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# Insect Pests of Green Gram *Vigna radiata* (L.) Wilczek and Their Management

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## 1. Introduction

### 1.1 Importance of the crop and its cultivation

Pulses, the food legumes, have been grown by farmers since millennia providing nutritionally balanced food to the people of India (Nene, 2006) and many other countries in the world. The major pulse crops that have been domesticated and are under cultivation include black gram, chickpea, cowpea, faba bean, grass pea, green gram, horse gram, lablab bean, lentil, moth bean, pea and pigeon pea. The probable geographical origin of the more common pulses has been reported as:

| Crop | Geographical origin and domestication |
|---|---|
| Black gram | Indian subcontinent |
| Chickpea | Turkey Syria |
| Cowpea | West Africa |
| Faba bean | West Africa |
| Grass pea | Southern Europe |
| Green gram | Indian subcontinent |
| Horse gram | Indian subcontinent |
| Lablab bean | Indian subcontinent |
| Lentil | Southwest Asia (Turkey-Cyprus) |
| Moth bean | Indian subcontinent |
| Pea | Southern Europe |
| Pigeonpea | India |

Source: Nene, 2006

A low input, short duration, high value crop, mung bean fits very well into rice-wheat cropping systems and other crop rotations. It fixes nitrogen in the soil, requires less irrigation than many crops to produce a good yield, and helps maintain soil fertility and texture. Including green gram to the cereal cropping system has the potential to increase farm income, improve human health and soil productivity, save irrigation water and promote long term sustainability of agriculture (Chadda, 2010).

### 1.2 The plant

*Vigna radiata* (L.) Wilczek [Synonyms: *Phaseolus radiatus* L. (1753), *Phaseolus aureus* Roxb. (1832)], often known as green gram/mung bean, is native to India and Central Asia. It has been grown in these regions since prehistoric times (Vavilov, 1926) and as an important legume crop in India throughout the year. The Sanskrit name for green gram is *mudgaparni* or *mashaparni* as per ancient Indian literature the *Yajurveda* (c. 7000 BC). While green gram cultivation spread over to many countries, especially in tropical and subtropical Asia, black gram (*Vigna mungo*) cultivation has remained more or less confined to South Asia. The progenitor of these pulses is believed to be *Vigna trilobata*, which grows wild in India (Nene, 2006). The more common vernacular names include: mung bean, green gram, golden gram (En). Haricot mungo, mungo, ambérique, haricot doré (Fr). Feijão mungo verde (Po). Mchooko, mchoroko (Sw) (Mogotsi, 2006).

The genus *Vigna* comprises about 80 species and occurs throughout the tropics. *Vigna radiata* belongs to the subgenus *Ceratotropis*, a relatively homogenous and morphologically and taxonomically distinct group, primarily of Asian distribution. Other cultivated Asiatic *Vigna* species in this subgenus include *Vigna aconitifolia* (Jacq.) Maréchal (moth bean), *Vigna angularis* (Willd.) Ohwi & Ohashi (adzuki bean), *Vigna mungo* (L.) Hepper (black gram or urd bean), *Vigna trilobata* (L.) Verdc. (pillipesara) and *Vigna umbellata* (Thunb.) Ohwi & Ohashi (rice bean). Hybrids have been obtained between many of these species. The species have often been confounded, especially *Vigna radiata* and *Vigna mungo*. The wild types of mung bean, which are usually smaller in all parts than cultivated types, are usually classified into 2 botanical varieties: – var. *sublobata* (Roxb.) Verdc., occurring in India, Sri Lanka, South-East Asia, northern Australia (Queensland), in tropical Africa from Ghana to East Africa, southern Africa and Madagascar; – var. *setulosa* (Dalzell) Ohwi & Ohashi, with large, almost orbicular stipules and dense long hairs on the stem, and occurring in India, China, Japan and Indonesia. The cultivated types of mung bean are grouped as *Vigna radiata* var. *radiata*, although a classification into cultivar groups would be more appropriate. Two types of mung bean cultivars are usually distinguished, based mainly on seed colour: – golden gram, with yellow seeds, low seed yield and pods shattering at maturity; often grown for forage or green manure; – green gram, with bright green seeds, more prolific, ripening more uniformly, less tendency for pods to shatter. Two additional types are recognized in India, one with black seeds and one with brown seeds (Mogotsi, 2006).

### 1.3 Uses

Mature mung bean seeds or flour enter a variety of dishes such as soups, porridge, snacks, bread, noodles and even ice-cream. In Kenya mung bean is most commonly consumed as whole seeds boiled with cereals such as maize or sorghum. Boiled whole seeds are also fried with meat or vegetables and eaten as a relish with thick maize porridge ('ugali') and pancakes ('chapatti'), whereas consumption of split seeds (dhal) is common among people of Asian descent. In Ethiopia the seeds are used in sauces. In Malawi the seeds are cooked as a side dish, mostly after removing the seed coat by grinding. In India and Pakistan the dried seeds are consumed whole or after splitting into dhal. Split seeds are eaten fried and salted as a snack. The seeds may also be parched and ground into flour after removing the seed coat; the flour is used in various Indian and Chinese dishes. The flour may be further processed into highly valued starch noodles, bread, biscuits, vegetable cheese and extract for the soap industry. Sprouted mung bean seeds are eaten raw or cooked as a vegetable; in French they are erroneously called '*germes de soja*', in English 'bean sprouts'. Immature pods and young leaves are eaten as a vegetable. Plant residues and cracked or weathered seeds are fed to livestock. Mung bean is sometimes grown for fodder, green manure or as a cover crop. The seeds are said to be a traditional source of cures for paralysis, rheumatism, coughs, fevers and liver ailments (Mogotsi, 2006).

### 1.4 Nutritional facts

Green gram is an important source of easily digestible high quality protein for vegetarians and sick persons. It contains 24 per cent protein, 0.326 per cent phosphorus, 0.0073 per cent iron, 0.00039 per cent carotene, 0.0021 per cent of niacin and energy 334 cal/100g of green gram. The gap between realizable and actual yields needs to be bridged up with appropriate technologies. The latter basically revolves around two aspects: production and protection. Although the former has been a subject of greater emphasis at all levels of strategy, yet the latter continues to suffer from neglect and a sort of apathy under the cover of ignorance, economic status of the farmers and many more factors. In India, Acharya (1985) has pointed out that plant protection remains a most neglected aspect in pulse cultivation; further stating that only 5 to 6 per cent of the growers use plant protection measures in only 1.5 per cent of the total area under this crop. In view of the above facts, for the control of various pests in green gram, only certain insecticides have been recommended by several workers.

The composition of mature mung bean seeds per 100 g edible portion is: water 9.1 g, energy 1453 kJ (347 kcal), protein 23.9 g, fat 1.2 g, carbohydrate 62.6 g, dietary fibre 16.3 g, Ca 132 mg, Mg 189 mg, P 367 mg, Fe 6.7 mg, Zn 2.7 mg, vitamin A 114 IU, thiamin 0.62 mg, riboflavin 0.23 mg, niacin 2.3 mg, vitamin $B_6$ 0.38 mg, folate 625 µg and ascorbic acid 4.8 mg. The essential amino-acid composition per 100 g edible portion is: tryptophan 260 mg, lysine 1664 mg, methionine 286 mg, phenylalanine 1443 mg, threonine 782 mg, valine 1237 mg, leucine 1847 mg and isoleucine 1008 mg. The starch consists of 28.8per cent amylose and 71.2per cent amylopectin. Mung bean seed is highly digestible and low in antinutritional factors. It causes less flatulence than the seed of most other pulses, making it suitable for children and older people. Mung bean starch is considered to have a low glycaemic index, i.e. to raise the blood sugar level slowly and steadily. The composition of sprouted mung bean seeds per 100 g edible portion is: water 90.4 g, energy 126 kJ (30 kcal), protein 3.0 g, fat 0.2 g, carbohydrate 5.9 g, dietary fibre 1.8 g, Ca 13 mg, Mg 21 mg, P 54 mg, Fe 0.9 mg, Zn 0.4 mg, vitamin A 21 IU, thiamin 0.08 mg, riboflavin 0.12 mg, niacin 0.75 mg, vitamin $B_6$ 0.09 mg, folate 61 µg and ascorbic acid 13.2 mg. The essential amino-acid composition per 100 g edible portion is: tryptophan 37 mg, lysine 166 mg, methionine 34 mg, phenylalanine 117 mg, threonine 78 mg, valine 130 mg, leucine 175 mg and isoleucine 132 mg. Sprouting especially leads to an increased ascorbic acid concentration. Mung bean hay contains: moisture 9.7 per cent, crude protein 9.8 per cent, fat 2.2 per cent, crude fibre 24.0 per cent, ash 7.7 per cent, N-free extract 46.6 per cent, digestible crude protein 7.4 per cent, total digestible nutrients 49.3per cent. Aqueous extracts of mung bean seeds have shown in-vivo hypotensive and hepatoprotective effects in rats. Extracts from mung bean seeds and husks have shown antioxidative effects.

The chemical composition of green gram (dal) has been worked out as:

| Calorific value (cal./ 100g) | Crude protein (%) | Fat (%) | Carb-ohyd-rate (%) | Ca (mg/ 100g) | Fe (mg/ 100g) | P (mg/ 100g) | Vitamine(mg/100g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $B_1$ | $B_2$ | Niacine |
| 334 | 24.0 | 1.3 | 56.6 | 140 | 8.4 | 280 | 0.47 | 0.39 | 2.0 |

**Source:** Pulse Crops, by B.Baldev, S.Ramanujam and H.K.Jain, PP. 563.

### 1.5 Cultivation in Kenya

Green gram is a warm-season crop and grows mainly within a mean temperature range of 20–40°C, the optimum being 28–30°C; hence, can be grown in summer and monsoon season/autumn in warm temperate and subtropical regions and at altitudes below 2000 m in the tropics. It is sensitive to frost. It is mostly grown in regions with an average annual rainfall of 600–1000 mm, but it can do with less. It withstands drought well, by curtailing the period of flowering and maturation, but it is susceptible to water-logging. High humidity at maturity causes damage to seeds leading to seed discoloration or sprouting while still in the field. Green gram cultivars differ markedly in photoperiod sensitivity, but most genotypes show quantitative short-day responses, flower initiation being delayed by photoperiods longer than 12–13 hours. The crop grows well in a wide range of soil types, but prefers well-drained loams or sandy loams with pH (5–) 5.5–7 (–8). Some cultivars are tolerant to moderate alkaline and saline soils (Mogotsi, 2006).

Green gram is propagated by seed. There is no seed dormancy, but germination can be affected by a hard seed coat. Green gram seeds are broadcast or dibbled in hills or in rows. Recommended sowing rates are 5–30 kg/ha for sole crops, and 3–4 kg/ha under intercropping. Recommended spacing ranges within 25–100 cm × 5–30 cm; whereas, for the more modern cultivars ripening in 60–75 days, maximum yields are obtained at plant densities of 300,000–400,000 plants/ha. The later-maturing traditional cultivars generally need wider spacing. Recommended spacing for sole crop of green gram in Kenya are 45 cm between rows and 15 cm within the row, with a seed rate of 6–10 kg/ha and a sowing depth of 4–5 cm. Mung bean can be grown mixed with other crops such as sugar cane, maize, sorghum or tree crops in agroforestry systems. Short-duration mung bean is often relay-cropped to make use of a short cropping period. In Kenya mung bean is usually intercropped with maize, sorghum or millet; it is occasionally grown in pure stands or intercropped with other pulses. The usual practice here is to place 1–2 rows of mung bean between rows of a cereal, or to plant mung bean in the cereal row. In pure stands, 1–2 weedings are necessary during the early stages of growth. In Kenya weeding is done using hoes and machetes. Farmers do not normally apply any inorganic fertilizer to a mung bean crop. Mung bean uses residues from fertilizer applications to the main crops in the system, though it responds well to phosphorus. Nutrient removal per ton of seed harvested (dry weight) is 40–42 kg N, 3–5 kg P, 12–14 kg K, 1–1.5 kg Ca, 1.5–2 kg S and 1.5–2 kg Mg. The nutrient removal is much higher when crop residues are removed to be used for fodder. In its major area of cultivation, the monsoon tropics, mung bean is mainly grown as a rainy season crop on dryland or as a dry-season crop after the monsoon in rice-based systems on wetland, making use of residual moisture or supplementary irrigation. In some areas where adequate early rains occur, an early-season crop can be grown before the monsoon. In semi-arid regions of Kenya with 600–800 mm rainfall evenly distributed over 2 rainy seasons, 2 mung bean crops are grown per year. In the Wei Wei Integrated Development Project in Sigor, Kenya, mung bean is grown under irrigation. In India mung bean is often sown as a fallow crop on rice land as a green manure (Mogotsi, 2006).

### 1.6 Cultivation in India

#### 1.6.1 Historical background

India has been universally accepted as the original home of these two pulse crops. While green gram was spread to many countries, especially in tropical and subtropical Asia, black gram has remained more or less confined to South Asia. Currently, green gram is being grown in USA.

#### 1.6.2 Area and production

India is reportedly the largest pulse growing country in the world both in terms of area as well as production covering 43.30 per cent of land area under pulses with 33.15 per cent production. In another report, it has been described that India is the largest producer and consumer of pulses in the world accounting for 33 per cent of world's area and 22 per cent of world's production of pulses. Green gram is one of the most widely cultivated pulse crops after chickpea and pigeonpea. The major producing states in India are Andhra Pradesh, Orissa, Maharashtra, Madhya Pradesh and Rajasthan accounting for about 70 per cent of total production.

Reliable production statistics for mung bean are difficult to obtain, as its production is often lumped together with that of other *Vigna* and *Phaseolus* spp. India is the main producer, with an estimated production in the late 1990s of about 1.1 million t. China produced 891,000 t (19per cent of total pulse production in China) from 772,000 ha in 2000. No mung bean production statistics are available for Africa. China exported 110,000 t in 1998, 290,000 t in 1999 and 88,000 t in 2000. All mung bean produced in India is for domestic consumption. In most parts of Africa where there are Asian communities, mung bean food products are sold in the cities (Mogotsi, 2006).

In India it is cultivated in two seasons: *kharif* and summer. However, peak market arrivals are from September to October (*kharif*) and June to July (summer). Green gram is mostly grown as a *kharif* crop (monsoon season) in the states of Rajasthan, Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Madhya Pradesh and Uttar Pradesh; but, in Tamil Nadu, Punjab, Haryana, Uttar Pradesh and Bihar it is grown as a summer crop. Green gram is a short duration crop; the canopy closes in earlier than in cereal crops. Therefore, the critical period for crop-weed interference is limited to the first 30 days after sowing. However, the presence of weeds during this period may lead to 20 to 40 percent reduction in yield. The most phenomenal way of reducing weed infestation include preventive measures like use of clean crop seed and pre-planting destruction of existing weeds by tillage. In the standing crop, one inter-row hoeing and weeding at 25 to 30 days after sowing is good enough to check potential losses. Sometimes in the monsoon crop, due to incessant rains, tillage operations are not feasible; hence, the use of pre-plant incorporation of fluchloralin or pendimethalin at the rate of 0.75 to 1.0 kg per hectare is recommended.

### 1.6.3 Cropping systems

The common crop rotations followed in India include: green gram – mustard; green gram – safflower; green gram – linseed; and green gram – wheat. In *kharif*, intercropping with maize, pearl millet, sesame, pigeon pea, and cotton is common. Spring or summer green gram is grown as a catch crop. The crop sequences that have been successful are green gram – maize – wheat, green gram – rice – wheat, green gram – maize – toria – wheat, green gram – maize – potato – wheat. In spring planted sugarcane, it is also grown as an intercrop. During *rabi*, it is grown in rice fallows of southern and south eastern region (ICAR, 2006).

The area (m-ha), production (m-t) and Productivity (kg/ha) in India

| Years | Area | Production | Productivity |
|---|---|---|---|
| 2004-05 | 3.34 | 1.06 | 415 |
| 2005-06 | 3.10 | 0.95 | 428 |
| 2006-07 | 3.19 | 1.12 | 440 |
| 2007-08 | 3.43 | 1.52 | 510 |
| 2008-09 | 3.30 | 1.24 | 425 |

Source: Directorate of pulses development Bhopal

## 2. Insect pests and their associated natural enemies

### 2.1 Qualitative and quantitative abundance

Methodology used to quantify major insect pests of green gram and the associated natural enemies:

Study on population dynamics of insect pests and natural enemies:

i. Population of jassids (nymphs & adults) and white flies (adults) can be estimated by the visual count technique during early hours of the day from requisite plants per replication (usually counting from 1/5$^{th}$ of total plant population per plot), selected at random and tagged. The top, middle and bottom parts of the tagged plants should be given due consideration. Alternatively, the sudden trap method using a cubical iron-frame trap of 45cm x 45cm base and 60cm height clothed in high density polythene can be used to trap the adult jassids and whiteflies for easy counting. The nymphs can be counted adopting the visual/sight-count technique from the plants by gently turning the leaves. Similarly, for aphids, the nymphs and adults can be counted on the plants directly taking observations from at least a 10cm top shoot/twig for sampling. Yellow pan-traps or sticky traps can also be used for counting the jassids and whiteflies.

The population of jassds and whiteflies can be estimated by the sudden trap method using a cubical iron-frame trap of 45cm x 45cm base and 60cm height clothed in high density polythene or covered by muslin cloth on three sides, while one side and the top can be clothed with high density polythene for viewing the adults captured in the trap. This is possible when the crop is 35 to 40 day-old; thereafter, we have to rely on visual count technique as it is not feasible to use the sudden trap because as per agronomical practices the spacing is recommended as 30cm between the rows and 10cm between two pants in a row; though, we may go for a spacing of 45cm (row to row) by 15cm (plant to plant in a row). Yes, an aspirator should be used to suck the adults for a reliable count. The few adults that might escape while counting from each tagged plant or replicate is a common error and will be taken care of if the sample size is more. The jassid nymphs move sideways but do not leave the foliage while observing, hence their count is reliable.

Data from visual counts can be homogenized by following the square root transformation method, especially when zero counts are recorded. We add 0.5 or 1.0 to the visual count data and find the square root before analysis that has to be retransformed after analysis for interpretation. In case of percentage data, if the percentage values range between 30 and 80, usually arc sine (angular) transformation would not be required; however, if the percentage values happen to be less than 30 and/ or more than 80, then angular transformation is required before analysis of data.

Green gram being an indeterminate plant, vegetative growth and flowering go together when the plant is 35 to 40 days of age; hence, using a suction trap (battery operated/electric) might not be successful, as it will cause more harm to the plant and at the same time disturb the insects. We can use the suction trap if the field/plot size is large so that sampling can be taken from distant areas within the field being observed without disturbing the insect species on adjacent plants.

ii. The associated natural enemies like syrphid flies, coccinellids and others, can be recorded by the visual/sight count technique from the same number of plants per replication (1/5$^{th}$ of total population) randomly tagged, during early hours of the day. Observations can be taken to study the predator-prey function under caged conditions.
iii. Observations can be taken on a weekly basis or a 10-day basis and the prevailing abiotic conditions of the atmosphere can also be recorded accordingly to work out the correlation coefficients between the populations and the abiotic factors of the environment.

It is true that correlations do not establish the cause and effect relationships and must be interpreted with caution. Therefore, further working out the simple regression lines or linear regressions through regression equations enables us to know the effect of the abiotic factors (independent variable) on the population (dependent variable). Data so collected and collated over many years (at least for 5 years in succession) will give a good understanding of the population trend.

The equation of a line of regression (Y on X) is given as:

$$Y = a + bX$$

The data can be entered and processed in "MS-Excel" using the correlation function and make a chart in excel using the custom type Classic Combination Chart (either line-column on two axes or lines on two axes) that also enables to have the regression equation and coefficient of determination ($R^2$).

iv. Estimation of the population density of insect pests and their natural enemies in the different treatments can be made and expressed as a percentage after comparing the data from the control treatment or the standard check. Wherever applicable, diversity indices can be computed using suitable techniques (Shanon-Weiner or Simpson Diversity Index).

The following mathematical/ statistical analysis can be made towards estimating the species richness and diversity:

Mean density:

$$\text{Mean density} = \Sigma \frac{Xi}{\text{N}} \times 100$$

Where,

*Xi* = No. of insects or natural enemies in $i^{th}$ sample
*N* = Total number of plants sampled.

Shannon-Weiner diversity index (H'):

Shannon-Weiner diversity index

$$(\text{H}') = -\Sigma \ \text{p}i \ ln \ pi$$

Where, p*i* = the decimal fraction of individuals belonging to $i^{th}$ species.

However, along with the Shanon Diversity Index the Simpson's Index can also be computed.

Simpson's index is calculated using the equation:

$$\text{Ds} = \frac{\text{N(N-1)}}{\sum \text{n(n-1)}}$$

N= Total number of individuals of all species
n= Number of individuals of a species

v. To record the incidence of blister beetles at flowering stage the numbers of beetles per plant for a fixed time interval during the morning hours (8 to 10am) or evening hours (3 to 5pm) of the day can be observed on the randomly tagged plants. However, some species visit during early hours while others late; hence, a preliminary observation on their behaviour shall become essential before standardizing the methodology for blister beetle counts.

vi. To note the damage of pod borers, the numbers of healthy and damaged pods can be counted from a known (pre-decided) sample of pods (say 100) taken from the tagged plants and the data expressed as a percentage of the total. Usually the pods are split open to record the species of the borer under study.

vii. For the estimation of the population of soil dwelling predators, especially carabids, pitfall traps (500ml capacity glass jars) should be laid out in each replication and at least 3 traps should be randomly placed in each plot of 18 sq. m. (6m X 3m as length X breadth). For instant killing of the predatory insects and to avoid cannibalism (as in carabid grubs), ethylene glycol or formalin (1-2%) can be used in the traps. Comparisons among the treatments can be accounted for.

### 2.2 Loss estimation and establishment of economic threshold for the pod borer

In order to asses the losses caused by insect pests of green gram the paired plot experiment, as suggested by Leclerg (1971), can be adopted. The method involves growing the crop in 26 plots, each measuring preferably 6m X 3m. Each plot should be separated by a buffer strip of one meter all around. One set of plots has to be kept protected from insect infestation by regular need-based application of recommended insecticides. The other set of plots has to be exposed to natural infestation and thus called unprotected. Observations on the plant height, number of primary branches, pod length, pod and grain damage (%), and any other yield attributing parameter recorded from five randomly selected plants from each plot at maturity should be taken. Loss in yield can be calculated by comparing the yield obtained from protected and unprotected plots using the following formula:

$$\text{Loss in yield}\,(\%) = \frac{X_1 - X_2}{X_1} \times 100$$

Where

$X_1$ = Yield in treated plot
$X_2$ = Yield in untreated plot

The yield data can be analyzed statistically and significance tested using the "t" test.

$$\text{Standard deviations (s)} = \frac{\text{Sum of square of the deviation from the mean difference}}{\text{Number of paired plots} - 1}$$

$$\text{Standard error of mean difference (Sd)} = \frac{\text{Standard deviation (s)}}{\text{Number of paired plots (n)}}$$

$$t = \frac{Y_1 - Y_2}{sd}$$

Where

$Y_1$ = Average yield in treated plot; $Y_2$ = Average yield in untreated plot

sd = Standard error of mean difference

### 2.3 Determination of economic threshold level for the lycaenid pod borer

In order to calculate the economic injury level for the pod borer, losses in grain weight due to various levels of larval density of the pod borer has to be estimated. Green gram can be sown in pots of suitable size and the neonate larvae can be released on the developing tender pods or flowers at different population densities (1, 2, 3 and 4 larvae per plant or in a geometrical progression as 2, 4, 8 and 16). A no-larval release control should also be taken side by side on the pot plants. The plants should be caged properly and the treatments replicated. Observations on the number of healthy and damaged pods, and grain weight per plant should be recorded. Taking the reduction in yield due to different levels of larval density release, the regression analysis can be worked out to quantify the damage. The economic injury level for the pod borer on green gram can be determined by using the method suggested by Hammond and Pedigo (1982).

$$\text{Gain threshold (G.T.)} = \frac{\text{Management Cost (Rs/ha)}}{\text{Marketed value of Mungbean (Rs/kg)}} = \text{kg/ha}$$

$$\text{Economic injury level (EIL)} \frac{\text{Gain threshold (kg/ha)}}{\text{Loss per insect (kg/insect)}} = \text{insect/ha}$$

The economic threshold level can be calculated by the method suggested by Johnston and Bishop (1987). They established economic threshold level as the population of economic injury level minus the increase in population of the pest concerned per day. The increasing rate of larval population under natural field conditions can be determined by recording the weekly population of the pod borer during larval activity. The rate of increase in population can be calculated arithmetically.

### 2.4 Farmscaping in green gram with annual marigold and niger

Early flowering marigold variety must be sown in well prepared, raised nursery beds at least 45 days before transplanting. Niger crop has to be directly sown 28 to 30 days before sowing the main crop of green gram. In short, sowing should be adjusted in such a manner that flowering of niger/marigold and green gram should coincide so that nectar/pollen feeding natural enemies would be attracted to the farmscape plants. The sowing operations for green gram and the different farmscape plants should be as:

1. In the green gram and niger farmscaping (3: 1 ratio), niger sowing is done first and followed by sowing of green gram a month later.
2. In the green gram and marigold farmscaping (3: 1 ratio), transplanting of marigold on ridges should be carried out 45 days after sowing green gram.

The row to row distance and plant to plant spacing for green gram can be 60cm and 10cm, respectively or 45cm and 10cm, respectively; whereas, mature seedlings of marigold are to be transplanted in between two rows of green gram at a distance of 30cm.

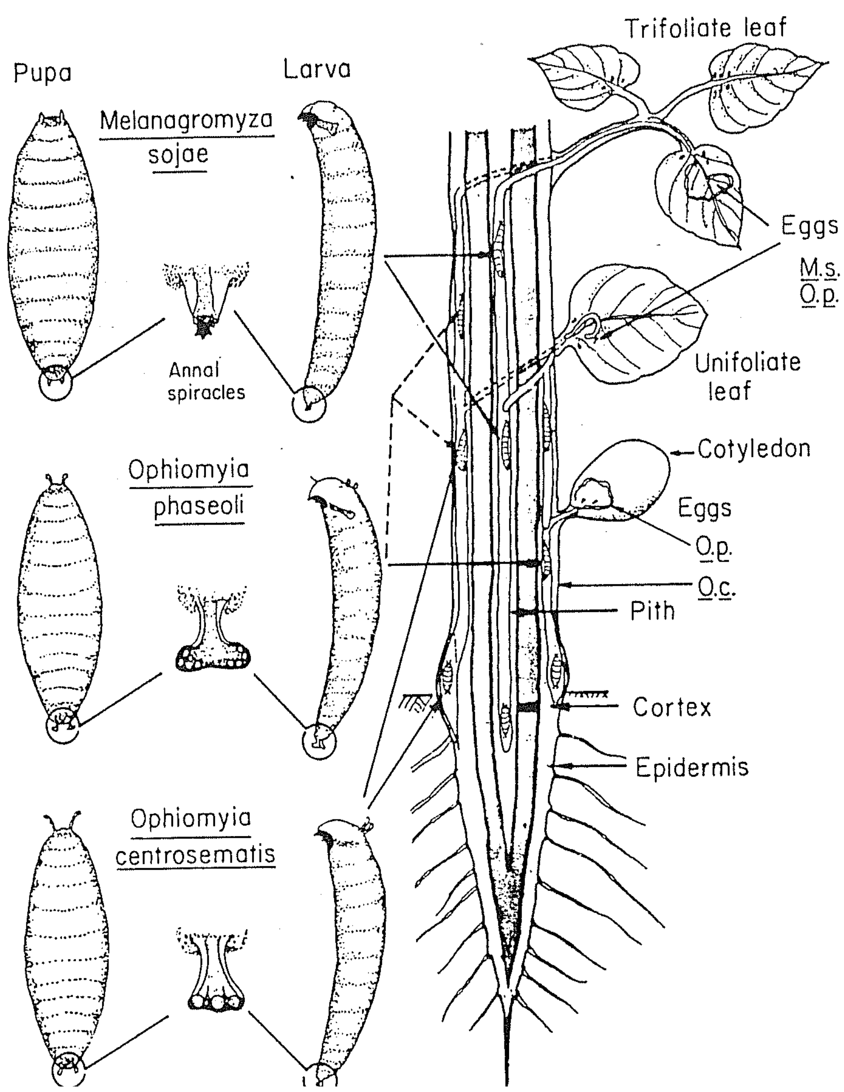
## 3. Pest management strategies

### 3.1 The pest insects

An estimated 200 insect pests that belong to 48 families in Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera, Orthoptera, Thysanoptera, and 7 mites of the order Acarina are known to infest green gram and black gram. Under severe cases stem fly may alone cause more than 90 per cent damage with a yield loss of 20 per cent (Talekar, 1990). The galerucid beetle, *Madurasia obscurella* causes damage up to 20 – 60 per cent. Whitefly, a potential vector of mungbean yellow mosaic virus (MYMV), can cause losses ranging from 30–70 per cent. The major insect pests, particularly those often cited, have been enlisted in Table - 1.

The insect pests that infest green gram are better classified according to their appearance based on crop phenology. Accordingly, they can be: (1) stem feeders, (2) foliage feeders, (3) pod feeders, and (4) pests of stored grains; which are also convenient to access their economic importance so as to devise suitable management measures.

At the seedling stage are the agromyzid flies, also known as bean flies (possibly few species), *Melanagromyza* (*Ophiomyia*) *phaseoli* (Tryon) being of more common occurrence. *Ophiomyia phaseoli* larva is a cortex feeder and pupates in the cortex mostly at the root-shoot junction. Sometimes pupae can be seen sticking under the membranous epidermis. In India the girdle beetle, *Oberiopsis brevis* (Swedenbord), a major pest of soybean, sometimes infests mungbean locally (Talekar, 1990).




(*M. s.* = *M. sojae*, *O. p.* = *O. phaseoli*, *0. c.* = *O. centrosematis*; please note, *O. phaseoli* does not lay eggs in the cotyledons of green gram) [Ref.: Talekar, 1990]

Fig. 1. Location of ovipositional and larval feeding sites in soybean plant

The foliage feeders, especially defoliators that belong to Lepidoptera and Coleoptera include: the leaf folder, *Lamprosema indica* (F.); caterpillars of *Spodoptera exigua* (Hubner), *Anticarsia irrorata* (F.) the tobacco caterpillar, *Spodoptera litura* (F.), the hornworms, *Agris convolvuli* (L.) and *Acherontia styx* (Westwood); the Bihar hairy caterpillar, *Spilosoma obliqua* (Walker), the tussock caterpillars, *Euproctis fraterna* (Moore), *Dasychira mendosa*; the weevils, *Cyrtozemia dispar* Pascoe, *Myllocerus undecimpustulatus maculosus* Desbr., *Myllocerus discolor* Boheman, *Myllocerus viridanus* Boheman, *Episomus lacerata* Fabr.; the hada beetle, *Henosepilachna* spp., chrysomelid (leaf) beetles, *Monolepta signata*, and the grasshopper, *Attractomorpha crenulata crenulata*.

Among the sap feeding insects the more common are aphids, especially black bean aphids, *Aphis craccivora* Koch; jassids, *Empoasca kerri* Pruthi; white flies, *Bemisia tabaci* Gennadius, thrips belonging to genus *Megalurothrips* and *Caliothrips indicus* Bagnall; the plant bugs, *Riptortus* spp., *Nezara viridula* L., *Plautia fimbriata* (Fabricius) and the pod bug, *Clavigralla* spp. They cause significant damage to green gram foliage and pods; besides causing damage to other related legumes. It was observed that green gram cultivated in the vicinity of pigeon pea was heavily infested and rather preferred by the pigeon pea pod bug, *Clavigralla* spp. (Swaminathan, *et al*., 2007). A linear relationship was observed between pod feeder infestation and seed loss, with the rate of seed loss being greater for *Riptortus linearis* and *Nezara viridula* than for *Maruca testulalis* (Hussain and Saharia, 1994).

The blister beetles (species of *Mylabris*) cause serious damage to the flowers, especially to the second and third flush during August – September months in most green gram cultivation areas in India.

The key pod borers include the lepidopteran caterpillars – the spotted pod borer, *Maruca testulalis* (Geyer) [*Maruca vitrata*] and the spiny pod borer, *Etiella zinckenella* Tretsche; however, the blue butterflies, *Lampides boeticus* Linnaeus and *Catechrysops cnejus* Fabricius; the gram caterpillar, *Helicoverpa armigera* (Hubner) have also been reported among the major pests.

The primary insect pests of stored green gram include species of bruchids belonging to the genus *Callosobruchus*. The annual yield loss is estimated to be 20 per cent in pigeonpea, 15 per cent in chickpea and 30 per cent in black gram and green gram. On an average 2.5 to 3.0 million tonnes of pulses are lost annually due to pests (Ali, 1998). Damage due to bruchids, *Callosobruchus chinensis* (L.) begins right from the field; adults emerging from the stored seeds lay eggs on healthy grains. The field infestation ranges from 7.8–9.9 per cent (Banto and Sanchez, 1972) and 100 per cent destruction of seeds occurred at 9.9 per cent field infestation.

### 3.2 Pest management strategies

#### 3.2.1 Organic approach

Of late, use of various cultural practices and framscaping for the management of insect pests of green gram seems to gain importance. Adjusting the sowing dates, use of resistant varieties and growing inter or trap crops can be followed depending on the availability and effectiveness in a particular location. Since use of bio-control agents has not been successful in these crops although it is a viable alternative despite the record of several natural enemies in the field, their augmentation through farmscaping is a viable option.

Farmscaping is an ecological approach to pest management; comprising the use of hedgerows, insectary plants, cover crops, and water reservoirs to attract and support populations of beneficial organisms such as insects, bats, and birds of prey. Such mini-livestock requires adequate supplies of nectar, pollen, and herbivorous insects and mites as food to sustain and increase their populations. The best source of these foods is flowering plants. Flowering plants are particularly important to adults of the wasp and fly families, which require nectar and pollen sources in order to reproduce the immature larval stages that parasitize or prey on insect pests. However, using a *random* selection of flowering plants to increase the biodiversity of a farm may favor pest populations over beneficial organisms. It is important to identify those plants, planting situations, and management practices that best support populations of beneficial organisms.

There are many approaches to farmscaping: some farmers, after observing a cover crop harboring beneficial insects, plant strips of it in or around their crop fields. The advantages of this kind of approach are that it is simple to implement, is often very effective and the farmer can modify the system after observing the results. Problems arise when the beneficial insect habitat, without the knowledge of the cultivator, also harbors pest species. In other instances the beneficials may not exist in numbers sufficient to control pest populations, *especially during the time when pest populations generally increase*. Predator/prey population balances are influenced by the *timing* of availability of nectar, pollen and alternate prey/hosts for the beneficials; therefore, essentially efforts must be made to for have year-round beneficial organism habitat and food sources. The beneficial habitat season may be extended by adding plants that bloom sequentially throughout the growing season or the whole year (Rex Dufor, 2000).

The mechanisms by which insectary plantings can help natural enemies of crop pests and other beneficial arthropods are complex, and their effectiveness can vary greatly from site to site depending on the specific situation. For this reason, it is especially important that insectary plantings are planned and assessed on a case-by-case basis, and integrated into whole-farm plans for pest management and other farm operations. Insectary plantings that are well thought out can maximize the benefits to natural enemies and minimize the benefits to pest species (Pfiffner and Wyss 2004, Quarles and Grossman 2002).

The goal of farmscaping is to prevent pest populations from becoming economically damaging. This is accomplished primarily by providing habitat to beneficial organisms that increase ecological pressures against pest populations. Farmscaping requires a greater investment in knowledge, observation, and management skill than conventional pest management tactics, while returning multiple benefits to a farm's ecology and economy. However, farmscaping alone may not provide adequate pest control. It is important to monitor pest and beneficial populations so that quick action can be taken if beneficials are not able to keep pest populations in check. Measures such as maintaining healthy soils and rotating crops are complementary to farmscaping and should be integrated with farmscaping efforts. Bio-intensive Integrated Pest Management (IPM) measures, such as the release of commercially-reared beneficials (applied biological control) and the application of soft pesticides (soaps, oils, botanicals) can be used to augment farmscaping efforts.

In a case study on the impact of farmscaping in greengram on the major insect pests and their natural enemy complex at the College farm, Udaipur, India, a comparison of the seasonal mean abundance of the major foliage feeding and pod damaging insect pests showed a significant difference among the treatments. The Shanon Weiner diversity index was the maximum under green gram + marigold weeded and unweeded farmscape conditions being 0.7936 and 0.7790. The sole crop of green gram had the lowest diversity index of 0.6622 for weeded and 0.6863 for unweeded conditions. Comparisons made for the associated natural enemy complex in the different treatments showed that the farmscape treatment green gram + niger under unweeded conditions had the highest Shanon Weiner diversity index of 1.5932 followed by that for green gram + marigold under unweeded conditions with an index of 1.5716. Green gram sole crop had the lowest diversity indices being 1.2882 and 1.3854 under weeded and unweeded conditions, respectively. Niger, by virtue of being taller than green gram, acts as a physical barrier to blister beetle infestation on green gram floral parts. Some blister beetles may happen to alight on niger flowers and cause some damage, thereby safeguarding damage to green gram. Marigold is preferred by *Helicoverpa armigera* (Hubner) for laying eggs; thereby, the main crop of mung bean/green gram significantly escapes the pest infestation (Unpublished data – Swaminathan, 2011).

### 3.3 Cultural practices

Different cultural practices have been advocated from time to time; however, these traditional practices and those improved happen to vary from place to place and have responded in a varied manner. Intercropping green gram with cereals/millets (maize, sorghum and pearl millet) is often in vogue. Green gram is sown by keeping the row to row spacing at 30 cm and plant to plant distance at 10 cm. In the inter-cropped system, green gram and maize (in 1: 1 ratio) are sown in alternate rows at a distance of 30cm apart. In spring planted sugarcane, 1 or 2 rows of green gram can be planted in between the sugarcane rows. Intercropping of green gram can also be done in *Mentha*. Similarly, in the newly planted poplar crop and in horticultural plants or orchards (papaya, pomegranate) intercropping green gram is a viable option.

Weed-free crop of green gram harboured lower populations of major insect pests, while weedy crop was conducive to their population build-up. With respect to insect infestation, keeping the field weed-free throughout the crop period was equivalent to removal of weeds up to the vegetative-3 stage of the crop. The effectiveness of weeding however varied according to the pest species (Rekha Das Dutta, 1997).

Showler and Greenberg (2003) observed that the presence of weeds in cotton was associated with greater populations of 9 of the 11 prey arthropod groups, and 9 of the 13 natural enemy arthropod groups counted. These trends were mostly evident late in the season when weed biomass was greatest. Weed-free cotton harboured more cotton aphids (*Aphis gossypii*), early in the season and silver leaf whiteflies (*Bemisia argentifoli*) later in the season than weedy cotton on some of the sampling dates. Diversity (Shannon's index) within the selected arthropod groups counted was significantly greater in DVAC samples from the weed foliage than from weed-free cotton plants during both years, and diversity on weedy cotton plants was greater than on weed-free cotton plants during 2000. Boll weevil oviposition injury to squares was unaffected by weeds, but the higher weed-associated predator populations mainly occurred after most squares had become less vulnerable bolls. Weed competition resulted in lower lint yields of 89 and 32 per cent in 2 years.

Some of the more recent literature on the impact of intercropping on insect pest situation has been reviewed herein. Populations of *O. phaseoli* on *V. mungo* and *B. tabaci* on cowpea increased when these crops were intercropped with maize. The incidence of yellow mosaic was lower in intercrops of *V. radiata* with maize and sorghum than in monocultures. Conversely, pod borer damage to *V. radiata* was lower in monocultures than in intercrops. There was no significant difference in populations of *A. soccata* and *C. partellus* on pure and intercrops (Natarajan *et al.*, 1991). Rekha Das Dutta (1996) observed that intercropping *Vigna radiata* with maize resulted in reduced populations of the pests *viz*., *Monolepta signata*, *Aphis craccivora*, *Nacolea vulgaris*, *Nezara viridula* and *Riptortus linearis* on *V. radiata* than when intercropped with other legumes like *Vigna umbellata* (rice bean), *Glycine max* (soybean), *Vigna mungo* (black gram) and *Arachis hypogea* (groundnut). Intercropping maize and sorghum along the periphery significantly reduced the whitefly (*Bemisia tabaci*) population and the damage caused by the pod borers (*Maruca testulalis* [*M. vitrata*] and *Lampides boeticus*). All intercrops resulted in increased yields over the sole crops; however, maize and sorghum intercropped along the periphery was more promising (Dar *et al.*, 2003).

Various forms of farmscaping in the form of permanent hedgerows or temporary insectary strips in vegetable fields to increase the activity of beneficial insects have shown that data on the effectiveness of these practices is sparse at best, as is information on the best plant species to use. The primary pest target is often aphids. The use of sweet alyssum (*Lobularia maritima*) provides long periods of flowering and fits into most grower operations, yet was chosen originally for its ability to attract and provide resources to hymenopteran aphid parasitoids. Now that the aphid species of concern has shifted from green peach aphid (*Myzus persicae*) to lettuce aphid, the natural enemy of greatest importance has also shifted to hoverfly (Diptera: Syrphidae) larvae (Chaney, 2004).

Higher numbers of arthropod pests were observed in onion plants 30 m from the marigold strip, while higher numbers of predators and parasitoids were found at 5 m distance. Species richness and Shannon's diversity index were higher at 5 m from marigold. Therefore, marigold rows next to onion fields resulted in higher number of entomophagous species, potentially enhancing the natural control of onion pests (Silveira et al., 2009).

Evaluating the suitability of some farmscaping plants as nectar sources for the parasitoid wasp, *Microplitis croceipes* (Hymenoptera: Braconidae), Nafziger and Fadamiro (2011) observed that the greatest longevity (~16 days) was recorded for honey-fed wasps (positive control). Buckwheat significantly increased the lifespan of female and male wasps by at least two-fold as compared to wasps provided water only (longevity=3-4 days). Licorice mint significantly increased female longevity and numerically increased male longevity. Sweet alyssum slightly increased longevity of both sexes though was not significantly different from the water only control. Females had a significantly longer longevity than males on all the diet treatments. The greatest carbohydrate nutrient levels (sugar content and glycogen) were recorded in honey-fed wasps followed by wasps fed buckwheat, whereas very little nutrients were detected in wasps provided sweet alyssum, licorice mint or water only. However, female wasps were observed to attempt to feed on all three flowering plant species.

Insect pest tolerant/resistant varieties have been evaluated often, but there is no single variety of green gram that might offer resistance to the major insect pests; however, some varieties are less preferred than others. Of 20 cultivars of green gram (*Vigna radiata*) screened in the field in Madhya Pradesh, India, for resistance to 8 species of insect pests, PDM-84-139 and ML-382 were promising against *Caliothrips indicus*, an unidentified chrysomelid and a galerucid beetle, BM-112 against *Raphidopalpa* sp. [*Aulacophora* sp.] and TAM-20, PDM-84-143 and Pusa-105 against *Aphis craccivora*, *Amrasca kerri* [*Empoasca kerri*] and *Myllocerus undecimpustulatus* (Devasthali and Joshi, 1994). Green gram cultivar, MV 1-6 was relatively less susceptible to both paddy grasshopper and cotton grey weevil. MI 7-21 was found to be promising against pea thrips, semilooper and cotton grey weevil but was most susceptible to paddy grasshopper. MI-131-(Ch) was less attacked by blue beetle. The variety MI-67-9 was less infested by bean aphid but was most susceptible to blue beetle. Infestation of jassid was comparatively less in varieties MI-67-3 and MI-29-22 (Devasthali and Saran, 1998).

### 3.4 Bio-pesticide use

Pesticides of biological origin offer good response in the management of some of the major insect pests of green gram. The fungus, *Nomuraea rileyi* (2 x 106 spores/ml) has been reported highly virulent under laboratory trials resulting in approximately 97.5, 93.33, 80.0 and 100.0 per cent mortality of *Thysanoplusia orichalcea*, *Spodoptera litura*, *Spilosoma obliqua* and *Helicoverpa armigera*, respectively (Ingle *et al*., 2004). The fungus, *Paecilomyces lilacinus* (0.02%) caused higher reduction in the larval population of *Lampides boeticus*, followed by *Verticillium lecani* (0.02%) and *Beauveria bassiana* (0.02%). While comparing the *neem* products, *neem* (*Azadirachta indica*) oil (0.05%) was better than *neem* seed kernel extract (5%) in reducing the pod borer larval population (Arivudainambi and Chandar, 2009).

### 3.5 Integrated approach

Integrated management strategies involve the use of resistant varieties, use of disease free seeds, manipulation of cultural practices, management of vectors, and biological and chemical control methods (Raguchandar *et al.,* 1995; Vidhyasekaran and Muthamilan, 1995). In a 2-year study (2001 and 2002), the maximum yield of maize and green gram in the intercropped pattern (1: 1 ratio) and that as sole crop of green gram, as well as the maximum rupee equivalent yield value was recorded for the management schedule comprising release of the green lace wing, *Chrysoperla carnea* at 25 DAS, spray of *Azadirachta indica* oil at 40 DAS and a contact insecticide, endosulfan at 55 DAS (Kan Singh *et al*., 2009). Earlier, Kan Singh (2002) observed that for every unit increase in the larval density there was a significant and subsequent decrease in the number of pods per plant. The linear relationship between larval density and the reduction in number of pods per plant caused by borer damage was positive and significant for both the years. The increased reduction in number of pods as a result of increased larval density was significant. Likewise, for every unit increase in larval density there was a significant reduction in number of grains, which was reflected in the losses caused. The estimated losses to grains were the maximum at a larval density of 4 per plant, 78.87 and 68.01 per cent for *kharif* 2001 and 2002, respectively. Obviously, the linear relationship between larval density and reduction in yield was significantly positive.

| **Insect Pest** | **Taxonomic Position Order/Family** | **Plant Part Damaged** |
|---|---|---|
| *Alcidodes collaris* Pasc. | Coleoptera Cuculionidae | Stem |
| *Amsacta albistriga* W. | Lepidoptera Arctiidae | Foliage |
| *Anarsia* spp. | Lepidoptera Gelechiidae | Shoot webber feeding within |
| *Anoplocnemis phasiana* Fabr. | Hemiptera Coreidae | Pods |
| *Anticarsia irrorata* (F.) | Lepidoptera Noctuidae | Foliage |
| *Aphis craccivora* Koch. | Hemiptera Aphididae | Leaves |
| *Apion ampulum* Fst. | Coleoptera Apionidae | Buds, flowers and pods |
| *Aspongopus janus* Fabr. | Hemiptera Dinidoridae | Plant parts |
| *Attractomorpha crenulata* Fabr. | Orthoptera Pyrgomorphidae | Leaves |
| *Callosobruchus* spp. | Coleoptera Bruchidae | Pods |
| *Catechrysops cnejus* Fabricius | Lepidoptera Lycaenidae | Flowers and pods |
| *Chrotogonus* spp. | Orthoptera Pyrgomorphidae | Pods |
| *Colemania sphenarioides* B. | Orthoptera Pyrgomorphidae | Leaves |
| *Coptosoma cribria* Fabr. | Hemiptera Plataspidae | Plant parts, leaf axils, shoots |
| *Cyrtozemia dispar* Pascoe | Coleoptera Curculionidae | Foliage |
| *Dolycoris indicus* Stal. | Hemiptera Pentatomidae | Plant parts, pods |
| *Empoasca kerri* Pruthi<br>*Empoasca* spp. | Hemiptera Jassidae | Leaves |
| *Eucosma melanaula* Meyr | Lepidoptera Gelechiidae | Flowers and pods |
| *Helicoverpa armigera* (Hubner) | Lepidoptera Noctuidae | Pods |
| *Herse convolvuli* L. | Lepidoptera Sphingidae | Foliage |
| *Hyalospila leuconeurella* Rag. | Lepidoptera Pyralidae | Seeds in pods |

| **Insect Pest** | **Taxonomic Position Order/Family** | **Plant Part Damaged** |
|---|---|---|
| *Lampides boeticus* (L.) | Lepidoptera Lycaenidae | Flowers and pods |
| *Lamprosema indicata* Fabr. | Lepidoptera Pyralidae | Tender foliage |
| *Liogryllus bimaculatus* DeGeer (= *Gryllus bimaculatus*) | Orthoptera Gryllidae | Pods |
| *Maruca testulalis* G. (= *Maruca vitrata*) | Lepidoptera Pyralidae | Flowers and pods |
| *Melanagromyza phaseoli* Coq. | Diptera Agromyzidae | Stem |
| *Mylabris pustulata* Thunberg | Coleoptera Meloidae | Buds and flowers |
| *Myllocerus* spp. | Coleoptera Cuculionidae | Foliage |
| *Nacolea vulgalis* Gn. | Lepidoptera Pyralidae | Tender foliage |
| *Nezara viridula* Linneaus | Hemiptera Pentatomidae | Plant parts, pods |
| *Pachytychius mungosis* Marsh. | Coleoptera Cuculionidae | Seeds |
| *Piezodorus rubrofasciatus* Fabr. *P. hybneri* Gmel | Hemiptera Pentatomidae | Plant parts, pods |
| *Plautia fimbriata* (Fabricius) | Hemiptera Pentatomidae | Plant parts, pods |
| *Riptortus pedestris* Fabr., *R. linearis*, *R. fuscus* | Hemiptera Coreidae | Pods |
| *Spilosoma obliqua* (W.) | Lepidoptera Arctiidae | Foliage |
| *Spilostethus pandurus* (Scopoli) | Hemiptera Lygaeidae | Shoots/leaves |
| *Spodoptera litura* (Fabr.) | Lepidoptera Noctuidae | Foliage |
| *Thrips* (*Megalurothrips*) *distans* Ky., | Thysanoptera Thripidae | Tender leaves and flowers |

**Note**: The spider mites also happen to be serious arthropod pests of green gram, foliage especially during the warmer months of the year.

Table 1. Record of insect pests that infest green gram

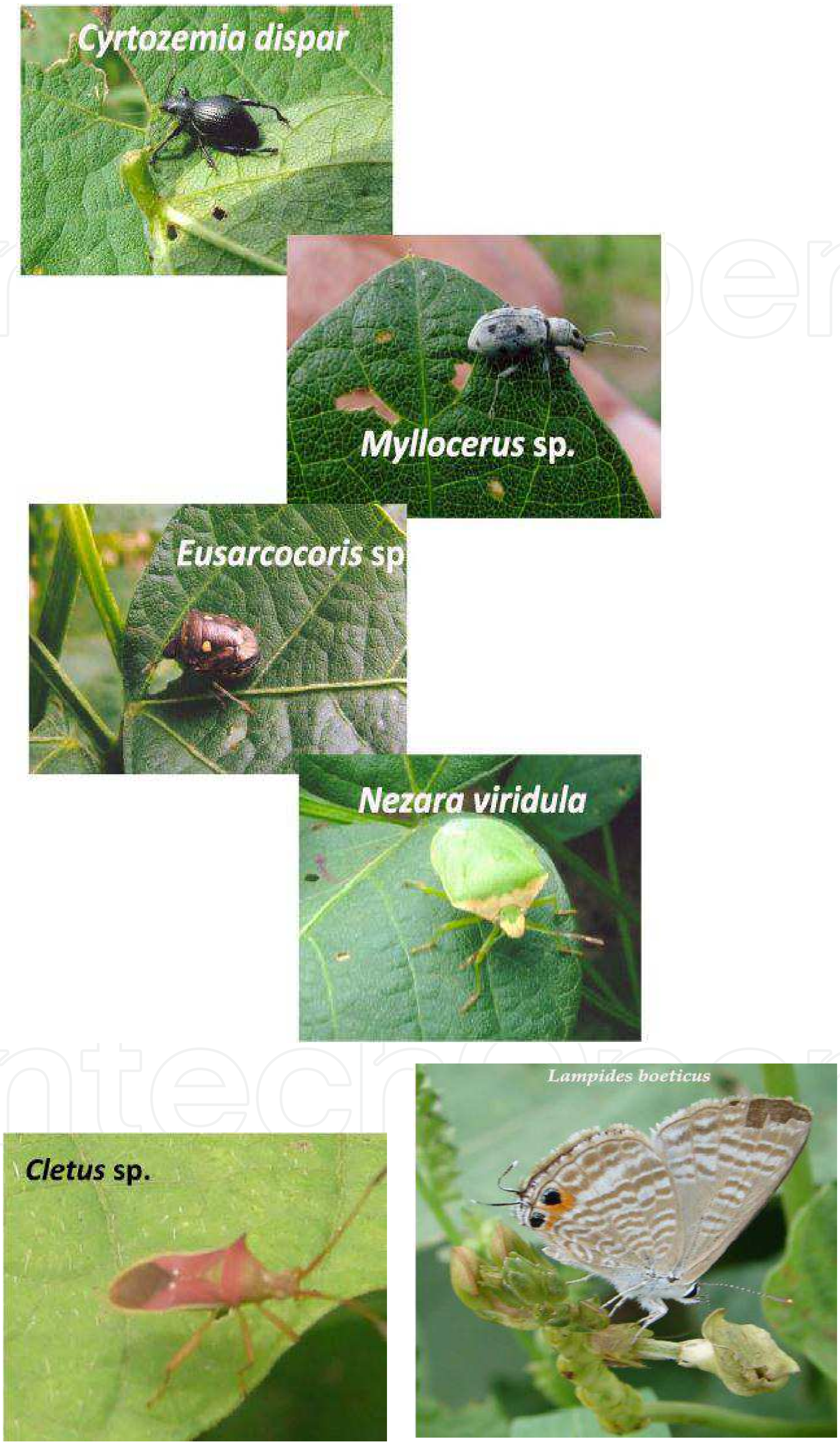



Plate 1 (a). Major insect pests of green gram at Udaipur (India)


Plate 1 (b). Major insect pests of green gram at Udaipur (India)


Plate 1 (c). Major insect pests of green gram at Udaipur (India)

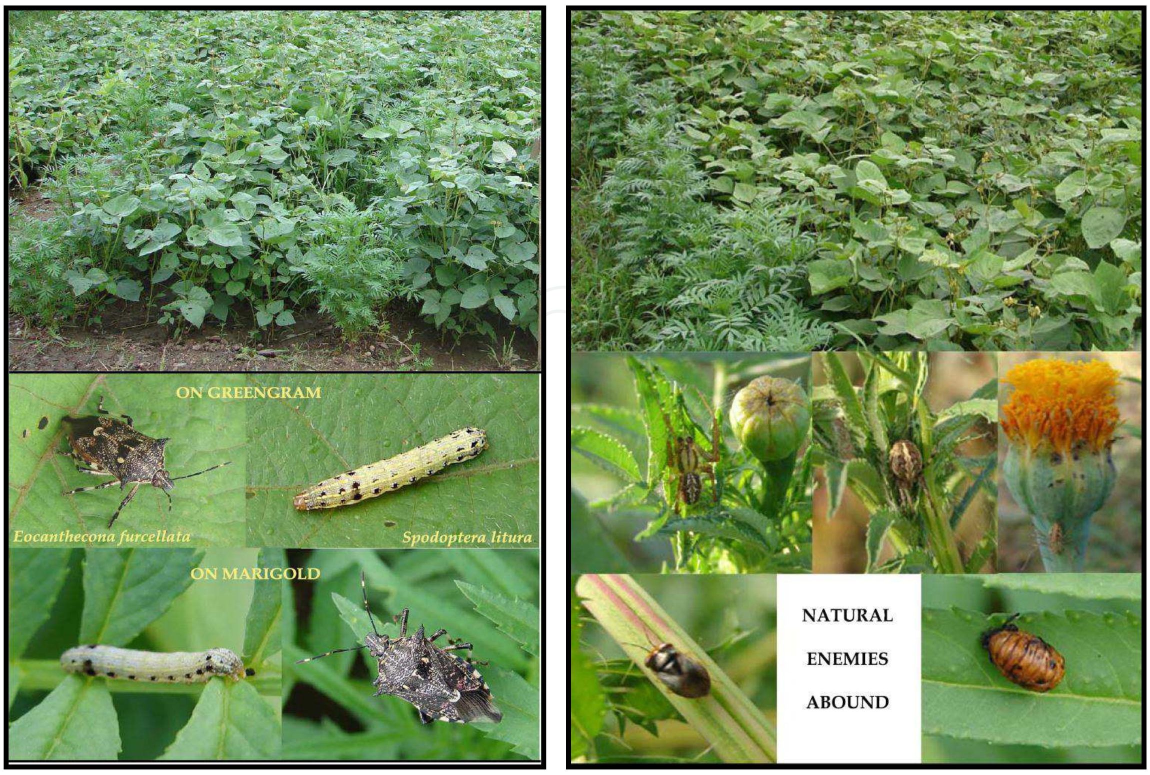



Plate 2 (a). Farmscaping in green gram with marigold

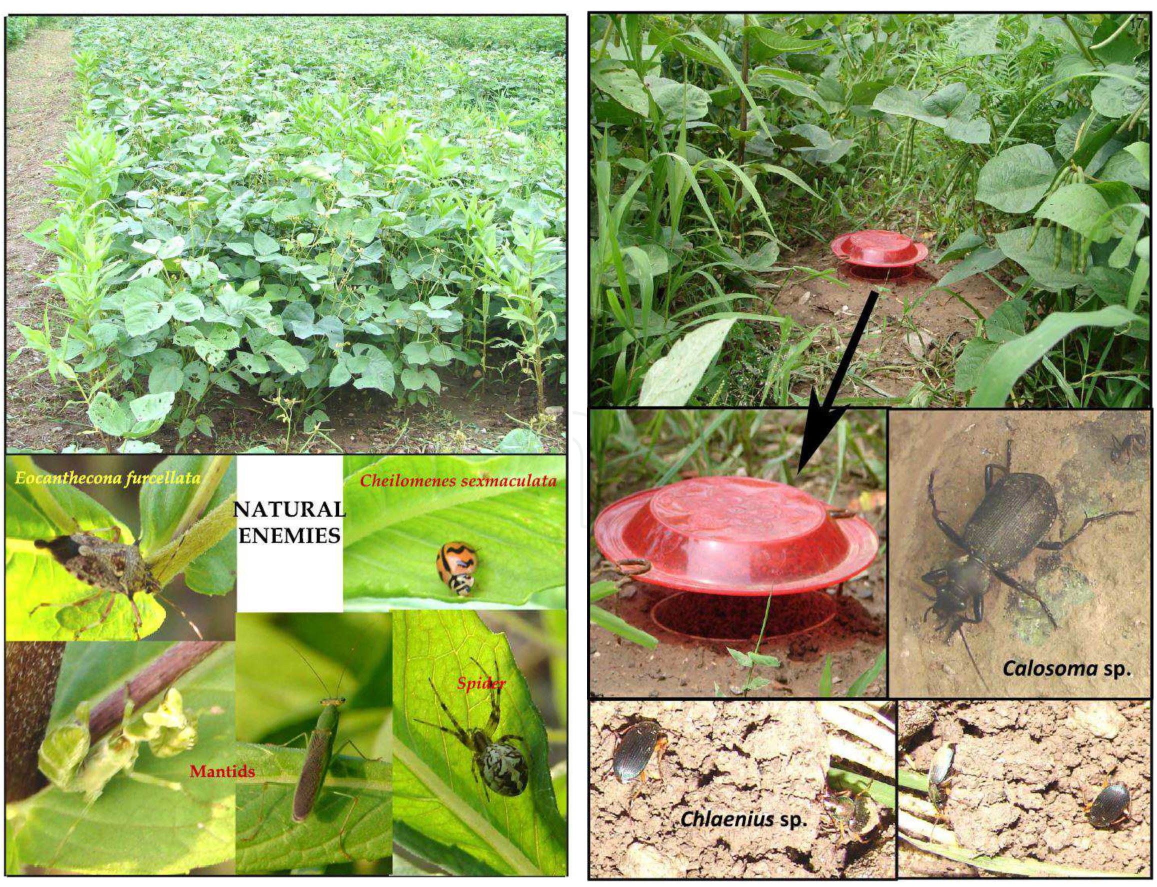



Plate 2 (b). Farmscaping in green gram with niger


Plate 2 (c). The Plate has two different aspects: (1) Benefits of farmscaping in green gram: Niger intercrop helps to escape blister beetle (*Mylabris* spp.) infestation in green gram. (2) Severe pest infestation in sole green gram: blister beetle (*Mylabris* spp.) and the coreid bug (*Riptortus pedestris*).

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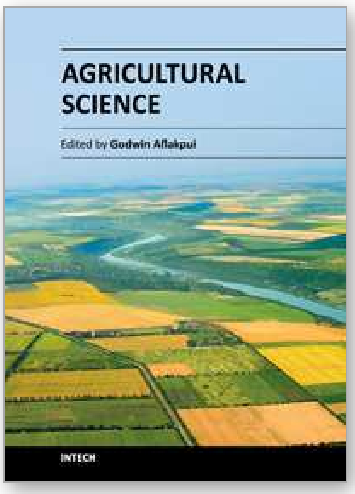


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This book covers key areas in agricultural science, namely crop improvement, production, response to water, nutrients, and temperature, crop protection, agriculture and human health, and animal nutrition. The contributions by the authors include manipulation of the variables and genetic resources of inheritance of quantitative genes, crop rotation, soil water and nitrogen, and effect of temperature on flowering. The rest are protecting crops against insect pests and diseases, linking agriculture landscape to recreation by humans, and small ruminant nutrition. This book is a valuable addition to the existing knowledge and is especially intended for university students and all professionals in the field of agriculture.