EFFECT OF INTERCROPPING ON THE INCIDENCE OF INSECT PESTS OF *Cicer arietinum* L. (CHICKPEA)

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EFFECT OF INTERCROPPING ON THE INCIDENCE OF INSECT PESTS OF *Cicer arietinum* L.(CHICKPEA)

BY

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TO

MY BELOVED PARENTS

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Memo No: SAU/Entomology/2010/

CERTIFICATE

This is to certify that thesis entitled, **"Effect of Intercropping on the incidence of Insect Pests of *Cicer arietinum* L. (Chickpea)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **Khaleda Adib**, **Registration No. 04-01465** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

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EFFECT OF INTERCROPPING ON THE INCIDENCE OF INSECT PESTS OF *Cicer arietinum* L. (CHICKPEA)

ABSTRACT

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2008 to March, 2009. The experiment consists of seven treatments such as- T_1: Gram sole (control), T_2: Gram + Wheat (*Triticum aestivum* L.), T_3: Gram + Lentil (*Lens Culinaris*), T_4: Gram + Mustard (*Brassica* spp.), T_5: Gram + Coriander (*Coriandrum sativum L.*), T_6: Gram + Garlic (*Allium sativum* L.) and T_7: Gram + Radhuni (*Coriandrum* spp.). It was laid out in Randomized Complete Block Design with three replications. The lowest average pod infestation per plant in number (3.75%) was observed from T_6 and the highest average pod infestation per plant (9.40%) was recorded from T_1 treatment. The minimum average pod infestation per plant in weight (3.53%) was recorded from T_6 treatment and the maximum pod infestation per plant (9.66%) was found from T_1 treatment. Among the treatment combinations, Gram + Garlic was more effective as intercropped for the controlling of insect pests as well as highest yield contributing characters and yield of gram.

CHAPTER I

INTRODUCTION

Chickpea (*Cicer arietinum* L.), commonly known as gram, is one of the important pulse crops in Bangladesh as well as in the world. It is an important grain legume in Asia, Africa and America (FAO, 2006). The crop is variously known as chola, boot or botjam in different parts of Bangladesh. In Bangladesh, about 85% of the gram is grown in greater districts of Faridpur, Jessore, Kustia, Rajshahi and Pabna. It is generally grown under rain-fed or residual soil moisture conditions in rabi season. Among the major pulses grown in Bangladesh, gram ranked fifth in area and production but second in consumption priority. It covers an area of 16,446 ha producing 12,315 tons of yields with national average of 761 kg ha^{-1} (BBS, 2008).

Gram plays a vital role in human and animal nutrition having 20.8% protein (Gowda and Kaul, 1982). It is a major source of dietary protein to the large vegetarian population of South Asian countries. Its dry stems and husks serve as good source of animal feeds (Kay, I979). Taking gram in “Iftar” during *Ramadan* is a common food in Bangladesh. As well as being an important source of human food and animal feed, it also helps in the management of soil fertility through symbiotic nitrogen fixation from the atmosphere, particularly in dry lands (Sharma and Jodha, 1984; Suzuki and Konno, 1982). According to the FAO (2006) yield of gram in Bangladesh is miserably low (761 kg ha^{-1}) as compared to that of other countries like India (833 kg ha^{-1}), Myanmar (1106 kg ha^{-1}), Mexico (1600 kg ha^{-1}), Israel (1813 kg ha^{-1}), Russian Federation (2400 kg ha^{-1}), Kazakjhastan (3000 kg ha^{-1}) and China (6000 kg ha^{-1}). There are many factors responsible for low yield of gram of which insect pests appear to be the most vital factor. In Bangladesh, gram is attacked by eleven species of insect pests (Rahman *et al.*, 1982). Among these pests the pod borer, *Helicoverpa armigera* (Hubner) is one of the most serious pests of gram in Bangladesh (Begum *et al.*, 1992).

In a countrywide survey, an average of 30 to 40% pod damage due to chickpea/gram pod borer was reported in Bangladesh (Sachan and Katti, 1994). The young larvae of this pest feed on the foliage for some time and later bore into the pod. In favourable condition, the pod damage goes up to 90-95% (Shongal and Ujagir, 1990). Farmers are being reluctant to cultivate gram due to its susceptibility to pod borer. The young larva skeletonizes the leaves, while grown up larva bores the pods and feeds on the seeds, thereby rendering them unfit for human consumption. On the other hand, other insects like aphids (*Aphis craccivora* Koch.) and whitefly (*Bemesia tabaci* G.) attack in vegetative stage and cause a considerable damage of the crop.

At present, effective control techniques other than insecticide application against the pest are not available. But continuous use of insecticides leads to the hazardous effect on the pollinator's, natural enemies likes predators, parasitoids and also cause the environmental pollution (Nugrar and More, 1998). Under these circumstances, it becomes necessary to find out some eco-friendly alternative methods for pest management of gram. Among the various alternatives, the exploitation of host plant resistance is perhaps the most effective, convenient, economical and environmentally acceptable method of insect control (Dhaliwal and Dilawary, 1993). Now-a-days, effective control techniques other than insecticide application against insect and pest of agricultural crops are highly demanding. Considering the above aspects, management of insect pests in gram through agronomic manipulation may be considered as one of the possible alternative options. An agronomic practice like intercropping of crops of diver's growth habits may be found as a very useful technique in controlling a large number of crop pests.

Intercropping is an age old practice and it has been recognized as a very common practice throughout the developing tropics (Willey, 1979). It is considered as the practical application of ecological principles such as diversity, crop interaction and other natural regulation mechanisms. Intercropping is defined as the growth of two or more crops in proximity in the same field during a growing season to promote interaction between them. The rationale behind intercropping is that the different crop plants are unlikely to share the same insect pests. Intercropping reduces the insect pests population because of the diversity of the crops grown. When other crops are present in the field, the insect pests are confused and they need more time to look for their favorite plants. Other factor is that relative most stable population of natural enemies can persist in intercropping due to the continuous availability of food sources and microhabitats.

The olfactory stimulus offered by the main crops could be camouflaged by various intercrops (Aiyer, 1949). Many photophilic pests avoid short crops when they are shaded by taller crops. In intercropping system, two or more plant species in the field may disrupt the host plant finding behavior of insect. Intercropping can affect the microclimate of the agro-ecosystem, which ultimately produces an unfavorable environment for pest (Singh and Singh, 1978). Other advantages of intercrop are more efficient use of field and spreading of the risk of monoculture failure. However, any advantage from intercropping compared with monoculture depends on achieving a relative yield total (RYT)>1. Intercropping of gram with wheat and mustard was found prospective (Hossain *et al*., 1998).

Under the above perspective, intercropping has been thought to be an environment friendly option for the management of insect pests in gram. However, very little attention has been given in this area in Bangladesh. Therefore, the present study has been planned and designed with the following objectives:

- To find out the effect of intercropping on insect pests and natural enemies in *Cicer arietinum* L.
- To observe the infestation level of insect pests in the *Cicer arietinum* L. and
- To observe the productivity.

CHAPTER II

REVIEW OF LITERATURE

The pod borer, *Helicoverpa armigera* (Hubner) is the main and serious pest of gram in Bangladesh and elsewhere in the world. For better understanding, efforts have been made to review the available literature related to this pest distribution, pest status and host range, and its biology is necessary. Another way a number of studies on intercropping or mixed cropping and their relationship with pest management of gram have been done and reported elsewhere in the world. However, studies in this area appeared very limited in Bangladesh. For a better understanding and to know the research status on impact of intercropping on insect pest management of gram, the relevant available literature on this crop and others have been reviewed and presented below.

2.1 Distribution of pod borer

Pod borer is a polyphagous pest, which spreads in wide geographical areas and it extends from Cape Verde Islands in the Atlantic, through Africa, Asia and Autralasia, to the South Pacific Islands and from Germany in the north to New Zealand in the south (Hardwick, 1965). Rao (1974) stated that in India, *H. armigera* is distributed over a wide range and caused serious losses to many crops, including chickpea, particularly in the semi-arid tropics. Ibrahim (1980) observed that *Heliothis* spp. is of considerable economic importance as pests on many Egyptian crops but *H. armigera* is the most abundant species throughout Egypt. Zalucki *et al.* (1986) reported that *H. armigera* was one of the widest distributions of any agricultural pests, occurring throughout Asia, Australia, New Zealand, Africa, Southern Europe and many Pacific Islands.

2.2 Pest status and host range of pod borer

Jayaraj (1962) reported that *Heliothis* could breed on a wide range of plants. The crops attacked in many countries were maize, sorghum, oat, barley, pearl millet, chickpea, pigeonpea, cowpea, pea, various bean, cotton, sunflower, safflower, tobacco, tomato, brinjal, cucurbits, sweet potato, groundnut, flax, citrus, sunhemp, potato etc. Bhatnagar and Davies (1978) reported that 50 species of crop plants and

48 species of wild and weed species of plants found for attacking by *H. armigera* at Patancheru, Andhra Pradesh, India, whereas 96 crops and 61 weeds and wild species have been recorded elsewhere in India. The most important carryover weed hosts in the hot summer season are *Datura metel*, *Acanthospernium hispidum* and *Gynandropsis gynandra* for *H. armigera, H. assulta* and *H. pelligera.*

Reed and Pawar (1982) observed that *H. armigera* was the dominant and primary pest of cotton, maize and tomatoes in some countries of Africa, Europe, America, Australia and Asia. In India, it was a dominant pest on cotton in some areas and in most of the areas, on several other crops particularly pigeon pea and chickpea. On both the major pulse crops, *H. armigera* commonly destroyed more than 50% of the yield. Garg (1987) studied the host range of *H. armigera* in the Kumaon Hills, India and found that the larvae of *H. armigera* infested different plant parts of variety of crops like wheat, barley, maize, chickpea, pea, tomato, pigeonpea, lentil, onion and okra. He also pointed out that chickpea appeared to be the most susceptible crop followed by pigeonpea, tomato and pea. In addition to these cultivated plants, it was also observed on some wild grasses and ornamental plants such as roses and chrysanthemums.

Fitt (1991) cited from an experiment conducted in the South Asian region that *Helicoverpa* was a serious pest of cotton, chickpea, pigeonpea, groundnut, cowpea, *Vigna* species, okra, tomato, castor, sunflower, maize, sorghum and many other crops.

2.3 Biology of pod borer

2.3.1 Host preference for oviposition

Parsons *et al.* (1937) reported that chickpea was most attractive for oviposition of pod borer, while Reddy (1973) and Loganathan (1981) reported that pigeon pea was the preferred host for pod borer oviposition.

Vijayakumar and Jayaraj (1981) studied the preferred host plants for oviposition by *H. armigera* and found in descending order, pigeonpea > fieldpea > chickpea> tomato> cotton> chillics> mungbean> sorghum.

Plate 1. Photograph showing pod borer in a pod of chickpea

2.3.2 Mating and oviposition

The eggs were laid singly, late in the evening, mostly after 21.00 hr to midnight. On many host plants, the eggs were laid on the lower surface of the leaves, along the midrib. Eggs were also laid on buds, flowers and in between the calyx and fruit (Continho, 1965).

Roome (1975) studied the mating activity of *H. armlgera* and reported that from 02.00 to 04.00 hr the males flew above the crop while the females were stationary and released a pheromone. During this period males were highly active and assembled around females.

Singh and Singh (1975) found that the pre-oviposition period ranged from 1 to 4 days, oviposition period 2 to 5 days and post-oviposition period 1 to 2 days. Eggs were laid late in the evening, generally after 2100 hours and continued up to midnight. However, maximum numbers of egg were laid between 2100 and 2300 hours. The moths did not oviposit during the daytime. Loganathan (1981) observed peak mating activity at 04.00 hr.

Tayaraj (1982) reported that oviposition usually started in early June, with the on set of pre-monsoon showers, adults possibly emerging from diapausing pupae and also from larvae that had been carried over in low numbers on crops and weeds during the summer. Reproductive moths were recorded throughout the year ovipositing on the host crops and weeds with flowers. The pest multiplied on weeds, early-sown corn, sorghum, mungbean and groundnut before infesting pigeon pea in October-November and chickpea in November-March.

Zalucki *et al.* (1986) reported that females laid eggs singly or in groups of 2 or 3, on flowers, fruiting bodies, growing tips and leaves. During their two weeks life span, females laid approximately 1400 eggs.

Bhatt and Patel (2001) cited that the pre-oviposition period ranged from 2 to 4 days, oviposition period 6 to 9 days and post-oviposition period 0 to 2 days. Moth oviposited 715 to 1230 eggs with an average of 990.70 ± 127.40.

2.3.3 Egg

The eggs of *H. armigera* are nearly spherical, with a flattened base, giving a somewhat dome-shaped appearance, the apical area surrounding the micropyles smooth, the rest of the surface sculptured in the form of longitudinal ribs, The freshly laid eggs are 0.4 to 0.55 mm in diameter, yellow-white, glistening, changing to dark brown before hatching .The incubation period of the eggs is longer in cold weather and shorter in hot weather, being 2 to 8 days in South Africa and 2.5 to 17 days in the United States and 2 to 5 days in India (Srivastava and Saxena, 1958; Singh and Singh, 1975).

2.3.4 Larva

The newly hatched larva is translucent and yellowish white in color, with faint yellowish orange longitudinal lines. The head is reddish brown, thoracic and anal shields and legs brown and the setae dark brown. The full-grown larva is about 35 to 42 mm long; general body color is pale green, with one broken stripe along each side of the body and one line on the dorsal side. Short white hairs are scattered all over the body. Prothorax is slightly more brownish than meso and metathorax. Crochets are arranged in biordinal symmetry on the prolegs. The underside of the larva is uniformly pale. The general color is extremely variable; and the pattern may be in shades of green, straw yellow and pinkish to reddish brown or even black (Neunzig, 1964; Singh and Singh, 1975).

Temperature affects the development of the larva considerably. The larval duration varied from 21 to 40 days in California, 18 to 51 days in Ohio, and 8 to 12 days in the Punjab, India (Singh and Singh, 1975) on the same host, tomato. The larval stage lasted for 21 to 28 days on chickpea (Srivastava and Saxena, 1958); 2 to 8 days on maize silk; 33.6 days on sunflower corolla (Coaker, 1959).

There are normally six larval instars in *H. armigera* (Bhatt and Patel, 2001), but exceptionally, during the cold season, when larval development is prolonged, seven instars regularly found in Southern Rhodesia.

2.3.5 Pupa

The pupa is 14 to 18 mm long, mahogany-brown, smooth-surfaced and rounded both anteriorly and posteriorly, with two tapering parallel spines at the posterior tip (Singh and Singh, 1975). The pupa of *H. armigera* undergoes a facultative diapause. The non-diapause pupal period for *H. armigera* was recorded as 14 to 40 days in the Sudan Gezira, 14 to 57 days in Southern Rhodesia, 14 to 37 days in Uganda and 5 to 8 days in India (Jayaraj, 1982). According to Bhatt and Patel (2001) the pupal period ranged from 14 to 20 days in Gujarat, India.

2.3.6 Adult

The female moth of *H. armigera* is a stout-bodied, 18 to 19 mm long, with a wingspan of 40 mm. The male is smaller, wing span being 35 mm. Forewings are pale brown with marginal series of dots; black kidney shaped mark present on the underside of the forewing; hind wings lighter in color with dark colored patch at the apical end. Tufts of hairs are present on the tip of the abdomen in females (ICRISAT, 1982). The female lived long. The length of life is greatly affected by the availability of food, in the form of nectar or its equivalent; in its absence, the female fat body is rapidly exhausted and the moth dies when only 3 to 6 days old (Jayaraj, 1982).

The longevity of laboratory reared males and females were 3.13 ± 0.78 and 6.63 ± 0.85 days, respectively (Singh and Singh, 1975). According to Bhatt and Patel (200l), adult period in male ranged from 8 to 11 days with an average of 9.15 ± 0.90 days and in females 10 to 13 days with an average of 11.40 ± 0.91 days.

2.3.7 Generations

Hsu *et al.*, (1960) observed three generations of *H. armigera* each year in China while Reed (1965) reported that the pest completed four generations from September to March under western Tanganyika conditions. Singh and Singh (1975) reported that *H. armigera* passed through four generations in the Punjab, India; one on chickpea during March; two on tomato, from the end of March to May; and one on maize and tomato in July-August. Bhatnagar (1980) observed that seven to eight generations of *H. armigera* were present each year in Andhra Pradesh, India.

2.4 Effect of intercropping in pest incidence

Aiyer (1949) formulated a three part hypothesis like- (1) host plants are more widely spread in intercrops, meaning they are harder to find, (2) the species serves as a trap crop to bypass the pest from finding the other crop, and (3) one species served as a repellent to the pest.

Intercropping (i.e., growing more than one crop simultaneously in the same area) is one way of increasing vegetational diversity. According to Van Emden (1965), intercropping or polyculture are ecologically complex because inter-specific and intra-specific plant competition occurs simultaneously with herbivores, insect predators, and insect parasitoids. Southwood (1975) stated that elimination of alternate habitats might lead to decreased predator and parasitoid populations and increased insect pest populations.

Southwood and Way (1970) cited that the type and abundance of biodiversity in agriculture will differ across agro-ecosystems which differ in age, structure and management. In fact there is a great variability in basic ecological and agronomic patterns among the various dominant agro-ecosystems. In general, the degree of biodiversity in the agro-ecosystems depend on four main characteristics of the agro ecosystem: (1) the diversity of vegetation within and around the agro-ecosystem, (2) the permanence of the various crops within the agro-ecosystem, (3) the intensity of management and (4) the extent of the isolation of the agro-ecosystem from natural vegetation.

Saxena (1988) stated that a proper combination of crops is important for the success of inter cropping systems, when two are to be grown together. It is imperative that the peak period of growth of the two crop species should not coincide. However, yields of both the crops are reduced when grown as mixed or intercropped, compared with the crops when grown alone but in most cases combined yield per unit area from intercropping are higher.

The magnitude of yield advantage of intercropping system could be determined by the use of land equivalent ratio (LER) value (Ofori and Stern, 1987). The concept of land equivalent ratio or relative yield total assumed to be an important method in evaluating the benefit of intercropping of two dissimilar crops grown in the same land (Fisher, 1977). If LER is more than 1.00 then intercropping gives agronomic advantages over monoculture practice. The higher is the LER, the more is the agronomic benefits of intercropping systems. The land equivalent ratio is the most frequently used index to determine the effectiveness of intercropping relative to growing crops separately (Willey, 1985).

Risch *et al.* (1983) reported that population density of herbivorous insects are frequently lower in polyculture habitats. Two hypotheses have been proposed to explain this phenomenon (1) the associational resistance or resource concentration hypotheses (Roots, 1973), which proposes that the specialist herbivores are generally less abundant in vegetationally diverse habitat because their food sources are less concentrated and natural enemies are more abundant and (2) The natural enemies hypothesis (Russell, 1989), which states that a diversity of plant species may provide important resources for natural enemies such as alternate prey, nactar and pollen or breeding sites.

A specialist insect is less likely to find its hosts in diverse plant communities because of the presence of confusing or masking chemical stimuli, physical barriers to movement, and other adverse environmental factors. Consequently, insect survival may be lower (Baliddawa, 1985).

Altieri (1994) stated that a key strategy in sustainable agriculture is to restore functional bio-diversity of the agricultural landscape. Most studies of the effects of biodiversity enhancement on insect populations have been conducted at the field level, rarely considering larger scales such as the landscape level. It is well known that spatial patterns of landscapes influence the biology of arthropods both directly and indirectly. One of the principal distinguishing characteristics of modern agricultural landscape is the large size and homogeneity of crop monocultures, which fragment the natural landscape. This can directly affect abundance and diversity of natural enemies as the larger the area under monoculture the lower the viability of given population. Diversity can be enhanced in time through crop rotations and sequences and in space in the form of cover crops, intercropping, agro-forestry, crop/livestock mixtures etc. Correct bio-diversification results in pest regulation through restoration of natural control of insect pests, diseases and nematodes and also produces optimal nutrient cycling and soil conservation by activating soil biota. All factors leading to sustainable yields, energy conservation and less dependence on external inputs.

2.5 Relationship between intercropping with insect pests and their natural enemies:

2.5.1 Insect pests

Casagrande and Haynes (1976) pointed out an interesting potential for integration of plant resistant and polyculture practices. They compared damage by the cereal leaf beetle, *Oulema melanopus* L. in mixed and pure strands of resistant and susceptible wheat varieties. They reported that biological control was more effective in the mixed cropping of beetle-resistant and beetle susceptible wheat varieties than in a pure stand of either one of those varieties on a region wide basis. Of the variety of factors that might be involved in the facilitative production principle, the one cited and perhaps the best documented is the reduction in pest attack frequently found in intercrops (Risch *et al.*, 1983). Earlier reviews found similar results (Dempster and Coaker, 1974; Litsinger and Moody, 1976; Kass, 1978) that pests tend to be reduced in intercrops, although not by any means always. While these reviews tend to concentrate on insects, there is also evidence that intercrops reduce nematode attack (Khan *et al*., 1971; Egunjobi, 1984) and diseases (Moreno and Mora, 1984).

Raymundo and Aclcazar (1983) claimed that potato plants grown in association with tomato, onion, maize, soybean bean (*Phaseolus*) had significantly less tuber damage from *Phthorimaea operculella* (Zell.) than for potato alone. Sharma and Pandey (1993) carried out field studies in Navgaon, Rajasthan, India during 1984-86. The early maturing pigeonpea cv. UPAS-120 and the mid maturing cv. BDN-1 were intercropped with blackgram (*Vigna mungo*) greengram *(V. radiata*), pearl millet and sorghum and the infestation by *Exelastis atomosa* and *Melanagromyza obtusa* was compared with that of pigeonpeas grown as a sole crop. They found no marked effect of intercropping on pest incidence. In the sole crop, insect infestation ranged between 42.5 to 52.66% in UPS-120 and between 57.0 to 62.16% in BDN-1. Lal (1991) reported that larval infestations of *Phthorimaea operculella* on potatoes were consistently reduced when potatoes were grown with chillies (*Capsicum*), onions and peas compared to potato alone. Similarly, plots associated with capsicum, onions, and peas (11.11 and 13% respectively) compared to 20% in potato alone.

Rheeneu *et al.* (1981) found lower attack rayes of *Spodoptera frugiperda* in maize + bean intercrop as compared to a maize monoculture. In an elegant experiment, Beach (1981) reasoned that plant “quality” might be affected by intercropping to their pests than individuals in monocultures. He found that *Acalymma vittatum* preferred cucumber leaves taken from monocultures to those taken from cucumber plants intercropped with tomatoes.

Mahadevan and Chelliah (1986) reported that growing sorghum in association with cowpea (*Vigna unguiculata*) or lablab (*Lablab purpureus*) reduced the infestation of the sorghum by the pyralid *Chilo partellus* in Tamil Nadu, India.

Intercropping of tomato (Roltsh and Gage, 1990), garlic (Halepyatic *et al*., 1987), onion (Johnson and Mau, 1986) and ginger (Chowdhury, 1988) with different crops have been reported to reduce the population of different target pests. Hussain and Samad (1993) reported that intercropping chili with Brinjal reduces the population of Aphis gossypii in brinjal. Simmonds *et al.* (1992) reported plants with anti-feedant activities. Among them, *Allium* spp. is reportedly very effective. Kirtikar and Basu (1975) reported that onion, garlic, coriander (*Coriandrum sativum L.*) had also strong pungent repellent action.

Letourneau (1986) examined the effect of crop mixtures on squash herbivore density in the tropical low lands of Mexico. He found that *Diaphania hyalinata* (L.), the most abundant insect in the system, generally had lower population density in intercropping (maize + cowpea + squash) than in monoculture (squash alone) system. The total crop yield in intercropping was higher when estimated as a land equivalent ratio.

Dash *et al.* (1987) observed the highest pod infestation (45.80%) by *Helicoverpa armigera* in monoculture of arhar (*Cajanus cajan*) while the pod damage was the lowest (34.46%) when *C. cajan* was intercropped with blackgram (*Vigna mungo*).

Patanaik *et al*. (1989) observed the severest attack by *Helicoverpa armigera* on sole cropped pegion peas, followed by pegion peas intercropped with groundnuts, mungbeans (*Vigna radiata*), blackgram (*Vigna mungo*) while it was the lowest in pegionpea intercropped with finger millet.

Prasad and Chand (1989) reported that intercropping of chickpea (*Cicer arietinum*) with barley, mustard and wheat suppressed numbers of *Helicoverpa armigrera* by 59.56 and 47%, respectively. They concluded that barley, mustard and wheat are compatible crops for the intercrop of *C. arietinum.* In case of severe infestation in one crop, the financial return from the other crop is ensured.

Andow (1991) found that polycultures had lower pest populations than monocultures, and even then, it occurred intermittently. Severe competition from the other plants in the polyculture might limit the ability of the crop to compensate for pest injury and crop tolerance, or resistance to pest injury might other wise limit yield losses in polycultures. In addition, the data suggested that pest injury is likely to exceed economic injury thresholds in monocultures. Again he claimed that absolute yield benefits in polyculture were higher than yields in monocultures.

Ofuya (1991) found that when cowpea was intercropped with tomato, damage caused by *Helicoverpa armigera* was reduced and grain filling was increased compared to mono cropped cowpeas.

Pawar (1993) showed that short duration pigeon peas grown adjacent to a strip-intercropped with sorghum suffered less damage by *Helicoverpa armigera.*

Hossain *et al.* (1998) reported that intercropping exhibited a significant effect on pod borer infestation in chickpea in case of mid and late sowing dates. The dates of sowing irrespective of the intercropping displayed a significant effect on pod borer infestation with the early sowing contributing to the significant reduction of pod borer infestation. In case of late sowing, chickpea should be preferably intercropped with wheat to protect it against chickpea pod borer infestation ensuring higher yield.

Manisegaran *et al.* (2001) found that incidence of shoot webber was significantly lower in sesame intercropped with pearl millet 4:1 (11.2%), pearl millet 6:1 (12.2%), blackgram 4:1 (12.5%) and green gram (13.3%) compared with the sole sesame crop (24.9%). In general, the incidence of shoot webber was reduced in sesame when it was intercropped, although incidence increased in the ground nut intercropping system. Sesame yield was the highest as a sole crop (634 kg ha^{-1}) followed by intercropping with pearl millet (553-556 kg ha^{-1}).

Sardana (2001) observed a significantly lower incidence of root borer, *Emmaiocera depressella* Swinhoe in sugarcane when intercropped with blackgram compared to the sugarcane mono crop. Sachan and Katti (1994) observed the effect of maize-cowpea intercropping on three lepidopteran stem borer and their natural enemies in Kenya. Oviposition was not affected by intercropping but significantly fewer larvae and pupae were found in the intercrop.

Insect pests are perhaps the most important constraint to cowpea (*Vigna unguiculata*) production. In Uganda, aphids (including *Aphis craccivora*), thrips (including *Megalurothrips sjostedti*), pod sucking bugs (including *Clavigralla sp*. and *Leptoglossus sp*.) and pod borers (such as *Maruca vitrata*) are ubiquitous and very devastating, sometimes leading to total crop failure. On-farm studies were conducted by Nampala *et al*. (2002) at 3 sites in eastern Uganda for three consecutive seasons (during the long rains of 1997, short rains of 1997 and long rains of 1998) to evaluate the use of intercropping as a pest control strategy in cowpea. Two local cowpea cultivars, Ebelat (erect) and Icirikukwai (spreading), were grown as sole crops or intercropped with a local cultivar of green gram (*Vigna radiata*) or sorghum (*Sorghum bicolor*) cv. Seredo. Aphids and thrips populations were significantly reduced in the cowpea + sorghum intercrop but were higher in the cowpea + green gram intercrop. In contrast, pod borer and pod sucking bug infestations and their associated damage were significantly higher in the cowpea + sorghum intercrop than in the other cropping systems. These results contradict previous reports and indicate that (a) not all pests are controlled by intercropping, (b) to be effective, intercropping has to be part of a pest management system that involves other control strategies, and (c) choice of a cropping system for integrated pest management should consider the pest profile.

Devendra and Binay (2002) carried out a field experiment in the research farm of Birsa Agricultural University, Kanke, Ranchi, Bihar, India, during 1997-98 to find out the effect of intercropping and endosulfan on the incidence of *Helicoverpa armigera* infesting chickpea. In general, all the intercrops, barley, linseed, coriander and Indian mustard were effective in suppressing the larval population by 39.43-58.62, 26.00-46.56, 35.72-60.25 and 32.86-52.72%, respectively, compared to the sole crop of chickpea. The best performance was achieved with the application of endosulfan 35 EC (0.07%), reducing the larval population of *H. armigera* by 48.29 to 86.21%. A similar trend was obtained in terms of pod damage caused by *H. armigera*. Intercrops reduced the pod damage by 18.00-28.10% more than the sole crop of chickpea. However, endosulfan suppressed the pod damage to 40.5%.

Uddin *et al*. (2002) observed that polyculture generally had a greater diversity index and higher equitability of insect community. Richness of taxonomic categories was lower in wheat +chickpea, wheat + potato, chickpea + potato and wheat + chickpea + potato polyculture system compared to the combination of their component sole crops. A combination of pitfall reap and sweeping net methods for the whole crop growth period revealed a highly significant positive relation between richness (x) and diversity index (y), but a negative relationship between richness (x) and equitability (y).

An experiment was conducted by Rao *et al*. (2003) to find out the effects of intercropping pigeon pea cultivars ICPL84031 (short duration), PRG-100 (medium duration) and LRG-30 (long duration) with sorghum, green gram and castor (*Ricinus communis*) on the occurrence of *Helicoverpa armigera*, *Maruca vitrata*, *Exelastis obtusa* and *Melanogromyza obtusa* were determined in Hyderabad, India during the rainy seasons of 1999-2000. Pod damage by *H. armigera*, *E. atomosa* and *Melanogromyza obtusa* increased with longer duration of pigeon pea cultivars, whereas that of *Maruca vitrata* was highest in the short duration cultivar. Intercropping with castor and sorghum reduced pod damage by *Melanogromyza obtusa*, *Maruca vitrata* and *Helicoverpa armigera*. Lepidopteran damage was lowest in the short duration cultivar and highest in the long duration cultivar.

An experiment was conducted by Nath *et al*. (2003) during the rainy seasons of 1997, 1998 and 1999 in Varanasi, Uttar Pradesh, India, to study the effect of intercropping on the incidence of Bihar hairy caterpillar (*Spilarctia obliqua*), leaf webber and capsule borer (*Antigastra catalaunalis*), gall fly (*Asphondylia sesami*) and hawk moth (*Acherontia styx*). Sesamum cv. Gujarat-1 was intercropped with pigeon pea cv. Bahar, a local green gram cultivar, a local black gram cultivar, a local soyabean cultivar, a local sunn hemp cultivar, maize cv. Jounpur, sorghum cv. HOS, a local pearl millet cultivar, and groundnut cv. Chitra. After every 3 rows of sesame, one row of the selected intercrop was grown. Sesamum in association with pearl millet significantly reduced the incidence of insect pests except Bihar hairy caterpillar, which was recorded to be minimum in the sesamum intercropped with pigeon pea.

An experiment was conducted by Bhushan and Nath (2006) at the Agriculture Research Farm of the Banaras Hindu University to study the effect of intercropping on the grain damage by pod borer complex (*Melanagromyza obtusa*, *Helicoverpa armigera*, *Exelastis atomosa* and *Clavigralla gibbosa*) and yield of pigeonpea during 1999-2000 and 2000-01. Pigeonpea was intercropped with greengram, blackgram, sesamum, sorghum and pearlmillet in various combination and row ratio. The result showed that the intercrop combination of pigeonpea + blackgram exhibited minimum grain damage.

Roshan and Rohilla (2007) reported that pulses are the richest source of plant protein and play a vital role in the diet of vegetarians. India is a major pulse growing country of the world, sharing 35-36% area and 27-28% production. Chickpea, pigonpea, mungbean, urdbean, housegram, mothbean, lathyrus, lentil, cowpea, drybean and peas are commonly grown and rice-bean and fababean are minor crops and grown in specific areas only. However, among these chickpea, *Cicer arietinum*, pigeonpea, *Cajanus cajan*, mungbean, *Vigna radiata* and urdbean, *Vigna mungo* are important ones. The productivity of these crops, in general, is poor because of many constraints of which the incidence of insect pests has its own importance. Out of an array of insects attacking these crops, pulse borer, *Helicoverpa armigera*, pod bug; *Clavigralla gibbosa*; pod fly, *Melanagromyza obtusa*; blister beetle, *Mylabris* spp.; hairy caterpillars, *Spilosoma obliqua* and *Amsacta moorei*; cutworms, *Agrotlis ypsilon* and *A. flammatra*; semilooper, *Autographa nigrisigna* bean aphid, *Aphis craccivora*; termites, *Odonototermes obesus* arid, *Microtermes obesi* pod borer, *Etiella zinckenella* and whitefly, *Bemissia tabaci* are important ones. Various methods employed in the management of insect pests of four major crops i.e. chickpea, pigeonpea, mungbean and urdbean have been delt with. The various methods of management includes host plant resistance, sowing time and methods, pest monitoring, destruction of alternate hosts, intercropping, biological control including biopesticides and plant products, IGR, transgenics, mechanical control and need based application of synthetic chemical molecules.

2.5.2 Natural enemies

Speight and Lawton (1976) and Altieri *et al.* (1977) reported a higher abundance of predators in a weedy crop than in a comparable monoculture.

Gavarra and Raros (1975) reported spiders to be more effective against corn borers in an intercrop of corn and groundnuts than in monoculture of corn.

Hansen (1983) clearly demonstrated the increased abundance of several predator species in an intercrop system of maize and cowpea in Southern Mexico, suggesting an explanation for the over yielding of that system as reported by Vandermeer *et al.* (1983).

Andow and Risch (1985) observed that predaceous coccinellid beetles, *Coleomegilla maculata* (Dey.) and its prey (aphids) were more abundant on sole crops than on mixed maize and beans.

Perfecto *et al.* (1986) demonstrated that carabid beetles immigrated more rapidly from patches of monoculture of tomatoes and beans from intercrops of the two.

In Kenya, Kyamanywa *et al.* (1993) evaluated the influence of cowpea + maize intercropping on generalist predators and population density of flower thrips *Megalurothrips sjostedti* Trybom. Interestingly, abundance of the *Orius sp,* lady bird beetle, earwigs and spiders were not enhanced by planting cowpea as a mixed crop with maize. In contrast, Ogenga-Latigo *et al.* (1993) found *Aphis fabae* and coccinellid beetles at higher density on sole crop Phaseolus beans than in a mixture with maize.

Nampala *et al.* (1999) observed that abundance of coccinellids and syrphid larvae were neither influenced by the cowpea genotype nor cropping systems. Contrastingly the abundance of predatory *Orius sp.* spiders and earwigs differed significantly among the cowpea cropping systems, being more common in the cowpea pure stands and cowpea + green gram than in the cowpea + sorghum intercrops.

Srikanth *et al.* (2000) examined that the incidence of shoot borer, *Chilo infuscatellus* Snellen (Lepidoptera: Crambidea) did not differ significantly when sugarcane intercropped with blackgram, cowpea greengram and soybean. The incidence of top borer, *Sircocphaga excerptalis* Wlk. (Lepidoptera: Pyralidae), was negligible in all combinations. Counts of predators, comprising spiders and coccinellids, showed marginal differences. In another experiment, they also claimed that mean predator number did not differ significantly between intercrop and monocrop.

Mote *et al.* (2001) found that the population of sucking pests of cotton was minimum when insecticide sprays were imposed on main crop only. Intercropping of cowpea as well as greengram and cotton proved to be better in suppressing the population of sucking pests. The incidence on bollworm complex in fruiting bodies was the lowest in plots in which insecticides were applied but was the highest in untreated plots. Minimum incidence of bolloworm complex was recorded in cotton + cowpea system. Regarding predators and parasitoids, the untreated crops showed maximum number of predators followed by sprays on intercrop only, however, cowpea intercrop system showed maximum number. Spraying of insecticide on cotton only produced a higher yield. Cotton + greengram produced the same yield of as sole cotton.

Amin *et al*. (2003) studied the effect of intercropping of brinjal with onion, garlic, chilli and coriander. They recorded significantly the lowest number of fruit infestation were in brinjal + coriander intercrop system. They also observed that the percent reduction of infestation by weight over sole brinjal was the highest in brinjal + coriander (31.16%) system.

2.6 Benefits from intercropping

Khehra *et al*. (1979) in an experiment found that blackgram consistently gave higher yield when intercropped with maize, although the blackgram as intercropped depressed the maize yield. Rathore *et al*. (1980) conducted an intercropping experiment of maize with pulses and found that maize + blackgram combination produced the highest grain yield.

Using LER as criteria, Bhuiyan (1981) examined mixed crop combinations of lentil, gram and soybean with wheat under different proportion and recorded the highest LER (1.47) in gram and wheat at 100:75 seeding ratio followed by lentil and wheat at 100:75, 100:50 and 100:25 seeding ratio with LER values 1.37, 1.23 and 1.15, respectively.

Study of Krishna and Raikhelkar (1997) in maize-legumes intercropping systems found that maize + blackgram (3.8 t ha^{-1}), maize + green gram (3.6 t ha^{-1}) and maize + pegionpea (3.53 t ha^{-1}) gave significantly higher seed yield than other systems. Considering maize equivalent yield, maize + pegionpea (4.88 t ha^{-1}) and maize + blackgram (4.66 t ha^{-1}) gave significantly higher equivalent yield than the other intercropping systems.

An experiment was conducted by Thakur *et al*. (2000) during the winter (rabi) seasons of 1995-97 in Madhya Pradesh, India, to determine the productivity and economics of gram (*Cicer arietinum*) based intercropping systems. Treatments comprised: sole chickpea, sole Indian mustard, sole safflower (*Carthamus tinctorius*), sole linseed (*Linum usitatissimum*), chickpea + Indian mustard (at 3:2 or 6:2 row ratio), chickpea + safflower (at 3:1 or 6:2 row ratio) and chickpea + linseed (at 3:1 or 6:2 row ratio). Safflower and linseed were suitable substitutes for gram in terms of gram equivalent yield, monetary advantages and benefit: cost ratio. Gram + safflower intercropping at 3:1 and 6:2 rows 30-cm apart proved more advantageous than pure stands of either crop components and other intercropping systems in terms of gram equivalent yield, land equivalent ratio (LER), monetary returns and benefit : cost ratio.

A field experiments were conducted at Solapur, Maharashtra, India, during the 1993/94-2000/01 kharif seasons to study the performance of various vegetable crops in red gram [*Cajanus cajan*] based intercropping system and to identify the vegetable crop suitable for intercropping with red gram on medium deep soils under dry land conditions by Koli *et al*. (2003). The mean grain yield of sole red gram was 713 kg ha^{-1}, which was more than the rest of the intercropping systems followed by red gram + cluster bean (*Cyamopsis tetragonoloba*) at 630 kg ha^{-1}. Intercropping of red gram + cluster bean (1:2) recorded significantly higher monetary return Rs 19,459/ha than the standard control with sole red gram Rs 10,820/ha and intercropping of red gram + pearl millet (1:2) Rs 12 833/ha.

A field experiment was conducted by Devendra *et al*. (2004) during 1997-98 and 1998-99 in Bihar, India, to study the insect pest incidence in linseed (cv. Neelum) intercropped with safflower (cv. A-300), Indian mustard (cv. Varuna) or gram (cv. Pant G-114) at 4:2 or 5:1 linseed : intercrop ratios. The height of linseed plants was reduced by intercropping, especially when safflower was used as the intercrop. The incidence of *Dasineura lini* in 1997-98 (26.0%) and 1998-99 (28.25%) was highest in linseed sole crop, but was significantly reduced under intercropping. The lowest incidence of *D. lini* was observed in linseed intercropped with Indian mustard at 4:2 (19.36% in 1997-98 and 21.67% in 1998-99) and 5:1 (19.99 and 22.50%), and with safflower at 4:2 (19.45 and 21.69%) and 5:1 (20.43 and 23.70%). A higher population of *Helicoverpa armigera* was recorded for linseed intercropped with gram. The lowest incidence of *H. armigera* (0.27 larva/MRL) was recorded for linseed intercropped with Indian mustard at both combinations. The highest linseed equivalent yields in 1997-98 (1071 kg ha^{-1}) and 1998-99 (852.46 kg ha^{-1}) were obtained with linseed intercropped with Indian mustard and gram at 4:2, respectively.

Arjun *et al*. (2004) conducted a field experiment on shallow black soils in Dharwad, Karnataka, India to evaluate the productivity of different pigeonpea-based intercropping systems. The treatments consisted of 2 pigeonpea genotypes (ICPL-87119 and ICP-8863) intercropped with little millet [*Panicum sumatrense*] (TNAU-63), foxtail millet (SIA-2642), green gram (China mung) and bajra [*Pennisetum glaucum*] (ICTP-8203) in 2:1 row proportion. Sowing was done in June during 1999/2000 and in July during 2000/01 and 2001/02. ICPL-

87119+green gram and ICP-8863+green gram, respectively, recorded the highest values for pigeonpea equivalent yield (17.48 and 16.33 q/ha) and land equivalent ratio (1.47 and 1.49). These respective intercropping systems also recorded the highest net income (Rs. 19 560 and 16 888/ha) and benefit : cost ratio (2.32 and 2.03).

A field experiment was conducted by Biru *et al*. (2004) in the deep black soil of Karnataka, India, to investigate the intercropping of grain legumes (French bean, *Phaseolus vulgaris* cv. Arka Komal; cowpea cv. C-152; soyabean cv. JS-335; blackgram cv. T-9; and groundnut cv. JL-24) with sorghum (cultivars DSH-3 and DSV-2) in a 1:2 row proportion, Sorghum was grown at a spacing of 90 × 5 cm and 45 × 10 cm in intercropping and sole cropping treatments. Sole sorghum showed higher yield compared to sorghum intercropped with legumes. Sorghum intercropped with French bean, soyabean and blackgram were comparable to the sole crop in terms of yield. Among intercrops, the highest grain yield was obtained with soyabean intercropped with DSV-2, followed by soyabean intercropped with DSH-3 and French bean intercropped with DSV-2. DSV-2 intercropped with French bean or soyabean at a wider spacing produced higher net returns and benefit: cost ratio compared to the other cropping systems.

A field experiment was conducted by Paras and Chakravorty (2005) in the cropping season of 1996-97 and 1997-98 at the Agriculture Research Farm of the Banaras Hindu University, Varanasi to find out the suitability of various intercrops with chickpea in minimizing the population of chickpea pod borer, the damage inflicted by them to the pods and seeds and on the yield of chickpea. The chickpea intercropped with coriander harboured the minimum population, and the damage inflicted by the larvae as recorded in the same intercrop was also the minimum among the various intercrops. Highest seed yield was obtained in the chickpea intercropped with coriander.

Khosravi and Mashhadi (2006) caaried out an experiment with Black zira is a perennial plant that after two years of vegetative growth produces seed. This study was aimed at assessing intercropping system with annual plants for better utilization of resources in two years of vegetative growth of black zira. Black zira as a base crop was intercropped with annual crops as main plots and black zira sowing rates (5, 10, 15 and 20 kg ha^{-1}) as subplots. Yield of annual plants in first two years and black zira in second two years evaluated annually and periodically. Monetary Equivalent Ratio (MER) for black zira + cumin was 1.30, black zira + chickpea 1.27 and black zira + barley 0.76. The MER showed increasing yield for black zira + cumin 30%, black zira + chickpea 27% and decreasing 24% for black zira + barley compared with monoculture black zira. In terms of sowing rate of black zira, it seems 10-15 kg ha^{-1} is the most suitable for monoculture and intercropping.

A field experiment was conducted by Sukhvinder *et al*. (2006) in Punjab, India, during the 1993/94 and 1994/95 rabi seasons to evaluate the productivity potential of chickpea in relation to raya intercropping in different planting patterns and row orientation under rainfed conditions. All the chickpea based intercropping systems resulted in higher chickpea equivalent yield (CEY) compared to sole cropping. Sowing of chickpea in north-south direction recorded 10.2% higher mean seed yield over its sowing in east-west direction. Intercropping of raya with chickpea 3.0-3.5 m apart resulted in the highest mean crop equivalent yield, net returns and benefit : cost ratio compared to the other treatments.

A field experiment was conducted during 1998/99-2000/01 at the Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India by Ravi *et al*. (2006) to study the genotypic compatibility in kabuli chickpea (*Cicer arietinum* cultivars L 550, BG 1003 abd KAK 2) and Indian mustard (*Brassica juncea* cultivars Varuna and Vardan) in chickpea + Indian mustard intercropping system. The sole crop of chickpea cv. BG 1003 recorded significantly highest growth and yield attributes than the other genotypes of chickpea. Among the various intercropping systems, BG 1003 chickpea + Vardan Indian mustard recorded significantly highest growth and yield attributes of chickpea and Indian mustard than the other intercropping systems. However, the highest 100-seed weight of chickpea was recorded in chickpea KAK 2 in the chickpea + Vardan Indian mustard intercropping system at 6:2 row ratio. Yield reduction of chickpea was recorded higher in Indian mustard genotypes of Varuna than Vardan. Significantly higher chickpea-equivalent yield, land-equivalent ratio (LER), net returns and benefit:cost ratio (B:C ratio) were recorded in BG 1003+Vardan intercropping system than the other intercropping system. Higher seed yield of component crops in intercropping system showed complimentary relationship which resulted in higher chickpea-equivalent yield.

A field experiment was conducted by Kedar *et al*. (2006) Kanpur, Uttar Pradesh, India during rabi 2001-02 and 2003-04 to screen the most suitable cultivar of mustard grown in association with chickpea and to evaluate the effect of mustard cultivars on the yield of chickpea and vice-versa. Seven mustard cultivars were tested with chickpea in 1:4 row ratio. Intercropped chickpea produced statistically lower grain yield than sole crop during both years on area basis. On an average, intercropping of mustard cultivars with chickpea reduced the grain yield of chickpea to the extent of 10.15, 9.40, 5.01, 5.50, 9.44, 5.05 and 8.31% with Varuna, Vaibhav, Urvashi, Kanti, Vardan, Basanti and Rohini, respectively. Intercropped mustard gave significantly lower yield than pure cropping during both years on area basis. The positive effects of chickpea on the seed yield of mustard cultivars on mean basis were 14.04, 15.49, 22.41, 9.16, 16.55, 14.04 and 12.44% in Varuna, Vaibhav, Urvashi, Kanti, Vardan, Basanti and Rohini, respectively. Intercropping of mustard cv. Urvashi proved to be the most suitable for association with chickpea (1:4 row ratio) as it gave the highest seed yield of 11.65 q ha^{-1}, chickpea equivalent yield of 36.94 q ha^{-1}, net profit of Rs 33359 ha^{-1}, land equivalent ratio (1.18) and monetary advantage index of Rs 7321 ha^{-1}, followed by Basanti.

A field experiment was carried out by Reddy *et al*. (2007) for two years during kharif 2002-2003 and 2003-2004 at Agricultural Research Station, Warangal on clay loamy soil to know the influence of pigeonpea genotypes on productivity in intercropping system under rainfed conditions. Eight treatments comprising four genotypes (WRG 53, WRG 27, CORG 9701 and WRG 56) and two intercrops (mungbean and urdbean) were laid out in randomized block design with three replications. Intercropping of WRG 53 either with mungbean or urdbean produced significantly higher yield of pigeonpea, mungbean, urdbean and pigeonpea equivalent yield (PEY). It was also realized that incidence of pod damage caused by pod borer was minimum (5.1%), when pigeonpea genotype WRG 53 was intercropped with mungbean.

Thus different intercropping systems had lower insect infestation and higher abundance of natural enemies. Intercropping system has proven to show greater productivity and higher economic return than mono-cropping system. It can also reduce dependency on chemical insecticides and ensure a greater environmental protection. As intercropping has a great scope in managing insect pests, it is therefore necessary to speculate the lower incidence of insect pests, abundance of natural enemies, and productivity and economics of intercropping systems.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2008 to March, 2009 to find out the effect of intercropping on the incidence of insect pests of gram. This chapter presenting a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters under the following headings-

3.1 Location

The experiment was carried out in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix I.

3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting material

3.4.1 Description of gram

Seeds of gram variety BARI Chola-5 were used as a test crop for the study and the seeds of this variety were collected from Bangladesh Agricultural Research Institute, Gazipur. This variety was developed by BARI and exposed for cultivation in the year of 1996 (BARI, 2006) through the selection process among the different germplasms that generally has been cultivated in different areas of Bangladesh. It is a spreading type plant and can be easily grown in minimum or shading light.

3.4.2 Description of other intercrops

In this experiment wheat, lentil, mustard, coriander, garlic and radhuni were sown as intercrop with gram. All of the seeds of these crops were collected from local market.

3.5 Land preparation

The experimental field was first opened on November 5, 2008 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.6 Fertilizer application

Standard doses of fertilizers comprising N, P and K @ 40 kg, 25 kg and 25 kg per hectare in the form of urea, triple super phosphate and muriate of potash, were applied respectively as basal at the time of sowing seeds.

3.7 Seed processing and treatment

The seeds of BARI chola-5 of gram were collected from Bangladesh Agricultural Research Institute, Gazipur, Dhaka. The seeds of wheat, lentil, mustard, coriander, garlic and radhuni were collected from local market.

Germination test was done before sowing. The rate of germination was found to be more than 90% for all of the crops. The seeds were treated with Vitavax 200 at the rate of 2 g per kg seed to protect seedlings against foot and root rot diseases.

3.8 Sowing of seeds

The seeds of main and intercropped were sown on 15 November 2008 in rows with spacing of 30 cm × 30 cm for all intercropped but in sole crops it was sowing as spacing of 40 cm × 30 cm. There were 13 lines (07 for gram and 06 for intercrop) in each plot.

3.9 Treatments

There were 7 treatments among them 01 was used as sole crop and others as intercropped. The treatments presented below:

T_1: Gram sole (control)

T_2: Gram + Wheat

T_3: Gram + Lentil

T_4: Gram + Mustrad

T_5: Gram + Coriander

T_6: Gram + Garlic

T_7: Gram + Radhuni

3.10 Experimental design and layout

The experiments were laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly allotted in each block. The unit plot size was 4m × 3m with a distance of 50 cm between the plots and 100 cm between the replications. In unit plots garlic was planting with the distance of plant to plant were 30 cm and others crops were broadcast in row.

3.11 Intercultural operations

To avoid moisture stress and ensuring good germination, post-sowing irrigation was applied. Intercultural operations like thinning, weeding and mulching were done as and when necessary for proper growth and development of the crop.

3.12 Monitoring and data collection

The gram plants of different sowing dates were closely examined at regular intervals commencing from germination to harvest. The following data were collected during the course of the experiment.

The following parameters were considered during data collection.

- Incidence of insect
- Number of healthy fruits
- Number of infested fruit
- Fruit infestation in number (%)
- Weight of Healthy fruits
- Weight of Infested fruit
- Fruit infestation in weight (%)
- Yield per hectare (ton)

3.13 Determination of pod borer infestation per plant

Pod borer infestation per plant was recorded at weekly intervals from the randomly tagged 10 plants in central rows starting from flowering to pod maturity. The entire period was divided into early, mid and late fruiting stage and percentage of pod damage due to pod borer was calculated from the pods of 10 randomly selected plants from the central rows in number and weight basis.

3.14 Determination of pod borer damage in number

All the pods were counted from 10 randomly selected plants from middle rows of each plot and examined. The damaged (bored) and total numbers of pods were counted and the percent pod damage was calculated using the following formula:

$$\% \text{ Pod damage} = \frac{\text{Number of damaged pod}}{\text{Total number of pod}} \times 100$$

3.15 Determination of pod borer damage in weight

All the pods were counted from 10 randomly selected plants from middle rows of each plot and examined. The damaged (bored) and total numbers of pods were weighted the percent pod damage was calculated using the following formula:

$$\% \text{ Pod damage} = \frac{\text{Weight of damaged pod}}{\text{Total weight of pod}} \times 100$$

3.16 Diversity of insect community

The simplest measure of species diversity is counting of the number of species. The concept was extended up to order and family level. It was performed by two relative methods viz., pitfall and sweeping net.

3.16.1 Pitfall method

This method was used for the species that roam on the soil surface such as ground beetles, spiders, collembola etc. Small plastic pots having 6 cm diameter and 8 cm depth were used as pitfall traps each of which was half-filled with water. Three traps were placed in soil in each of the plots at early, mid and late stage of crops to trap the insects. The trap mouth of the pot was kept at the ground level so as not to obstruct insect movement. After 48 hours of setting traps, insects were collected from each plot/treatment and kept separately.

On the basis of phenotypic similarity, trapped insects were then sorted and identified to family and order in which they belong with the help of identified specimens kept with the museum of the Department of Entomology, Sher-e-Bangla Agricultural University and other standard taxonomic keys. Data were recorded against each treatment.

3.16.2 Sweeping net method

This method was used for counting flying and stationary insects on host plants to know the abundance pattern of insects in the present study. Five (5) times return sweeping was done in different days in each plot to make a composite sample by a sweeping net at early, mid and late crop stage. Each sample was examined separately without killing the insects and released them immediately after counting in the same plot. The individuals of each sample were counted by family.

3.16.3 Measurement of diversity index

To assess both the abundance pattern and the species richness, Simpson's diversity index was used (Simpson's, 1949).

$$\text{Simpson's Index (D)} = \frac{1}{\sum_{i=1}^{s} Pi^2}$$

Where, Pi is the proportion of individual for the ith insect family and S is the total number of insect family in the community (i.e., the richness).

The value of index depends on both the richness and the evenness (equitability) with which individuals were distributed among the families.

Equitability was quantified by expressing Simpson's index, D as a proportion of the maximum possible value of D.

$$\text{Equitability E} = \frac{D}{D_{max}} = \frac{1}{\sum_{i=1}^{s} Pi^2} \times \frac{1}{S}$$

3.17 Harvesting and yield

The plants of middle three rows, avoiding border rows, of each plot were harvested. The pods were then threshed; cleaned and dried in bright sunshine. The yield obtained from each plot was converted into yield per hectare.

3.18 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was done by the 'F' (variance ratio) test. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of intercropping on the incidence of insect pests of gram. The analysis of variance (ANOVA) of the data on insect incidence, number and weight of healthy pod, infested pod and pod infestation, yield contributing characters and yield of gram is given in Appendix III-XI. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Insect incidence

Incidence of insect was recorded for the entire cropping season and aphid, lady bird beetle and white fly was observed. Per plot data for the incidence of insect were presented at early mid and late fruiting stage.

4.1.1 Early fruiting stage

Statistically significant variation was recorded at early fruiting stage for insect incidence due to different treatment (Appendix III). In case of aphid, the lowest number (2.10) was recorded from T_6 (Gram + Garlic) which was closely followed (3.30 and 3.60) by T_4 (Gram + Mustard) and T_7 (Gram + Radhuni) treatment, respectively while the highest number (5.40) was found from T_1 (Gram sole) which was closely followed (4.70, 4.40 and 4.10) by T_2 (Gram + Wheat), T_3 (Gram + Lentil) and T_5 (Gram + Coriander), respectively (Table 1). In case of lady bird beetle, the lowest number (1.30) was obtained from T_6 which was followed by T_4 (1.90) and T_7 (2.20), whereas the highest number (4.90) was found from T_1 which was followed by T_2 (3.70), T_3 (3.30) and T_5 (2.50). In case of white fly, the lowest number (2.60) was recorded from T_6 which was closely followed by T_4 (3.90), T_7 (4.10) and T_5 (4.30) treatment, whereas the highest number (6.10) was recorded from T_1 which was followed by T_2 (5.30) and T_3 (4.90). Southwood (1975) stated that elimination of alternate habitats might lead to decreased predator and parasitoid populations and increased insect pest populations.

Table 1. Effect of intercropping on the incidence of insect at early, mid and late fruiting stage in terms of number of insect per plot

Treatment	Number of insect per plot								
	Early stage			Mid stage			Late stage		
	Aphid (*Aphis craccivora* Koch.)	Lady bird beetle (*Nymphula depunctalis*)	Whitefly (*Bemesia tabaci* G.)	Aphid (*Aphis craccivora* Koch.)	Lady bird beetle (*Nymphula depunctalis*)	Whitefly (*Bemesia tabaci* G.)	Aphid (*Aphis craccivora* Koch.)	Lady bird beetle (*Nymphula depunctalis*)	Whitefly (*Bemesia tabaci* G.)
T_1	5.40 a	4.90 a	6.10 a	6.80 a	6.50 a	6.70 a	7.80 a	5.90 a	7.40 a
T_2	4.70 b	3.70 b	5.30 b	5.50 b	5.10 b	5.80 b	6.70 b	4.80 b	6.30 b
T_3	4.40 b	3.30 c	4.90 b	5.20 bc	4.20 c	5.20 c	6.20 c	4.40 c	5.90 b
T_4	3.30 d	1.90 e	3.90 c	4.20 e	2.90 d	4.20 e	5.10 d	3.40 d	4.60 d
T_5	4.10 bc	2.50 d	4.30 c	4.90 cd	3.90 c	5.10 cd	6.00 c	4.20 c	5.20 c
T_6	2.10 e	1.30 f	2.60 d	3.40 f	2.00 e	3.10 f	4.20 e	2.70 e	3.50 e
T_7	3.60 cd	2.20 de	4.10 c	4.50 de	3.20 d	4.70 d	5.30 d	3.50 d	5.00 cd
$LSD_{(0.05)}$	0.595	0.390	0.481	0.513	0.432	0.425	0.373	0.398	0.557
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	8.50	7.75	6.06	5.84	6.12	7.79	6.57	5.39	9.78

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Gram sole (control) T_2: Gram + Wheat

T_3: Gram + Lentil T_4: Gram + Mustard

T_5: Gram + Coriander T_6: Gram + Garlic

T_7: Gram + Radhuni

4.1.2 Mid fruiting stage

At mid fruiting stage statistically significant variation was observed for insect incidence like the number of aphid, lady bird beetle and white fly for different intercropping pattern (Appendix III). Considering aphid, the lowest number (3.40) was obtained from T_6 which was closely followed by T_4 (4.20) and T_7 (4.50) treatment, respectively and the highest number (6.80) was found from T_1 treatment which was closely followed by T_2 (5.50) and T_3 (5.20) and from treatment T_5 total 4.90 number of aphid (Table 1). In case of lady bird beetle, the lowest number (2.00) was observed from T_6 which was closely followed by T_4 (2.90) and T_7 (3.20) treatment, while the highest number (6.50) was recorded from T_1 which was closely followed by T_2 (5.10) and total number of lady bird beetle 4.20 and 3.90 was found from the treatment T_3 and T_5, respectively. In case of white fly, the lowest number (3.10) was recorded from T_6 which was closely followed by T_4 (4.20) treatment. On the other hand, the highest number (6.70) was found from T_1 which was followed by T_2 (5.80).

4.1.3 Late fruiting stage

Insect incidence like insect of aphid, lady bird beetle and white fly showed significant differences at late fruiting stage for due to different intercropping pattern (Appendix III). In case of aphid, the lowest number (4.20) was found from T_6 which was closely followed by T_4 (5.10) and T_7 (5.30), respectively whereas the highest number (7.80) was obtained from T_1 which was followed by T_2 (6.70) treatment (Table 1). In case of lady bird beetle, the lowest number (2.70) was recorded from T_6 which was followed by T_4 (3.40) and T_7 (3.50) treatment, whereas the highest number of lady bird beetle (5.90) was found from T_1 which was closely followed by T_2 (4.80) and total number of lady bird beetle 4.40 and 4.20 was obtained from the treatment T_3 and T_5, respectively and they were statistically identical. In case of white fly, the lowest number (3.50) was recorded from T_6 which was closely followed by T_4 (4.60) and T_7 (5.00) treatment, while the highest number (7.40) was observed from T_1 which was followed by T_2 (6.30) and T_3 (5.90) and they were statistically similar. Risch *et al.* (1983) reported that population density of herbivorous insects are frequently lower in polyculture habitats. The natural enemies hypothesis, states that a diversity of plant species may provide important resources for natural enemies such as alternate prey, nactar and pollen or breeding sites (Russell, 1989). A specialist insect is less likely to find its hosts in diverse plant communities because of the presence of confusing or masking chemical stimuli, physical barriers to movement, and other adverse environmental factors. Consequently, insect survival may be lower (Baliddawa, 1985).

4.2 Pod bearing status by number

Pod bearing status by number of gram was recorded for early, mid and late stages in terms of healthy and infested fruit and then calculated infestation percentage and decrease of infestation over control.

4.2.1 Early fruiting stage

At early fruiting stage for different intercropping pattern showed statistically significant variation in number of healthy pod per plant (Appendix IV). The highest number of healthy pod per plant (45.43) was found from T_6 (Gram + garlic) treatment which was statistically similar (44.50, 44.10, 43.90 and 43.40) with T_4 (Gram + Mustard), T_7 (Gram + Radhuni), T_3 (Gram + Lentil) and T_5 (Gram + Coriander), respectively (Table 2). On the other hand, the lowest number of healthy pod (38.43) was obtained in T_1 (Gram sole) treatment which was statistically similar (41.93) with T_2 (Gram + Wheat).

Statistically significant variation was recorded in number of infested pod per plant at early fruiting stage for different treatment under the present trial (Appendix IV). The lowest number of infested pod per plant (1.27) was observed from T_6 treatment which was closely followed by T_4 (1.93) and T_7 (2.23) treatment (Table 2). Again, the highest number of infested pod (3.43) was obtained in T_1 treatment which was statistically similar with T_2 (2.93) and closely followed by T_3 (2.63) and T_5 (2.53).

Table 2. Effect of intercropping on the incidence of gram pod borer at early, mid and late fruiting stage in terms of healthy and infested pod per plant by number

Treatment	Early stage		Mid stage		Late stage	
	Healthy pod	Infested pod by pod borer	Healthy pod	Infested pod by pod borer	Healthy pod	Infested pod by pod borer
T_1	38.43 b	3.43 a	45.00 c	4.80 a	46.00 c	5.30 a
T_2	41.93 ab	2.93 ab	46.20 bc	4.07 b	47.30 bc	4.67 b
T_3	43.90 a	2.63 bc	48.00 abc	3.70 c	49.80 abc	4.10 c
T_4	44.50 a	1.93 d	51.70 ab	2.90 e	54.30 ab	3.10 ef
T_5	43.40 a	2.53 bc	48.90 abc	3.30 d	51.70 abc	3.80 cd
T_6	45.43 a	1.27 e	53.50 a	2.10 f	56.60 a	2.80 f
T_7	44.10 a	2.23 cd	50.50 abc	3.20 de	52.90 abc	3.40 de
$LSD_{(0.05)}$	3.966	0.568	5.108	0.342	6.545	0.464
Significance level	0.05	0.01	0.05	0.01	0.05	0.01
CV(%)	5.17	13.20	5.85	5.61	7.18	6.72

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Gram sole (control)
T_2: Gram + Wheat
T_3: Gram + Lentil
T_4: Gram + Mustard
T_5: Gram + Coriander
T_6: Gram + Garlic
T_7: Gram + Radhuni

For different treatment statistically significant variation was recorded in terms of pod infestation per plant in number at early fruiting stage (Appendix IV). The lowest pod infestation per plant in number (2.72%) was recorded from T_6 treatment which was closely followed by T_4 (4.15%) and T_7 (4.82%) treatment (Table 3). On the other hand, the highest pod infestation per plant in number (8.22%) was recorded in T_1 treatment which was closely followed by T_2 (6.54%), T_3 (5.67%) and T_5 (5.48%). In the consideration of decrease of pod infestation over sole crop in number of pods per plant the maximum decrease of pod infestation (66.91%) over sole crop was found from T_6 whereas the minimum decrease of pod infestation (20.44%) was recorded from T_2 treatment (Table 3). Bhushan and Nath (2006) reported earlier that pigeonpea was intercropped with greengram, blackgram, sesamum, sorghum and pearlmillet in various combination and row ratio. The result showed that the intercrop combination of pigeonpea + blackgram exhibited minimum grain damage.

4.2.2 Mid fruiting stage

Different intercropping pattern showed statistically significant variation in number of healthy pod per plant at mid fruiting stage for (Appendix IV). The highest number of healthy pod per plant in number (53.50) was recorded from T_6 treatment which was statistically similar with T_4 (51.70), T_7 (50.50), T_5 (48.90) and T_3 (48.00), respectively (Table 2). Again, the lowest number of healthy pod was found in T_1 (45.00) treatment which was statistically similar with T_2 (46.20).

Number of infested pod per plant showed significant differences at mid fruiting stage for different treatment (Appendix IV). The lowest number of infested pod per plant (2.10) was obtained from T_6 treatment which was closely followed by T_4 (2.90) and T_7 (3.20) treatment (Table 2). On the other hand, the highest number of infested pod (4.80) was recorded in T_1 treatment which was closely followed by T_2 (4.07) and T_3 (3.70).

Table 3. Effect of intercropping on the incidence of gram pod borer at early, mid and late fruiting stage in terms of % pod infestation and increase/decrease over sole crop per plant by number

Treatment	Early stage		Mid stage		Late stage	
	% pod infestation	Decrease over sole crop	% pod infestation	Decrease over sole crop	% pod infestation	Decrease over sole crop
T_1	8.22 a	--	9.64 a	--	10.33 a	--
T_2	6.54 b	20.44	8.10 b	15.98	8.98 b	13.07
T_3	5.67 bc	31.02	7.15 c	25.83	7.66 c	25.85
T_4	4.15 d	49.51	5.32 e	44.81	5.42 ef	47.53
T_5	5.48 bc	33.33	6.35 cd	34.13	6.85 cd	33.69
T_6	2.72 e	66.91	3.80 f	60.58	4.74 f	54.11
T_7	4.82 cd	41.36	5.96 de	38.17	6.07 de	41.24
$LSD_{(0.05)}$	1.175	--	0.823	--	1.164	--
Significance level	0.01	--	0.01	--	0.01	--
CV(%)	12.29	--	7.00	--	9.15	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Gram sole (control)
T_2: Gram + Wheat
T_3: Gram + Lentil
T_4: Gram + Mustard
T_5: Gram + Coriander
T_6: Gram + Garlic
T_7: Gram + Radhuni

Pod infestation per plant in number at mid fruiting stage showed significant differences for different treatment under the present trial (Appendix IV). The lowest pod infestation per plant in number (3.80%) was recorded from T_6 treatment which was closely followed by T_4 (5.32%) and T_7 (5.96%) treatment (Table 3). Again, the highest pod infestation per plant in number (9.64%) was found in T_1 treatment which was closely followed by T_2 (8.10%), treatment T_3 (7.15%) and T_5 (6.35%) gave statistically similar pod infestation in number. In the consideration of decrease of pod infestation over sole crop in number of pods per plant the maximum decrease of pod infestation (60.58%) over sole crop was obtained from T_6 whereas the minimum decrease of pod infestation (15.98%) was found from T_2 treatment (Table 3).

4.2.3 Late fruiting stage

Number of healthy pod per plant showed statistically significant variation at late fruiting stage for different intercropping pattern (Appendix IV). The highest number of healthy pod per plant in number (56.60) was observed from T_6 treatment which was statistically similar with T_4 (54.30), T_7 (52.90), T_5 (51.70) and T_3 (49.80), respectively (Table 2). On the other hand, the lowest number of healthy pod was found in T_1 (46.00) treatment which was statistically similar with T_2 (47.30).

Significant difference was recorded in number of infested pod per plant at late fruiting stage for different treatment under the present trial (Appendix IV). The lowest number of infested pod per plant (2.80) was obtained from T_6 treatment which was statistically identical (3.10) with T_4 and closely followed by T_7 (3.40) and T_5 (3.80) treatment (Table 2). Whereas, the highest number of infested pod (5.30) was recorded in T_1 treatment which was closely followed by T_2 (4.67) and T_3 (4.10).

At late fruiting stage different treatment varied significantly for of pod infestation per plant in number (Appendix IV). The lowest pod infestation per plant in number (4.74%) was recorded from T_6 treatment which was statistically identical with T_4 (5.42%) and closely followed by T_7 (6.07%) and T_5 (6.85%) treatment (Table 3). Again, the highest pod infestation per plant in number (10.33%) was observed in T_1 treatment which was closely followed by T_2 (8.98%). In the consideration of decrease of pod infestation over sole crop in number of pods per plant the maximum decrease of pod infestation (54.11%) over sole crop was recorded from T_6 whereas the minimum decrease of pod infestation (13.07%) was obtained from T_2 treatment (Table 3).

4.3 Pod bearing status by weight

At early, mid and late stages pod bearing status by weight of gram was observed for the parameters of healthy and infested fruit and then calculated infestation percentage and decrease of infestation over control.

4.3.1 Early fruiting stage

Weight of healthy pod per plant showed statistically significant variation at early fruiting stage for different intercropping pattern (Appendix V). The highest weight of healthy pod per plant (38.20 g) was found from T_6 (Gram + garlic) treatment which was statistically identical (36.20 g, 35.47 g, 35.10 g and 34.50 g) with T_4 (Gram + Mustard), T_7 (Gram + Radhuni), T_5 (Gram + Coriander) and T_3 (Gram + Lentil), respectively (Table 4) and the lowest weight of healthy pod (31.30 g) was obtained in T_1 (Gram sole) treatment which was statistically similar (32.20 g) with T_2 (Gram + Wheat).

Statistically significant difference was observed at early fruiting stage in terms of weight of infested pod per plant for different treatment under the present trial (Appendix V). The lowest weight of infested pod per plant (1.07 g) was observed from T_6 treatment which was closely followed by T_4 (1.57 g) treatment (Table 4). While, the highest weight of infested pod (3.07 g) was obtained in T_1 treatment which was statistically similar with T_2 (2.97 g) and closely followed by T_3 (2.37 g), T_5 (2.27 g) and T_7 (2.07 g) and they were statistically identical.

Table 4. Effect of intercropping on the incidence of gram pod borer at early, mid and late fruiting stage in terms of healthy and infested pod per plant by weight

Treatment	Early stage		Mid stage		Late stage	
	Healthy pod (g)	Infested pod by pod borer (g)	Healthy pod (g)	Infested pod by pod borer (g)	Healthy pod (g)	Infested pod by pod borer (g)
T_1	31.30 c	3.07 a	39.20 c	4.10 a	41.30 b	4.90 a
T_2	32.20 bc	2.97 a	40.40 bc	3.50 b	42.10 b	4.30 b
T_3	34.50 abc	2.37 b	41.10 bc	2.90 c	44.70 ab	3.50 c
T_4	36.20 ab	1.57 c	43.20 ab	2.10 d	47.40 a	2.60 de
T_5	35.10 abc	2.27 b	42.30 abc	2.70 c	45.20 ab	3.00 cd
T_6	38.20 a	1.07 d	45.00 a	1.60 e	49.80 a	2.30 e
T_7	35.47 abc	2.07 b	42.80 ab	2.50 c	46.30 ab	2.80 de
$LSD_{(0.05)}$	4.154	0.308	3.259	0.390	4.739	0.513
Significance level	0.05	0.01	0.05	0.01	0.05	0.01
CV(%)	6.73	7.92	8.36	7.91	5.89	8.64

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Gram sole (control)

T_2: Gram + Wheat

T_3: Gram + Lentil

T_4: Gram + Mustard

T_5: Gram + Coriander

T_6: Gram + Garlic

T_7: Gram + Radhuni

Significant variation was observed in terms of pod infestation per plant in weight for different intercropped pattern at early fruiting stage (Appendix V). The lowest pod infestation per plant in weight (2.73%) was recorded from T_6 treatment which was closely followed by T_4 (4.20%) treatment (Table 5). Again, the highest pod infestation per plant in weight (8.92%) was found in T_1 treatment which statistically similar with T_2 (8.45%) and closely followed by T_3 (6.48%) and T_5 (6.09%) and T_7 (5.51%) and they were statistically identical. In the consideration of decrease of pod infestation over sole crop in weight of pods per plant the maximum decrease of pod infestation (69.39%) over sole crop was observed from T_6 whereas the minimum decrease of pod infestation (5.27%) was recorded from T_2 treatment (Table 5). Rao *et al*. (2003) reported that pod damage by *H. armigera*, *E. atomosa* and *Melanogromyza obtusa* increased with longer duration of pigeon pea cultivars, whereas that of *Maruca vitrata* was highest in the short duration cultivar. Intercropping with castor and sorghum reduced pod damage by *Melanogromyza obtusa*, *Maruca vitrata* and *Helicoverpa armigera*.

4.3.2 Mid fruiting stage

At mid fruiting stage weight of healthy pod per plant differ significantly for different intercropping pattern (Appendix V). The highest weight of healthy pod per plant (45.00 g) was observed from T_6 treatment which was statistically identical with T_4 (43.20 g), T_7 (42.80 g) and T_5 (42.30 g), respectively (Table 4). Again, the lowest weight of healthy pod (39.20 g) was found in T_1 (Gram sole) treatment which was statistically similar with T_2 (40.40 g) and T_3 (41.10 g).

Significant variation was recorded for different treatment under the present trial in weight of infested pod per plant at mid fruiting stage (Appendix V). The lowest weight of infested pod per plant (1.60 g) was obtained from T_6 treatment which was closely followed by T_4 (2.10 g) treatment (Table 4). While, the highest weight of infested pod (4.10 g) was recorded in T_1 treatment which was closely followed by T_2 (3.50 g) and treatment T_3 (2.90 g), T_5 (2.70 g) and T_7 (2.50 g) gave infested pod they were statistically similar.

Table 5. Effect of intercropping on the incidence of gram pod borer at early, mid and late fruiting stage in terms of % fruit infestation and increase/decrease over sole crop of pod per plant by weight

Treatment	Early stage		Mid stage		Late stage	
	% pod infestation	Decrease over sole crop	% pod infestation	Decrease over sole crop	% pod infestation	Decrease over sole crop
T_1	8.92 a	--	9.47 a	--	10.59 a	--
T_2	8.45 a	5.27	7.97 b	15.84	9.28 b	12.37
T_3	6.48 b	27.35	6.59 c	30.41	7.29 c	31.16
T_4	4.20 c	52.91	4.66 e	50.79	5.20 de	50.90
T_5	6.09 b	31.73	6.01 cd	36.54	6.22 cd	41.27
T_6	2.73 d	69.39	3.43 f	63.78	4.42 e	58.26
T_7	5.51 b	38.23	5.54 de	41.50	5.73 d	45.89
$LSD_{(0.05)}$	1.299	--	0.921	--	1.112	--
Significance level	0.01	--	0.01	--	0.01	--
CV(%)	12.06	--	8.30	--	10.98	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Gram sole (control) T_2: Gram + Wheat

T_3: Gram + Lentil T_4: Gram + Mustard

T_5: Gram + Coriander T_6: Gram + Garlic

T_7: Gram + Radhuni

Pod infestation per plant in weight differs significantly for different treatment at mid fruiting stage (Appendix V). The lowest pod infestation per plant in weight (3.43%) was obtained from T_6 treatment which was closely followed by T_4 (4.66%) and T_7 (5.54%) treatment (Table 5). Again, the highest pod infestation per plant in weight (9.47%) was observed in T_1 treatment which was closely followed by T_2 (7.97%). In the consideration of decrease of pod infestation over sole crop in weight of pods per plant the maximum decrease of pod infestation (63.78%) over sole crop was recorded from T_6 whereas the minimum decrease of pod infestation (15.84%) was found from T_2 treatment (Table 5).

4.3.3 Late fruiting stage

At late fruiting stage for different intercropping pattern showed statistically significant variation in weight of healthy pod per plant (Appendix V). The highest weight of healthy pod per plant (49.80 g) was recorded from T_6 treatment which was statistically identical with T_4 (47.40 g), T_7 (46.30 g), T_5 (45.20 g) and T_3 (44.70 g), respectively (Table 4). On the other hand, the lowest weight of healthy pod (41.30 g) was obtained in T_1 (Gram sole) treatment which was statistically similar with T_2 (42.10 g) treatment.

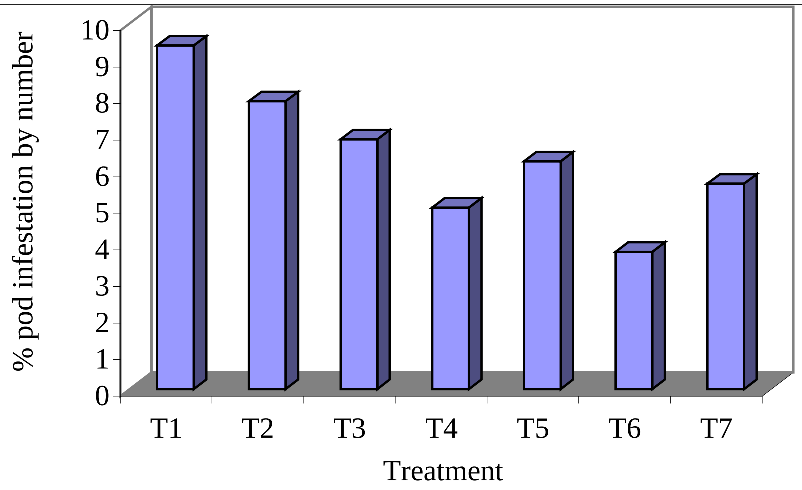
Weight of infested pod per plant at late fruiting stage for different treatment under the present trial showed statistically significant differences (Appendix V). The lowest weight of infested pod per plant (2.30 g) was recorded from T_6 treatment which was statistically similar with T_4 (2.60 g) and T_7 (2.80 g) treatment (Table 4) and the highest weight of infested pod (4.90 g) was observed in T_1 treatment which was closely followed by T_2 (4.30 g).

Different treatments differ significantly in terms of pod infestation per plant in weight at late fruiting stage (Appendix V). The lowest pod infestation per plant in weight (4.42%) was found from T_6 treatment which was statistically similar with T_4 (5.20%) and closely followed by T_7 (5.73%), T_5 (6.22%) treatment (Table 5). Again, the highest pod infestation per plant in weight (10.59%) was recorded in T_1 treatment which was closely followed by T_2 (9.28%). In the consideration of decrease of pod infestation over sole crop in weight of pods per plant the maximum decrease of pod infestation (58.26%) over sole crop was obtained from T_6 whereas the minimum decrease of pod infestation (12.37%) was recorded from T_2 treatment (Table 5).

4.4 Average infestation by number and weight

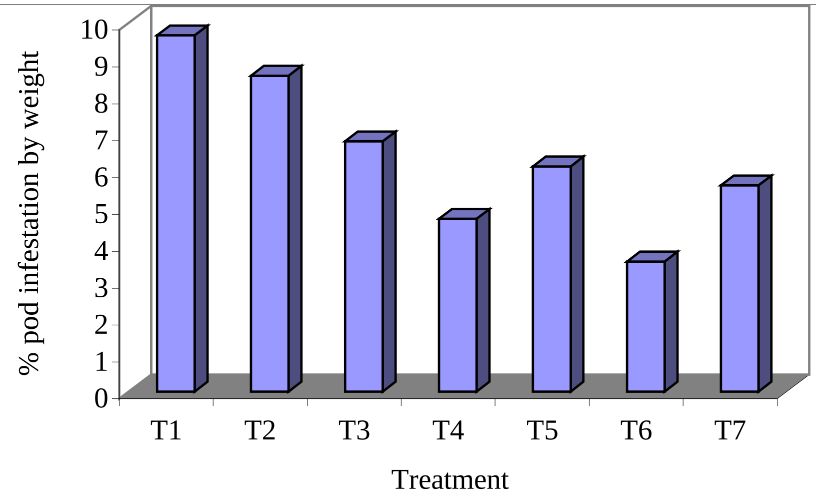
Average pod infestation per plant in number for different treatment showed a significant variation (Appendix IV). The lowest average pod infestation per plant in number (3.75%) was observed from T_6 which was statistically similar with T_4 (4.96%) and closely followed by T_7 (5.62%). Again, the highest average pod infestation per plant (9.40%) was recorded from T_1 which was closely followed by T_2 (7.87%) treatment (Figure 1).

Statistically significant difference was observed for average pod infestation per plant in weight for different treatment under the present trial (Appendix V). The minimum average pod infestation per plant in weight (3.53%) was recorded from T_6 treatment which was statistically similar with T_4 (4.69%) and closely followed by T_3 (5.59%). While, the maximum pod infestation per plant (9.66%) was found from T_1 which was statistically similar with T_2 (8.57%) treatment (Figure 2).



T_1: Gram sole (control) T_2: Gram + Wheat
T_3: Gram + Lentil T_4: Gram + Mustard
T_5: Gram + Coriander T_6: Gram + Garlic
T_7: Gram + Radhuni

Figure 1. Effect of intercropping on the % pod infestation of gram per plant by number



T_1: Gram sole (control) T_2: Gram + Wheat
T_3: Gram + Lentil T_4: Gram + Mustard
T_5: Gram + Coriander T_6: Gram + Garlic
T_7: Gram + Radhuni

Figure 2. Effect of intercropping on the % pod infestation of gram per plant by weight

4.5 Yield

Yield per hectare of gram showed significant variation for different treatment under the present trial (Appendix VI). The highest yield (2.05 t ha^{-1}) was found from T_1 treatment which was statistically identical with T_6 (2.02 t ha^{-1}) and T_4 (1.96 t ha^{-1}) treatment (Table 6). On the other hand, the lowest yield (1.80 t ha^{-1}) was recorded in T_2 treatment. Saxena (1988) stated that yields of both the crops are reduced when grown as mixed or intercropped, compared with the crops when grown alone but in most cases combined yield per unit area from intercropping are higher.

4.6 Diversity of insect community

Trends in diversity pattern of insects in intercropping under different treatments using relative methods viz. pitfall trap and sweeping net at early, mid and late stages of crop growth are shown after combining the data from collected samples in Appendix VI-XI and Table 6 & 7. Some neutral insects which are not regarded as crop pest were also trapped incidentally in both the methods. These were also included in data because the relative significance of their presence in a particular ecosystem is not clearly known to us.

4.6.1 Pit fall trap method

Diversity index of an insect community under different crop combinations using pit fall method at early, mid and late stages of crop growth are presented in Table 6.

At early crop growth stage the higher richness and also the highest diversity index were observed in T_1 (6.12) whereas the lowest was recorded from T_6 (1.96), and the highest equability was observed in T_6 (0.98) and the lowest (0.71) was recorded for T_3 and T_4. At mid crop growth stage the higher richness and also the highest diversity index were observed in T_1 (6.39) whereas it was the lowest in T_6 (2.79), and the highest equability was observed in T_6 (0.93) and the lowest (0.74) was found for T_2. At late crop growth stage, the higher richness and also the highest diversity index were observed in T_1 (8.34) whereas the lowest was obtained from T_6 (3.67), and the highest equability was observed in T_6 (0.92) and the lowest (0.78) was found for T_5 (Table 6).

Table 6. Diversity and equitability of insect community under different crop combinations using pit fall trap method at early, mid and late stage of crop growth

Treatment	Early stage			Mid stage			Late stage		
	Number of insect	Diversity index (D)	Equitability (E)	Number of insect	Diversity index (D)	Equitability (E)	Number of insect	Diversity index (D)	Equitability (E)
T_1	19	6.12	0.87	21	6.39	0.80	22	8.34	0.83
T_2	18	5.06	0.84	19	5.92	0.74	20	8.00	0.89
T_3	16	4.27	0.71	19	4.81	0.80	19	5.39	0.77
T_4	08	2.13	0.71	10	3.33	0.83	12	4.24	0.85
T_5	13	3.93	0.79	15	4.41	0.88	17	5.45	0.78
T_6	07	1.96	0.98	09	2.79	0.93	11	3.67	0.92
T_7	12	3.79	0.95	14	4.26	0.85	16	4.57	0.76

T_1: Gram sole (control)
T_2: Gram + Wheat
T_3: Gram + Lentil
T_4: Gram + Mustard
T_5: Gram + Coriander
T_6: Gram + Garlic
T_7: Gram + Radhuni

4.6.2 Sweeping net method

Diversity index of an insect community under different crop combinations using sweeping net method at early, mid and late stages of crop growth are presented in Table 7.

Using sweeping net method at early crop growth stage the higher richness and also the highest diversity index were obtained from T_1 (4.92) whereas the lowest was recorded from T_6 (1.92), and the highest equability was observed in T_2, T_4 and T_6 (0.96) and the lowest (0.74) was recorded for T_5. At mid crop growth stage the higher richness and also the highest diversity index were observed in T_1 (4.76) whereas it was the lowest in T_6 (2.78). On the other hand and the highest equability was observed in T_6 (0.93) and the lowest (0.68) was recorded for and T_1 and T_2. At late crop growth stage the higher richness and also the highest diversity index were found in T_1 (5.92) whereas the lowest was recorded from T_6 (2.57), and the highest equability was observed in T_4 (0.89) and the lowest (0.70) was obtained for T_3 (Table 7).

Table 7. Diversity and equitability of insect community under different crop combinations using sweeping net method at early, mid and late stage of crop growth

Treatment	Early stage			Mid stage			Late stage		
	Number of insect	Diversity index (D)	Equitability (E)	Number of insect	Diversity index (D)	Equitability (E)	Number of insect	Diversity index (D)	Equitability (E)
T_1	16	4.92	0.82	18	4.76	0.68	19	5.92	0.74
T_2	15	4.79	0.96	17	4.74	0.68	18	5.40	0.77
T_3	12	3.13	0.78	15	4.59	0.77	17	4.90	0.70
T_4	05	1.92	0.96	06	3.60	0.90	08	3.56	0.89
T_5	10	2.94	0.74	12	3.60	0.72	15	5.77	0.82
T_6	05	1.92	0.96	05	2.78	0.93	06	2.57	0.86
T_7	09	2.45	0.82	11	3.46	0.69	13	4.12	0.69

T_1: Gram sole (control)

T_2: Gram + Wheat

T_3: Gram + Lentil

T_4: Gram + Mustard

T_5: Gram + Coriander

T_6: Gram + Garlic

T_7: Gram + Radhuni

4.7 Relationship between number of insect with diversity index

A positive relationship was observed between the number of insect in different families and diversity index in all the crop growth stages (Table 8 and Figure 3 & 4). In case of pit fall trap method all the crop growth stages significant relationships between richness and diversity index of insects community was observed (r = 0.976, 0.958 and 0.899). In the same way in case of sweeping net method for all the crop growth stages significant relationships between richness and diversity index of insect community was observed (r = 0.966, 0.915 and 0.930). The results revealed a highly significant positive relationship, which clearly indicates that diversity index of insects community is influenced by the number of insects (i.e. richness) in diversity agro-ecosystems.

4.8 Relationship between number of insect with equitability

Number of insect in different families and equitability in all the crop growth stages showed a positive relationship (Table 9 and Figure 5 and 6). In case of pit fall trap method, all the crop growth stages except early stage showed significant relationships between richness and equitability of insects community was observed (r = 0.167, 0.749 and 0.339). On the other hand, in case of sweeping net method for all the crop growth stages significant relationships between richness and equitability of insects community was observed (r = 0.347, 0.866 and 0.703).

Value of diversity index depends on both the species richness and the evenness (equitability) with which individuals are distributed among the species. For a given richness, ‘D’ increases with equitability and for a given equitability ‘D’ increases with richness (Begon *et al.*, 1990). Uddin *et al.* (2002) observed that polyculture generally had a greater diversity index and higher equitability of insect community. They also reported that a combination of pitfall reap and sweeping net methods for the whole crop growth period revealed a highly significant positive relation between richness and diversity index, but a negative relationship between richness and equitability.

Table 8. Relationship between the number of insect families (X) and diversity index (D) at different crop growth stages

Crop growth stages	Relationship between		Equation	Correlation value	Probability (P)
Pit fall trap method					
Early stage	No. of insects	Diversity index	Y = 0.3108x - 0.2343	0.976	0.01
Mid stage	No. of insects	Diversity index	Y = 0.2665x + 0.4849	0.958	0.01
Late stage	No. of insects	Diversity index	Y = 0.4025x - 1.062	0.899	0.01
Sweeping net method					
Early stage	No. of insects	Diversity index	Y = 0.2753x + 0.3215	0.966	0.01
Mid stage	No. of insects	Diversity index	Y = 0.1379x + 2.2782	0.915	0.01
Late stage	No. of insects	Diversity index	Y = 0.2301x + 1.4503	0.930	0.01

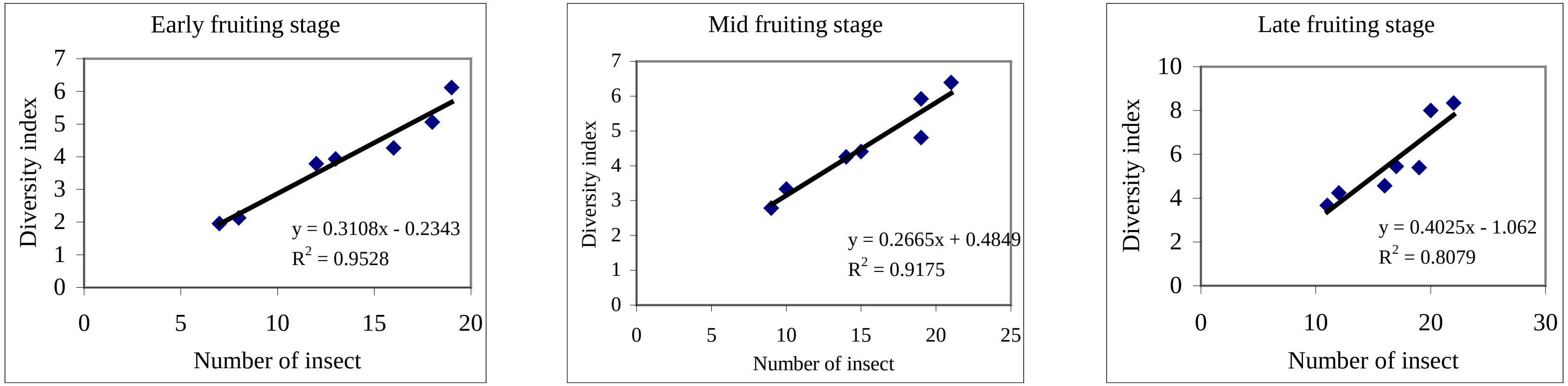


Figure 3. Relationship between number of insect families and insect diversity index of insect community in chickpea sole and intercrop combinations for early, mid and late crop growth period using pit fall trap method

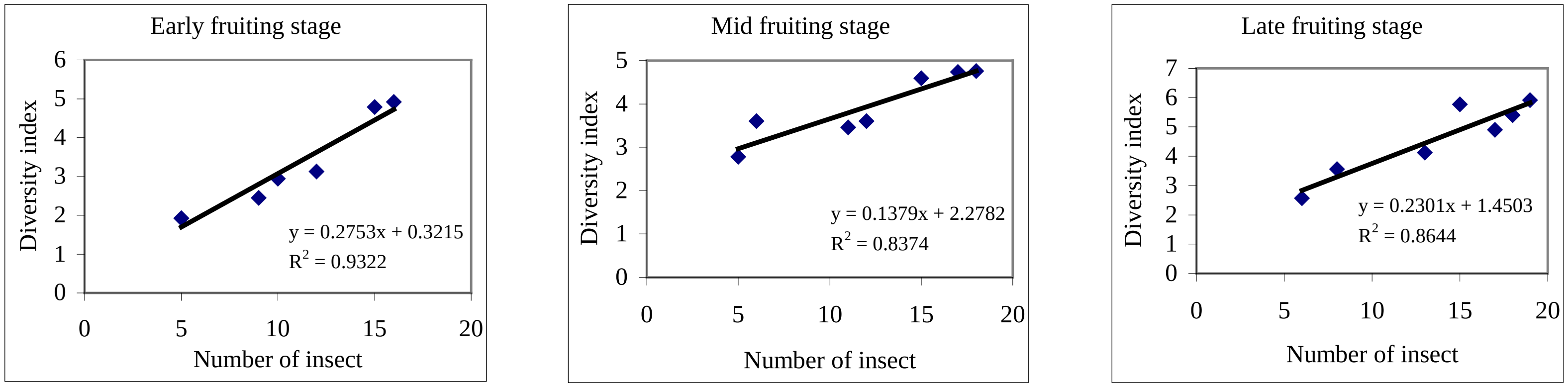


Figure 4. Relationship between number of insect families and insect diversity index of insect community in chickpea sole and intercrop combinations for early, mid and late crop growth period using sweeping net method

Table 9. Relationship between the number of insect families (X) and equitability (E) at different crop growth stages

Crop growth stages	Relationship between		Equation	Correlation value	Probability (P)
Pit fall trap method					
Early stage	No. of insects	Equitability	Y = -0.0038x + 0.8864	0.167	NS
Mid stage	No. of insects	Equitability	Y = -0.0099x + 0.9847	0.749	0.01
Late stage	No. of insects	Equitability	Y = -0.0052x + 0.9148	0.339	0.05
Sweeping net method					
Early stage	No. of insects	Equitability	Y = -0.0075x + 0.94	0.347	0.05
Mid stage	No. of insects	Equitability	Y = -0.018x + 0.9833	0.866	0.01
Late stage	No. of insects	Equitability	Y = -0.0109x + 0.9306	0.703	0.01

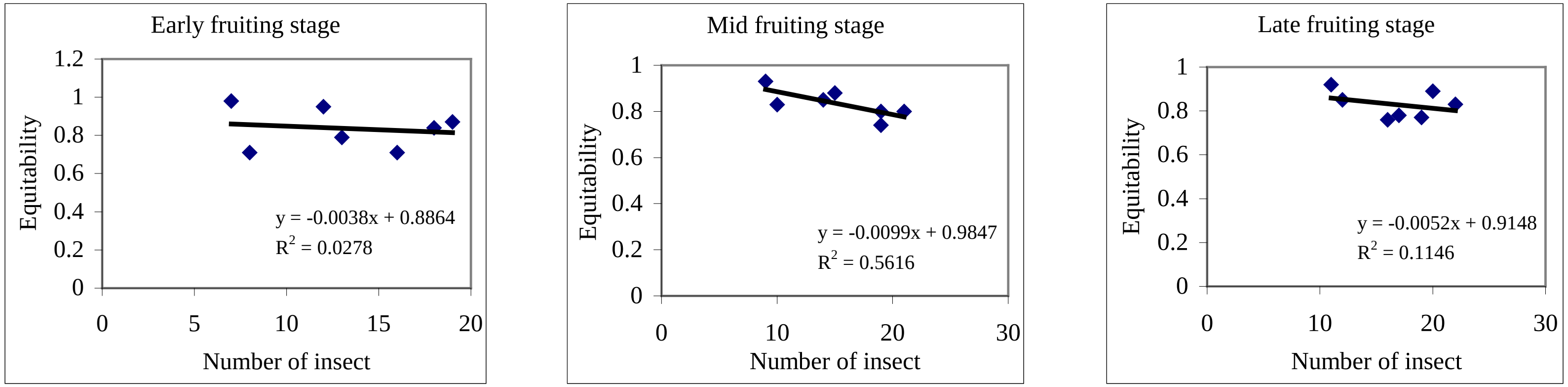


Figure 5. Relationship between number of insect families and insect equitability of insect community in chickpea sole and intercrop combinations for early, mid and late crop growth period using pit fall trap method

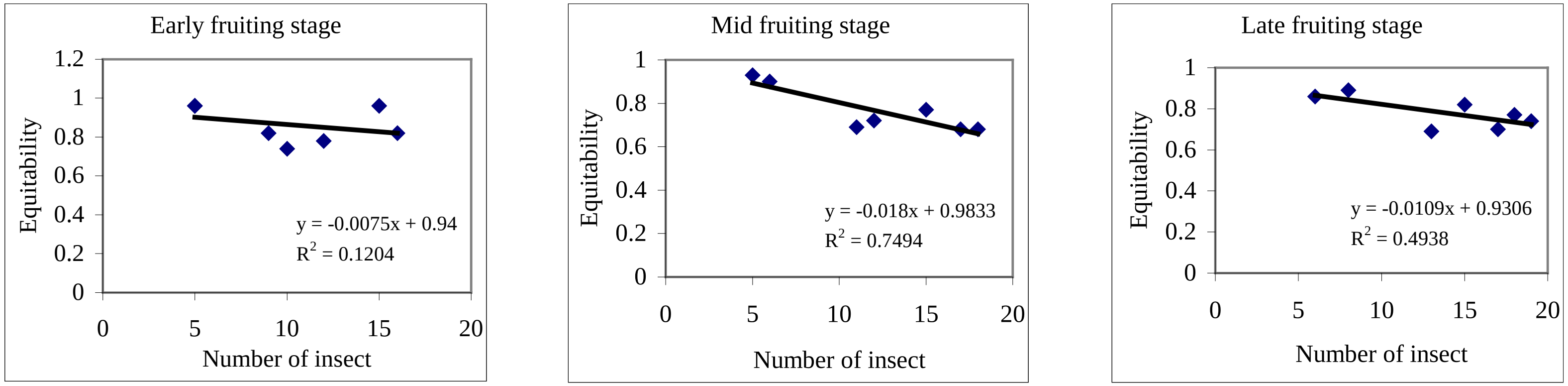


Figure 6. Relationship between number of insect families and equitability of insect community in chickpea sole and intercrop combinations for early, mid and late crop growth period using sweeping net method

When diversity was assessed in pit fall trap method gram and wheat intercropped showed generally higher diversity index among all the crop combinations at early, mid and late stages of crop. Thus in the intercropping system, insects observed belong to different families, which indicates that specific pest insects were less abundant and the insects observed might belong to the natural enemies and beneficial categories. Diversity index assessed through sweeping net method also revealed that insects were less abundant in intercropping system. This result is in conformity with that of Roots (1973) hypothesis. He proposed that the specialist herbivores are generally less abundant in vegetationally diverse habitats because their food sources are less concentrated and natural enemies are more abundant. May (1975) also report that diversity index strongly influenced by the richness of species.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2008 to March, 2009 to find out the effect of intercropping on the incidence of insect pests of gram. The experiment consists of seven treatments such as- T_1: Gram sole (control), T_2: Gram + Wheat, T_3: Gram + Lentil, T_4: Gram + Mustrad, T_5: Gram + Coriander, T_6: Gram + Garlic and T_7: Gram + Radhuni. The experiment was laid out in Randomized Complete Block Design with three replications. Data on insect incidence, number and weight of healthy pod, infested pod and pod infestation in number and weight, yield contributing characters and yield of gram, diversity of insect community were recorded.

Statistically significant variation was recorded at early, mid and late fruiting stage for arthropod incidence. At early fruiting stage, the lowest number of aphid (2.10), lady bird beetle (1.30) and white fly (2.60) was recorded from T_6 whereas the highest numbers were recorded in T_1 treatment (5.40, 4.90 and 6.10, respectively). At mid fruiting stage, the lowest number of aphid (3.40), lady bird beetle (2.00) and white fly (3.10) was recorded from T_6 whereas the highest numbers were recorded in T_1 treatment (6.80, 6.50 and 6.70, respectively). At late fruiting stage, the lowest number of aphid (4.20), lady bird beetle (2.70) and white fly (3.50) was recorded from T_6 whereas the highest numbers were recorded in T_1 treatment (7.80, 5.90 and 7.40, respectively).

Pod infestation per plant by number and weight of gram showed significant differences for early, mid and late stages. At early, mid and late fruiting stages the lowest pod infestation per plant in number (2.72%, 3.80% and 4.74%) was recorded from T_6 treatment whereas the highest (8.22%, 9.64% and 10.33%) was recorded in T_1 treatment. Pod infestation per plant by weight at early, mid and late fruiting stages the lowest pod infestation per plant in number (2.73%, 3.43% and

4.42%) was recorded from T_6 treatment whereas the highest (8.92%, 9.47% and 10.59%) was recorded in T_1 treatment.

For pit fall trap method, at early crop growth stage the higher richness and also the highest diversity index were observed in T_1 (6.12) whereas it was the lowest was recorded from T_6 (1.96), and the highest equability was observed in T_6 (0.98) and the lowest (0.71) was recorded for T_3 and T_4. At mid crop growth stage the higher richness and also the highest diversity index were observed in T_1 (6.39) whereas it was the lowest was recorded from T_6 (2.79), and the highest equability was observed in T_6 (0.93) and the lowest (0.74) was found for T_2. At late crop growth stage, the higher richness and also the highest diversity index were observed in T_1 (8.34) whereas it was the lowest was obtained from T_6 (3.67), and the highest equability was observed in T_6 (0.92) and the lowest (0.78) was found for T_5. Using sweeping net method at early crop growth stage the higher richness and also the highest diversity index were obtained from T_1 (4.92) whereas it was the lowest was recorded from T_6 (1.92), and the highest equability was observed in T_2, T_4 and T_6 (0.96) and the lowest (0.74) was recorded for T_5. At mid crop growth stage the higher richness and also the highest diversity index were observed in T_1 (4.76) whereas it was the lowest was recorded from T_6 (2.78). On the other hand and the highest equability was observed in T_6 (0.93) and the lowest (0.68) was recorded for and T_1 and T_2. At late crop growth stage the higher richness and also the highest diversity index were found in T_1 (5.92) whereas it was the lowest was recorded from T_6 (2.57), and the highest equability was observed in T_4 (0.89) and the lowest (0.70) was obtained for T_3.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other crop as intercrop may be included in the future study;
3. Row combination for best intercrop may be included for further study.

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APPENDICES

Appendix I. Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2008 to March 2009

Month	*Air temperature (^{o}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2008	25.82	16.04	78	00
December, 2008	22.4	13.5	74	00
January, 2009	24.5	12.4	68	00
February, 2009	27.1	16.7	67	30
March, 2009	31.4	19.6	54	11

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix III. Analysis of variance of the data on the incidence of insect at early, mid and late fruiting stage in terms of number of insect per plot as influenced by intercropping

Source of variation	Degrees of freedom	Mean square								
		Number of insect per plot								
		Early stage			Mid stage			Late stage		
		Aphid	Lady bird beetle	Whitefly	Aphid	Lady bird beetle	Whitefly	Aphid	Lady bird beetle	Whitefly
Replication	2	0.036	0.001	0.143	0.013	0.036	0.010	0.074	0.013	0.001
Treatment	6	3.429**	4.487**	3.759**	3.477**	6.677**	3.957**	4.120**	3.317**	4.754**
Error	12	0.112	0.048	0.073	0.083	0.059	0.057	0.044	0.050	0.098

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on the incidence of gram pod borer at early, mid and late fruiting stage in terms of healthy, infested pod and % infestation per plant by number as influenced by intercropping

Source of variation	Degrees of freedom	Mean square									
		Early stage			Mid stage			Late stage			Average % infestation
		Healthy	Infested by pod borer	% infestation	Healthy	Infested by pod borer	% infestation	Healthy	Infested by pod borer	% infestation	
Replication	2	1.170	0.009	0.104	0.670	0.020	0.115	0.001	0.025	0.063	0.045
Treatment	6	16.137*	1.475**	9.184**	27.274*	2.237**	10.905**	43.057*	2.348**	11.868**	12.421**
Error	12	4.970	0.102	0.436	8.243	0.037	0.214	13.535	0.068	0.428	0.511

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on the incidence of gram pod borer at early, mid and late fruiting stage in terms of healthy, infested pod and % infestation per plant by weight as influenced by intercropping

Source of variation	Degrees of freedom	Mean square									
		Early stage			Mid stage			Late stage			Average % infestation
		Healthy	Infested by pod borer	% infestation	Healthy	Infested by pod borer	% infestation	Healthy	Infested by pod borer	% infestation	
Replication	2	0.619	0.002	0.046	3.023	0.001	0.104	2.830	0.030	0.051	0.036
Treatment	6	16.549*	1.537**	14.503**	11.190*	2.107**	12.248**	26.129*	2.709**	15.160**	16.723**
Error	12	5.452	0.030	0.533	3.356	0.048	0.268	7.097	0.083	0.391	0.421

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability

Appendix VI. Diversity and equitability of insect community under different crop combinations using pit fall trap method at early stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Araneidae	2	0.11	0.0111	6.12	0.87
	Formicidae	4	0.21	0.0443		
	Gryllidae	1	0.05	0.0028		
	Coccinellidae	3	0.16	0.0249		
	Formicinae	4	0.21	0.0443		
	Muscidae	3	0.16	0.0249		
	Spider	2	0.11	0.0111		
Gram + Wheat	Araneidae	2	0.11	0.0123	5.06	0.84
	Formicidae	5	0.28	0.0772		
	Formicinae	3	0.17	0.0278		
	Muscidae	3	0.17	0.0278		
	Spider	1	0.06	0.0031		
	Culicidae	4	0.22	0.0494		
Gram +Lentil	Formicidae	1	0.06	0.0039	4.27	0.71
	Gryllidae	5	0.31	0.0977		
	Coccinellidae	5	0.31	0.0977		
	Formicinae	2	0.13	0.0156		
	Tripidae	1	0.06	0.0039		
	Muscidae	2	0.13	0.0156		
Gram + Mustard	Araneidae	2	0.25	0.0625	2.13	0.71
	Coccinellidae	5	0.63	0.3906		
	Tripidae	1	0.13	0.0156		
Gram + Coriander	Formicidae	3	0.23	0.0533	3.93	0.79
	Gryllidae	5	0.38	0.1479		
	Formicinae	2	0.15	0.0237		
	Tripidae	1	0.08	0.0059		
	Muscidae	2	0.15	0.0237		
Gram + Garlic	Gryllidae	3	0.43	0.1837	1.96	0.98
	Muscidae	4	0.57	0.3265		
Gram + Radhuni	Formicidae	3	0.25	0.0625	3.79	0.95
	Coccinellidae	4	0.33	0.1111		
	Formicinae	2	0.17	0.0278		
	Muscidae	3	0.25	0.0625		

Appendix VII. Diversity and equitability of insect community under different crop combinations using pit fall trap method at mid stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Araneidae	2	0.10	0.0091	6.39	0.80
	Formicidae	4	0.19	0.0363		
	Gryllidae	3	0.14	0.0204		
	Formicinae	1	0.05	0.0023		
	Tripidae	5	0.24	0.0567		
	Muscidae	1	0.05	0.0023		
	Carabidae	2	0.10	0.0091		
	Spider	3	0.14	0.0204		
Gram + Wheat	Araneidae	3	0.16	0.0249	5.92	0.74
	Formicidae	1	0.05	0.0028		
	Gryllidae	2	0.11	0.0111		
	Formicinae	2	0.11	0.0111		
	Tripidae	5	0.26	0.0693		
	Muscidae	1	0.05	0.0028		
	Spider	4	0.21	0.0443		
	Culicidae	1	0.05	0.0028		
Gram +Lentil	Araneidae	6	0.32	0.0997	4.81	0.80
	Formicidae	1	0.05	0.0028		
	Gryllidae	3	0.16	0.0249		
	Formicinae	2	0.11	0.0111		
	Tripidae	4	0.21	0.0443		
	Muscidae	3	0.16	0.0249		
Gram + Mustard	Araneidae	4	0.40	0.1600	3.33	0.83
	Formicidae	1	0.10	0.0100		
	Formicinae	2	0.20	0.0400		
	Tripidae	3	0.30	0.0900		
Gram + Coriander	Formicidae	5	0.33	0.1111	4.41	0.88
	Gryllidae	3	0.20	0.0400		
	Formicinae	2	0.13	0.0178		
	Tripidae	3	0.20	0.0400		
	Muscidae	2	0.13	0.0178		
Gram + Garlic	Araneidae	4	0.44	0.1975	2.79	0.93
	Formicidae	2	0.22	0.0494		
	Tripidae	3	0.33	0.1111		
Gram + Radhuni	Formicidae	4	0.29	0.0816	4.26	0.85
	Gryllidae	3	0.21	0.0459		
	Formicinae	2	0.14	0.0204		
	Tripidae	4	0.29	0.0816		
	Muscidae	1	0.07	0.0051		

Appendix VIII. Diversity and equitability of insect community under different crop combinations using pit fall trap method at late stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Araneidae	3	0.14	0.0186	8.34	0.83
	Formicidae	2	0.09	0.0083		
	Gryllidae	1	0.05	0.0021		
	Coccinellidae	3	0.14	0.0186		
	Formicinae	2	0.09	0.0083		
	Tripidae	4	0.18	0.0331		
	Muscidae	1	0.05	0.0021		
	Carabidae	3	0.14	0.0186		
	Spider	2	0.09	0.0083		
	Culicidae	1	0.05	0.0021		
Gram + Wheat	Araneidae	2	0.10	0.0100	8.00	0.89
	Formicidae	1	0.05	0.0025		
	Gryllidae	3	0.15	0.0225		
	Coccinellidae	3	0.15	0.0225		
	Formicinae	2	0.10	0.0100		
	Tripidae	3	0.15	0.0225		
	Muscidae	1	0.05	0.0025		
	Carabidae	3	0.15	0.0225		
	Culicidae	2	0.10	0.0100		
Gram +Lentil	Formicidae	4	0.21	0.0443	5.39	0.77
	Gryllidae	5	0.26	0.0693		
	Coccinellidae	4	0.21	0.0443		
	Formicinae	2	0.11	0.0111		
	Tripidae	1	0.05	0.0028		
	Muscidae	1	0.05	0.0028		
	Culicidae	2	0.11	0.0111		
Gram + Mustard	Araneidae	4	0.33	0.1111	4.24	0.85
	Formicidae	1	0.08	0.0069		
	Gryllidae	3	0.25	0.0625		
	Formicinae	2	0.17	0.0278		
	Muscidae	2	0.17	0.0278		
Gram + Coriander	Araneidae	3	0.18	0.0311	5.45	0.78
	Gryllidae	5	0.29	0.0865		
	Coccinellidae	2	0.12	0.0138		
	Formicinae	2	0.12	0.0138		
	Tripidae	1	0.06	0.0035		
	Muscidae	1	0.06	0.0035		
	Spider	3	0.18	0.0311		
Gram + Garlic	Formicidae	4	0.36	0.1322	3.67	0.92
	Formicinae	2	0.18	0.0331		
	Muscidae	2	0.18	0.0331		
	Spider	3	0.27	0.0744		

Gram + Radhuni	Araneidae	5	0.31	0.0977	4.57	0.76
	Formicidae	1	0.06	0.0039		
	Gryllidae	3	0.19	0.0352		
	Formicinae	2	0.13	0.0156		
	Tripidae	1	0.06	0.0039		
	Muscidae	4	0.25	0.0625		

Appendix IX. Diversity and equitability of insect community under different crop combinations using sweeping net method at early stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Araneidae	3	0.19	0.0352	4.92	0.82
	Formicidae	1	0.06	0.0039		
	Gryllidae	5	0.31	0.0977		
	Formicinae	2	0.13	0.0156		
	Muscidae	2	0.13	0.0156		
	Spider	3	0.19	0.0352		
Gram + Wheat	Araneidae	2	0.13	0.0178	4.79	0.96
	Gryllidae	3	0.20	0.0400		
	Tripidae	4	0.27	0.0711		
	Muscidae	3	0.20	0.0400		
	Culicidae	3	0.20	0.0400		
Gram +Lentil	Coccinellidae	2	0.17	0.0278	3.13	0.78
	Tripidae	1	0.08	0.0069		
	Muscidae	5	0.42	0.1736		
	Spider	4	0.33	0.1111		
Gram + Mustard	Formicidae	2	0.40	0.1600	1.92	0.96
	Muscidae	3	0.60	0.3600		
Gram + Coriander	Araneidae	1	0.10	0.0100	2.94	0.74
	Formicinae	2	0.20	0.0400		
	Muscidae	5	0.50	0.2500		
	Culicidae	2	0.20	0.0400		
Gram + Garlic	Formicidae	2	0.40	0.1600	1.92	0.96
	Gryllidae	3	0.60	0.3600		
Gram + Radhuni	Formicinae	2	0.22	0.0494	2.45	0.82
	Muscidae	5	0.56	0.3086		
	Culicidae	2	0.22	0.0494		

Appendix X. Diversity and equitability of insect community under different crop combinations using sweeping net method at mid stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Araneidae	4	0.22	0.0494	4.76	0.68
	Formicidae	1	0.06	0.0031		
	Gryllidae	6	0.33	0.1111		
	Formicinae	2	0.11	0.0123		
	Muscidae	1	0.06	0.0031		
	Spider	3	0.17	0.0278		
	Culicidae	1	0.06	0.0031		
Gram + Wheat	Araneidae	6	0.35	0.1246	4.74	0.68
	Formicidae	3	0.18	0.0311		
	Formicinae	2	0.12	0.0138		
	Tripidae	1	0.06	0.0035		
	Muscidae	1	0.06	0.0035		
	Spider	3	0.18	0.0311		
	Culicidae	1	0.06	0.0035		
Gram +Lentil	Formicidae	1	0.07	0.0044	4.59	0.77
	Gryllidae	5	0.33	0.1111		
	Formicinae	3	0.20	0.0400		
	Muscidae	1	0.07	0.0044		
	Spider	3	0.20	0.0400		
	Culicidae	2	0.13	0.0178		
Gram + Mustard	Gryllidae	2	0.33	0.1111	3.60	0.90
	Formicinae	2	0.33	0.1111		
	Muscidae	1	0.17	0.0278		
	Spider	1	0.17	0.0278		
Gram + Coriander	Araneidae	1	0.08	0.0069	3.60	0.72
	Gryllidae	5	0.42	0.1736		
	Coccinellidae	2	0.17	0.0278		
	Muscidae	1	0.08	0.0069		
	Culicidae	3	0.25	0.0625		
Gram + Garlic	Formicidae	1	0.20	0.0400	2.78	0.93
	Formicinae	2	0.40	0.1600		
	Spider	2	0.40	0.1600		
	Gryllidae	5	0.45	0.2066	3.46	0.69
	Formicinae	2	0.18	0.0331		
	Muscidae	1	0.09	0.0083		
	Carabidae	1	0.09	0.0083		
	Culicidae	2	0.18	0.0331		

Appendix XI. Diversity and equitability of insect community under different crop combinations using sweeping net method at late stage of crop growth

Treatment	Insect & spider families	No. of individual	Proportion of individual (Pi)	Pi^2	Diversity Index (D)	Equitability (E)
Gram Sole	Formicidae	1	0.05	0.0028	5.92	0.74
	Gryllidae	5	0.26	0.0693		
	Coccinellidae	4	0.21	0.0443		
	Formicinae	2	0.11	0.0111		
	Tripidae	1	0.05	0.0028		
	Muscidae	1	0.05	0.0028		
	Carabidae	3	0.16	0.0249		
	Culicidae	2	0.11	0.0111		
Gram + Wheat	Araneidae	5	0.28	0.0772	5.40	0.77
	Formicinae	2	0.11	0.0123		
	Tripidae	1	0.06	0.0031		
	Muscidae	4	0.22	0.0494		
	Carabidae	3	0.17	0.0278		
	Spider	1	0.06	0.0031		
	Culicidae	2	0.11	0.0123		
Gram +Lentil	Araneidae	2	0.12	0.0138	4.90	0.70
	Formicidae	3	0.18	0.0311		
	Gryllidae	5	0.29	0.0865		
	Formicinae	2	0.12	0.0138		
	Muscidae	1	0.06	0.0035		
	Spider	4	0.24	0.0554		
Gram + Mustard	Formicinae	2	0.25	0.0625	3.56	0.89
	Muscidae	1	0.13	0.0156		
	Carabidae	2	0.25	0.0625		
	Culicidae	3	0.38	0.1406		
Gram + Coriander	Araneidae	3	0.20	0.0400	5.77	0.82
	Coccinellidae	2	0.13	0.0178		
	Formicinae	2	0.13	0.0178		
	Muscidae	1	0.07	0.0044		
	Carabidae	4	0.27	0.0711		
	Spider	2	0.13	0.0178		
	Culicidae	1	0.07	0.0044		
Gram + Garlic	Araneidae	3	0.50	0.2500	2.57	0.86
	Muscidae	1	0.17	0.0278		
	Culicidae	2	0.33	0.1111		
Gram + Radhuni	Formicidae	1	0.08	0.0059	4.12	0.69
	Coccinellidae	5	0.38	0.1479		
	Tripidae	1	0.08	0.0059		
	Muscidae	1	0.08	0.0059		
	Carabidae	2	0.15	0.0237		
	Culicidae	3	0.23	0.0533		