of the weather parameters as independent variables (X) (Panse and Sukhatme, 1967).

3.3. Studies on the biology of stem fly

The mass culturing of stem fly was initiated by collecting stem fly puparia from affected blackgram stems from the infested field. The collected puparia were maintained in the glass vials for the adult emergence. On emergence the female flies were identified based on their prominent ovipositor from that of males with blunt abdomen. A total of six blackgram plants were raised in small pots (15 x 15 cm) for oviposition. These plants were confined with mylar film cage (30 x 13 cm). A pair of freshly emerged stem fly was released for oviposition. Ten such replicates were maintained (Plate 2).

The presence of stem fly eggs were observed by staining the leaves of blackgram by following the staining method of Parella and Robb (1982) who used against serpentine leaf miner, *Liriomyza trifolii* which is also an agromyzid fly. The leaves were boiled for three to five minutes in lactophenol acid fuschin solution (one part each of distilled water, lactic acid and phenol and two parts of glycerine were added to make a solution. To this acid fuschin was added at the rate of 1:1000) which was then allowed to cool for three to five hours. Excess stain was removed by rinsing with warm water and leaves were transferred to small Petridish containing warm water which were kept under microscope for the examination of eggs of the stem fly.

The egg period was assessed by staining the leaves harbouring the eggs. The leaves with hatched eggs will be showing only ovipositional punctures. The time gap between the presence of eggs and leaves with empty egg laid space was considered as egg period. The egg period was assessed by removing three leaves per replication, a total of 30 leaves were observed from 10 replications. Two such observations, eight were made on 4^{th} and 6^{th} day after the adult release. After the egg period one plant in each replication was removed and split open the stem for the presence of first instar maggot. Based on the earlier report on larval period (9-12 days) three observation were made in

nine days. Six days after the first observation, one plant in each replication was removed and observed for the pupal formation. Third observation was made 3 days after the second observation and observed for the pupal formation. Based on the above information the larval period was computed. A total of 30 puparia were collected from the remaining plants and kept in glass vials for the adult emergence. The pupal period was computed based on the time gap between the pupal initiation and till the emergence of adults.

The fecundity of stem fly was studied by releasing a pair of stem fly adults in a pot with mylar film cage having six plants at two leaves stage, ten such replicates were maintained. After the death of released adults all the leaves were observed for the presence of eggs. Based on the total number of eggs laid the fecundity of a female was assessed.

3.4. Occurrence of natural enemies

The stem fly puparia from the affected black gram plants were collected at regular intervals and observed for parasitoid / stem fly adult emergence. The different species of parasitoid emerged and their per cent parasitism was worked out based on the number of parasitoids / stem fly adults emerged. The different species of parasitoids that emerged from the stem fly puparia were sent to Project Directorate of Biological Control, Bangalore for the species identity.

3.5. Screening of greengram and blackgram germplasm

A total of 126 blackgram and 114 greengram germplasm received from the Department of Pulses, Tamil Nadu Agricultural University, Coimbatore were field evaluated during *kharif* 2005 for their relative resistance / susceptibility to stem fly in comparison with the latest released blackgram variety CO 5 and greengram variety CO 6. Each entry was sown in two rows of 5 m length with a spacing of 30 x 10 cm (unreplicated). Recommended agronomic practices were followed for raising the crops

except plant protection measures. The Pest Susceptibility Index (PSI) grade for each accession was worked out based on the All India Coordinated Pulses Improvement Project methodology (Durairaj, 2006). The accessions which recorded less than 10 per cent of stem fly damage during *Kharif* 2005 were again screened during *Rabi* 2005 for further confirmation.

3.5.1. Pest Susceptibility Index (PSI)

The relative resistance / susceptibility of blackgram and greengram accessions were assessed by using the following formula and rating scale (AICRP, 2003).

$$PSI = \frac{\text{\% damage in check entry} - \text{\% damage in test entry}}{\text{\% damage in check entry}} \times 100$$

PSI grade	PSI value
1	>101
2	76 to 100
3	51 to 75
4	26 to 50
5	11 to 25
6	10 to -10
7	-11 to -25
8	-26 to -50
9	>-51

3.6. Biochemical basis of resistance

The blackgram and greengram accessions which showed very low damage of stem fly on both seasons (*Kharif* and *Rabi* 2005) were subjected to chemical analysis for the biochemical basis of resistance. The total phenol, tannin, phenylalanine ammonia lyase and reducing sugars content were analysed on the above blackgram and greengram

accessions along with check varieties based on the earlier works of Murugan (2003) and Jeyakumar (1995) who stated that above chemical constituents may contribute resistant to dipteran insects. Biochemical analyses were made on 7^{th} and 15^{th} day after sowing of blackgram and green gram which are the critical stages for stem fly damage.

3.6.1. Estimation of total phenol

The total phenol was estimated by Folin-ciocalteau reagent method as described by Malik and Singh (1980). For this 0.5g of greengram / blackgram stem was taken and ground thoroughly with a pestle and mortar with 5 ml of 80 per cent boiling ethanol. The extract was centrifuged at 10,000 rpm for 10 minutes. The supernatant was made upto 25 ml with distilled water and used for phenol estimation.

From the ethanol extract 0.1 ml was taken in test tubes and evaporated in boiling water bath. To this 6 ml, water was added and shaken well. Then 0.5 ml of Folin-ciocalteau reagent was added to each test tube and 2 ml of 20 per cent sodium carbonate was added after 5 minutes. After 30 minutes the blue colour developed was measured at 660 nm in a Spectrophotometer (Malik and Singh, 1980). From the standard graph the amount of phenol present was calculated and expressed as mg/g of plant tissues.

3.6.2 Estimation of phenylalanine ammonia lyase (PAL)

3.6.2.1. Enzyme extraction

Blackgram and greengram stems (1g each) were homogenized individually with 10 ml of sodium phosphate buffer (pH 7.0) and centrifuged at 1000 rpm for 15 minutes, the supernatant was used as enzyme source.

3.6.2.2. Assay of phenylalanine ammonia lyase activity

PAL assay was conducted as per the method described by Ross and Sederoff (1992). The assay mixture containing 100 ml of enzyme, 500 ml of 50 m M Tris HCL (pH 8.8) and 600 ml of phenylalanine was incubated for an hour. The reaction was arrested by

adding 2N HCl. Later 1.5 ml of toluene was added and vortexted for 30 seconds then centrifuged at 1000 rpm for 15 minutes. The toluene fraction containing Trans Cinnamic Acid (TCA) was separated. The toluene phase was measured at 290 nm against the blank of toluene. Standard curve was drawn with graded amount of cinnamic acid. The enzyme activity was expressed as µ moles of cinnamic acid / minute / g plant tissue.

3.6.3. Estimation of tannin (Schanderl, 1970)

For this 0.5 g of blackgram / greengram stem was taken in a 250 ml conical flask and 75 ml of water was added and boiled gently for 30 minutes. The extract was cooled and the volume made upto 100 ml. The extract was centrifuged at 2000 rpm for two minutes. The supernatant was used for tannin estimation. From the extract, 1 ml aliquot was taken and 5 ml Folin-Denis reagent were added followed by 10 ml sodium carbonate solution and mixed after each addition and the volume was made upto 100 ml. The colour that developed was measured in a Spectrophotometer at 700 nm after 30 minutes. Tannic acid was used as standard. From the standard graph the amount of tannin present was calculated and expressed as mg/g of plant tissues.

3.6.4. Estimation of reducing sugars (Somogyi, 1952)

One gram of blackgram / greengram was weighed separately and extracted with 80 per cent ethanol in a pestle and mortar. The reducing sugars when heated with alkaline copper tartarate reduced the copper in the cupric state into cuprous state. When the cuprous ion was treated with arsenomolybdate, reduction of molybdic acid to molybdenum blue takes place. The blue colour was measured at 620 nm. Glucose served as standard. From the standard graph the amount of reducing sugars present was calculated and expressed as mg/g of plant tissues.

3.7. Field evaluation of insecticides and fungicides as seed treatment against stem fly

A field trial with blackgram variety CO 5 and greengram variety CO 6 was laid out at Department of Pulses, Tamil Nadu Agricultural University, Coimbatore during *Rabi* 2005. The seeds of blackgram and green gram were treated with insecticides, fungicides and microbial agents as detailed below.

Treatments	Dose / kg of seed
T_1 - Dimethoate	5 ml
T_2 - Carbosulfan	2 ml
T_3 - Carbendazim	2g
T_4 - *Trichoderma viride*	4g
T_5 - *Pseudomonas fluorescens*	10g
T_6 - Dimethoate + Carbendazim	5 ml + 2 g
T_7 - Dimethoate + *T. viride*	5 ml + 4 g
T_8 - Dimethoate + *P. fluorescens*	5ml + 10g
T_9 - Carbonsulfan + Carbendazim	2 ml + 2g
T_{10} - Carbosulfan + *T. viride*	2 ml + 4g
T_{11} - Carbosulfan + *P. fluorescens*	2 ml + 10g
T_{12} - Untreated check	-

This experiment was conducted in a randomized block design in a plot size of 5 x 4 m and replicated thrice. Separate experiment was conducted for black gram and greengram. All the recommended package of practices were followed for raising the crop.

3.7.1. Stem fly damage assessment

The stem fly damage was assessed on 15th and 30th day after sowing by collecting 100 plants at random for each observation. The stem fly damage (%) was worked out as described in the earlier studies.

3.7.2. Root rot damage

The root rot damage (%) was also recorded from the plants removed for stem fly damage and the per cent damage was worked out.

3.7.3. Stem fly and root rot complex

Observations on the plants showing the symptom of both stem fly and root rot damage on the same plant were also made and per cent stem fly and root rot complex damage was worked out.

All the above observations were made both for blackgram and greengram.

3. 8. Field evaluation of insecticides and fungicides as soil application against stem fly

Soil application of various insecticides, fungicides and combination of insecticides and fungicides that were tried against stem fly are as detailed below. The following treatments were imposed in the soil before sowing. This experiment was conducted in a randomized block design with a plot size of 5 x 4 m and replicated thrice. The crop was raised by following the recommended package of practices.

Treatment		Dose / ha
Neem cake	(T_1)	625 kg
Carbendazim (drenching)	(T_2)	0.1%
Carbofuran	(T_3)	1 kg a.i.
Lindane	(T_4)	0.5 kg a.i.
Phorate	(T_5)	0.5 kg a.i.
Neem cake + Carbendazim	(T_6)	625 kg + 0.1%
Carbofuran + Carbendazim	(T_7)	1 kg a.i + 0.1%
Lindane + Carbendazim	(T_8)	0.5 kg a.i + 0.1%
Phorate + Carbendazim	(T_9)	1 kg a.i + 0.1%
$ZnSO_4$	(T_{10})	25 kg
Untreated check	(T_{11})	--

The stem fly, root rot and stem fly-root rot complex damage were assessed in each treatment as described earlier.

3.9. Compatibility test with biocontrol agents

The fungal biocontrol agent, *Trichoderma viride* Pers. ex Gray and the bacterial biocontrol agent, *Pseudomonas fluorescens* Migula were tested for their compatibility with insecticides, dimethoate and carbosulfan.

3.9.1. Compatibility test with *Trichoderma viride*

Potato Dextrose Agar (PDA) was used as the basal medium. The sterilized and molten medium was mixed thoroughly by gently swirling the flask, poured 15 ml in each sterile Petri dish and allowed to solidify. Blackgram seeds were sterilized by using 0.1 % mercuric chloride in order to prevent the seed borne contamination. The calculated quantity of insecticides *viz.*, dimethoate and carbosulfan was separately treated with the blackgram seeds to give required concentrations *viz.*, 250, 500, 1000 ppm and 750, 1500 and 3000 ppm for carbosulfan and dimethoate respectively. After treating with insecticides the seeds were treated with recommended dose of *T. viride* (4g/kg) commercial product obtained from Pathology Department, Tamil Nadu Agricultural University.

The seeds were placed on the plates at five numbers per plate and incubated at room temperature (28 ± 2°C). The seeds without insecticidal treatment inoculated with *T. viride* alone served as control. Five replications were maintained for each concentration. The radial growth of mycelium was observed periodically at 24, 48 and 72 hours after inoculation.

3.9.2. Compatibility test with *Pseudomonas fluorescens*

King's B (KB) medium was used as the basal medium. The procedure mentioned earlier for *T. viride* was followed. The seeds were treated with recommended dose of *P. fluorescens* commercial product (10g/kg) obtained from the Pathology Department,

Tamil Nadu Agricultural University. The treated seeds were placed on the Petri plate and incubated at room temperature (28 ± 2°C). The seeds without insecticidal treatment inoculated with *P .fluorescens* served as control. Five replications were maintained for each concentration. The growth of bacteria was observed at 24, 48 and 72 hours after inoculation.

3.10. Statistical analysis

The statistical analyses for the various experiments were made by following the standard procedure as described by Panse and Sukhatme (1967). Statistical analysis of field data was done under FRBD. The percentage data were subjected to arcsine transformation. Mean values of treatments were classified by adopting Duncan's multiple range test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

EXPERIMENTAL RESULTS

Studies were carried out on the seasonal incidence, biology, natural enemies, screening of germplasm and chemical control for the stem fly, *Ophiomyia phaseoli* of blackgram and greengram. The results of the various experiments conducted are presented in this chapter.

4.1. Seasonal incidence of stem fly

Quantum of the stem fly damage (%) in different monthly sowings is presented in Fig 1. In general, the stem fly infestation was more in blackgram than in greengram. On blackgram the damage ranged from 36.0 and 73.0 per cent in November and August respectively. In other monthly sowings the damage was by 40 - 60 per cent. However in greengram the damage was varied from 2.0 to 12.0 per cent. This clearly showed that blackgram is more susceptible to stem fly than greengram. The variation in stem fly damage in blackgram and greengram over the period is presented in Fig 1.

4.2. Influence of weather parameters on the incidence of *O. phaseoli*

The per cent infestation of *O. phaseoli* was correlated with previous month mean weather parameters. A multiple regression analysis was made. Details of weather data are furnished in the appendix. The correlation matrix showing the relationship with the *O. phaseoli* incidence on blackgram is furnished in Table 1. The stem fly damage had a significant negative association with rainfall (r = -0.814) and rainy days (r = -0.840). However, the influence of maximum temperature minimum temperature, RH and wind speed on *O. phaseoli* incidence was not significant. Though the RH was not significant, it also negatively influenced on stem fly damage (r = 0.551 evening RH). The results of multiple regression analysis showed an R^2 value of 0.71 revealing that 71 per cent of variation in *O. phaseoli* incidence was influenced by the weather parameters (Table 2).

The multiple regression equation fitted with weather parameters to predict the *O. phaseoli* incidence is

$$Y = 59.49 + 0.032\ X_5 - 2.59\ X_6$$

This indicated that an increase of one unit of rainfall and rainy day would lead to a decrease of 0.032 and 2.59 in *O. phaseoli* incidence respectively.

The results of the correlation studies of *O. phaseoli* on green gram with mean weather parameters are presented in Table 3. While considering individually, the influence of minimum temperature, evening RH, rainfall and rainy days on *O. phaseoli* incidence on green gram was not significant. However considering as a whole *O. phaseoli* incidence exerted a negative association with the above weather parameters. Results of the multiple regression analysis showed an R^2 value of 0.52 revealed that 52 per cent of the variation in *O. phaseoli* was influenced by the weather parameters.

4.3. Biology

The adult female was found to wander over the surface of the leaves to locate a suitable spot for oviposition. After selecting a convenient spot, the female inserted her ovipositor vertically into the leaf and laid the eggs. Mostly the eggs were laid close to the midrib of the leaf. The eggs were laid singly on both the surface of the leaves. But more number of eggs were laid on the lower surface of the leaves. Though many punctures were detected, only a few contained eggs.

The egg was oval, elongate and whitish with a transparent surface. The egg appeared light green in colour due to the colour of the plant tissues in which it was embedded (Plate 3). The incubation period varied from 2.5 to 3.5 days with an average of 3.1 days (Table 4).

The newly hatched maggot was yellowish white in colour. The maggot after hatching mined the leaf gradually towards the midrib. It entered the midrib and continued mining towards the leaf stalk and reached the main stem. Then it tunneled down the main stem upto ground level. A white mine with frass particles was left behind during tunneling. The fully developed maggot was deep yellow in colour. Before pupation the maggot made an exit hole in the stem for the emergence of adults. The larval period varied from six to eight with an average of 7.2 days (Plate 3).

The fully developed maggot changed into pupa inside a small barrel shaped yellow puparium, which later became dark brown. Pupation occurred under the thin epidermis of the damaged stem. The pupal period lasted from 8 to 10 days with an average of 9.4 days (Plate 4).

The fully developed adult was metallic black in colour. The female was slightly bigger than the male. The female had a prominent ovipositor and while the male had a blunt abdomen (Plate 4).

4.4. Species complex of stem fly

The studies on the species complex of stem fly revealed that the specimens collected from this location were identified as *Ophiomyia phaseoli*. The following facts confirm the above statements.

4.4.1. Egg

In the present study, the eggs were laid on the leaves both on upper and lower surface, but mostly on the lower surface. Often the eggs were situated near the midrib. This was a prominent feature of *O. phaseoli,* whereas *O. centrosematis* and *O. spencerella* laid eggs in the hypocotyl region only (Plate 5).

4.4.2. Larva

The study revealed that larva was a feeder of cortex region in the stem. This is also a prominent feature of *O. phaseoli*, whereas *O. centrosematis* was found to feed on the cortex of tap root (Plate 5).

4.4.3. Pupa

The present investigation revealed that puparium was pale yellow, straw coloured or light brown during early stages and became dark brown at maturity (Plate 5). This is the most prominent character of *O. phaseoli* that distinguishes it from *O. spencerella* which had shiny black pupae which could be seen even without removing stem epidermis. In the present study, it was observed that pupation occurred on the root-shoot junctions, which is identical to *O. phaseoli*, whereas in *O. centrosematis* the puparium was found in both stem and root region (Plate 5).

4.4.4. Adult

The present study revealed that the body of the adult fly was dark with fine pubescence. Mesonotum and abdominal tergites were clearly shining. Frons appeared darkish. These are the characteristics features of *O. phaseoli*, whereas in case *O. spencerella*, first halves of abdominal tergites were dark reddish or brownish and second halves were black in appearance. The above characteristic features of the egg, larva, pupa and adult instars revealed that the stem fly species found in this location was *O. phaseoli*.

4.5. Record of parasitoids

The study revealed that maggots of *O. phaseoli* were parasitized by seven species of hymenopteran parasitoids, of which three are from Pteromalids, *Sphegigaster brunneicornis* Ferrier, *Syntomopus nigrus* Sureshan and Narendran, and *Halticoptera propinqua* Waterston, a Braconid, *Opius* sp., an Eurytomid, *Eurytoma* sp., an Eulophid, *Aprostoporoides curiosus*

Narendran, and an Eucoilid, *Eucoilidea* spp. (Table 5). All these parasitoids were seemed to attack egg-larval instars as it was found to be parasitized during larval stage and emerged from the pupal stage of stem fly. The parasitism by various species was found to vary significantly (Plate 6 & 7). Among these parasitoids *Opius spp.* was found to be predominant with a maximum parasitisation of 24.0 per cent followed by *S. brunneicornis* (14.0 %) and other species had less than 10.0 per cent (Fig. 2).

4.6. Germplasm screening

4.6.1. Screening of blackgram entries for their relative resistance / susceptibility to stem fly *O. phaseoli*

The relative resistance / susceptibility of blackgram entries against stem fly during *Kharif* 2005 are presented in Table 6. All the blackgram entries were infested with stem fly at ranging levels. A minimum of four per cent was recorded in COBG 671, AC 222 and COBG 672 to a maximum of 94 per cent in AC 31and PANT U 02/3 with a Pest Susceptibility Index (PSI) of 2 to 8 rating scale respectively. Among 126 entries tested, only ten entries viz., COBG 671, AC 222, COBG 672, AC 297, COBG 660, SM 114, COBG 624, AC 258, AC 218, and SM 107 registered less than 10 per cent damage with a PSI grade of 2. The above entries were found to be superior over the released blackgram variety CO 5. Overall performance of entries as per the PSI grade recorded are detailed below.

PSI Grade	Damage range (%)	No. of entries
2	76 to 100	8
3	51 to 75	19
4	26 to 50	33
5	11 to 25	15
6	10 to -10	31
7	-11 to -25	5
8	-26 to -50	4

4.6.2. Screening of greengram entries for their relative resistance / susceptibility to stem fly *O. phaseoli*

Details of reaction of greengram entries against stem fly and PSI grades during *Kharif* 2005 are presented in Table 7. Damage by the stem fly on the test entries ranged from four per cent in COGG 912 to 42 per cent in SM 207, with PSI range from 2 to 9 respectively. Among 114 entries tested, only 10 entries viz., COGG 912, ML1256, COGG 917, ML 881, MGG 351, LM 360, LM 255, COGG 923, TM 2000-58 and COGG 924 registered less than 10 per cent of stem fly damage with PSI grade of 3. The above entries were found to be superior than the released greengram variety CO 6. The other entries recorded the PSI grade as below,

PSI Grade	Damage range (%)	No. of entries
4	26 to 50	20
5	11 to 25	18
6	10 to -10	20
7	-11 to -25	10
8	-26 to -50	15
9	> -51	30

4.6.3. Screening of promising blackgram entries against stem fly during *Rabi* 2005

Ten entries of blackgram which recorded less than 10 per cent of stem fly damage were reevaluated during *Rabi* 2005 for further confirmation. This study showed that only four entries *viz*., AC 222, COBG 671, COBG 660 and COBG 672 recorded less than 10 per cent stem fly damage (Plate 8) and were subjected to biochemical analysis (Table 8).

4.6.4. Screening of promising greengram entries against stem fly during *Rabi* 2005

Details of the reaction of greengram entries against stem fly and PSI grades during *Rabi* 2005 are presented in Table 9. Ten entries of greengram which recorded less than

10 per cent of stem fly damage were re-evaluated during *Rabi* 2005 for further confirmation. This study showed that only four entries viz., COGG 912, COGG 917, ML 1256 and LM 360 recorded less than 10 per cent damage (Plate 8) and were subjected to biochemical analysis.

4.7. Biochemical basis of resistance in blackgram and greengram accessions

The biochemical constituents such as total phenols, tannins, phenylalanine ammonia lyase activity and reducing sugars were estimated in blackgram entries such as AC 222, COBG 671, COBG 660, COBG 672 and CO 5. Similarly in greengram entries such as COGG 912, COGG 917, ML 1256, LM 360 and CO 6 were analysed for the biochemical basis of resistance to stem fly (Fig 3 & 4).

4.7.1. Total phenol

The phenolic content of the resistant and check entries of blackgram is presented in Table 10. All the entries were found to contain higher amount of phenol content on both 7 and 15 DAS than the check. The total phenol content was found to be more at 15 DAS than 7 DAS in all the entries tested. On 15 DAS a maximum phenol content of 1.50 mg/g was observed in AC 222 more than in check variety CO 5 (1.00 mg/g). The other entries COBG 671, COBG 672 and COBG 660 recorded the phenolic content of 1.25, 1.25 and 0.95 mg/g respectively (Table 10). Similar trend was observed in greengram entries also. Among the greengram entries analysed the entry COGG 912 recorded the maximum amount of phenol (2.80 mg/g) as against 1.40 mg/g in CO 6 on 15 DAS (Table 11). The other entries COGG 917, ML 1256 and LM 360 recorded the phenol content of 2.40, 2.10 and 2.00 mg/gm respectively.

4.7.2. Tannin content

The tannin content also was found to be more at 15 DAS than 7 DAS in all the entries tested except check CO 5. On 15 DAS a maximum tannin content of 0.63 mg/g was observed in AC 222 than on check variety CO 5 (0.34 mg/gm). The other entries

COBG 672, COBG 671 and COBG 660 recorded the tannin content of 0.44, 0.40 and 0.36 mg/gm respectively (Table 10). Similar trend was observed in greengram entries also. However the tannin content was more in blackgram than greengram. Among the green gram entries analysed the entry LM 360 contained the maximum amount of tannin (0.44 mg/gm) as against 0.30 mg/gm in check entry CO 6 on 15 DAS. While the other entries COGG 912, ML 1256 and COGG 917 had 0.42, 0.38 and 0.36 mg/gm respectively (Table 11).

4.7.3. Phenylalanine Ammonia Lyase (PAL)

All the blackgram accessions showed significantly higher activity of PAL at 15 DAS than 7 DAS. On 15 DAS higher PAL activity of 0.74 µ mol TCA / min / g of stem tissue was observed in COBG 671 as against 0.30 µ mol TCA / min / g of stem tissue in check CO 5. The other entries COBG 660, AC 222 and COBG 672 recorded the PAL activity of 0.55, 0.40 and 0.28 µ mol TCA / min / g of stem tissue respectively (Table 12). Similar trend was observed in greengram entries also. However the PAL activity in both blackgram and greengram entries was almost similar. Among the greengram entries analysed, the entry COGG 912 recorded the PAL activity of 0.65 µ mol TCA / minutes / g of stem tissue as against 0.28 µ mol TCA / min / g of stem tissue in check CO 6 on 15 DAS. The other entries LM 360, ML 1256 and COGG 912 recorded the PAL activity of 0.55, 0.46 and 0.18 µ mol TCA / minutes / g of stem tissue respectively (Table 13).

4.7.4. Reducing sugars

The reducing sugars content were found more at 7 DAS than 15 DAS in all the entries tested. All the blackgram accessions recorded minimum level of reducing sugars compared to check on 7 and 15 DAS. The entry AC 222 recorded lower level of reducing sugars 0.85 mg/g as against 1.60 mg/g in check entry CO 5 on 15 DAS. The other entries like COBG 671, COBG 672 and COBG 660 recorded 1.10, 1.35 and 1.45 mg/g respectively (Table 12). Similar

trend was observed in greengram entries also. However the reducing sugars content was low in greengram than in blackgram. Among the greengram entries analysed, the entry LM 360 recorded the lowest amount of reducing sugars content 0.85 mg/gm against 1.50 mg/gm on check entry CO 6. While the other entries COGG 912, ML 1256 and COGG 917 had 1.10, 1.30 and 1.50 mg/gm respectively (Table 13).

4.7.5. Biochemical constituents in Blackgram and greengram at 15 DAS

It was found that except phenol all the other biochemicals such as tannin, phenylalanine ammonia lyase and reducing sugars were found in almost equal amount in blackgram and greengram. While phenol was very high in greengram (2.32 mg/g of plant tissue) as against 1.28 mg/g of plant tissue in blackgram (Table 14).

4.8. Effect of seed treatment on stem fly and root rot complex in blackgram

The stem fly incidence on 30 DAS ranged from 37.25 to 60.75 per cent in carbosulfan + *T. viride* (2 ml + 4g per kg of seed) and *T. viride* (4 g per kg of seed) respectively on blackgram. The incidence of root rot ranged from 2.90 to 23.55 per cent in Dimethoate + carbendazim (5 ml + 2 g per kg of seed) and untreated check respectively. The combined incidence of stem fly and root rot complex ranged from 0.29 to 23.55 per cent in carbosulfan + carbendazim and untreated check respectively. Among the different treatments, carbosulfan + *T. viride* (2 ml + 4 g per kg of seed) and dimethoate + *T. viride* (5 ml + 4 g per kg of seed) was found to be significantly effective in reducing the incidence stem fly and root rot complex damage (0.29 to 9.27%) (Table 15). The incidence of stem fly, root rot and Stem fly - root rot complex was minimum in 15 DAS than 30 DAS.

4.8.1. Effect of seed treatment on stem fly and root rot complex in greengram

In the case of greengram, the stem fly incidence on 30 DAS ranged from 4.92 to 23.55 per cent in Dimethoate + *T. viride* (5 ml + 4g per kg of seed) and untreated check respectively. The incidence of root rot ranged from 16.35 to 43.07 per cent in Dimethoate

+ carbendazim (5 ml + 2 g per kg of seed) and carbosulfan respectively. The combined incidence of stem fly and root rot complex ranged from 2.90 to 23.55 per cent in carbosulfan + *T. viride* (2 ml + 4 g per kg of seed) and untreated check respectively. Among the different treatments, carbosulfan + *T. viride* (2 ml + 4 g per kg of seed) and dimethoate + *T. viride* (5 ml + 4 g per kg of seed) was found to be significantly effective in reducing the incidence of stem fly and root rot complex damage (2.90 to 6.65%) respectively (Table 16.). The incidence of stem fly, root rot and Stem fly - root rot complex was minimum in 15 DAS than 30 DAS.

4.8.2. Effect of soil application on stem fly and root rot complex in blackgram

On 30 DAS the stem fly damage in various soil application treatments ranged from 25.08 to 61.73 per cent in phorate (0.5 kg a.i / ha)+ carbendazim (0.1% drenching) and untreated check respectively. The root rot incidence in different treatments ranged from 5.52 per cent to 25.08 per cent. The combined incidence of stem fly and root rot complex ranged from 0.29 per cent to 20.23 per cent in carbofuran (1 kg a.i / ha) + carbendazim (0.1% drenching) and untreated check respectively. Among the treatments the phorate (0.5 kg a.i / ha)+ carbendazim (0.1% drenching), carbofuran (1 kg a.i / ha) + carbendazim (0.1% drenching) were found to be significantly effective as it recorded a very low damage of 0.29 per cent of stem fly and root rot damage as against 20.23 per cent in untreated check (Table 17). The incidence of stem fly, root rot and stem fly - root rot complex damage was comparatively low on 15 DAS than 30 DAS.

4.8.2.1. Effect of soil application on stem fly and root rot complex in greengram

On 30 DAS the stem fly damage in various soil application treatments ranged from 0.29 to 21.94 per cent in carbofuran (1 kg a.i / ha)+ carbendazim (0.1% drenching) and untreated check respectively. The root rot incidence in different treatments ranged from 5.52 per cent to 33.59 per cent. The combined incidence of stem fly and root rot

complex ranged from 0.29 per cent to 16.35 per cent in carbofuran (1 kg a.i / ha) + carbendazim (0.1% drenching) and un treated check respectively. Among the treatments the phorate (0.5 kg a.i / ha)+ carbendazim (0.1% drenching), carbofuran (1 kg a.i / ha) + carbendazim (0.1% drenching) were found to be significantly effective as it recorded a very low damage of 0.29 per cent of stem fly and root rot damage as against 16.35 per cent in untreated check (Table 18). The incidence of stem fly, root rot and stem fly - root rot complex damage was comparatively low on 15 DAS than 30 DAS.

4.9. Compatibility of insecticides and biocontrol agents

4.9.1. Effect of carbosulfan and dimethoate on the growth of *Trichoderma viride*

The results on the effect of carbosulfan and dimethoate on the growth of *T. viride* is presented in Table 19 on 3 DAT. It was found that carbosulfan and Dimethoate at all the doses tested did not inhibit the growth of *T. viride*. The radial mycelial growth was uniform in all the doses of carbosulfan and dimethoate (Plate 9).

4.9.2. Effect of carbosulfan and dimethoate on the growth of *Pseudomonas fluorescens*

The influence of carbosulfan and dimethoate on the growth of *P. fluorescens* was studied under laboratory conditions (Plate 10). On 3 DAT the results of the experiment revealed that the growth of *P. fluorescens* was very low at all doses of carbosulfan and dimethoate (Table 20).

CHAPTER V

DISCUSSION

Investigations were carried out on the seasonal incidence, biology, host plant resistance and management of stem fly *O. phaseoli* during 2005-06. The results obtained from those studies are discussed here under with already available information.

Studies on the seasonal incidence of stem fly in blackgram showed that a maximum incidence of 73 per cent was recorded during August 2005 and was followed by March 2006 (59%). It was also observed that there was significant variation in stem fly incidence between blackgram and greengram. In blackgram the incidence was recorded more than 70 per cent, while it was 12 per cent in greengram. There was no much variation in stem fly damage in green gram in different monthly sowings. Based on the above fact that it may be concluded that crop sown during summer months with high temperature recorded more damage than winter months. This finding is in accordance with Uihanco (1934), Morgan (1938), Caldwell (1939), Abul-Nasr and Assem (1966), Singh and Beri (1971) and Singh and Ipe (1973).

The stem fly incidence at different monthly sowings was correlated with weather factors like temperature, Relative Humidity and rainfall to study their association. The incidence of stem fly was negatively correlated with total rainfall and rainy days with 'r' values of -0.0814 and –0.840 respectively. This finding is in consonance with the observation of Manohar (1978) who stated that the incidence of stem fly was increased or decreased according to the increase or decrease in rainfall. However the relationship between stem fly incidence and other weather factors were not statistically significant. It is to be noted that the stem fly damage in greengram is not having any relationship with weather parametres as the damage was less than 12 per cent with less variation in different months.

The stem fly species that attacks blackgram and greengram was identified as *O. phaseoli* based on their oviposition site, larval feeding, colour of puparium and morphological characters of adult, etc., which are all the distinct features of *O. phaseoli*. Based on the present investigation the other species such as *O. centrosematis* and *O. spencerella* are not prevalent in blackgram and greengram. Earlier Singh (1982) reported the occurrence of *O. phaseoli* in blackgram and greengram in India. However the incidence of other species, *O. centrosematis* was reported from India on pigeonpea and pea (ICRISAT, 1976). The females of *O.phaseoli* laid eggs singly on both upper and lower surfaces of leaves, but mostly on the lower surface, which is the distinct feature of *O. phaseoli* than that of *O. centrosematis* and *O. spencerella* which lay their eggs on the hypocotyl region. Similar kind of observation on the ovipositional characters and maggot movement of *O. phaseoli* was earlier reported by Pandey (1962), Bindra and Singh (1969), Talekar and Chen (1985) and Manohar (1978).

The present study revealed that the duration of egg, maggot and puparium were 2.5 to 3.5 days, 6 to 8 days and 8 to 10 days respectively. Earlier similar developmental period was reported by Talekar and Chen (1985). The biological studies of *O. phaseoli* was confined to only oviposition and developmental stages. To understand the complete biology of this pest, studies on the movement of hatched maggot from the egg laying site to the stem region, development of various larval instars, adult longevity, time of adult emergence and sex ratio are to be made in a systematic manner. Based on the available literatures, it was found that work on the biology and species complex of stem fly was meagre and much results is need to be made for IPM.

Among 126 blackgram entries screened against stem fly, none of them was free from stem fly damage. However, it could be inferred that only AC 222, COBG 671, COBG 660 and COBG 672 recorded a very low damage (around 10 %) on both *Kharif*

and *Rabi* seasons (2005) indicating its tolerance nature against stem fly. Similar to that of blackgram, 114 greengram entries were screened against stem fly and found none of them was free from stem fly damage. The greengram entries COGG 912, COGG 917, ML 1256 and LM 360 alone recorded minimum stem fly damage in both the seasons. The low level of damage in all the above entries might be due to morphological characters such as toughness of stem and degree of pubescence. Similar kind of inference was made by Balboa (1972) and Lin (1979).

Through present investigations, it is inferred that the biochemical constituents such as phenol, tannin, phenylalanine ammonia lyase and reducing sugars would have been influenced on stem fly in offering resistance. The quantity of the above compounds varies with accessions and between blackgram and greengram. It was observed that the content of the various biochemicals in the stem on 7 and 15 DAS varied much. Most of the compounds were found to be higher on 15 DAS than 7 DAS. This might be the reason for stem fly not infesting the crop after 15 DAS on both blackgram and greengram. In blackgram on 15 DAS the mean content of phenol (mean of resistant entries) was 1.28 mg/g of plant tissue against 1.00 mg/g of the check variety CO-5 (Table.14). Similarly the mean value of tannin and PAL was found to be more than the check variety. In contrast the content of reducing sugars was less (1.18 mg/g of plant tissue) in resistant entries than the check (1.60). Similar trend was observed on greengram also (Table 14) Based on the above fact it is inferred that higher content of phenol, tannin, phenylalanine ammonia lyase and lower content of reducing sugars are responsible for resistance against stem fly .The above inference is in accordance with the work of the following researchers of phenol, tannin, phenylalanine ammonia lyase and reducing sugars. Pitcher *et al.* (1960), Brueske and Dropkin (1973), (Brueske, 1980).

In the present study, the stem fly damage was low in greengram than blackgram in all the experiments on seasonal incidence, host plant resistance and management studies. Hence an in depth analysis was made on the content of phenol, tannin, phenylalanine ammonia lyase and reducing sugars in blackgram and greengram. It was found that except phenol content all the other compounds such as tannin, phenylalanine ammonia lyase and reducing sugars were found to be almost equal in blackgram and greengram. Only the phenol content was very high in greengram (2.32 mg/g of plant tissue) than black gram (1.28 mg/g of plant tissue). The higher content of phenol in greengram might be the reason for low damage of stem fly.

A total of 7 hymenopteran parasitoids were recorded from the puparia of *O. phaseoli*. Among them the level parasitisation by two species *Opius* sp. and *Sphegigaster brunneicornis* (Ferrier) was found to be higher than other parasitoids. Earlier, Manohar (1978) reported the parasitism by *Sphegigaster* sp. and *Eucoilidea* sp. on stem fly in blackgram. Singh (1982) reported that *Opius phaseoli* and *Eurytoma* sp. were the parasitoids of stem fly in India and on *Melanogromyza obtusa* in Tamil Nadu (Durairaj, 1995). Parasitism by *Opius phaseoli, Eurytoma* sp., *Aprostoporoides curiosus*, *Halticoptera propinqua* and *Syntomopus nigrus* on stem fly maggot is reported for first time from Tamil Nadu. Similarly parasitism by eulophid *Aprostoporoides curiosus* on stem fly is reported for the first time in India.

As blackgram and greengram are being cultivated mostly under rainfed situations, studies were conducted to find out the effective combination of insecticide and fungicide for the management of stem fly and root rot disease complex. Similarly various treatment combination were evaluated as seed treatment and soil application against above pest and disease complex. In blackgram, among the seed treament with insecticide and fungicide combination, carbosulfan + *T. viride* (2ml + 4g / kg of seed) and dimethoate + *T. viride*

(5ml +4g / kg of seed) were equally effective in reducing the stem fly (37.3 to 38.0 %) and root rot (5.5 to 6.7 %). In untreated plot the stem fly and root damage was 58.6 per cent and 23.55 percent respectively. Similar trend was observed in greengram also. The carbosulfan + *T. viride* (2ml + 4g / kg of seed) and dimethoate + *T. viride* (5ml+4g/ kg of seed) treatment combination effectively reduced the stem fly (4.9 to 6.7 %) and root rot (23.6 to 25.1 %). In untreated plot the stem fly and root damage was 23.6 per cent and 41.9 percent respectively.

The present finding is in accordance with Ramadoss (1985) who stated that seed treatment, of carbendazim, carbendazim + carbosulfan, were highly effective. The results obtained by Ramadoss and Sivaprakasam, (1993) are also in conformity with the present results.

According to Chander and Singh (1991) seed treatment with dimethoate at 10 ml per kg of seed, gave better results against stem fly. This findings is also supporting authors work. Mote and Shah (1983) noted the effective protection due to carbosulfan seed treatment to French bean. Sinha and Khare (1977) reported that carbendazim when used as a seed dressing gave good control of *M. phaseolina* in cowpea. This is in accordance with the present findings. The efficacy of *T. viride* (4 g / kg of seed), as seed treatment in oil seeds and pulses was earlier reported by Ramakrishnan *et al.,* (1995); Raguchander *et al*., (1995); Adekunle *et al*., (2001).

Among the various treatment combination evaluated as soil application against stem fly and root rot complex, phorate (0.5 kg a.i / ha)+ carbendazim (0.1 % drenching), carbofuran(1 kg a.i / ha) + carbendazim(0.1 % drenching) and were found to be highly effective as it recorded a very low damage of(25.08 to 26.55 %) stem fly and (0.29 to 2.90 %) of root rot damage. Whereas in untreated plots, the stem fly and root rot damage were (61.73 and 24.55 %) respectively. Similar trend was observed in greengram also.

phorate (0.5 kg a.i / ha)+ carbendazim (0.1 % drenching), carbofuran(1 kg a.i / ha) + carbendazim(0.1 % drenching)were found to be highly effective as it recorded a very low damage of (2.90 %) stem fly and (5.52 to 13.30 %) of root rot damage. In untreated plots, the stem fly and root rot damage was 21.94 to 33.59 per cent respectively

The present work gained the support form the work of Bindra and Singh (1969), Pablo and Pangga (1971), Naresh and Thakur (1972). Similarly Kapoor *et al*. (1973) proved the effectiveness of phorate at 2 kg a.i/ha as a soil treatment to soybean. Kundu and Trimohan (1989) reported that maximum control was obtained with phorate and rhizobium combination. Soil application of carbendazim had been reported to be effective in the control of *M. phaseolina* in blackgram (Samiyappan, 1976), bengal gram (Chandrasekaran, 1979).

The yield parameters for the seed treatment and soil application trials were not presented due to the removal of plants at periodical intervals for the various observations on stem fly and root rot damage.

Studies on the compatibility of insecticides with biocontrol agents on both the crops revealed that dimethoate + *T. viride* (5ml+4g / kg of seed) and carbosulfan + *T. viride* (2ml+4g / kg of seed) combinations were found to be compatible without affecting the growth of *T.viride.* Earlier Jayachandran and Chandramohan (1977) obtained that Carbosulfan had stimulatory effect on the growth and sporulation of *T. viride.* Carbofuran application in rice crop at 4 kg a.i / ha at 20 days and at 50 days after transplanting increased the number of microbes in the rhizosphere.

Hence, it is possible that the *T. viride* can be used along with carbosulfan and dimethoate as seed treatment As this practice is being followed at the time of sowing the crop will be protected from stem fly and other early season pests such as aphids and whiteflies in addition to the control of root rot, which is also a major problem in the early

stage of the crops. The results of compatibility of carbosulfan and dimethoate with *P. fluorescens* revealed that carbosulfan 25 EC and dimethoate 30 EC had the low bacterial growth. On the contrary to the present findings, Venkateshwaralu *et al*. (1977) reported that *Pseudomonas sp*. was well compatible with carbofuran, parental compound of carbosulfan. Hence, it is not beneficial to combine the *P.fluorescens* with carbosulfan and dimethoate as seed treatment.

Based on the above findings it can be concluded that, summer cropping of blackgram and greengram can be avoided in the endemic areas in order to avoid serious losses due to stem fly. Stem fly resistant blackgram entries such as COBG 671, AC 222, COBG 660 and COBG 672 and greengram entries such as COGG 912, COGG 917, LM 360 and ML 1256 can be used as donor for breeding stem fly resistant varieties. Naturally occurring parasitoids such as *Opius* sp. and *Sphegigaster brunneicornis* was found to be effective in controlling the stem fly. So these parasitoids can be conserved by limited and need based application of insecticides. Seed treatment with carbosulfan + *T. viride* @ 2 ml + 4g /kg of seed or carbosulfan + carbendazim @ 2 ml + 2g/kg of seed or dimethoate + *T. viride* @ 5 ml + 4g/kg of seed was found to be very effective in controlling the stem fly and root rot complex. In case of soil application, phorate + carbendazim @ 0.5 kg a.i + 0.1% drenching /ha or carbofuran + carbendazim @ 1 kg a.i. + 0.1% drenching /ha was found to very effective in controlling the stem fly and root rot complex. So these combination of insecticides, fungicides and bio inoculants can be recommended as seed treatment and soil application for the management of stem fly and root rot complex in black gram and green gram.

CHAPTER VI

SUMMARY

Studies were carried out on the seasonal incidence, biology, natural enemies, screening of germplasm and chemical control of stem fly *O. phaseoli* in blackgram and greengram. The results of various experiments are summarized below.

- The stem fly damage in blackgram ranged from 36.0 and 73.0 per cent in November and August respectively and in greengram it was between 2.0 to 12.0 per cent, indicating that blackgram is more susceptible to stem fly than greengram.

- *Ophiomyia phaseoli* incidence exerted a significant negative association with rainfall (r = -0.814) and rainy days (r = -0.840). However, the influence of maximum temperature, minimum temperature, RH and wind speed was not significant.

- The multiple regression analysis showed a R^2 value of 0.71 revealing that 71 per cent of variation in *O. phaseoli* incidence was influenced by rainfall and rainy days. This indicated that an increase of 1 unit of rainfall and rainy day would lead to a decrease of 0.032 and 2.59 per cent of *O. phaseoli* incidence respectively.

- The influence of weather parameters on *O. phaseoli* incidence was not significant in greengram.

- The adult female laid eggs close to the midrib of the leaf on the lower surface and the fecundity of a female was worked out as 23.1.

- The eggs were oval, elongate and whitish with a transparent surface. The incubation period varied from 2.5 to 3.5 days with an average of 3.1 days.

- The newly hatched maggots were yellowish white, while the fully developed maggots were deep yellow. The larval period ranged from 6 to 8 days with an average of 7.2 days.

- The fully developed maggots changed into pupae inside the small barrel shaped yellow puparia. Pupation occurred under the thin epidermis of the damaged stem. The pupal period lasted for 8 to 10 days with an average of 9.4 days.

- The fully developed adults were metallic black in colour. The females had prominent ovipositor, while the males had blunt abdomen.

- The stem fly *O. phaseoli* was the only species found to attack on blackgram and greengram.

- The maggots of *O. phaseoli* were parasitized by seven species of hymenopteran parasitoids, of which three are Pteromalids, (*Sphegigaster brunneicornis*, *Syntomopus nigrus*, and *Halticoptera propinqua*), a Braconid, *Opius* sp., an Eurytomid, *Eurytoma* sp., an Eulopid, *Aprostoporoides curiosus* Narendran, and an Eucoilid, *Eucoilidea* sp.

- Among the seven parasitoids, *Opius* sp. was found to be predominant with a maximum parasitisation of 24.0 per cent followed by *S. brunneicornis* (14.0 %) and other species had less than 10.0 per cent.

- Among 126 blackgram entries tested, only four entries *viz*., COBG 671, AC 222, COBG 672, and COBG 660 were identified as resistant to stem fly with a PSI grade of 2.

- Among 114 greengram entries tested, only four entries viz., COGG 912, ML1256, COGG 917 and LM360 were found to be resistant to stem fly damage with PSI grade of 3.

- The mean phenol content of resistant blackgram entries was 1.28 mg/g as against 1.00 mg/g in the check variety CO 5. The mean values of other compounds such as tannin, PAL and reducing sugars were 0.46 mg/g, 0.49 µ mol TCA min^{-1} g^{-1} and 1.18 mg/g respectively, where as in CO 5 it was 0.34 mg/g, 0.30 µ mol TCA min^{-1} g^{-1} and 1.60 mg/g respectively.

- Likewise in greengram the mean phenol content was 2.32 mg/g as against 1.40 mg/g in check. The content of compounds like tannin, PAL and reducing sugars was 0.40 mg/g, 0.46 µ mol TCA min^{-1} g^{-1} and 1.18 mg/g respectively.

- Low stem fly damage in greengram greengram was due to higher phenol content (2.32 mg/g) than in blackgram (1.28 mg/g). Tannin, PAL and reducing sugars were more or less same in blackgram and greengram..

- The seed treatment with carbosulfan + *T. viride* (2 ml + 4g / kg of seed), dimethoate + *T. viride* (5 ml + 4g / kg of seed) and carbosulfan + carbendazim (2ml + 2g / kg of seed) was found to be very effective as evidenced by low damage (37.25 to 43.84 %) and root rot (4.04 to 6.65 %) in blackgram. While in untreated plot the stem fly and root rot damage were 58.61 and 23.55 respectively. Similar trend was observed in greengram.

- As soil application, combinations of phorate + carbendazim (0.5 kg a.i / ha + 2g / kg of seed) and carbofuran + carbendazim (1 kg a.i / ha + 2g / kg of seed) were found highly effective in blackgram, recording the low stem fly damage (25.08 to 28.55 %) and root rot (5.52 + 7.79 %) while in untreated plot the stemfly and root rot damage were 61.73 and 24.55 per cent respectively. similar trend was also observed in greengram.

- Carbosulfan and dimethoate at all the doses tested did not inhibit the growth of *T. viride* indicating its compatibility to insecticides. The growth of *P. fluorescens* at different concentrations of carbosulfan and dimethoate was low.

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* Originals not seen

Table 3. Correlation matrix of the relationship between incidence of stem fly and weather parameters in greengram

	Parameters	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y	Stem fly incidence (%)	1							
X_1	Maximum Temp. (°C)	-0.021^{NS}	1						
X_2	Minimum Temp. (°C)	-0.555^{NS}	0.183^{NS}	1					
X_3	Relative Humidity Morning (%)	-0.266^{NS}	-0.594^{NS}	-0.498^{NS}	1				
X_4	Relative Humidity Evening (%)	-0.547^{NS}	-0.557^{NS}	0.689^{NS}	0.138^{NS}	1			
X_5	Rainfall (mm)	-0.523^{NS}	-0.291^{NS}	0.318^{NS}	0.476^{NS}	0.634^{NS}	1		
X_6	Rainy days (nos.)	-0.594^{NS}	-0.315^{NS}	0.433^{NS}	0.412^{NS}	0.733*	0.984**	1	
X_7	Wind speed (KMPH)	0.002^{NS}	0.558^{NS}	0.686^{NS}	-0.949**	0.050^{NS}	-0.396^{NS}	-0.304^{NS}	1

* Significant at the 0.05 levels

** Significant at the 0.01 levels

^{NS} Non significant

Table 1. Correlation matrix of the relationship between incidence of stem fly and weather parameters in blackgram.

	Parameters	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y	Stem fly incidence (%)	1							
X_1	Maximum Temp. (°C)	0.215^{NS}	1						
X_2	Minimum Temp. (°C)	-0.302^{NS}	0.183^{NS}	1					
X_3	Relative Humidity Morning (%)	-0.539^{NS}	-0.595^{NS}	-0.499^{NS}	1				
X_4	Relative Humidity Evening (%)	-0.551^{NS}	-0.557^{NS}	0.689^{NS}	0.139^{NS}	1			
X_5	Rainfall (mm)	-0.814*	-0.291^{NS}	0.318^{NS}	0.477^{NS}	0.634^{NS}	1		
X_6	Rainy days (nos.)	-0.840**	-0.315^{NS}	0.433^{NS}	0.413^{NS}	0.733*	0.984**	1	
X_7	Wind speed (KMPH)	0.361^{NS}	0.559^{NS}	0.687^{NS}	-0.950**	0.051^{NS}	-0.396^{NS}	-0.304^{NS}	1

* Significant at the 0.05 levels

** Significant at the 0.01 levels

^{NS} Non significant

Table 2. Multiple regression analysis of the weather parameters and stem fly incidence in blackgram

Weather parameter	Regression co-efficient	Standard error
X5 – Rain fall (mm)	-0.032*	0.112
X6 – Rainy days (no.s)	-2.591**	2.892

* Significant at 5.00 % level

** Significant at 1.00 % level

NS Non significant

Constant "a" = 59.49

F Value = 6.11*

Adjusted R^2 = 0.71*

Table 4. Developmental periods of *O. phaseoli* on Blackgram

Stage	Appearance	Duration (Days)*
Egg	Oval, white and transparent	3.1 ± 0.74
Maggot	Yellowish white to dark yellow	7.2 ± 0.79
Pupa	Barrel shaped with dark brown colour	9.4 ±0.52
Fecundity (numbers)	Adult - Metallic black	23.1 ±3.48

* mean of ten replications

Table 5. Parasitoids of stem fly with their level of parasitism (*Kharif*, 2005) at Coimbatore

Parasitoid species	**Taxonomic position**	**Victim**	**Type of parasitoid**	**Parasitism (%) ***
Opius sp.	Braconidae: Hymenoptera	Larva	Larval pupal	24.0
Sphegigaster brunneicornis (Ferrier)	Pteromalidae: Hymenoptera	Larva	Larval pupal	14.0
Halticoptera propinqua (Waterston)	Pteromalidae: Hymenoptera	Larva	Larval pupal	8.0
Eurytoma sp.	Eurytomidae: Hymenoptera	Larva	Larval pupal	8.0
Aprostoporoides curiosus Narendran	Eulophidae: Hymenoptera	Larva	Larval pupal	4.0
Syntomopus nigrus Sureshan & Narendran	Pteromalidae: Hymenoptera	Larva	Larval pupal	2.0
Eucoilidea sp.	Eucoilidae: Hymenoptera	Larva	Larval pupal	2.0

* Average of ten replications.

Table 6. Reaction of blackgram germplasm against stem fly (*Kharif* 2005)

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
1.	COBG 671	4	2	Resistant
2.	AC 222	4	2	Resistant
3.	COBG 672	4	2	Resistant
4.	AC 297	6	2	Resistant
5.	COBG 660	6	2	Resistant
6.	SM 114	8	2	Resistant
7.	COBG 624	8	2	Resistant
8.	AC 258	8	2	Resistant
9.	AC 218	8	2	Resistant
10.	SM 107	10	2	Resistant
11.	CO 2 / 9	12	2	Resistant
12.	CO 2 / 4	12	2	Resistant
13.	SM 111	12	2	Resistant
14.	CO 2 / 74	16	2	Resistant
15.	TMV 1	16	2	Resistant
16.	P 133/14	16	2	Resistant
17.	SM 104	16	2	Resistant
18.	CO 2 / 103	16	2	Resistant
19.	VBN 4	18	3	Resistant
20.	KU5 535	18	3	Resistant
21.	KU5 571	18	3	Resistant
22.	KU5 526	20	3	Resistant
23.	SM 106	22	3	Resistant
24.	P 133/18	22	3	Resistant
25.	AC 227	22	3	Resistant
26.	AC 247	24	3	Resistant
27.	AC 295	24	3	Resistant
28.	CO 2 / 21	26	3	Resistant
29.	COBG 663	26	3	Resistant
30.	KU5 544	26	3	Resistant

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
31.	AC 235	26	3	Resistant
32.	AC 293	28	3	Resistant
33.	CO 2 / 23	28	3	Resistant
34.	SM 113	28	3	Resistant
35.	U 106	28	3	Resistant
36.	ADT 5	30	3	Resistant
37.	SM 102	30	3	Resistant
38.	KU5 568	34	4	Resistant
39.	IPU 02/04	34	4	Resistant
40.	P 133/32	34	4	Resistant
41.	P 13	34	4	Resistant
42.	NDU 3/5	34	4	Resistant
43.	AC 292	36	4	Resistant
44.	CO 2/102	36	4	Resistant
45.	CO 2/28-2	36	4	Resistant
46.	COBG 643	36	4	Resistant
47.	P 133/39	36	4	Resistant
48.	VBN 1	36	4	Resistant
49.	AC 226	38	4	Resistant
50.	AC 239	38	4	Resistant
51.	CO 2	38	4	Resistant
52.	CO 2/ 1	38	4	Resistant
53.	LU 18	40	4	Resistant
54.	P 3	40	4	Resistant
55.	KU5 551	40	4	Resistant
56.	KU5 521	44	4	Resistant
57.	SM 109	44	4	Resistant
58.	SM 110	44	4	Resistant
59.	COBG 662	44	4	Resistant
60.	KU5 532	46	4	Resistant

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
61.	AC 221	46	4	Resistant
62.	AC 237	48	4	Resistant
63.	AC 251	48	4	Resistant
64.	AC 31/1	48	4	Resistant
65.	CO 2 / 104	48	4	Resistant
66.	SM 105	50	4	Resistant
67.	TU 17/4	50	4	Resistant
68.	KU5 523	50	4	Resistant
69.	SM 108	50	4	Resistant
70.	SM 103	50	4	Resistant
71.	COBG 593	52	5	Resistant
72.	PLS 364/40	52	5	Resistant
73.	CO 2 /69	52	5	Resistant
74.	CO 2 /81	54	5	Resistant
75.	COBG 630	54	5	Resistant
76.	LU 65	54	5	Resistant
77.	PLS 364/92	56	5	Resistant
78.	KU5 555	56	5	Resistant
79.	SELECTION 98	56	5	Resistant
80.	KU5 531	56	5	Resistant
81.	KU5 553	58	5	Resistant
82.	KU5 547	60	5	Resistant
83.	KU5 554	60	5	Resistant
84.	AC 229	60	5	Resistant
85.	KU5 537	60	5	Resistant
86.	NDU 3 / 4	62	6	Resistant
87.	P 150	62	6	Resistant
88.	P 217	62	6	Resistant
89.	P 47	62	6	Resistant
90.	PLS 364 / 77	64	6	Resistant

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
91.	SM 205	64	6	Resistant
92.	TU 17 / 9	64	6	Resistant
93.	AC 264	64	6	Resistant
94.	P 170	66	6	Resistant
95.	IPU O2/14	66	6	Resistant
96.	COBG 632	66	6	Resistant
97.	KU5 573	66	6	Resistant
98.	KU5 540	66	6	Resistant
99.	AC 291	66	6	Resistant
100.	SM 101	68	6	Resistant
101.	KU5 549	68	6	Resistant
102.	KU5 542	68	6	Resistant
103.	CO 4	68	6	Resistant
104.	KU5 533	68	6	Resistant
105.	KU5 528	70	6	Susceptible
106.	KU5 538	70	6	Susceptible
107.	KU5 527	72	6	Susceptible
108.	KU5 551	72	6	Susceptible
109.	LM 237	72	6	Susceptible
110.	AC 301	72	6	Susceptible
111.	P 64	74	6	Susceptible
112.	KU5 546	74	6	Susceptible
113.	AC 305	76	6	Susceptible
114.	KU5 550	76	6	Susceptible
115.	COBG 627	76	6	Susceptible
116.	P 57	76	6	Susceptible
117.	CO2/79	78	7	Susceptible
118.	KU5 543	80	7	Susceptible
119.	AC 267	80	7	Susceptible
120.	AC 303	80	7	Susceptible

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
121.	P 49	82	7	Susceptible
122.	AC 323	86	8	Susceptible
123.	KU5 553	86	8	Susceptible
124.	PANT U 02/3	94	8	Susceptible
125.	AC 31	94	8	Susceptible
126.	CO 5 (Check)	68	-	-

Table 7. Reaction of greengram germplasm against stem fly (*Kharif* 2005)

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
1.	COGG 912	4	2	Resistant
2.	ML 1256	4	2	Resistant
3.	COGG 917	4	2	Resistant
4.	ML 881	4	2	Resistant
5.	MGG 351	6	3	Resistant
6.	LM 360	6	3	Resistant
7.	LM 255	8	3	Resistant
8.	COGG 923	8	3	Resistant
9.	TM 2000-58	8	3	Resistant
10.	COGG 924	10	3	Resistant
11.	KM5 186	12	4	Resistant
12.	LM 352	12	4	Resistant
13.	LM 298	12	4	Resistant
14.	ML 1260	12	4	Resistant
15.	LM 294	12	4	Resistant
16.	SM 211	14	4	Resistant
17.	VBN 1	14	4	Resistant
18.	LM 392	14	4	Resistant
19.	SM 214	14	4	Resistant
20.	SM 217	14	4	Resistant
21.	GM 4	14	4	Resistant
22.	LM 269	16	4	Resistant
23.	KM5 189	16	4	Resistant
24.	LM 334	16	4	Resistant
25.	LM 369	16	4	Resistant
26.	SM 212	16	4	Resistant
27.	SM 213	16	4	Resistant
28.	AC 292	16	4	Resistant
29.	LM 274	16	4	Resistant
30.	LM 279	16	4	Resistant

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
31	LM 387	18	5	Resistant
32.	PAIYUR 1	18	5	Resistant
33.	IPM 03-2	18	5	Resistant
34.	KM5 162	18	5	Resistant
35.	LM 275	18	5	Resistant
36.	LM 328	18	5	Resistant
37.	LM 344	18	5	Resistant
38.	LM 391	18	5	Resistant
39.	VBN 2	20	6	Resistant
40.	KM5 180	20	6	Resistant
41.	LGG 483	20	6	Resistant
42.	LM 263	20	6	Resistant
43.	LM 307	20	6	Resistant
44.	COGG 913	20	6	Resistant
45.	KM5 156	22	6	Resistant
46.	LM 272	22	6	Resistant
47.	LM 384	22	6	Resistant
48.	SM 218	22	6	Resistant
49.	LM 399	22	6	Resistant
50.	LM 13	22	6	Resistant
51.	LM 289	22	6	Resistant
52.	LM 394	22	6	Resistant
53.	UPM 02-17	22	6	Resistant
54.	KM5 155	24	6	Susceptible
55.	LM 253	24	6	Susceptible
56.	LM 292	24	6	Susceptible
57.	LM 331	24	6	Susceptible
58.	LM 401	24	6	Susceptible
59.	TMB 13	26	7	Susceptible
60.	KM5 152	26	7	Susceptible

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
61.	SM 220	26	7	Susceptible
62.	SM 216	26	7	Susceptible
63	LM 330	26	7	Susceptible
64.	COGG 953	26	7	Susceptible
65.	LM 25	26	7	Susceptible
66.	SM 210	26	7	Susceptible
67.	KM5 168	26	7	Susceptible
68.	LM 296	26	7	Susceptible
69.	LM 336	28	8	Susceptible
70.	LM 354	28	8	Susceptible
71.	LM 66	28	8	Susceptible
72.	LM 304	28	8	Susceptible
73.	LM 405	28	8	Susceptible
74.	MH 2-15	28	8	Susceptible
75.	SM 219	28	8	Susceptible
76.	KM5 165	28	8	Susceptible
77.	LM 309	28	8	Susceptible
78.	LM 338	28	8	Susceptible
79.	KM5 160	30	8	Susceptible
80.	KM5 175	30	8	Susceptible
81.	KM5 183	30	8	Susceptible
82.	LM 319	30	8	Susceptible
83.	LM 409	30	8	Susceptible
84.	LM 290	34	9	Susceptible
85.	LM 314	34	9	Susceptible
86.	LM 365	34	9	Susceptible
87.	KM5 199	34	9	Susceptible
88.	KM5 153	34	9	Susceptible
89.	KM5 176	34	9	Susceptible
90.	LM 68	34	9	Susceptible

Contd.,

S. No.	Germplasm	Infestation (%)	Pest Susceptibility Index	Resistant / susceptible over the check
91.	KM5 184	36	9	Susceptible
92.	TARM 1	36	9	Susceptible
93.	LM 406	36	9	Susceptible
94.	SM 215	36	9	Susceptible
95.	KM5 182	36	9	Susceptible
96.	AC 164	36	9	Susceptible
97.	AC 199	36	9	Susceptible
98.	PLS 267/1	36	9	Susceptible
99.	AC 192	38	9	Susceptible
100.	AC 204	38	9	Susceptible
101.	SM 204	38	9	Susceptible
102.	SM 201	38	9	Susceptible
103.	AC 248	38	9	Susceptible
104.	SM 203	38	9	Susceptible
105.	PLS 305	40	9	Susceptible
106.	AC 241	40	9	Susceptible
107.	PLS 286	40	9	Susceptible
108.	AC 196	40	9	Susceptible
109.	SM206	40	9	Susceptible
110.	AC 307	40	9	Susceptible
111.	SM 208	42	9	Susceptible
112.	SM 202	42	9	Susceptible
113.	SM 207	42	9	Susceptible
114.	CO 6 (Check)	22	-	-

Table 8. Confirmatory studies on reaction of promising blackgram accessions against stem fly during *Kharif* and *Rabi* seasons

S. No.	Germplasm	*Kharif* 2005		*Rabi* 2005	
		Damage (%)	Pest Susceptibility Index	Damage (%)	Pest Susceptibility Index
1.	AC 222	4	2	2	2
2.	COBG 671	4	2	2	2
3.	COBG 660	6	2	4	2
4.	COBG 672	4	2	8	2
5.	AC 297	6	2	12	2
6.	AC 258	8	2	12	2
7.	SM 114	8	2	12	2
8.	COBG 624	8	2	16	3
9.	SM 107	10	2	18	3
10.	AC 218	8	2	18	3
11.	CO 5 (Check)	68	-	56	-

Table 9. Confirmatory studies of promising greengram accessions against stem fly during *Kharif* and *Rabi* seasons

S. No.	Germplasm	*Kharif* 2005		*Rabi* 2005	
		Damage (%)	Pest Susceptibility Index	Damage (%)	Pest Susceptibility Index
1.	COGG 912	4	2	6	3
2.	COGG 917	4	2	8	3
3.	ML 1256	4	2	8	3
4.	LM 360	6	3	8	3
5.	ML 881	4	2	12	4
6.	COGG 923	8	3	12	4
7.	MGG 351	6	3	14	5
8.	COGG 924	10	3	14	5
9.	TM 2000-58	8	3	14	5
10.	LM 255	8	3	20	6
11.	CO 6 (Check)	22	-	18	-

Table 10. Phenol and tannin contents of resistant blackgram accessions

S. No.	Germplasm	Phenol (mg / g of plant tissue)			Tannin (mg / g of plant tissue)		
		7 DAS	15 DAS	% increase over control	7 DAS	15 DAS	% increase over control
1.	COBG 660	0.95^{ab}	1.10^{bc}	10	0.10^{d}	0.36^{bc}	5.88
2.	COBG 671	1.06^{a}	1.25^{b}	25	0.20^{c}	0.40^{b}	17.65
3.	COBG 672	0.84^{b}	1.25^{b}	25	0.26^{c}	0.44^{b}	29.41
4.	AC 222	0.95^{ab}	1.50^{a}	50	0.60^{a}	0.63^{a}	82.29
5.	CO 5 (Check)	0.50^{c}	1.00^{c}	-	0.40^{b}	0.34^{bc}	-

In vertical column means followed by same letter are not different statistically (P = 0.05) by DMRT

Table 12. Constitution of Phenylalanine ammonia lyase and reducing sugar in resistant blackgram accessions

S. No.	Germplasm	Phenylalanine ammonia lyase (µ mol TCA min^{-1} g^{-1} of plant tissue)			Reducing sugar (mg / g of plant tissue)		
		7 DAS	15 DAS	% increase over control	7 DAS	15 DAS	% decrease over control
1.	COBG 660	0.18^{a}	0.55^{b}	83.33	3.00^{b}	1.45^{ab}	-9.38
2.	COBG 671	0.22^{a}	0.74^{a}	146.66	1.85^{c}	1.10^{bc}	-31.25
3.	COBG 672	0.15^{a}	0.28^{d}	-6.66	3.10^{ab}	1.35^{ab}	-15.63
4.	AC 222	0.20^{a}	0.40^{bc}	33.33	1.25^{c}	0.85^{c}	-46.88
5.	CO 5 (Check)	0.21^{a}	0.30^{d}	-	3.80^{a}	1.60^{a}	-

In vertical column means followed by same letter are not different statistically (P = 0.05) by DMRT

Table 11. Contents of phenol and tannin in resistant greengram accessions

S. No.	Germplasm	Phenol (mg / g of plant tissue)			Tannin (mg / g of plant tissue)		
		7 DAS	15 DAS	% increase over control	7 DAS	15 DAS	% increase over control
1.	COGG 912	2.40[a]	2.80[a]	100	0.20[b]	0.42[a]	40.00
2.	COGG 917	2.00[b]	2.40[ab]	71.43	0.26[a]	0.36[ab]	20.00
3.	ML 1256	1.50[c]	2.10[b]	50.00	0.20[b]	0.38[ab]	26.66
4.	LM 360	1.40[c]	2.00[b]	42.85	0.20[b]	0.44[a]	46.66
5.	CO 6 (Check)	1.20[c]	1.40[c]	-	0.10[c]	0.30[b]	-

In vertical column means followed by same letter are not different statistically (P = 0.05) by DMRT

Table 13. Constitution of phenylalanine ammonia lyase and reducing sugar in resistant greengram accessions

S. No.	Germplasm	Phenylalanine ammonia lyase (μ mol TCA min^{-1} g^{-1} of plant tissue)			Reducing sugar (mg / g of plant tissue)		
		7 DAS	15 DAS	% increase over control	7 DAS	15 DAS	% decrease over control
1.	COGG 912	0.18^{a}	0.65^{a}	132.14	2.80^{c}	1.10^{ab}	-26.66
2.	COGG 917	0.14^{a}	0.18^{d}	35.71	3.30^{bc}	1.50^{bc}	-
3.	ML 1256	0.15^{a}	0.46^{b}	64.29	3.20^{bc}	1.30^{ab}	-13.33
4.	LM 360	0.22^{a}	0.55^{b}	96.43	3.70^{b}	0.85^{c}	-43.33
5.	CO 6 (Check)	0.17^{a}	0.28^{c}	-	4.60^{a}	1.50^{a}	-

In vertical column means followed by same letter are not different statistically (P = 0.05) by DMRT

Table 14. Comparative biochemical constituents in Blackgram and greengram at 15DAS

Biochemicals	Blackgram	Greengram
Phenol (mg/g)	1.28 (1.00)	2.32 (1.40)
Tannin (mg/g)	0.46 (0.34)	0.40 (0.30)
Phenylalanine ammonia lyase (μ mol TCA min^{-1} g^{-1} of plant tissue)	0.49 (0.30)	0.46 (0.28)
Reducing sugars (mg/g)	1.18 (1.60)	1.18 (1.50)

Values in parentheses are the values of check varieties of the respective crops

Table 16. Effect of seed treatment on stem fly, root rot and stem fly root rot complex on greengram

Treatments	Stem fly incidence (%)		Root rot incidence (%)		Stem fly & root rot complex (%)	
	15 DAS	**30 DAS**	**15 DAS**	**30 DAS**	**15 DAS**	**30 DAS**
Dimethoate 5ml / kg of seed	2.90^{b} (9.80)	6.65^{b} (14.94)	31.91^{d} (34.39)	41.16^{e} (39.90)	2.90^{b} (9.80)	4.04^{b} (11.59)
Carbosulfan 2ml / kg of seed	2.90^{b} (9.80)	7.79^{b} (16.20)	29.72^{d} (33.03)	43.07^{f} (41.01)	2.90^{b} (9.80)	2.90^{a} (9.80)
Carbendazim 2g / kg of seed	14.93^{e} (22.73)	19.05^{e} (25.87)	16.35^{a} (23.85)	18.38^{b} (25.38)	0.29^{a} (3.08)	7.79^{c} (16.20)
T. viride 4g / kg	15.68^{ef} (23.32)	21.41^{ef} (27.56)	14.05^{a} (22.01)	25.08^{cd} (30.05)	5.52^{c} (13.50)	17.02^{d} (24.36)
P. fluorescens 10g / kg	13.17^{e} (21.27)	20.23^{ef} (26.75)	19.05^{b} (25.87)	27.00^{d} (31.30)	6.65^{c} (14.90)	20.23^{de} (26.73)
Dimethoate + Carbendazim 5ml + 2g	0.29^{a} (3.08)	9.27^{c} (17.72)	18.38^{b} (25.38)	16.35^{a} (23.85)	2.90^{b} (9.80)	5.52^{b} (13.58)
Dimethoate + *T. viride* 5ml + 4 g	2.90^{b} (9.80)	4.92^{a} (12.81)	20.23^{bc} (26.73)	23.55^{c} (29.03)	2.90^{b} (9.80)	6.65^{c} (14.94)
Dimethoate + *P. fluorescens* 5ml +10g	4.04^{c} (11.59)	9.27^{c} (17.72)	20.23^{bc} (26.73)	27.47^{d} (31.60)	5.52^{c} (13.50)	9.27^{cd} (17.72)
Carbosulfan+ Carbendazim 2ml + 2g	2.90^{b} (9.80)	5.52^{ab} (13.58)	16.35^{a} (23.83)	20.23^{b} (26.73)	0.29^{a} (3.08)	5.52^{b} (13.58)
Carbosulfan + *T. viride* 2ml + 4g	2.90^{b} (9.80)	6.65^{b} (14.94)	18.38^{b} (25.38)	25.08^{cd} (30.05)	2.90^{b} (9.80)	2.90^{a} (9.80)
Carbosulfan + *P. fluorescens* 2ml + 10g	9.27^{d} (17.72)	12.42^{d} (20.63)	19.66^{b} (26.32)	28.85^{de} (32.48)	5.52^{c} (13.58)	10.40^{cd} (18.81)
Untreated check	17.10^{f} (24.42)	23.55^{f} (29.03)	30.19^{d} (33.33)	41.93^{e} (40.35)	15.68^{d} (22.32)	23.55^{e} (29.03)

DAS – Days After Sowing

Values in parentheses are Arcsine transformed values

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

Table 15. Effect of seed treatment on stem fly, root rot and stem fly root rot complex on blackgram

Treatments	Stem fly incidence (%)		Root rot incidence (%)		Stem fly & root rot complex (%)	
	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
Dimethoate 5ml / kg of seed	30.65^{b} (33.61)	43.85^{bc} (41.46)	17.71^{d} (24.88)	20.23^{d} (26.73)	14.05^{e} (22.01)	17.10^{d} (24.42)
Carbosulfan 2ml / kg of seed	27.91^{a} (31.89)	40.36^{b} (39.44)	18.20^{d} (25.25)	19.66^{d} (26.32)	10.40^{d} (18.81)	16.35^{d} (23.85)
Carbendazim 2g / kg of seed	47.32^{d} (43.46)	59.04^{f} (50.20)	0.29^{a} (3.08)	2.90^{a} (9.80)	2.90^{b} (9.80)	0.29^{a} (3.08)
T. viride 4g / kg	43.85^{c} (41.46)	60.75^{f} (51.20)	0.29^{a} (3.08)	9.27^{c} (17.72)	0.29^{a} (3.08)	0.29^{a} (3.08)
P. fluorescens 10g / kg	45.39^{cd} (42.35)	55.78^{e} (48.32)	2.90^{b} (9.80)	5.52^{b} (13.58)	0.29^{a} (3.08)	5.52^{b} (13.58)
Dimethoate + Carbendazim 5ml + 2g	31.94^{b} (34.41)	46.53^{d} (43.01)	2.90^{b} (9.80)	2.90^{a} (9.80)	2.90^{b} (9.80)	0.29^{a} (3.08)
Dimethoate + *T. viride* 5ml + 4 g	27.92^{a} (31.89)	38.03^{a} (38.07)	0.29^{a} (3.08)	6.65^{bc} (14.94)	0.29^{a} (3.08)	6.65^{bc} (14.94)
Dimethoate + *P. fluorescens* 5ml +10g	28.40^{a} (32.20)	43.08^{bc} (41.02)	5.52^{c} (13.58)	9.27^{c} (17.72)	5.52^{c} (13.58)	5.52^{bc} (13.58)
Carbosulfan+ Carbendazim 2ml + 2g	31.91^{b} (34.39)	43.84^{bc} (41.46)	0.29^{a} (3.08)	4.04^{b} (11.59)	0.29^{a} (3.08)	0.29^{a} (3.08)
Carbosulfan + *T. viride* 2ml + 4g	26.55^{a} (31.01)	37.25^{a} (37.61)	0.29^{a} (3.08)	5.52^{b} (13.58)	0.29^{a} (3.08)	9.27^{c} (17.72)
Carbosulfan + *P. fluorescens* 2ml + 10g	29.72^{ab} (33.03)	39.21^{ab} (38.76)	5.52^{c} (13.58)	6.65^{bc} (14.94)	5.52^{c} (13.58)	6.65^{bc} (14.94)
Untreated check	45.77^{cd} (42.57)	58.61^{ef} (49.95)	17.10^{d} (24.42)	23.55^{e} (29.03)	16.35^{e} (23.85)	23.55^{e} (29.03)

DAS – Days After Sowing
Values in parentheses are Arcsine transformed values
In a column means followed by the same alphabet are not significantly different (P=0.05) by DMRT

Table 18. Effect of soil application on stem fly, root rot and stem fly root rot complex on greengram

Treatments	Stem fly incidence (%)		Root rot incidence (%)		Stem fly & root rot complex (%)	
	15 DAS	**30 DAS**	**15 DAS**	**30 DAS**	**15 DAS**	**30 DAS**
Neem cake 625 kg / ha	10.40^{d} (18.81)	15.68^{e} (23.32)	23.55^{h} (29.03)	30.19^{h} (33.03)	9.27^{c} (17.72)	13.30^{e} (21.38)
Carbendazim (drenching) 0.1%	16.35^{g} (23.85)	20.23^{f} (26.73)	5.52^{c} (13.58)	14.05^{d} (22.01)	2.90^{b} (9.80)	5.52^{c} (13.58)
Carbofuran 1 kg a.i./ ha	2.90^{b} (9.80)	5.52^{c} (13.58)	20.76^{f} (27.10)	31.48^{i} (34.13)	2.90^{b} (9.80)	0.29^{a} (3.08)
Lindane 0.5 kg a.i./ ha	5.52^{c} (13.58)	6.65^{d} (14.94)	20.23^{e} (27.15)	27.96^{f} (31.92)	0.29^{a} (3.08)	2.90^{b} (9.80)
Phorate 1 kg a.i. / ha	0.29^{a} (3.08)	0.29^{a} (3.08)	21.84^{g} (27.86)	28.83^{g} (32.47)	2.90^{b} (9.80)	0.29^{a} (3.08)
Neem cake + Carbendazim 625 kg / ha + 0.1%	13.30^{e} (21.38)	15.68^{e} (23.32)	5.52^{c} (13.58)	7.79^{b} (16.20)	9.27^{c} (17.72)	11.28^{d} (19.62)
Carbofuran + Carbendazim 1 kg a.i / ha + 0.1%	2.90^{b} (9.80)	2.90^{b} (9.80)	0.29^{a} (3.08)	13.30^{c} (21.38)	2.90^{b} (9.80)	0.29^{a} (3.08)
Lindane + Carbendazim 0.5 kg a.i / ha + 0.1%	5.52^{c} (13.58)	5.52^{c} (13.58)	2.90^{b} (9.80)	5.52^{a} (13.58)	2.90^{b} (9.80)	5.52^{c} (13.58)
Phorate + Carbendazim 1 kg a.i / ha + 0.1%	0.29^{a} (3.08)	2.90^{b} (9.80)	2.90^{b} (9.80)	5.52^{a} (13.58)	0.29^{a} (3.08)	0.29^{a} (3.08)
$ZnSO_4$ 25 kg / ha	13.30^{e} (21.38)	15.68^{e} (23.32)	10.40^{d} (18.81)	19.66^{e} (26.72)	10.40^{d} (18.81)	14.93^{f} (22.73)
Untreated check	15.68^{f} (23.32)	21.94^{g} (27.93)	26.04^{i} (30.68)	33.59^{j} (37.42)	12.42^{e} (20.83)	16.35^{g} (23.85)

DAS – Days After Sowing
Values in parentheses are Arcsine transformed values
In a column means followed by the same alphabet are not significantly different (P=0.05) by DMRT

Table 17. Effect of soil application on stem fly, root rot and stem fly root rot complex on blackgram

Treatments	Stem fly incidence (%)		Root rot incidence (%)		Stem fly & root rot complex (%)	
	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
Neem cake 625 kg / ha	43.85^{d} (41.46)	57.81^{d} (49.49)	15.68^{d} (23.32)	23.04^{d} (28.68)	12.16^{cd} (20.40)	19.61^{de} (26.28)
Carbendazim (drenching) 0.1%	52.10^{f} (46.20)	59.29^{de} (50.35)	0.29^{a} (3.08)	5.52^{a} (13.58)	0.29^{a} (3.08)	2.90^{b} (9.80)
Carbofuran 1 kg a.i./ ha	25.08^{b} (30.05)	27.96^{ab} (31.92)	13.30^{cd} (21.38)	21.94^{cd} (22.93)	10.40^{c} (18.80)	12.16^{cd} (20.40)
Lindane 0.5 kg a.i./ ha	26.55^{bc} (31.01)	30.65^{b} (33.61)	14.80^{d} (22.62)	25.08^{e} (30.05)	12.16^{cd} (20.40)	15.68^{d} (23.32)
Phorate 1 kg a.i. / ha	21.37^{a} (27.53)	26.06^{a} (30.69)	17.02^{de} (24.36)	23.50^{d} (28.99)	10.40^{c} (18.81)	7.79^{c} (16.20)
Neem cake + Carbendazim 625 kg / ha + 0.1%	42.71^{d} (40.80)	55.16^{cd} (47.96)	0.29^{a} (3.08)	5.52^{a} (13.58)	0.29^{a} (3.08)	5.52^{bc} (13.58)
Carbofuran + Carbendazim 1 kg a.i / ha + 0.1%	25.08^{b} (30.05)	26.55^{a} (31.01)	2.90^{b} (9.80)	5.52^{a} (13.58)	2.90^{b} (9.80)	0.29^{a} (3.08)
Lindane + Carbendazim 0.5 kg a.i / ha + 0.1%	33.25^{c} (35.85)	33.18^{bc} (35.17)	2.90^{b} (9.80)	7.79^{b} (16.20)	2.90^{b} (9.80)	5.52^{bc} (13.58)
Phorate + Carbendazim 1 kg a.i / ha + 0.1%	20.23^{a} (26.73)	25.08^{a} (30.05)	0.29^{a} (3.08)	5.52^{a} (13.58)	0.29^{a} (3.08)	2.90^{b} (9.80)
$ZnSO_4$ 25 kg / ha	48.08^{e} (43.90)	57.77^{d} (49.47)	10.40^{c} (18.81)	17.77^{c} (24.93)	5.52^{bc} (13.58)	17.10^{de} (24.42)
Untreated check	49.25^{e} (44.57)	61.73^{e} (51.78)	18.38^{e} (25.38)	24.55^{de} (29.70)	16.35^{d} (23.85)	20.23^{e} (26.72)

DAS – Days After Sowing
Values in parentheses are Arcsine transformed values
In a column means followed by the same alphabet are not significantly different (P=0.05) by DMRT

Table 19. Effect of Carbosulfan and Dimethoate on the growth of *Trichoderma viride* on blackgram and green gram

Treatment No.	Treatments	Growth of *T. viride*		
		24 HAT	48 HAT	72 HAT
T_1	Carbosulfan 25 EC @ 250 ppm	+	++	+++
T_2	Carbosulfan 25 EC @ 500 ppm	+	++	+++
T_3	Carbosulfan 25 EC @ 1000 ppm	+	++	+++
T_4	Dimethoate 30 EC @ 750 ppm	+	++	+++
T_5	Dimethoate 30 EC @1500 ppm	+	++	+++
T_6	Dimethoate 30 EC @ 3000 ppm	+	++	+++
T_7	Untreated check	+	++	+++

\- : No growth
\+ : Fair growth
++ : Medium growth
+++ : Good growth
++++ : Profuse growth

Table 20. Effect of Carbosulfan and Dimethoate on the growth of *Pseudomonas fluorescens* on blackgram and green gram

Treatment No.	Treatments	Growth of *P. fluorescens*		
		24 HAT	48 HAT	72 HAT
T_1	Carbosulfan 25 EC @ 250 ppm	+	+	+
T_2	Carbosulfan 25 EC @ 500 ppm	-	-	-
T_3	Carbosulfan 25 EC @ 1000 ppm	-	-	-
T_4	Dimethoate 30 EC @ 750 ppm	-	-	-
T_5	Dimethoate 30 EC @1500 ppm	-	-	-
T_6	Dimethoate 30 EC @ 3000 ppm	-	-	-
T_7	Untreated check	-	-	-

- : No growth
+ : Fair growth
++ : Medium growth
+++ : Good growth
++++ : Profuse growth

APPENDIX

King's B medium (Kings *et al*., 1954)

Peptone	:	20.0 g
Dipotassium hydrogen phosphate	:	1.5 g
Magnesium sulphate	:	1.5 g
Glycerol	:	10.0 ml
Agar	:	15 g
Distilled water	:	1000 ml

DATA OF WEATHER PARAMETERS

Month	Temperature (°c)		Morning RH (%)	Evening RH (%)	Wind speed (KMPH)	Rainfall (mm)	Number of rainy days
	Maximum	Minimum					
July	30.6	23.2	76	56	23.4	56.4	3
August	30.7	23.4	79	59	17.55	40.1	3
September	31.4	22.5	84	53	10.72	84.5	4
October	31.2	22.6	86	55	6.45	25.4	3
November	30.7	22.2	92	62	4.04	333.1	13
December	28.1	20.3	92	66	1.7	196.6	9
January	29.2	19.1	93	55	0.0	60.1	3
February	29.7	18.2	90	47	0.0	28.2	1
March	31.8	16.9	87	31	24.2	0	0

IPM Module for Stem fly Management

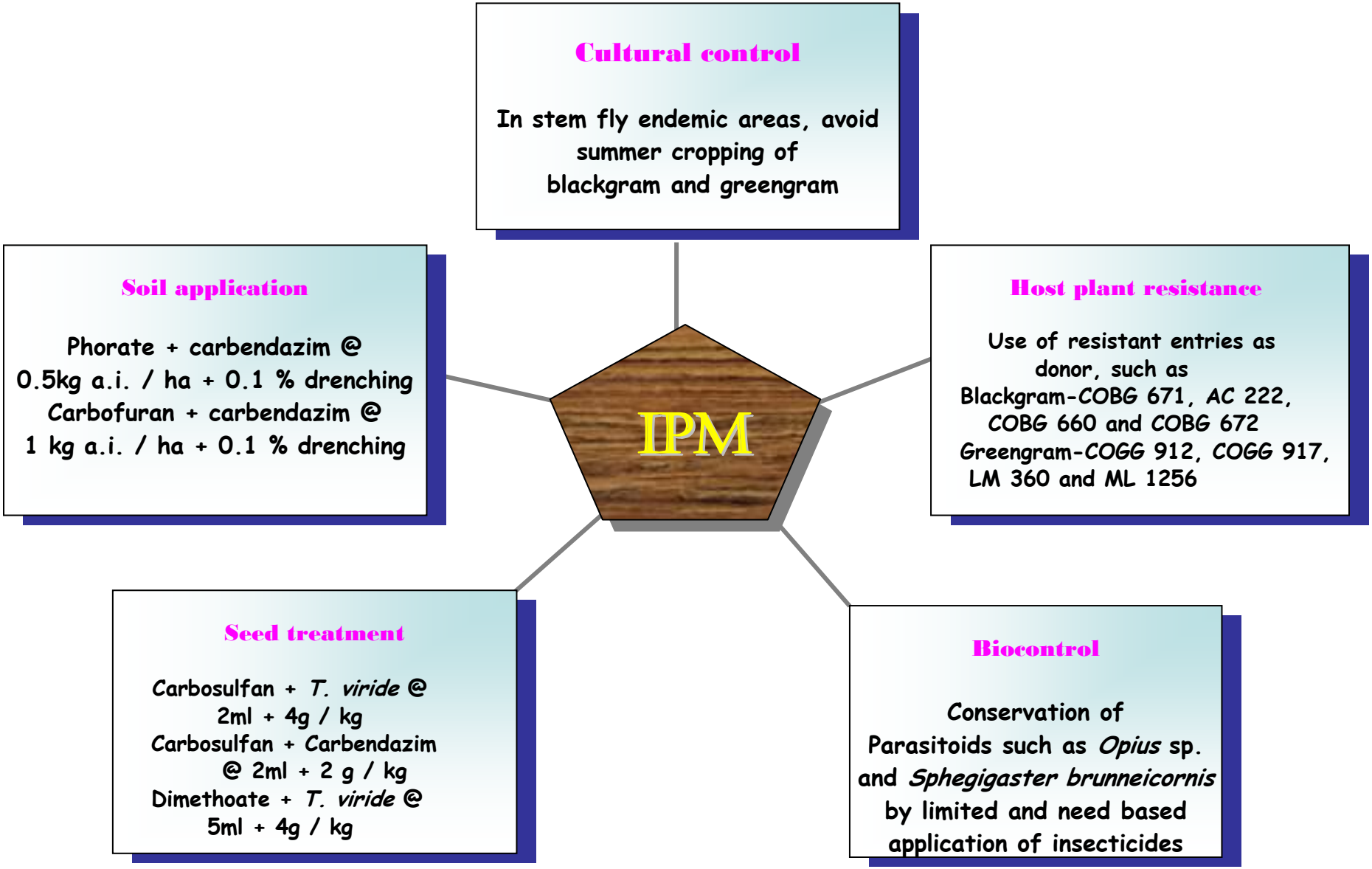

Fig. 4 Relative Biochemical contents in resistant Greengram entries

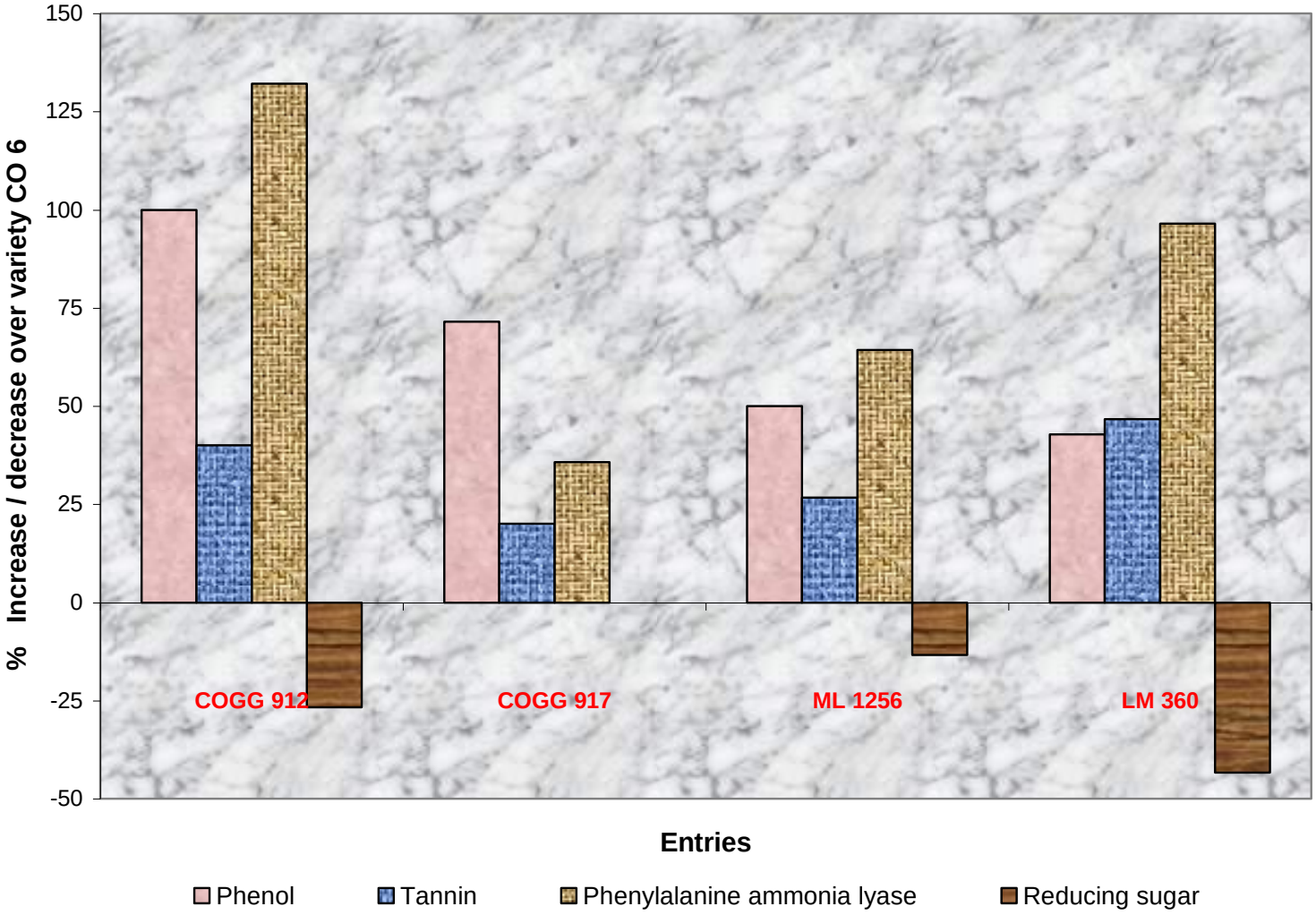

Fig.2 Parasitoids of stem fly with their level of parasitism (%)

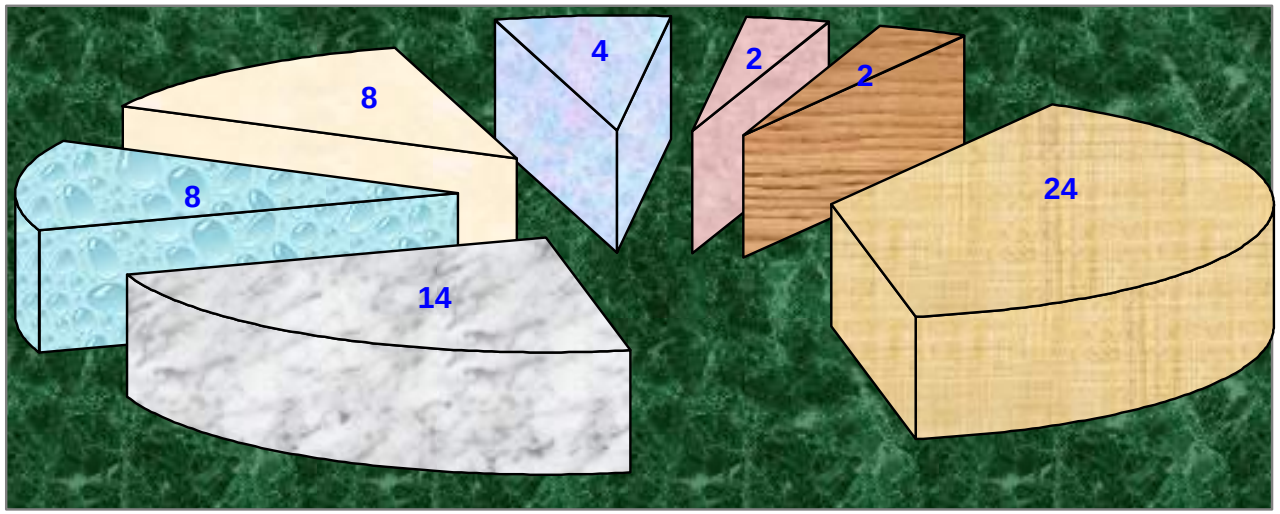

Fig. 1 Seasonal incidence of Stemfly on Blackgram and Greengram

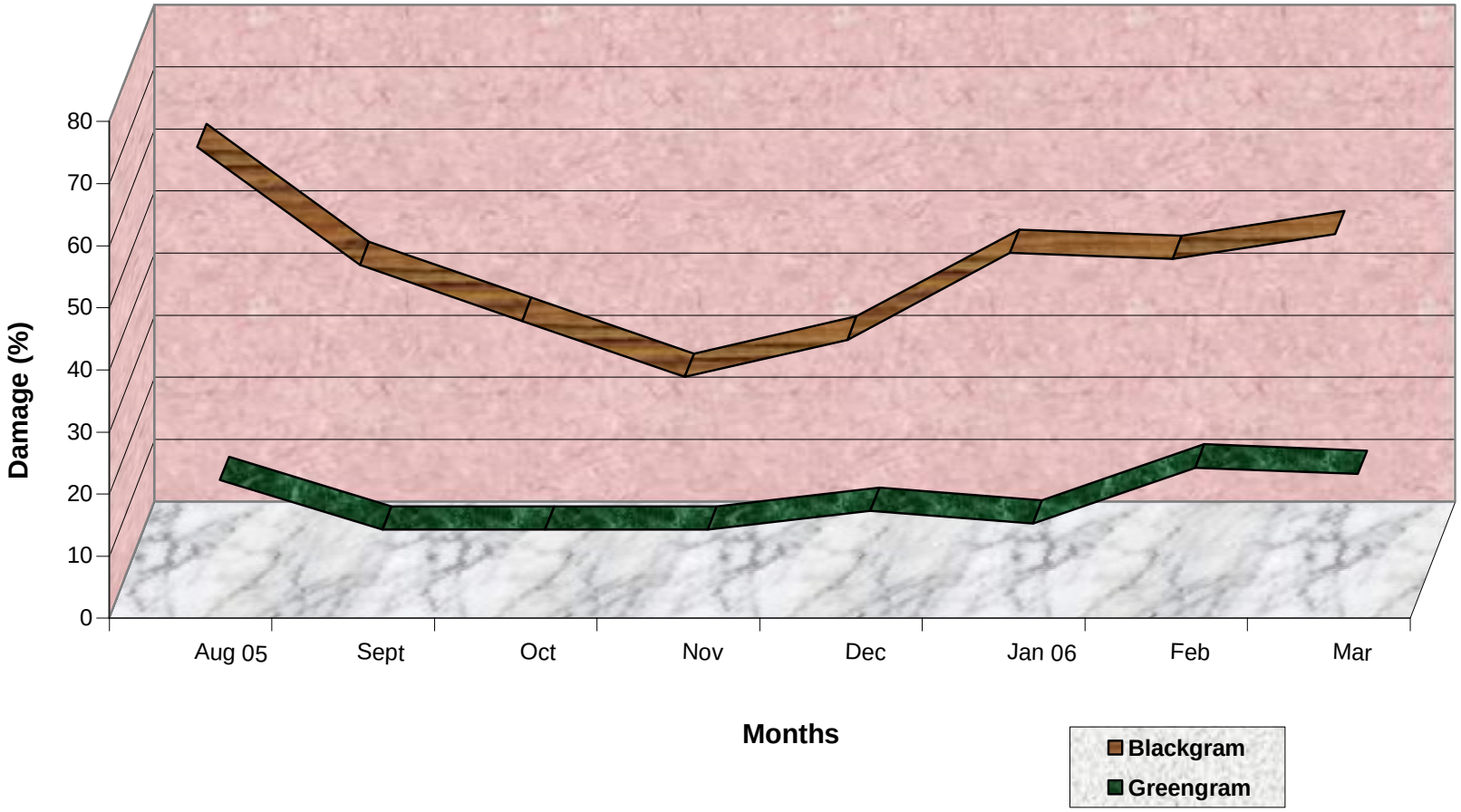

Fig. 3 Relative Biochemical contents in resistant Blackgram entries