EFFECT OF BORDER CROPS ON THE INCIDENCE OF INSECT PESTS AND PREDATORS IN GRAM

A THESIS

BY

TONIMA FARHAT

MASTER OF SCIENCE
IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

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CERTIFICATE

This is to certify that thesis entitled, **"Effect of Border Crops on the Incidence of Insect Pests and Predators in Gram"** 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 **Tonima Farhat**, **Registration No. 04-01417** 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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Declaration

The author hereby declare that, this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institutions and that to the best of knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

The author

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ABSTRACT

The primary objective of this study is to measure the effect of border crops on the incidence of insect pests and predators in gram. The present study was conducted in the experimental field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh during the period from December, 2010 to April, 2011. The experiment was laid out in Randomized Complete Block Design using eight treatments with three replications. The treatments were T_1: Gram sole (control), T_2: Gram + Onion (*Allium cepa*), T_3: Gram + Garlic (*Allium sativum* L.), T_4: Gram + Coriander (*Coriandrum sativum* L.), T_5: Gram + Radhuni (*Coriandrum* spp.), T_6: Gram + Mustard (*Brassica* spp.), T_7: Gram + Methi (*Trigonella foenumgraecum*) and T_8: Gram + Wheat (*Triticum aestivum*). Aphid, whitefly, butterfly, grasshopper, cutworm were found as the insect pests and lady bird beetle, ant, spider, syrphid fly, rove beetle were found as predators in gram agroecosystem. The lowest population of aphid (4.28/plant), butterfly (1.00/plot), grasshopper (1.33/plant), whitefly (2.00/plant), cutworm (0.00/plot) was found in T_3 (Gram border cropping with garlic) at vegetative stage. At reproductive stage, similar trend of insect pests' incidence was found in T_3 treatment. Population incidence of predators was observed highest in T_7 (Gram border cropping with methi). Garlic was more effective as border crop for the management of insect pests of gram.

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CHAPTER I

INTRODUCTION

Pulse crops are those plants belonging to the legume family with papilionaceous flowers and pods containing seeds. Most legumes do not need industrial fertilisers due to their natural symbiosis with Rhizobium which provides them with organic proteins made directly from atmospheric nitrogen. Grain legumes are cultivated primarly for their seeds which are rich in energy and protein. About a dozen pulse crops are grown in the winter and summer seasons in Bangladesh. Among these, grass pea, lentil, chickpea, black gram, mung bean, field pea, cowpea, and fava bean are grown during the winter season (November– March). Black gram and mung bean can also be grown in late winter (June–March) in southern region of Bangladesh such as the Bhola, Barisal, and Chittagong districts.

Pulses occupy about 4 percent of the total cropped area and contribute about 2 percent to the total grain production of Bangladesh. In 2010, the total pulse production was recorded 218000 metric ton. The area and production of pulse production has decreased continuously for the past 10 years. Cultivation of pulses is mainly concentrated within the Ganges floodplain areas of the northern districts and in some southern districts of the country. Soils of this area are calcareous, loamy in the ridges, and clayish in the basin. The average annual yield of the different pulses ranges from 700 to 800 kg per hectare. In Bangladesh but it has a great importance in the dietary menu, it is the great source of plant protein for the people who are not able to get regularly animal protein (from meat and fish) because of high price. Moreover, availability of phosphorus, calcium, molybdenum, and boron are the most essential elements for legume crops are relatively high in pulses. But they are treated as minor crops and receive little attention from farmers and policymakers.

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 locally 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 the 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 border cropping of crops of diver's growth habits may be found as a very useful technique in controlling a large number of crop pests.

Border cropping is the cultivation of two crops on the same field. It is situated in the border of the main crops. Border cropping 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 in hot solution pressure. Under the above perspective, border cropping 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. Considering the above facts, the present study was carried out with the following objectives:

i. to find out the effect of border crops on incidence of insect pests and predators in gram and
ii. to find out the suitable border crop for the management of insect pests of gram.

CHAPTER II
REVIEW OF LITERATURE

2.1 Effect of border cropping on 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.

Border cropping (i.e., growing more than one crop simultaneously in the same area) is one way of increasing vegetational diversity. According to Van Emden (1965), border cropping 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 decrease 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 border crop, compared with the crops when grown alone but in most cases combined yield per unit area from border cropping are higher.

The magnitude of yield advantage of border cropping 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 border cropping of two dissimilar crops grown in the same land (Fisher, 1977). If LER is more than 1.00 then border cropping gives agronomic advantages over monoculture practice. The higher is the LER, the more is the agronomic benefits of border cropping systems. The land equivalent ratio is the most frequently used index to determine the effectiveness of border cropping 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, border cropping, 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.

2.2 Relationship between border cropping with insect pests and their natural enemies:

2.2.1 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 border cropped 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 border cropping 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 border cropping to their pests than individuals in monocultures. He found that *Acalymma vittatum* preferred cucumber leaves taken from monocultures to those taken from cucumber plants border cropped 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.

Border cropping 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 border cropping 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 border cropping (maize + cowpea + squash) than in monoculture (squash alone) system. The total crop yield in border cropping 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 border cropped with blackgram (*Vigna mungo*).

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

Prasad and Chand (1989) reported that border cropping 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 border cropped 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-border cropped with sorghum suffered less damage by *Helicoverpa armigera.*
Hossain *et al.* (1998) reported that border cropping 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 border cropping 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 border cropped 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 border cropped with pearl millet 4:1 (11.2%), pearl millet 6:1 (12.2%), black gram 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 border cropped, although incidence increased in the ground nut border cropping system. Sesame yield was the highest as a sole crop (634 kg ha^{-1}) followed by border cropping with pearl millet (553-556 kg ha^{-1}).

Sardana (2001) observed a significantly lower incidence of root borer, *Emmaiocera depressella* Swinhoe in sugarcane when border cropped with blackgram compared to the sugarcane mono crop. Sachan and Katti (1994) observed the effect of maize-cowpea border cropping on three lepidopteran stem borer and their natural enemies in Kenya. Oviposition was not affected by border cropping 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 regatting 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 border cropping as a pest control strategy in cowpea. Two local cowpea cultivars, Ebelat (erect) and Icirikukwai (spreading), were grown as sole crops or border cropped 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 border cropping, (b) to be effective, border cropping 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 border cropping 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 trap 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 border cropping 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. Bordercropping 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 border cropping 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 border cropped with pigeon pea cv. Bahar, a local green gram cultivar, a local black gram cultivar, a local soyabean cultivar, a local sun 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 border cropped 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 border cropping on the grain damage by pod borer complex (*Melanagromyza obtusa*, *Helicoverpa armigera*, *Exelastis atomosa* and *Clavigralla gibbosa*) and yield of pigeon pea during 1999-2000 and 2000-01. Pigeon pea was border cropped with green gram, black gram, sesamum, sorghum and pearl millet in various combination and row ratio. The result showed that the intercrop combination of pigeon pea + black gram 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 pest monitoring, destruction of alternate hosts, border cropping, biological control including biopesticides and plant products, IGR, transgenics, mechanical control and need based application of synthetic chemical molecules.

2.2.2 Effect of broder crops on 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 border cropping 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 border cropped with black gram, cowpea green gram 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. Border cropping of cowpea as well as green gram 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 + green gram produced the same yield of as sole cotton.

Amin *et al*. (2003) studied the effect of border cropping of brinjal with onion, garlic, chilli and coriander. They recorded significantly the lowest number of fruit infestation 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.

2.3 Benefits from border cropping

Khehra *et al*. (1979) in an experiment found that black gram consistently gave higher yield when border cropped with maize, although the black gram as border cropped depressed the maize yield. Rathore *et al.* (1980) conducted an border cropping experiment of maize with pulses and found that maize + black gram 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 border cropping systems found that maize + black gram (3.8 t ha^{-1}), maize + green gram (3.6 t ha^{-1}) and maize + pegion pea (3.53 t ha^{-1}) gave significantly higher seed yield than other systems. Considering maize equivalent yield, maize + pegion pea (4.88 t ha^{-1}) and maize + black gram (4.66 t ha^{-1}) gave significantly higher equivalent yield than the other border cropping 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 border cropping 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 border cropping at 3:1 and 6:2 rows 30-cm apart proved more advantageous than pure stands of either crop components and other border cropping systems in terms of gram equivalent yield, land equivalent ratio (LER), monetary returns and benefit : cost ratio.

A field experiments was 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 border cropping system and to identify the vegetable crop suitable for border cropping 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 border cropping systems followed by red gram + cluster bean (*Cyamopsis tetragonoloba*) at 630 kg ha^{-1}. Border cropping of red gram + cluster bean (1:2) recorded significantly higher monetary return of Rs 19,459/ha than the standard control with sole red gram of Rs 10,820/ha and border cropping of red gram + pearl millet (1:2) of 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) border cropped 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 border cropping, 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 border cropping. The lowest incidence of *D. lini* was observed in linseed border cropped 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 border cropped with gram. The lowest incidence of *H. armigera* (0.27 larva/MRL) was recorded for linseed border cropped 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 border cropped 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 pigeon pea-based border cropping systems. The treatments consisted of 2 pigeon pea genotypes (ICPL-87119 and ICP-8863) border cropped 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 pigeon pea equivalent yield (17.48 and 16.33 q/ha) and land equivalent ratio (1.47 and 1.49). These respective border cropping 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 border cropping of grain legumes (French bean, *Phaseolus vulgaris* cv. Arka Komal; cowpea cv. C-152; soyabean cv. JS-335; black gram 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 border cropping and sole cropping treatments. Sole sorghum showed higher yield compared to sorghum border cropped with legumes. Sorghum border cropped with French bean, soyabean and black gram were comparable to the sole crop in terms of yield. Among intercrops, the highest grain yield was obtained with soyabean border cropped with DSV-2, followed by soyabean border cropped with DSH-3 and French bean border cropped with DSV-2. DSV-2 border cropped 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 border cropped 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 border cropped 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 border cropping 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 border cropped 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 border cropping.

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 border cropping in different planting patterns and row orientation under rainfed conditions. All the chickpea based border cropping 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. Border cropping 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 border cropping 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 border cropping systems, BG 1003 chickpea + Vardan Indian mustard recorded significantly highest growth and yield attributes of chickpea and Indian mustard than the other border cropping systems. However, the highest 100-seed weight of chickpea was recorded in chickpea KAK 2 in the chickpea + Vardan Indian mustard border cropping 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 border cropping system than the other border cropping system. Higher seed yield of component crops in border cropping 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. Border cropped chickpea produced statistically lower grain yield than sole crop during both years on area basis. On an average, border cropping 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. Border cropped 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. Border cropping 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 pigeon pea genotypes on productivity in border cropping 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. Border cropping of WRG 53 either with mungbean or urdbean produced significantly higher yield of pigeon pea, mungbean, urdbean and pigeon pea equivalent yield (PEY). It was also realized that incidence of pod damage caused by pod borer was minimum (5.1%), when pigeon pea genotype WRG 53 was border cropped with mungbean.

Thus different border cropping systems had lower insect infestation and higher abundance of natural enemies. Border cropping 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 border cropping 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 border cropping 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 December, 2010 to April, 2011 to find the effect of border crops on incidence of pests and predators in 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 sub 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).

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.

3.4 Planting material

3.4.1 Description of gram

Seeds of gram variety BARI chola 2 were used as a test crop for the study and the seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. This variety was developed by BARI and released for cultivation in the year of 1996 (BARI, 2006). It is a spreading type plant and can be easily grown in minimum or shading light.

3.4.2 Description of other border crops

In this experiment onion (*Allium cepa*), garlic (*Allium sativum*), coriander (*Coriandrum sativum*), radhuni (*Coriandrum* spp.), mustard (*Brassica campestris*), Methi (*Trigonella foenumgraecum*) and wheat (*Triticum aestivum*) were sown as border crop 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 December 7, 2010 with the help of a power tiller and prepared by three successive ploughing and cross-ploughing. 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 (size,no,distance between plot etc.) were cleaned and finally leveled with the help of wooden plank.

Plate 1. The experimental plot at SAU, Dhaka

3.6 Fertilizer application

Standard doses of fertilizers urea 1kg, triple super phosphate 2.0kg, Muriate of Potash (MP), 1.0 kg, Gypsum 1.0 kg and cowdung 100.0 kg were applied as basal dose at the time of sowing seeds.

3.7 Seed processing and treatment

The seeds of BARI chola 2 were collected from BARI, Gazipur, Dhaka. The seeds of onion, garlic, coriander, radhuni, mustard, methi and wheat 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.

3.8 Sowing of seeds

The seeds of main and border crop were sown on 07 December 2010 in rows with spacing of 30 cm × 30 cm for all border crop but in sole crops it was sown at a spacing of 40 cm × 30 cm.

3.9 Treatments

There were 8 treatments among them 01 was used as sole crop and others with border crop. The details of the treatments are presented below:

T_1: Gram sole (control)

T_2: Gram + Onion

T_3: Gram + Garlic

T_4: Gram + Coriander

T_5: Gram + Radhuni

T_6: Gram + Mustard

T_7: Gram + Methi

T_8: Gram + Wheat

3.10 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly allotted in each block. The unit plot size was 3.0m × 3.0m with a distance of 1.0 m between the plots and 1.0 m between the replications.

3.11. Intercultural operations

To avoid moisture stress and ensuring good germination, 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 data were collected from each plot at weekly interval commencing from germination to harvest. Five plants were selected randomly from each plot and insect pests infested plant by aphid (plate4), whitefly, butterfly, grasshopper (plate7), cutworm (plate5) and predators like lady bird beetle (plate12), ant (plate13), spider (plate11), syrphid fly (plate9) and rove beetle (plate10) were observed regularly and recorded. After last observation, the population of aphid, whitefly and grasshopper was converted number per plant and that was butterfly and cutworms were converted per plot.

3.17. Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significant 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).

Plate 2. Photograph showing pod borer in a pod of chickpea

Plate 3. Infested pod of chickpea

Plate 4 . Aphids

Plate 5 . Larva of Cutworm

Plate -6. Pod borer

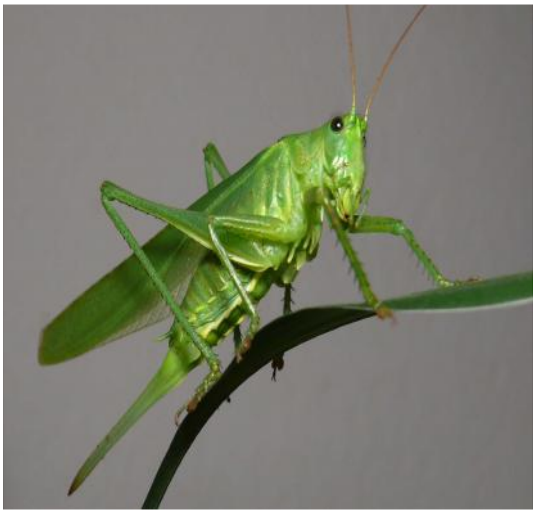

Plate -7. Grasshopper

Some harmful insect pests of gram

Plate 9. Syrphid fly adult

Plate 10. Rove beetle

Plate 11. Spider

Plate 12 . Lady bird beetle

Plate 13. Ant

Some predators found in gram

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of border cropping on the incidence of insect pests and predators 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 have been presented. The results have been presented, discussed and possible explanations have been given under the following sub headings:

4.1 Insect incidence

Incidence of insects on gram agro ecosystem was recorded under different treatments for the entire cropping season; Aphid, butterfly, grasshopper, whitefly, cutworm, ladybird beetle, ant, syrphid fly, and rove beetle were observed. The data for the incidence of insects per plot are presented before flowering and after flowering stage and presented in different Tables.

4.1.1 Incidence of insect pests

The data on incidence insect pests viz., aphid, whitefly, butterfly, grasshopper, cutworm show significant variation under different treatments before and after flowering stage of gram.

Aphid is one of the most important sucking insect of field crops. The population level of aphids on gram under different border crops has been presented in Table 1. The data express that the lowest number of aphid (4.28/plant) was recorded at vegetative stage from T_3 (gram + garlic) which was statistically similar to treatment combinations T_1 (4.33/plant) (Gram sole), T_4 (4.33/plant) (Gram + Coriander) and T_2 (5.00/plant) (gram + onion) but statistically different form those of T_5 (Gram+ Radhuni) and T_8 (Gram + Wheat) which had highest number of aphid (8.00/plant) per plant. However, Aphid per plant recorded in T_8 was statistically similar with treatment combinations T_7 (Gram + Methi) and T_5 (Gram + Radhuni). Similarly, at reproductive stage the T_3 (Gram + Garlic) had the lowest number of aphid (0.00/plant) followed by 1.00 in T_5 (Gram + Radhuni) treatments while the highest number (4.00) was found from T_1 (Gram sole) followed by T_6 (Gram + Mustard) and T_8 (Gram + Wheat) treatments which 3.00 were statistically different form that of T_2 (Gram + Onion) (3.00) and T_4 (Gram + Coriander) (3.00) treatments.

Table 1. Mean population of aphid under different treatments at vegetative and reproductive stages

Treatments	Number of aphid plant^{-1}	
	Vegetative stage	Reproductive stage
T_1	4.33 c	4.00 b
T_2	5.00 bc	3.00 bc
T_3	4.28 c	0.00 d
T_4	4.33 c	3.00 bc
T_5	8.00 a	1.00 d
T_6	5.00 bc	4.00 b
T_7	7.00 ab	2.00 cd
T_8	8.00 a	4.00 b
$LSD_{(0.05)}$	2.320	1.486
CV(%)	14.77	7.75

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 + Onion
T_3: Gram + Garlic
T_4: Gram + Coriander
T_5: Gram + Radhuni
T_6: Gram + Mustard
T_7: Gram + Methi
T_8: Gram + Wheat

This result indicates that border cropping of gram with other crops has significant effect on incidence of aphid. Aphid population was increased in case of T_5 and T_8 (border cropping with radhuni and wheat). However the best effect was found in case of border cropping with garlic. This effect might be the repellent effect of garlic on aphid. The similar result was observed by Kirtkar and Basu (1975) who reported that garlic and coriander had strong repellent action against aphid and reduced their population in crop field.

Whiteflies are the most important sucking insects of gram which suck the cell sap from leaf, young shoot, inflorescence etc. The population of whitefly under different treatment combinations at vegetative and reproductive stages has been shown in Table 2. The data express that significantly lowest number of white fly (2.00/plant) was recorded from T_3 (Gram + Garlic) which was statistically identical to 3.00/plant in T_8 (Gram + Wheat). Although the highest number of whitefly (7.00/plant) was observed from T_5 (Gram + Radhuni) but not significantly different to that of T_6 (Gram + Mustard) (6.00/plant). Moreover, T_1 (Gram sole) and T_7 (Gram + Methi) had statistically similar population (4.00/plant) of whitefly.

Similarly, the lowest number (2.00/plant) was recorded from T_3 (Gram + Garlic) at reproductive stage, which was statistically identical to 3.00/plant in T_1 (Gram sole), T_2 (3.00/plant)(Gram + Onion) ,T_5 (3.00/plant)(Gram + Raduni), T_4 (4.00/plant)(Gram + Coriander) and T_8 (4.00/plant)(Gram + Wheat). On the other hand, the highest number (6.00/plant) was found in T_6 (Gram + Mustard) which was statistically similar to (5.00) by T_7 (Gram + Methi). This result indicates that border cropping of gram with other crops has significant effect on the incidence of whitefly.

However, the best effect was found in case of border cropping with garlic. This effect might be the repellent effect of border crops on whitefly as described in case of aphid infestation. The similar result was observed by Kirtkar and Basu (1975) who reported that garlic and coriander had strong repellent action against sucking insects and reduced their population in crop field.

Table 2. Mean population of whitefly recorded at vegetative and reproductive stages in different treatments with border crops.

Treatments	Number of whitefly plant^{-1}	
	Vegetative stage	Reproductive stage
T_1	4.00 cd	3.00 bc
T_2	5.00 bc	3.00 bc
T_3	2.00 e	2.00 c
T_4	5.00 bc	4.00 abc
T_5	7.00 a	3.00 bc
T_6	6.00 ab	6.00 a
T_7	4.00 cd	5.00 ab
T_8	3.00d e	4.00 abc
$LSD_{(0.05)}$	1.451	2.145
CV(%)	5.39	9.78

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 + Onion

T_3: Gram + Garlic T_4: Gram + Coriander

T_5: Gram + Radhuni T_6: Gram + Mustard

T_7: Gram + Methi T_8: Gram + Wheat

Butterflies are adult Lepidopteran insects and visit crop field for laying eggs or feeding nectar. Population of butterflies during vegetative and reproductive stage of gram under different treatments has been presented in Table 3. The data express that the lowest number (1.00) of butterfly was observed in T_3 (Gram + Garlic) was recorded at vegetative stage which was statistically similar to treatment combinations (2.00/plant) T_2 (Gram + Onion), T_4 (Gram + Coriander), T_5 (Gram + Radhuni) , T_6 (Gram + Mustard), T_7 (Gram + Methi) and T_8 (Gram + Wheat). On the other hand, the highest number (4.00/plot) was found in T_1 (Gram sole). followed by 2.00/plot in T_2 (Gram + Onion), T_4 (Gram + Coriander), T_5 (Gram + Radhuni) , T_6 (Gram + Mustard), T_7 (Gram + Methi) and T_8 (Gram + Wheat) having no significant difference among them. Similarly, the lowest number (1.00) of butterfly was found in T_3 (Gram + Garlic) at reproductive stage which was statistically identical to (2.00/plant) in T_1 (Gram sole), T_2 (Gram + Onion), T_4

(Gram + Coriander), T_6 (Gram + Mustard) and T_7 (Gram + Methi) treatments . Significantly highest number of butterfly (4.00/plot) was found in T_8 (Gram + Wheat) followed by 3.00/plot in T_5 (Gram + Radhuni).

These results indicate that border cropping of gram with other crops repels the butterfly away from the field. Although garlic showed the best performance . This effect might be repellent action of the border crop. These results agree with the findings of several researchers (Devendra and Binay 2002, Hosain *et al*. 1998). Who reported that garlic, wheat, mustard and coriander had strong repellent action against butterfly and reduced the population of visitors in the crop field.

Table 3. Mean population of butterfly under different treatments at vegetative and reproductive stages

Treatments	**Number of butterfly plot^{-1}**	
	Vegetative stage	**Reproductive stage**
T_1	4.00 a	2.00 b
T_2	2.00 b	2.00 b
T_3	1.00 a	1.00 a
T_4	2.00 ab	2.00 b
T_5	2.00 ab	3.00 ab
T_6	2.00 ab	2.00 b
T_7	2.00 ab	2.00 b
T_8	2.00 ab	4.00 a
$LSD_{(0.05)}$	1.857	1.767
CV(%)	6.06	5.84

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 + Onion

T_3: Gram + Garlic T_4: Gram + Coriander

T_5: Gram +Radhuni T_6: Gram + Mustard

T_7: Gram + Methi T_8: Gram + Wheat

Grasshoppers are chewing insects and their nymph and adults feed on leaves of filed crops. The population abundance of grasshopper has been presented in Table 4. The data reveal that the lowest numbers (1.33) of grasshopper were recorded from T_3 (gram + garlic) which was not statistically similar to other treatment combinations. Although the highest number of grasshopper (3.00/plant) per plant. However, T_1 was similar with other treatment combinations in terms of number of grasshopper per plant. Similarly, the T_3 (gram + garlic) had the lowest number of grasshopper (1.33/plant) was observed from T_8 (gram + Wheat) at reproductive stage. Another treatments (2.00) there is no significant difference between, T_1 (gram sole), T_2 (gram + Onion), T_4 (gram + Coriander), T_5 (gram + Radhuni), T_6 (gram + Mustard) , T_7 (gram + Methi) and T_8 (gram + Wheat) respectively.

This result indicates that border cropping of gram with other crops has significant effect on incidence of grasshopper. Grasshopper population was increased in case of T_8 (border cropping with wheat). However the best effect was found in case of effect of border crops on grasshopper. The similar result was observed by Halepyatic et al. (1987) who reported that garlic, mustard, methi and coriander had reduced the population of grasshopper.

Table 4. Mean population of grasshopper under different treatments at vegetative and reproductive stages

Treatments	Number of grasshopper plant^{-1}	
	Vegetative stage	Reproductive stage
T_1	2.00 ab	2.00 a
T_2	2.00 ab	2.00 a
T_3	1.33b	1.33 a
T_4	2.00ab	2.00 a
T_5	2.00 ab	2.00 a
T_6	2.00 ab	2.00 a
T_7	2.00 ab	2.00 a
T_8	3.00 a	2.00 a
$LSD_{(0.05)}$	1.442	1.109
CV(%)	6.12	7.84

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 + Onion

T_3: Gram + Garlic T_4: Gram + Coriander

T_5: Gram + Radhuni T_6: Gram + Mustard

T_7: Gram + Methi T_8: Gram + Wheat

The data (Table 5) express that the lowest number (0.00) of cutworm larvae was recorded from T_3 (Gram + Garlic) which was closely followed by 1.00/plot in T_1 (Gram sole), T_2 (Gram + Onion) and T_4 (Gram + Coriander) treatments having no significant difference between them. Significantly the highest number of cutworm (5.00/plot) was observed in T_6 (Gram + Mustard) followed by 3.00/plot in T_8 (Gram + Wheat). Similarly, the lowest number (0.67) was recorded from T_3 (Gram + Garlic) in reproductive stage while the highest number (2.00) was found from T_1 (Gram sole) , T_4 (Gram + Coriander) , T_6 (Gram + Mustard), T_7 (Gram+ Methi) , T_8 (Gram + Wheat) respectively.

This result indicates that border cropping of gram with other crops has significant effect on incidence of cutworm. However the best effect was found in case of border cropping with garlic. This effect might be the repellent effect of border crops on cutworm. The similar result was observed by Manisegaran et al. (2001) who reported that garlic and gram sole had strong repellent action against cutworm.

Table 5. Mean population of cutworm under different treatments at vegetative and reproductive stages

Treatments	**Number of cutworm larva per plot^{-1}**	
	Vegetative stage	**Reproductive stage**
T_1	1.00 c	2.00a
T_2	1.00 c	1.00 a
T_3	0.00 d	0.67 a
T_4	1.00 c	2.00 a
T_5	2.00 bc	1.00 a
T_6	5.00 a	2.00 a
T_7	2.00 bc	2.00 a
T_8	3.00 b	2.00 a
$LSD_{(0.05)}$	1.671	1.627
CV(%)	6.50	7.30

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 + Onion
T_3: Gram + Garlic T_4: Gram + Coriander
T_5: Gram + Radhuni T_6: Gram + Mustard
T_7: Gram + Methi T_8: Gram + Wheat

4.1.2 Incidence of Predators

The abundance of predators like lady bird beetle, ant, syrphid fly, spider, rove beetle was also affected by border crops. Population abundance lady bird beetle under different treatments is shown in Table 6. Data express that the highest number (13.0/plot) of lady bird beetle was found in T_7 (Gram+ Methi) at vegetative stage which was closely followed (10.7/plot) by T_2 (Gram + Onion) having significant difference between them. The lowest number (4.33/plot) was recorded from T_3 (Gram + Garlic) which was closely followed (6.00/plot) by T_4 (Gram + Coriander) treatment with no significant between them. However, no significant difference was observed in T_1 (Gram sole), T_5 (Gram +Radhuni), T_6 (Gram +Mustard) and T_8 (Gram + Wheat) in terms of number of lady bird beetle per plot. Similar trend of lady bird beetle abundance was observed at reproductive stage although their number was lower than vegetative stage.

This result indicates that border cropping of gram with other crops has significant effect on incidence of lady bird beetle. However, the highest numer was found in case of border cropping with methi and the lowest number was observed in case of border cropping with garlic (T_2). The lowest incidence of lady bird beetle might be the effect of lower incidence of its prey and might be the repellent action against lady bird beetle. The similar result was observed by Kyamanywa *et al.* (1993) who reported that garlic had strong repellent action against pests and predators.

Table 6. Mean population of lady bird beetle under different treatments at vegetative and reproductive stages

Treatments	Number of lady bird beetle per plot^{-1}	
	Vegetative stage	Reproductive stage
T_1	7.00 cd	2.00 c
T_2	10.7 b	1.00 d
T_3	4.33 e	0.33 e
T_4	6.00 de	0.67 de
T_5	8.00 c	3.00 b
T_6	7.00 cd	2.00 c
T_7	13.0 a	4.00 a
T_8	8.00 c	2.00 c
$LSD_{(0.05)}$	2.163	2.305
CV(%)	11.12	7.95

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 + Onion
T_3: Gram + Garlic T_4: Gram + Coriander
T_5: Gram + Radhuni T_6: Gram + Mustard
T_7: Gram + Methi T_8: Gram + Wheat

The population incidence of ant has been shown in Table 7. Data reveal that the highest number (3.00/plant) was recorded from T_7 (Gram + Methi) which was closely followed by 2.00/plant in T_1 (Gram sole), T_4 (Gram + Coriander) and T_5 (Gram + Radhuni) having no significant difference among them. On the other hand the lowest number (1.00/plant) was observed in T_3 (Gram + Garlic), T_6 (Gram + Mustard) and T_8 (Gram + Wheat) followed by 1.33/plant in T_2 (Gram + Onion) treatment without any significant difference among them. Similar trend of ant incidence was observed at reproductive stage of gram although their population level was higher. The maximum population (7.0/plant) was found in case of T_1 (Gram sole), T_4 (Gram +Coriander) and T_7 (Gram + Methi) at reproductive stage.

This result indicates that border cropping of gram with other crops has significant effect on incidence of ant. However, abundance of ant was minimum in case of border cropping with garlic. This effect might be the repellent effect of garlic on ant. This result could not compare with others due to lack of reference.

Table 7. Mean population of ant under different treatments at vegetative and reproductive stages

Treatments	Number of ant per plant^{-1}	
	Vegetative stage	Reproductive stage
T_1	2.00 b	7.00 a
T_2	1.33 bc	5.00 c
T_3	1.00 c	3.00 e
T_4	2.00 b	7.00 a
T_5	2.00 b	4.00 d
T_6	1.00 c	6.00 b
T_7	3.00 a	7.00 a
T_8	1.00 c	5.00 c
$LSD_{(0.05)}$	0.828	2.130
CV (%)	10.20	14.85

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 +Onion
T_3: Gram +Garlic
T_4: Gram +Coriander
T_5: Gram +Radhuni
T_6: Gram +Mustard
T_7: Gram +Methi
T_8: Gram+Wheat

Data in Table 8 express that the highest number (3.00/plant) of spider was found in T_7 (Gram + Methi) and T_8 (Gram + Wheat).Although the lowest number (1.00/plant) was recorded from T_1 (Gram sole), T_3 (Gram+ Garlic), T_4 (Gram + Coriander) and T_6 (Gram + Mustard) which was closely followed (2.00) by T_2 (Gram + Onion) and T_5 (Gram + Radhuni) treatments and no significant difference was found among the treatments regarding number of spider per plot. During reproductive stage, no spider was found in T_3 (Gram + Garlic) and the highest number of spider (2.67/plot) was recorded from T_8 (Gram+ Wheat) which was closely followed by 2.00/plot in T_2 (Gram + Onion), T_6 (Gram + Mustard) and T_7 (Gram + Methi). However, no significant difference was observed among the treatments in terms of number of spider per plant except T_3 (Gram + Garlic).

This result indicates that border cropping of gram with other crops has significant effect on incidence of spider. Spider population was increased in case of T_7 (border cropping with methi) because white colour of methi flower attracted spider and increased population. The best effect was found in case of border cropping with mustard. The similar result was observed by Gavarra and Raros (1975) who reported that population of spider and other predators were higher in border cropping with mustard and methi.

Table 8. Mean population of spider under different treatments at vegetative and reproductive stages

Treatments	Number of spider per plant^{-1}	
	Vegetative stage	Reproductive stage
T_1	1.00 a	1.00 a
T_2	2.00 a	2.00 a
T_3	1.00 a	0.00 b
T_4	1.00 a	1.33 a
T_5	2.00 a	1.00 a
T_6	1.00 a	2.00 a
T_7	3.00 a	2.00 a
T_8	3.00 a	2.67 a
$LSD_{(0.05)}$	2.515	1.581
CV(%)	11.50	10.20

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 + Onion

T_3: Gram + Garlic T_4: Gram + Coriander

T_5: Gram + Radhuni T_6: Gram + Mustard

T_7: Gram + Methi T_8: Gram + Wheat

The effect of border crops on population incidence of syrphid fly is presented in Table 9. The data reveal that the highest number of syrphid fly (3.00/plot) was recorded from T_5 (Gram+ Radhuni) and T_8 (Gram + Wheat) at vegetative stage which was closely followed (2.00/plot) by T_1 (Gram sole), T_3 (Gram + Garlic) and T_4 (Gram + Coriander). The lowest number syrphid fly (1.00/plot) was recorded from T_2 (Gram + Onion) and T_6 (Gram + Mustard) which was closely followed (1.33/plot) by T_7 (Gram + Methi) treatment. Similarly, the lowest number of syrphid fly (0.33/plot) was recorded from T_3 (Gram + Garlic) at reproductive stage which was closely followed (1.00/plot) by T_1 (Gram sole),) and T_7 (Gram + Methi) treatment. The highest number of syrphid fly (4.00/plot) was found in T_8 (Gram + Wheat) treatments having significant difference with others.

This result indicates that border cropping of gram with other crops has significant effect on incidence of syrphid fly. The best effect was found in case of border cropping with methi. White colour of methi flower attracted syrphid fly and increased population. The similar result was observed by Nampala et al. (1999) who reported that mustard and methi border crop attracted syrphid fly and other visitors.

Table 9. Mean population of syrphid fly under different treatments at vegetative and reproductive stages

Treatments	Number of syrphid fly per plot^{-1}	
	Vegetative stage	**Reproductive stage**
T_1	2.00 a	1.00 b
T_2	1.00 a	2.00 ab
T_3	2.00a	0.33 b
T_4	2.00 a	2.00 ab
T_5	3.00 a	2.00 ab
T_6	1.00 a	1.00 b
T_7	1.33 a	1.00 b
T_8	3.00 a	4.00 a
$LSD_{(0.05)}$	1.772	2.438
CV(%)	8.70	9.50

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 + Onion
T_3: Gram + Garlic
T_4: Gram + Coriander
T_5: Gram + Radhuni
T_6: Gram + Mustard
T_7: Gram +Methi
T_8: Gram+Wheat

The data in Table 10 represent the number of rove beetle on gram under different border crop treatments. The highest number (2.00/plot) was found in T_1 (Gram sole), T_4 (Gram+ Coriander), T_5 (Gram+ Radhuni), T_6 (Gram+ Mustard) and T_7 (Gram+ Methi) which was closely followed (1.00/plot) by T_2 (Gram + Onion) and

T_8 (Gram + Wheat). No significant difference was found among the treatments except T_3 (Gram + Garlic) which had no rove beetle at vegetative stage of gram. Similarly, the lowest number of rove beetle (0.33/plot) was recorded from T_1 (Gram sole) at reproductive stage which was closely followed (0.67/plot) by T_5 (Gram + Radhuni) treatment. The highest number of rove beetle (4.00/plot) was found in T_8 (Gram + Wheat) treatments having significant difference with others. Similarly, trend of population incidence was observed at reproduction stage of gram. This result indicates that border cropping of gram with other crops has significant effect on incidence of rove beetle. The best effect was found in case of border cropping with methi. This result support the findings of Kyamanywa *et al.* (1993) who reported that border crop increased population of predators in crop field.

Table 10. Mean population of rove beetle under different treatments at vegetative and reproductive stages

Treatments	**Number of rove beetle per plot^{-1}**	
	Vegetative stage	**Reproductive stage**
T_1	2.00 a	0.33 b
T_2	1.00 a	2.00 ab
T_3	0.00 b	2.00 ab
T_4	2.00 a	2.00 ab
T_5	2.00 a	0.67 b
T_6	2.00 a	2.00 ab
T_7	2.00 a	4.00 a
T_8	1.00 a	1.00 b
$LSD_{(0.05)}$	1.501	2.210
CV (%)	4.60	6.50

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 + Onion
T_3: Gram + Garlic T_4: Gram + Coriander
T_5: Gram + Radhuni T_6: Gram + Mustard
T_7: Gram + Methi T_8: Gram + Wheat

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December, 2010 to April, 2011 to find out the effect of border crops on incidence of pests and predators in gram. The experiment comprised of eight treatments such as T_1: Gram sole (control), T_2: Gram + Onion, T_3: Gram + Garlic, T_4: Gram + Coriander, T_5: Gram + radhuni, T_6: Gram + Mustard, T_7: Gram + Methi and T_8: Gram + Wheat. It was laid out in Randomized Complete Block Design (RCBD) with three replications.

Significant variation of insect population was observed on gram under different border crop treatments at vegetative and reproductive stage. Aphid, whitefly, butterfly, grasshopper, cutworm were found as the insect pests attacking gram. While lady bird beetle, ant, spider, syrphid fly, rove beetle were found as predators in the crop field.

The population abundance of aphid (4.28/plant), butterfly (1.00/plot), grasshopper (1.33/plant), whitefly (2.00/plant), cutworm (0.00/plot) was found lowest in T_3 (Gram border cropping with garlic) at vegetative stage. Similar trend of population abundance of different insect pests was also observed during reproductive stage of the gram. However, aphid population was found highest in T_8 (Gram border cropping with mustard) at both stage of gram and the whitefly population was observed maximum in T_6 (Gram border cropping with wheat). The population incidence of all the insect pests was higher in sole crops (Gram) at vegetative and reproductive stages of the crops.

Significant variation was observed among the treatments in case of population incidence of predators. The highest number of lady bird beetle (13.0/plot), ant (3.00/plant), spider (3.00/plant), syrphid fly (3.00/plant) was found in T_5 (Gram border cropping with radhuni) and T_8 (Gram border cropping with wheat) and rove beetle (2.00/plant) was found in T_7 (Gram sole), T_4 (Gram border cropping with coriander), T_5 (Gram border cropping with radhuni), T_6 (Gram border cropping with mustard) and T_7 (Gram border cropping with methi) at vegetative stage of the gram. The lowest number of predators was observed in T_3 (Gram border cropping with garlic). The results of the present study suggested that garlic is the best border crop against pest population of gram.

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

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

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