EFFECT OF FERTILIZERS ON INCIDENCE OF APHID AND BENEFICIAL ARTHROPODS IN MUSTARD

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CERTIFICATE

This is to certify that thesis entitled ***"EFFECT OF FERTILIZERS ON INCIDENCE OF APHID AND BENEFICIAL ARTHROPODS IN MUSTARD"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN ENTOMOLOGY****, embodies the result of a piece of bona fide research work carried out by* ***MD. SALAH UDDIN, Registration no. 14-06217*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

An experiment was conducted in the central field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2019 to February, 2020 to evaluate the effect of fertilizers on incidence of aphid in mustard. The experiment was laid out in Randomized Complete Block Design replicated with three times. For this study, treatments were- T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose; T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose; T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose and T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose. The incidence of aphid at early, mid and late flowering stage and fruiting stage, the number of infested plant and percent plant infestation become low (0.63, 0.83, 0.97, 1.33 aphid, 1.11 plant and 3.68%, respectively) at the treatment T_7 and number of aphid at inflorescence at early, mid and late flowering stage, number of infested inflorescence, percent inflorescence infestation, number of infested siliqua, percent siliqua infestation and average number of deformed siliqua (0.39 aphid, 0.46 aphid, 0.49 aphid, 0.81 inflorescence, 13.04%, 17.84 siliqua, 12.07% and 3.38 siliqua, respectively) was low at T_7 treatment. The number of healthy plant, number of lady bird beetle, number of field spider, number of ant, number of dragon fly, plant height, number of branches, number of siliqua, length of siliqua, seeds per siliqua, 1000 seeds weight and yield of mustard were high (30.13 plant, 2.13 lady bird beetle, 1.56 field spider, 1.12 ant, 0.98 dragon fly, 118.78 cm, 12.57 branches, 130.47 siliqua, 3.89 cm, 28.47 seeds, 3.82g and 2.78 t/ha, respectively) at T_7 treatment.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	**Full meaning**
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support Project
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

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CHAPTER I

INTRODUCTION

Mustard (*Brassica* sp.) is one of the most important oilseed crops throughout the world after soybean (FAO 2014) belongs to the family Cruciferae. It is one of the important oleiferous crops and constitute major source of edible oil for the human consumption and its' cake for animals (Bakhetia 1984). Among the oilseed crops grown in Bangladesh, mustard holds the first position in terms of area and production as of 6,67,000 ha and 3,12,000 tons, respectively (Yearbook of Agricultural Statistics 2019). Mustard seeds contain 40-45% oil and 20-25% protein. Using local ghani average 33% oil may be extracted. It is mainly a self-pollinating crop, although on an average 7.5 to 30% out-crossing does occur under natural field conditions (Abraham 1994; Rakow and Woods 1987). Oilseed crops play a vital role in human nutrition. It is used as a condiment, salad, green manure, fodder crop, and a leaf and stem as vegetable in the various mustard growing countries. Oil cake is a nutritious food item for cattle and fish. It is mainly a self-pollinating crop, although on an average 7.5 to 30% out-crossing does occur under natural field conditions (Abraham 1994; Rakow and Woods 1987). Oilseed crops play a vital role in human nutrition. It is used as a condiment, salad, green manure, fodder crop, and a leaf and stem as vegetable in the various mustard growing countries.

The Oliferous oil contained not only rich source of energy (about 9 Kcal/g) but also rich in fat soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6 g of oil for a diet with 2700 Kcal. On RDA basis, the edible oil need for 150 millions people are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC 1984).

More than three dozen of pests are known to be associated with various phenological stages of mustard crops (Singh and Singh 1983). Among them mustard aphid, sawfly, mustard leaf eating caterpillar etc. are the very important insect pests. Mustard aphid is the most serious and destructive pest and limiting factors for successful cultivation of mustard in South Asia (Zaman 1990; Bakhetia 1983).

The mustard aphid (*L. erysimi*) is found in colonies of hundreds and thousands on mustard plants and both the nymph and adult suck the plant sap from vegetative to siliqua maturity stage the infested leaves curl and turn yellowish, the inflorescence fade and dry. Severely infested plant fails to bear siliqua or end up with very poor pod setting (Das and Islam 1986). No precise report is available on the estimation of damages causes by the pest in Bangladesh. But it is reported in India that yield losses to mustard and rape seed due to attack of *L. erysimi* varied from 66.8% to 96.0% depending upon season (Vir and Henry 1987). It has been reported in Bangladesh yield loss due to its severe infestation range from 87.15% to 98.15% (Anon. 1995).

Nitrogen, phosphorus and potassium are play important role in controlling pest of mustard. A field trial was conducted in Bihar, India observed that an increase in the level of nitrogen in infestation of Indian mustard by *L. erysimi*, while significant reduction in infestation were observed due the addition of phosphorus and potassium (Singh *et al*. 1995). Better growth of plants and yield depends upon balanced fertilization, which in turn has indirect effect on pests. Nitrogen fertilizer is an important nutritional element, which affects the severity of aphids as well as yield of the crop. Khattak *et al*. (1996) reported that high level of Nitrogen favors the attack of aphid. They concluded that application of Nitrogen alone increased the aphid infestation, whereas Nitrogen and phosphorous in combination suppressed the aphid attack. Rohilla *et al*. (1991) reported that infestation of *Lipaphis erysimi* was higher on *Brassica napus* variety HNS-3 than other two genotypes while response of Nitrogen fertilizer was not significant for aphid infestation, whereas Kumar *et al*. (1998) concluded that mustard aphid infestation increased with increasing level of Nitrogen. According to Singh *et al*. (1995) an increase in the level of nitrogen application resulted in an increase in the infestation of Indian mustard by *Lipaphis erysimi*, while significant reductions in infestation were observed due to addition of phosphorus and potassium. Yadu and Dubey (1999) also reported that population of *Lipaphis erysimi* increased with increasing nitrogen doses. Choudhary *et al*. (2001) studied the incidence of *Lipaphis erysimi* and *Myzus persicae* on *Brassica* species at three NPK levels and reported that increasing the fertilizer level resulted in increased aphid incidence in all cultivars, except Ethiopian mustard, which was highly resistant to aphid at all fertilizer levels.

Keeping this point on mind some objectives were figured out for this study. They are:

i. To find out the efficacy of macro and micro nutrients in reducing aphid population on mustard.

ii. To find out the effect of macro and micro nutrients on yield attributes of mustard.

iii. Effects of macro and micro nutrients on incidence of beneficial arthropods in mustard field.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the important oil crop in Bangladesh and as well as many countries of the world. There are many insect pests of mustard among them aphids is the most important one. Farmers mainly control the insect pest through use of different chemicals. The concept of management of pest employing eco-friendly materials gained momentum as mankind became more safely about environment. But the research work in these aspects so far done in Bangladesh and elsewhere is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the control of insects and pests through using botanicals, chemicals and also their integrated uses so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Performance of aphid on different Brassica species

The black bean aphid is a major pest of sugar beet, bean, and celery crops, with large numbers of aphids cause stunting of the plants. Beans suffer damage to flowers and pods which may not develop properly. Early-sown crops may avoid significant damage if they have already flowered before the number of aphids builds up in the spring (RIR 2013). Celery can be heavily infested. The plants are stunted by the removal of sap, the stems are distorted, harmful viruses are transmitted, and aphid residues may contaminate the crop (Godfrey and Trumble 2009). As a result of infestation by this aphid, leaves of sugar beet become swollen, roll, and cease developing. The roots grow poorly and the sugar content is reduced. In some other plants, the leaves do not become distorted, but growth is affected and flowers abort due to the action of the toxic saliva injected by the aphid to improve the flow of sap (HYPP 2013).

To obtain enough protein, aphids need to suck large volumes of sap. The excess sugary fluid, honeydew, is secreted by the aphids. It adheres to plants, where it promotes growth of sooty molds. These are unsightly, reduce the surface area of the plant available for photosynthesis and may reduce the value of the crop. These aphids are also the vectors of about 30 plant viruses, mostly of the non-persistent variety. The aphids may not be the original source of infection, but are instrumental in spreading the virus through the crop (RIR 2013). Various chemical treatments are available to kill the aphids and organic growers can use a solution of soft soap (Godfrey and Trumble 2009).

Rana (2005) conducted a 2-year study on the preference and performance of *Lipaphis erysimi* on different Brassica species in the field and under greenhouse conditions revealed that rapeseed (*B. campestris* var. BSH-1, *B. campestris* var. YSPB-9) and mustard (*B. juncea* RH-30) were better hosts for this aphid than other Brassica species (*B. napus, B. nigra, Eruca sativa, B. carinata*). On the first group of plants, the rate of nymphal development, longevity and fecundity of this pest were significantly less than on the second group of plants. Development was significantly prolonged when the aphid was reared on second group of plants.

Experiment was conducted by Vekaria, and Patel (2005) during rabi 1993-94 and 1994-95 revealed that the incidence of aphid commenced 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AI) at 14 WAS coinciding with second week of February during 1993-94, however, during 1994-95 aphid incidence commenced late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AI) 13 WAS coinciding with first week of February.

The aphid population exceed fluctuated above (ETL) economic threshold level between 11 and 14 WAS coinciding with the third week of January to second week of February.

The incidence of mustard aphid (*Lipaphis erysimi*) in 8 *B. carinata* cultivars (C-3248-8, Peela Raya, Brown Raya, MMC-5, C-90-1063, UCD-593, C-90-1204 and C-90-1205) was studied by Rustamani *et al*. (2005) in Pakistan. The abundance of mustard aphid was evaluated when the plants were 2 weeks old; subsequent evaluation was conducted at weekly intervals. Aphid reproduction was also evaluated for 3 weeks. The aphid population, initially observed on the first week of December (1.45 per plant, on average), peaked on the first week of February (198.75 per plant, on average) in all cultivars, then declined until the maturity of the crop. UCD-593 (25.41 per plant) and Peela Raya (24.78 per plant) showed the lowest aphid densities, whereas MMC-5 recorded the highest aphid density (85.93 per plant). Peela Raya and UCD-593 were resistant to the aphid; the other cultivars were susceptible. The number of progenies remained below 10 per cage in Peela Raya, UCD-593 and C-90-1204.

A field experiment was conducted by Verma *et al*. (2005) during the rabi seasons of 2001/02 and 2002/03 at Kanpur, Uttar Pradesh, India to screen 16 mustard cultivars (15 *B. juncea* and one *B. nigra*) for their resistance to the mustard aphid, *Lipaphis erysimi*. Aphid infestation index (AII, 0-5 scale) was calculated at full flowering and full pod formation stages. Banarsi Rai and Rohini were considered highly resistant to aphid infestation, with AII of 0.56-0.67 and 0.79-069 in 2001/02 and 2002/03, respectively. RK-819, Krishna, RK-9304, RGN-19, RK-9801, RK-90, Basanti, SBG-51, Urvashi and MLN-157 were moderately resistant, with AII of 2.1-2.95 in both years. Varuna, Vaibhav, Vardan and UPN-9 were susceptible, with AII of 3.8-3.3, 3.8-3.0, 3.4-3.0 and 3.3-3.0 in both years.

Devi *et al*. (2004) reported that a mosaic disease of leaf mustard (*Brassica juncea* var. *rugosa*) was found widespread in different locations of Manipur (up to 90.50%) and prevalent in the market samples from different sources (up to 89.58%). Disease incidence was low during October-November and high during February-March months.

The causal virus was transmissible by sap (7.88%) and by three species of aphid (*Myzus persicae, Lipaphis erysimi* and *Brevicoryne brassicae*) but not through seeds.

Indian mustard seeds were sown on 8, 18 and 28 November, and 8 and 18 December in a field experiment conducted by Patel *et al*. (2004) in India during winter and reported that the critical period of mustard exposure to aphids was during the flowering stage of the crop. The aphid population increased in December.

Roy *et al*. (2004) conducted an experiment on aphid dynamics in mustard crop with reference to weather and phenological stages and reported that three Brassica cultivars, Agrani, Pusa Jaikisan and Varuna, were sown under 3 sowing dates, i.e. 1 October, 15 October and 1 November, in New Delhi, India, during the rabi seasons. The first crop season experienced relatively warmer temperature during seed filling and pod maturing stage compared to the second crop season. Early sowing resulted in early flowering, early pod development, longer seed filling period and maturity duration. Days taken to maturity were reduced with delayed sowing. Mustard aphid (*Lipaphis erysimi*) infestation started during either flowering or pod formation stage. Peak population of mustard aphid was mostly found during seed filling stage.

An experiment was conducted by Reza *et al*. (2004a) in Nadia, West Bengal, India, during the rabi season to investigate the effect of some abiotic factors on the population fluctuation of mustard aphid, *L. erysimi*. The population built up of mustard aphid was initiated in the 51st standard week during the end of December with initial intensity of 22.67/plant. The population increased up to 3rd standard week in January at the peak of 318.61. At the time of peak infestation, the maximum and minimum temperature was 27.37 and 14.620C, respectively.

The maximum and minimum relative humidity was 95.28 and 62.28%, respectively. In the 4^{th} and 5^{th} standard weeks, a rainfall of 7.40 and 13.10 mm, respectively, decreased down the aphid population from 274.33 to 186.33/plant. None of the ecological parameters alone was responsible for rapid multiplication of the aphid.

Thirteen new strains of *B. juncea*, developed through intraspecific hybridization, were grown during rabi, at Pura, Jammu, India, and evaluated by Gupta and Bijral (2004) for their resistance to mustard aphid (*Lipaphis erysimi*). RSPR-69 recorded the highest seed yield of 16.33 q/ha, followed by RSPRO-13 (13.133 q/ha). However, RSPRO-13 recorded the lowest plant infestation and aphid population both at the flower initiation and full bloom stages.

A laboratory study was conducted by Mishra and Kanwat (2003) with 5 promising Brassica genotypes, i.e. *B. juncea* cultivars Varuna and Kranti, *B. campestris* cv. BSH-1, *B. napus* cv. R-15 and *B. carinata* cv. HC-2, indicated that mustard aphid, *L. erysimi*, passed through 4 nymphal instars. The total nymphal period varied from 8.19 (Kranti) to 9.65 (BSH-1) days. The pre-reproductive, reproductive and post-reproductive periods ranged from 1.25 (HC-2) to 1.53 (Kranti), 14.33 (Varuna) to 17.20 (R-15) and 2.40 (Varuna) to 2.64 (BSH-1) days, respectively. The adult longevity varied from 13.53 (Varuna) to 16.77 (R-15) days. The daily fecundity varied from 4.93 (Varuna) to 6.02 (R-15) nymphs per female per day.

An investigation was carried out by Keot *et al*. (2002) in Assam, India, to know the insect pest associated with the brassica vegetables and their seasonal incidence. As many as ten insect pests under four orders and six families were recorded infesting the brassica vegetables right from the seedling stage to the harvest of the crop.

Four insects, cabbage butterfly (*Pieris canidia*), mustard aphid (*Lipaphis erysimi*), mustard sawfly (*Athalia lugens proxima*) and mustard flea beetle (*Phyllotreta cruciferae*) were found as major pests. Cutworm (*Agrotis ipsilon*), flea beetle (*Monolepta signata*), cabbage semilooper (*Plusia orichalcea* [*Thysanoplusia orichalcea*]), leaf eating caterpillar (*Spodoptera litura*) were found as minor pests.

For sucking pests, the mustard crop was the most favorable and its 6 varieties mostly attacked in Sindh, which could be controlled through biological control (Sahito *et al*. 2010). Due to various biotic and abiotic factors, this crop also suffers heavy loss in yield (Mahto and Mahto 2007), among these biotic components; the insect pests most damage the mustard yield.

2.2. Effect of different fertilizers on aphid

Pest populations per plant showed significant relation with dose of nitrogen fertilizer, maximum dose of Urea resulted in maximum pest population of aphid as compared to minimum dose rates where the predator population was also fluctuated with pest population (Wagan *et al*. 2015).

Aphids were more abundant in conventionally fertilized barley but the reason for this increased abundance was species specific. *Metopolophium dirhodum* was responding to fertilizer effects on plant morphology, whereas *Rhopalosiphum padi* was sensitive to the temporal availability of nutrients (Garratt *et al*. 2010).

Sinha *et al*., (2018) conducted an experiment and found that, the aphid incidence was highest in plots treated with higher dose of DAP at 120 kg/ha (117.97 aphids per ten cm twig), showing the adverse impact of application of higher dose of nitrogenous fertilizer. Application of neem cake also acted as fertilizer and recorded highest yield of 7.34 q/ha along with MOP at 80 kg/ha (7.34 q/ha). The impact of application of various organic and inorganic fertilizers on available soil nutrients, was also recorded after the completion of two year experiment during 2010–2011 (post-harvest soil samples).

Singh *et al*. (1995) who found highest aphid (*Lipaphis erysimi)* infestation with application of higher doses of Nitrogen fertilizer. In the present studies, the population was mostly non-significantly different on plants, which were supplied with different Nitrogen levels. However, maximum number of aphid was observed on plants treated with highest level of Nitrogen and minimum on plants receiving no Nitrogen. Kumar *et al*. (1998) also recorded maximum aphid infestation at high level of Nitrogen.

Insect pests pose a great challenge to Brassica crop production worldwide. So many insect pests attack Brassica species as preferred host plants (Sibanda *et al*. 2000). Among them aphid, flea beetle, sawfly and leaf eating caterpillar are highly destructive. Aphid is the most severe one (Das 2002) and flea beetles are also serious and widespread pests of mustard (Aslam and Gok 2006).

Rohilla *et al*. (1991) reported that population of *Lipaphis erysimi* was affected by varietal characters and found significantly different population on different cultivars. Similarly, Syed *et al*. (1999) also recorded highest population of aphid on variety Oscar. In the present study, the population of *L. erysimi* was also high on Oscar, which confirmed the results of the previous study.

Ramzan *et al*. (1992) who stated that high infestation of pest is correlated with the high use of nitrogenous fertilizers. They further described that split applications of nitrogen should be applied only when it is absolutely required, and suggested it as the most appropriate and successful strategy of pest management. The same statement stated by Ahmed *et al*. (2007) that the excessive dose of nitrogen fertilizer may produce lush green plants, which attract pest infestation; moreover higher doses of fertilizer also affect the crop maturity and heavy attack of sucking pest complex.

Study of Singh *et al*. (1990a) with 3 levels of nitrogen 0,80 and 120 kg.ha^{-1} on three genotypes of *Brassica* although reported difference in aphid population among the genotypes but it was non-significant for each genotype under the different fertilizer regimes.

2.3. Role of predators and parasites

A survey made by Singh *et al*., 2000 to record the coccinellid predators associated with mustard aphid, *L. erysimi* infesting mustard crop revealed that four species of coccinellids viz, *C. septeMoPunctata*, *C. transversalius*, *C. sexmaculata* and *B. suturalis* were present. Among these, *C. septeMoPunctata* and *C. transversalis* were important aphidiphagous coccinellid predators of the mustard aphid. The predator species such as green lace wing (*C. carnea*), eleven spotted ladybird beetle (*C. undecimpunctata*) and seven spotted ladybird beetle (*C. septempunctata*) were recorded when the pest population of aphids was sufficiently developed on the rape cultivars (Talpur and Khuhro 2004).

Kumar *et al*. (1988) revealed that number of syrphid species active on the crop was influenced by the level infestation by *L. erysimi*, Myzuspersicae and *Brevicoryne brassicae*.

Ohiman and Kumar (1986) reported *D. rapae* as an important parasitoid of *L. erysimi* in India and found it plays significant role in biological control of *L. erysimi*.

Kakakhel *et al*. (1998) reported that, *D. rapae* as an endoparasitoid of the turnip aphid *L. erysimi* with a wide geographical distribution.

Raj and Lakhanpal (1998) studied the efficacy of *D. rapae* on *L. erysimi* and found that the parasitism rate was 31.69% and parasitoid host ratio was about 1:5.6. Nevertheless, from the study conducted by Begam *et al*. (2016) revealed that *Coccinella transversalis* and *Micraspis discolor* were the most dominant predator species observed throughout the cropping season of BhutJalakia. Interestingly, while the number of Coccinellids increases leads to maximum quantity of cabbage yield, which is also an important cruciferous vegetable (Pradhan *et al*. 2020a; Borkakati *et al*. 2018; Borkakati *et al*. 2019).

Rai (1976) reported a total of 24 insect pests from India, whereas Bakhetia and Sekhon (1989) recorded 38 numbers of insect pests. Manzar *et al*. (1998) observed that only the predatory coccinellid *Coccinella* spp. had a regulatory effect on *L. erysimi*.

There have been attempts to enhance mortality due to natural enemies by the introduction of species that might complement existing natural enemies or be superior to them (Waterhouse 1993). Attempted introductions have included parasitoids of *Heliothis virescens* and *Helicoverpa zea* from the Americas as well as species from other parts of the range of *H. armigera*. Few of these have been successful. *Trichogramma pretiosum* and *T. perkinsi* from the USA are reported to have become established in Indonesia and South Africa, respectively. Other successful establishments are: India (*Chelonus blackburni*, *Eucelatoria bryani*, both from the USA, and *Bracon kirkpatricki* from Kenya); Fiji (*Cotesia marginiventris*, also from the USA); New Zealand (*Glabrobracon croceipes* from the USA); Western Australia (*Cotesia kazak* and *Hyposoter didymator*, both from Europe) (King and Jackson 1989).

Records of nematode parasites, usually Mermithidae, are available from all regions where inventories of natural enemies are available, however high rates of parasitism occur only sporadically when conditions are favourable. There is some evidence that, in India, they may be important in suppressing early season populations on wild hosts (e.g. *Acanthospermum hispidum*) and low-growing crops such as groundnut on alfisols (Bhatnagar *et al*. 1985).

Several species of fungi were tested as possible biocontrol agents against *P. latus* (Pena *et al.* 1996). Mortality of *P. latus* caused by *Beauveria bassiana* occurred fastest at densities fluctuating between 65 and 125 mites per leaf.

Prasad *et al*. (2009), monitoring aphids and their natural enemies in brassicas in British Columbia (Canada), observed a lag of several weeks in colonization by syrphids and other aphid predators. These authors concluded that syrphids act on aphids in a density-dependent manner, and hence they are often unable to control populations before damage exceeds threshold levels.

Previous sampling studies in Australian brassica crops found Lycosidae to be the most abundant predator in pitfall catches (Hosseini *et al*. 2008; Furlong *et al*. 2004b). Although Formicidae formed a large proportion of trap catch, activity was highly localized; large catches often occurred in a single trap at each site. Therefore, although results for Formicidae are presented, they were excluded from the calculation of relative abundance. The contribution of ants to biological control is uncertain: although they prey on a variety of pest species, they may also have a negative impact on some beneficial species, and can actively protect honeydew-producing hemipteran pests from natural enemies (Chong *et al*. 2010).

Predators included species of Araneae (Theridiidae, Clubionidae, Miturgidae, Lycosidae, Salticidae, Oxyopidae, Araneidae, Tetragnathidae, Thomisidae), Coleoptera

(Coccinellidae, Carabidae, Staphylinidae), Diptera (Syrphidae), Neuroptera (Hemerobiidae), Hemiptera (Miridae, Anthocoridae, Lygaeidae, Reduviidae, Nabidae), Dermaptera (Labiduridae) and Hymenoptera (Formicidae). Spiders were the most abundant predators, found consistently at all sampling sites from transplanting onwards. In comparison, populations of predatory insects varied between sampling sites, and foliage-dwelling predatory insects were generally absent from plants for the first two weeks post-transplanting (Senior and Healey 2011).

According to Nath and Sen (1976) adult of seven-spotted ladybird beetle consumed (95-104) aphids in 24 hours. While, averagely (284.60) aphids were devoured by a larva of seven-spotted ladybird beetle for becoming a pupa, although, adults consumed (95) aphids per day (Singh and Malhotra 1979).

Singh and Singh (1994) also reported that the lifespan of male *C. septempunctata* ranged from 19-26 days and of a female was 22-32 days and these devoured averagely (22 and 26) aphids per day per adult, respectively.

Sahito *et al*. (2019) conducted a research study and observations revealed that the first, second, third and fourth instar of larvae of *C. septempunctata* devoured an average of (1.74), (18.60), (33.75) and (47.70) aphids that show the full control measure of biological control that should be adopted to get rid of from the most toxic insecticides used in our agro-ecosystem. The current study recommends; the more experimental study should be done on the mustard insect pests properly for the betterment in the production of mustard edible oil as less work has been reported from this region.

Among coleopterans, Coccinellidae is a renowned and diversified family worldwide which contains about 6 thousand species of beetles (Akhavan *et al*. 2013). Predaceous coccinellid beetles are rapacious feeders of insects like aphids, jassids, whiteflies, psyllids, mealybugs, mites, scale insects and also on eggs miniature grubs of different insects and also play an important role in forest and agro-ecosystems as the grubs and adults of the majority of the beetles are predacious on large numbers of plant-eaters insect pests (Hodek and Honek 2009). These beetles are considered as beneficial insects, due to their predatory nature and as competent natural control agents against various insect pests (Ali and Agrawal 2014), on which its larvae and adult feed energetically. Natural control of aphids is the best alternative for very poisonous and hazardous pesticides which are commonly utilized for controlling plant pests (Bellows 2001).

The seven-spotted ladybird, *Coccinella septempunctata* Lin. is a key predator of many aphid species; larvae of the cotton leafworm, eggs of Jassids, eggs and small nymphs of mealybugs, (Ibrahim 1948 and 1955a). In both larval and adult stage, these ladybird beetles are vigorous and have an extensive range of prey such as aphids and scale insects; the most destructive group of insects. These are the most important of all predators (Shepard 1998).

The seven-spotted ladybird eat injurious sucking pests (especially aphid) and often play a certain role in bringing them under control. It preys on eggs, larvae, and adults of different species of insects and most importantly as a predator on aphids (Ibrahim 1955b). Adults of *C. septempunctata* can eat up to100 aphids per day (Arnett *et al*. 1980, Mutti 2006). The ladybug kills its prey completely and then devours it (Waldbaur 1998).

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted during the period from November 2019 to February 2020 to study the effect of fertilizers on incidence of aphid in mustard. The details of the materials and methods that used to conduct the experiment are presented below:

3.1. Location

The experiment was carried out in the central experimental field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is 23.46º N latitude and 90.23º E longitude and an elevation of 8.2 m from sea level (Anon. 1989).

3.2. Climate

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 I.

3.3. 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 II.

3.4. Materials

BARI sarisa-9 was used for this experiment. This variety was collected from the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.5. Treatments of the experiment

Different doses of macro nutrients such as urea, MoP and micro nutrients such as boron were applied in the mustard field as treatment. The name and doses of fertilizer are given below.-

T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose

T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose

T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose

T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose

T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose

T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose

T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose

T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose

3.6. Experimental design and layout

The experiment was laid out in Randomized CoMoPlete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing all of the treatments. Each experiment consists of total 24 plots of size 2.5 m × 2.0 m. All the 8 treatments of the experiment was assigned at random into 8 plots of each block/replication.

3.7. Growing of crops

The experiment plot was opened in the second week of November 2019 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for mustard seed sowing.

3.8. Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of Urea, TSP, MoP, Gypsum, Zinc sulphate and borax, respectively were applied. The entire amount of TSP, Gypsum and Zinc sulphate were applied during the final preparation of land.

3.9. Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mustard plant.

3.9.1. Irrigation and drainage

Single irrigation was provided before flowering stage and it was arranged well drained facilities as prevention process of removing rain water if any.

3.9.2. Weeding

Weeding was done in the field to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at flowering stage by mechanical means.

3.10. Harvesting, threshing and cleaning

The mustard was harvested at the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mustard. The seeds were cleaned and finally the weight was calculated and converted into per hectare yield.

3.11. Monitoring of insect pest and data collection

The mustard plants were closely examined at regular intervals commencing from flowering to pod maturity. Aphids from one square meter area were recorded at weekly intervals in central rows and starting from early flowering to pod maturity and converted. The aphid population was collected by a needle brush in a petridish. The entire period was divided into early, mid and late flowering and fruiting stage and the incidence of aphid was measured.

3.12. Determination of plant infestation

All the healthy and infested plant were counted from one square meter area in the middle of each plot and examined. The collected data were divided into early, mid and late flowering and fruiting stage. The healthy and infested plants were counted and the percent plant infestation was measured and recorded.

3.13. Data recording on aphid infestation of mustard

3.13.1. Aphid infestation at plant

Number of aphid was counted from the 10 tagged plants of a plot. Aphid was counted from the top twig of mustard plant through visual observation in the morning and data were recorded separately.

3.13.2. Aphid infestation at inflorescence

Number of aphid was counted from the 10 tagged plants of a plot. Aphid was counted from the inflorescence of mustard plant through visual observation in the morning and data were recorded separately.

3.13.3. Number of deformation of siliqua caused by aphid

Number of deformed siliqua was counted from the 10 tagged plants of a plot. Data were recorded separately.

3.14. Data recording on yield contributing characters and yield of mustard

Data were recorded on yield contributing characters and yield of mustard on the following parameters-

3.14.1. Plant height

The height of plant was recorded in centimeter (cm) at harvest in the experimental plots. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot after harvest. The height was measured from the ground level to the tip of the growing point of the main branch.

3.14.2. Number of branches per plant

The total number of branches arisen from the stem of a plant was counted as the number of branches per plant. 10 sample plants were counted and recorded data separately.

3.14.3. Number of inflorescence per plant

The total number of inflorescence arisen from the stem of a plant was counted as the number of inflorescence per plant. 10 sample plants were counted and recorded data separately.

3.14.4. Number of siliqua per plant

The total numbers of siliqua of the randomly selected 10 plants of a plot were recorded and then average number of siliqua was estimated.

3.14.5. Length of siliqua

Distance between the ends of the peduncle to the starting point of the beak was recorded as siliqua length and was presented in centimeter (cm).

3.14.6. Number of seeds per siliqua

Ten siliqua from each plant were selected randomly and number of seeds was counted and the average number of seed per siliqua was determined.

3.14.7. Weight of 1000 seeds

One thousand seeds were counted randomly from the total seeds of cleaned harvested seeds and then weighted in grams.

3.14.8. Yield per hectare

Seed weight per plot was measured from the harvested seeds of mustard and then converted into hectare yield and expressed in ton.

3.15. Statistical Analysis

The data related to aphid incidence and different yield contributing characters were statistically analyzed using MSTATC software to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of fertilizers on incidence of aphid and beneficial arthropods in mustard. The results have been presented with the help of different Table and Graphs possible interpretations are given under the following headings:

4.1 Aphid population

Number of aphid at early, mid, late flowering and fruiting stage due to integrated management of aphid in mustard plant showed significant variations (Table 1). Data indicate that at early flowering stage, the lowest number of aphid (51.59 aphids/10 plants) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (63.67), T_1 (76.13), T_4 (81.47) and T_5 (91.82). While the highest number of aphid (112.33 aphids/10 plants) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (102.27) and T_3 (98.33), respectively (Table 1).

In case of mid flowering stage, the lowest number of aphid (69.67 aphids/10 plants) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (83.67), T_1 (96.33), T_4 (101.92) and T_5 (111.36). While the highest number of aphid was observed from T_8 (122.72 aphids/10 plants) which was statistically similar with T_6 (117.11) and followed by T_3 (112.87), respectively (Table 1).

In case of late flowering stage, the lowest number of aphid (72.36 aphids/10 plants) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_2 (91.27), T_1 (99.77), T_4 (111.81) and T_5 (112.41). While the highest number of aphid (132.42 aphids/10 plants) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (122.67) and T_3 (119.33), respectively (Table 1).

Again in terms of fruiting stage, the lowest number of aphid (81.673 aphids/10 plants) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (97.63), T_1 (104.27), T_4 (114.11) and T_5 (118.23). Whereas the highest number of aphid (133.29 aphids/10 plants) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (127.33) and T_3 (122.77), respectively (Table 1).

In case of mean, the lowest number of aphid (68.82 aphids/10 plants) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (84.06), T_1 (94.13), T_4 (102.33) and T_5 (108.46). Whereas the highest number of aphid (125.19 aphids/10 plants) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (117.35) and T_3 (113.33), respectively (Table 1).

Table 1: Effect of different doses of fertilizers on the number of aphid per 10 tagged mustard plants

Treatments	Early flowering stage	Mid flowering stage	Late flowering stage	Fruiting stage	Mean
T_1	76.13 de	96.33 d	99.77 e	104.27 de	94.13 e
T_2	63.67 f	83.67 e	91.27 e	97.63 ef	84.06 f
T_3	98.33 bc	112.87 b	119.33 bc	122.77 bc	113.33 c
T_4	81.47 d	101.92 cd	111.81 cd	114.11 cd	102.33 de
T_5	91.82 c	111.36 b	112.41 cd	118.23 c	108.46 cd
T_6	102.27 b	117.11 ab	122.67 b	127.33 b	117.35 bc
T_7	51.59 g	69.67 f	72.36 f	81.67 g	68.82 g
T_8	112.33 a	122.72 a	132.42 a	133.29 a	125.19 a
CV (%)	7.38	8.76	8.46	7.83	6.69
$LSD_{(0.05)}$	7.73	9.11	8.59	8.13	7.82

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

From this above table it can be concluded that, the aphid infestation on mustard plant was remain low in T_7 which was comprised of Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose. Singh *et al*. (1990) conducted a study and the result also similar with this present study. Trend of the treatments used in this study was $T_7 < T_2 < T_1 < T_4 < T_5 < T_3 < T_6 < T_8$.

4.2. Plant infestation

Number of healthy plant, infested plant and percent plant infestation due to integrated management of aphid in mustard plant showed significant variations (Table 2). Data indicate that the highest number of healthy plant (30.13 plant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (29.72 plant) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the lowest number of healthy plant (25.21 plant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (26.19 plant) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 2).

In case of number of infested plant, the lowest number of infested plant (1.11 plant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest number of infested plant (3.37 plant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 2).

In terms of percent plant infestation, the lowest percent of plant infestation (3.68%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest percent of plant infestation (13.37 %) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 2).

Table 2: Effect of different doses of fertilizers on the number and status of infested mustard plant

Treatments	Healthy plant	Infested plant	%infestation
T_1	29.33 b	1.63 e	5.56 e
T_2	29.72 a	1.37 f	4.61 f
T_3	27.57 e	2.47 b	8.96 c
T_4	28.78 c	1.88 d	6.53 d
T_5	28.27 d	1.93 cd	6.63 d
T_6	26.19 f	3.07 ab	11.72 b
T_7	30.13 a	1.11 g	3.68 g
T_8	25.21 f	3.37 a	13.37 a
CV (%)	6.13	2.84	2.56
LSD $_{(0.05)}$	0.49	0.37	0.63

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

4.3. Aphid incidence on inflorescence

Number of aphid at early, mid, late flowering and fruiting stage due to integrated management of aphid in mustard inflorescence showed significant variations (Table 3).

Data indicate that at early flowering stage, the lowest number of aphid at inflorescence (0.39 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (0.48), and T_1 (0.51) followed by T_4 (0.76) and T_5 (0.82). While the highest number of aphid on inflorescence (1.03 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (0.97) followed by T_3 (0.89), respectively (Table 3).

In case of mid flowering stage, the lowest number of aphid on inflorescence (0.46 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (0.56), T_1 (0.56) and T_4 (0.83) followed by T_5 (0.96). While the highest number of aphid on inflorescence was observed from T_8 (1.27 aphid) which was statistically similar with T_6 (1.26 aphid) followed by T_3 (1.04), respectively (Table 3).

In case of late flowering stage, the lowest number of aphid (0.49 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (0.64 aphid) and T_1 (0.68) followed by T_4 (0.93) and T_5 (1.12). While the highest number of aphid on inflorescence (1.36 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (1.33 aphid) and T_3 (1.23 aphid), respectively (Table 3).

Again in terms of fruiting stage, the lowest number of aphid on inflorescence (0.52 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (0.69) followed by T_1 (0.77), T_4 (1.11) and T_5 (1.29). Whereas the highest number of aphid on inflorescence (1.46 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (1.43 aphid) followed by T_3 (1.39), respectively (Table 3).

In case of mean, the lowest number of aphid (0.47 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (0.59) followed by T_1 (0.63), T_4 (0.91) and T_5 (1.05). Whereas the highest number of aphid on inflorescence (1.46 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (1.25) and T_3 (1.14), respectively (Table 3).

Table 3: Effect of different doses of fertilizers on the number of aphid on inflorescence of mustard

Treatments	Early flowering stage	Mid flowering stage	Late flowering stage	Fruiting stage	Mean
T_1	0.51 de	0.56 e	0.68 e	0.77 d	0.63 d
T_2	0.48 de	0.56 e	0.64 e	0.69 de	0.59 ed
T_3	0.89 bc	1.04 bcd	1.23 ab	1.39 b	1.14 ab
T_4	0.76 cd	0.83 de	0.93 d	1.11 c	0.91 bc
T_5	0.82 bcd	0.96 cd	1.12 cd	1.29 bc	1.05 bc
T_6	0.97 ab	1.26 ab	1.33 a	1.43 a	1.25 a
T_7	0.39 e	0.46 e	0.49 e	0.52 e	0.47 e
T_8	1.03 a	1.27 a	1.36 a	1.46 a	1.28 a
CV (%)	3.36	3.48	3.67	3.39	3.42
$LSD_{(0.05)}$	0.33	0.37	0.42	0.46	0.39

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

From this above table it can be concluded that, the aphid infestation on inflorescence was remain low in T_7 which was comprised of Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose. Singh *et al*. (1990) conducted a study and the result also similar with this present study. Trend of the treatments used in this study was $T_7 < T_2 < T_1 < T_4 < T_5 < T_3 < T_6 < T_8$.

4.4. Inflorescence infestation

Number of healthy inflorescence, infested inflorescence and percent inflorescence infestation due to integrated management of aphid in mustard plant showed significant variations (Table 4). Data indicate that the highest number of total inflorescence (6.21 inflorescence) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (6.03 inflorescence) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the lowest number of total inflorescence (4.89 inflorescence) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (5.47 inflorescence) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

In case of number of infested inflorescence, the lowest number of infested inflorescence (0.81 inflorescence) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MOP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest number of infested inflorescence (2.37 inflorescence) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

In terms of percent inflorescence infestation, the lowest percent of inflorescence infestation (13.04%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest percent of inflorescence infestation (54.60 %) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Table 4: Effect of different doses of fertilizers on the number and status of infested mustard inflorescence

Treatments	Total inflorescence	Infested inflorescence	%infestation
T_1	6.03 a	1.61 e	26.70 f
T_2	5.72 ab	1.27 f	22.20 g
T_3	4.83 d	2.42 b	50.10 b
T_4	5.57 b	1.96 d	35.19 e
T_5	5.21 c	2.13 c	40.88 d
T_6	5.47 de	2.53 ab	46.25 c
T_7	6.21 a	0.81 g	13.04 h
T_8	4.89 e	2.67 a	54.60 a
CV (%)	4.67	2.37	3.33
$LSD_{(0.05)}$	0.36	0.32	0.47

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

4.5. Aphid incidence on siliqua

Number of aphid on siliqua at early, mid, late flowering stage due to integrated management of aphid in mustard plant showed significant variations (Table 5). Data indicate that at early flowering stage, the lowest number of aphid (11.89 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_1 (13.32), T_2 (13.63), T_4 (14.78), T_5 (15.82) and T_3 (16.76). While the highest number of aphid (18.89 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (17.13) (Table 5).

In case of mid flowering stage, the lowest number of aphid (13.72 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_1 (14.21) and T_2 (14.46), flowed by T_5 (17.78) and T_3 (18.98). While the highest number of aphid was observed from T_8 (21.17 aphid) which was statistically similar with T_6 (19.67 aphid) (Table 5).

In case of late flowering stage, the lowest number of aphid (14.16 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_2 (14.96 aphid) and T_1 (14.78) followed by T_4 (15.50) and T_5 (17.28). While the highest number of aphid (21.14 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (19.53 aphid) and T_3 (18.34 aphid), respectively (Table 5).

In case of mean, the lowest number of aphid (13.26 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_1 (14.10), T_2 (14.35), T_4 (15.50) and T_5 (17.28). Whereas the highest number of aphid (21.14 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (19.53) and T_3 (18.34), respectively (Table 5).

Table 5: Effect of different doses of fertilizers on the incidence of aphid on siliqua of mustard

Treatments	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean
T_1	13.32 b	14.21 cd	14.78 cd	14.10 c
T_2	13.63 b	14.46 cd	14.96 cd	14.35 c
T_3	16.76 ab	18.98 ab	19.27 ab	18.34 ab
T_4	14.78 ab	15.26 c	16.46 c	15.50 bc
T_5	15.82 ab	17.78 b	18.23 b	17.28 b
T_6	17.13 a	19.67 a	21.78 a	19.53 a
T_7	11.89 c	13.72 d	14.16 d	13.26 d
T_8	18.89 a	21.17 a	23.36 a	21.14 a
CV (%)	12.33	8.10	4.16	5.36
$LSD_{(0.05)}$	6.47	0.41	0.37	0.48

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

From this above table it can be concluded that, the aphid infestation on mustard siliqua was remain low in T_7 which was comprised of Urea ¾ of recommended dose + MOP recommended dose + Boron ¾ of recommended dose. Singh *et al*. (1990) conducted a study and the result also similar with this present study. Trend of the treatments used in this study was $T_7 < T_2 < T_1 < T_4 < T_5 < T_3 < T_6 < T_8$.

4.6. Siliqua infestation

Number of total siliqua, infested siliqua and percent siliqua infestation due to integrated management of aphid in mustard showed significant variations (Table 6). Data indicate that, the highest number of total siliqua (147.8 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and T_4 (Urea recommended dose +

MoP recommended dose + Boron ¾ of recommended dose) followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the lowest number of total siliqua (131.9 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose) (Table 6).

In case of number of infested siliqua, the lowest number of infested siliqua (17.84 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) followed by T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest number of infested siliqua (32.04 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose) (Table 6).

In terms of percent siliqua infestation, the lowest percent of siliqua infestation (12.07%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). While the highest percent of siliqua infestation (24.29 %) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose) (Table 6).

Table 6: Effect of different doses of fertilizers on the number and status of infested siliqua of mustard

Treatments	Total siliqua	Infested siliqua	% infestation
T_1	141.2 ab	19.74 de	13.98 e
T_2	142.3 ab	19.45 de	13.67 f
T_3	136.6 bc	25.31 bc	18.53 c
T_4	140.7 ab	20.77 d	14.76 d
T_5	138.6 b	22.63 c	16.33 d
T_6	133.3 bc	28.62 ab	21.47 b
T_7	147.8 a	17.84 e	12.07 g
T_8	131.9 c	32.04 a	24.29 a
CV (%)	7.73	1.88	1.54
$LSD_{(0.05)}$	0.56	0.36	0.31

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

From this above table it can be concluded that, the percent infestation of siliqua was remain low in T_7 which was comprised of Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose. Singh *et al*. (1990) conducted a study and the result also similar with this present study. Trend of the treatments used in this study was $T_7 < T_2 < T_1 < T_4 < T_5 < T_3 < T_6 < T_8$.

4.7. Number of deformation of siliqua

Number of deformed siliqua per plant caused by aphid at early, mid and late fruiting stage due to integrated management of aphid in mustard plant showed significant variations (Table 7). Data indicate that, at early fruiting stage, the lowest number of deformed siliqua (0.76 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_1 (0.88) followed by T_2 (0.92), T_4 (1.08) and T_5 (1.21). While the highest number of deformed siliqua (2.21 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (1.87) followed by T_3 (1.96) (Table 7).

In case of mid fruiting stage, the lowest number of deformed siliqua (4.56 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_1 (5.19), T_2 (5.46), T_4 (5.78) and T_5 (6.13). While the highest number of deformed siliqua (7.87 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with T_6 (7.19) and T_3 (6.67) (Table 7).

In case of late fruiting stage, the lowest number of deformed siliqua (4.82 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_1 (5.27), T_2 (5.69), T_4 (5.96) and T_5 (6.47). While the highest number of deformed siliqua (8.36 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_6 (7.56) and T_3 (6.87) (Table 7).

In case of mean, the lowest number of deformed siliqua (3.38 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from others and followed by T_1 (3.78), T_2 (4.02), T_4 (4.27) and T_5 (4.60). While the highest number of deformed siliqua

(6.15 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatment and followed by T_6 (5.54) and T_3 (5.08) (Table 7).

Table 7: Effect of different doses of fertilizers on the number of deformed siliqua of mustard caused by aphid

Treatments	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean
T_1	0.88 cd	5.19 c	5.27 e	3.78 e
T_2	0.92 c	5.46 bc	5.69 de	4.02 de
T_3	1.69 b	6.67 ab	6.87 c	5.08 bc
T_4	1.08 c	5.78 bc	5.96 d	4.27 d
T_5	1.21 bc	6.13 b	6.47 cd	4.60 cd
T_6	1.87 ab	7.19 a	7.56 b	5.54 b
T_7	0.76 d	4.56 d	4.82 f	3.38 f
T_8	2.21 a	7.87 a	8.36 a	6.15 a
CV (%)	0.53	0.63	0.38	0.36
$LSD_{(0.05)}$	0.36	0.43	0.63	0.34

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

From this above table it can be concluded that, the number of deformed siliqua caused by aphid was remain low in T_7 which was comprised of Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose. Singh *et al.* (1990) conducted a study and the result also similar with this present study. Trend of the treatments used in this study was $T_7 < T_2 < T_1 < T_4 < T_5 < T_3 < T_6 < T_8$.

4.8. Beneficial arthropods

Lady bird beetle: The highest number of lady bird beetle (2.13 lady bird beetle) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (2.06 lady bird beetle) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), (1.89 lady bird beetle) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), (1.63 lady bird beetle) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and (1.47 lady bird beetle) T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of lady bird beetle (0.63 lady bird beetle) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 3).

Field spider: The highest number of field spider (1.56 field spider) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (1.31 field spider) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), (1.19 field spider) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), (1.03 field spider) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of field spider (0.37 field spider) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (0.53 field spider) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 3).

Ant: The highest number of ant (1.12 ant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (1.04 ant) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (0.86 ant) (Urea recommended dose + MoP recommended dose + Boron recommended dose) and (0.73 ant) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of ant (0.27 ant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (0.39 ant) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 3).

Dragon fly: The highest number of dragon fly (0.98 dragon fly) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (0.87 dragon fly) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), (0.72 dragon fly) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and (0.63 dragon fly) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of dragon fly (0.27 dragon fly) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (0.33 dragon fly) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and (0.46 dragon fly) T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 3).

Table 8: Effect of different fertilizer doses on the incidence of beneficial arthropods (lady bug beetle, field spider, ant and dragonfly) in mustard field

Treatments	Lady bird beetle	Field spider	Ant	Dragon fly
T_1	1.89 a	1.19 a	0.86 a	0.72 a
T_2	2.06 a	1.31 a	1.04 a	0.87 a
T_3	1.23 b	0.71 b	0.47 b	0.46 b
T_4	1.63 a	1.03 a	0.73 ab	0.63 ab
T_5	1.47 ab	0.83 b	0.51 b	0.52 b
T_6	0.98 b	0.53 c	0.39 c	0.33 b
T_7	2.13 a	1.56 a	1.12 a	0.98 a
T_8	0.63 c	0.37 c	0.27 c	0.27 bc
CV (%)	4.72	4.17	5.78	4.67
$LSD_{(0.05)}$	0.72	0.63	0.43	0.39

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

4.4. Yield attributing characteristics

Plant height (cm): The highest plant height (118.78 cm) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest plant height (111.17 cm) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose), T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Number of branch: The highest number of branches (12.57 branches) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (12.33 branches) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and (12.17 branches) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of branches (10.18 branches) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatment and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Number of siliqua: The highest number of siliqua (130.47 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (129.82 siliqua) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and (129.82 siliqua) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of (126.49 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (127.72 similar) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Length of siliqua (cm): The highest length of siliqua (3.89 cm) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (3.73 cm) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), (3.67 cm) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and (3.43 cm) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest length of siliqua (3.07 cm) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (3.26 cm) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and (3.31 cm) T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Number of seeds per siliqua: The highest number of seeds per siliqua (28.47) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (28.21) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and

(28.07) T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest number of seeds per siliqua (25.56) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 4).

Table 9: Effect of different doses of fertilizers on plant height, number of branch, number of siliqua, length of siliqua and number of seeds per siliqua

Treatments	Plant height (cm)	Number of branches	Number of siliqua	Length of siliqua (cm)	Number of seeds per siliqua
T_1	116.67 bc	12.17 a	129.56 a	3.67 a	28.07 a
T_2	117.31 b	12.33 a	129.82 a	3.73 a	28.21 a
T_3	115.56 d	11.29 c	128.33 b	3.31 b	26.82 bc
T_4	116.37 c	11.63 b	129.29 b	3.43 ab	27.79 b
T_5	115.89 c	11.47 bc	128.67 b	3.33 b	27.33 b
T_6	113.29 e	10.76 d	127.72 c	3.26 b	26.39 c
T_7	118.78 a	12.57 a	130.47 a	3.89 a	28.47 a
T_8	111.17 f	10.18 d	126.49 c	3.07 b	25.56 d
CV (%)	8.89	9.32	9.56	7.84	6.67
$LSD_{(0.05)}$	1.23	0.63	1.11	0.41	0.83

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

1000 seeds weight: The highest weight of 1000 seeds of mustard (3.82 g) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (3.76 g) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose), (3.68 g)

T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose) and (3.47 g) T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and followed by T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest weight of 1000 seeds of mustard (3.06 g) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically similar with (3.17 g) T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and followed by T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 5).

Yield (t/ha): The highest yield of mustard (2.78 t/ha) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose) which was statistically similar with (2.56 t/ha) T_2 (Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose) and followed by T_1 (Urea recommended dose + MoP recommended dose + Boron recommended dose), T_4 (Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose) and T_5 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose). Whereas the lowest yield of mustard (2.03 t/ha) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) which was statistically different from other treatments and followed by T_6 (Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose) and T_3 (Urea recommended dose + MoP recommended dose + Boron recommended dose), respectively (Table 5).

Table 10: Effect of different levels of fertilizers on 1000 seeds weight and yield of mustard

Treatments	1000 seeds weight (g)	Yield (t/ha)
T_1	3.68 ab	2.47 b
T_2	3.76 a	2.56 ab
T_3	3.29 b	2.11 c
T_4	3.47 ab	2.36 b
T_5	3.33 b	2.23 bc
T_6	3.17 bc	2.07 c
T_7	3.82 a	2.78 a
T_8	3.06 c	2.03 d
CV (%)	5.98	4.48
$LSD_{(0.05)}$	0.36	0.28

In a column, means followed by the number of aphids per 10cm inflorescence of 10 plants

[Here, T_1: Urea recommended dose + MoP recommended dose + Boron recommended dose, T_2: Urea ¾ of recommended dose + MoP recommended dose + Boron recommended dose, T_3: Urea recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_4: Urea recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_5: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron recommended dose, T_6: Urea recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose, T_7: Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose, T_8: Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose.]

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the central field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2019 to February 2020 to study the effect of fertilizers on incidence of aphid in mustard. Seeds of BARI Sarisa-9 were used as a test crop for this experiment. Data on aphid population at early, mid and late flowering and fruiting stage, healthy and infested plant, % infestation and infestation reduction over control, different yield parameters and yield were recorded and significant variation was observed among different treatment.

At early flowering stage, the lowest number of aphid (0.63 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the highest number of aphid (2.23 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose). In case of mid flowering stage, the lowest number of aphid (0.83 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the highest number of aphid (2.57 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose). In case of late flowering stage, the lowest number of aphid (0.97 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the highest number of aphid (2.98 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

In terms of fruiting stage, the lowest number of aphid (1.33 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the highest number of aphid (3.47 aphid) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of healthy plant (30.13 plant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the lowest number of healthy plant (25.21 plant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose). In case of number of infested plant, the lowest number of infested plant (1.11 plant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the highest number of infested plant (3.37 plant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose). In terms of percent plant infestation, the lowest percent of plant infestation (3.68%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). While the highest percent of plant infestation (13.37 %) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

At early flowering stage, the lowest number of aphid at inflorescence (0.39 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mid flowering stage, the lowest number of aphid on inflorescence (0.46 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of late flowering stage, the lowest number of aphid (0.49 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In terms of fruiting stage, the lowest number of aphid on inflorescence (0.52 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mean, the lowest number of aphid (0.47 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose).

The highest number of total inflorescence (6.21 inflorescence) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of number of infested inflorescence, the lowest number of infested inflorescence (0.81 inflorescence) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In terms of percent inflorescence infestation, the lowest percent of inflorescence infestation (13.04%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose).

At early flowering stage, the lowest number of aphid (11.89 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mid flowering stage, the lowest number of aphid (13.72 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of late flowering stage, the lowest number of aphid (14.16 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mean, the lowest number of aphid (13.26 aphid) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose).

The highest number of total siliqua (147.8 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of number of infested siliqua, the lowest number of infested siliqua (17.84 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In terms of percent siliqua infestation, the lowest percent of siliqua infestation (12.07%) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose).

At early fruiting stage, the lowest number of deformed siliqua (0.76 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mid fruiting stage, the lowest number of deformed siliqua (4.56 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of late fruiting stage, the lowest number of deformed siliqua (4.82 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). In case of mean, the lowest number of deformed siliqua (3.38 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose).

The highest number of lady bird beetle (2.13 lady bird beetle) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of lady bird beetle (0.63 lady bird beetle) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of field spider (1.56 field spider) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of field spider (0.37 field spider) was observed from T_8

(Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of ant (1.12 ant) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of ant (0.27 ant) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of dragon fly (0.98 dragon fly) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of dragon fly (0.27 dragon fly) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest plant height (118.78 cm) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest plant height (111.17 cm) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of branches (12.57 branches) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of branches (10.18 branches) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of siliqua (130.47 siliqua) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of (126.49 siliqua) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest length of siliqua (3.89 cm) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest length of siliqua (3.07 cm) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest number of seeds per siliqua (28.47) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest number of seeds per siliqua (25.56) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest weight of 1000 seeds of mustard (3.82 g) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest weight of 1000 seeds of mustard (3.06 g) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

The highest yield of mustard (2.78 t/ha) was recorded from T_7 (Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose). Whereas the lowest yield of mustard (2.03 t/ha) was observed from T_8 (Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose).

5.2. Conclusion

From the present study, it may be concluded that the Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose plays a significant good role in case of aphid infestation along with the other yield attributing characteristics and yield. Whereas, the Urea ¾ of recommended dose + MoP ¾ of recommended dose + Boron ¾ of recommended dose showed lowest performance in mustard field. Urea ¾ of recommended dose + MoP recommended dose + Boron ¾ of recommended dose as treatment also showed the best performance in case of yield attributing characteristics as well as yield of mustard.

Considering the findings of the study the following recommendations can be drawn:

1. These treatments should be needed applied in another study in other locations of Bangladesh.
2. In another study should be needed to include more insect pests.

CHAPTER VI

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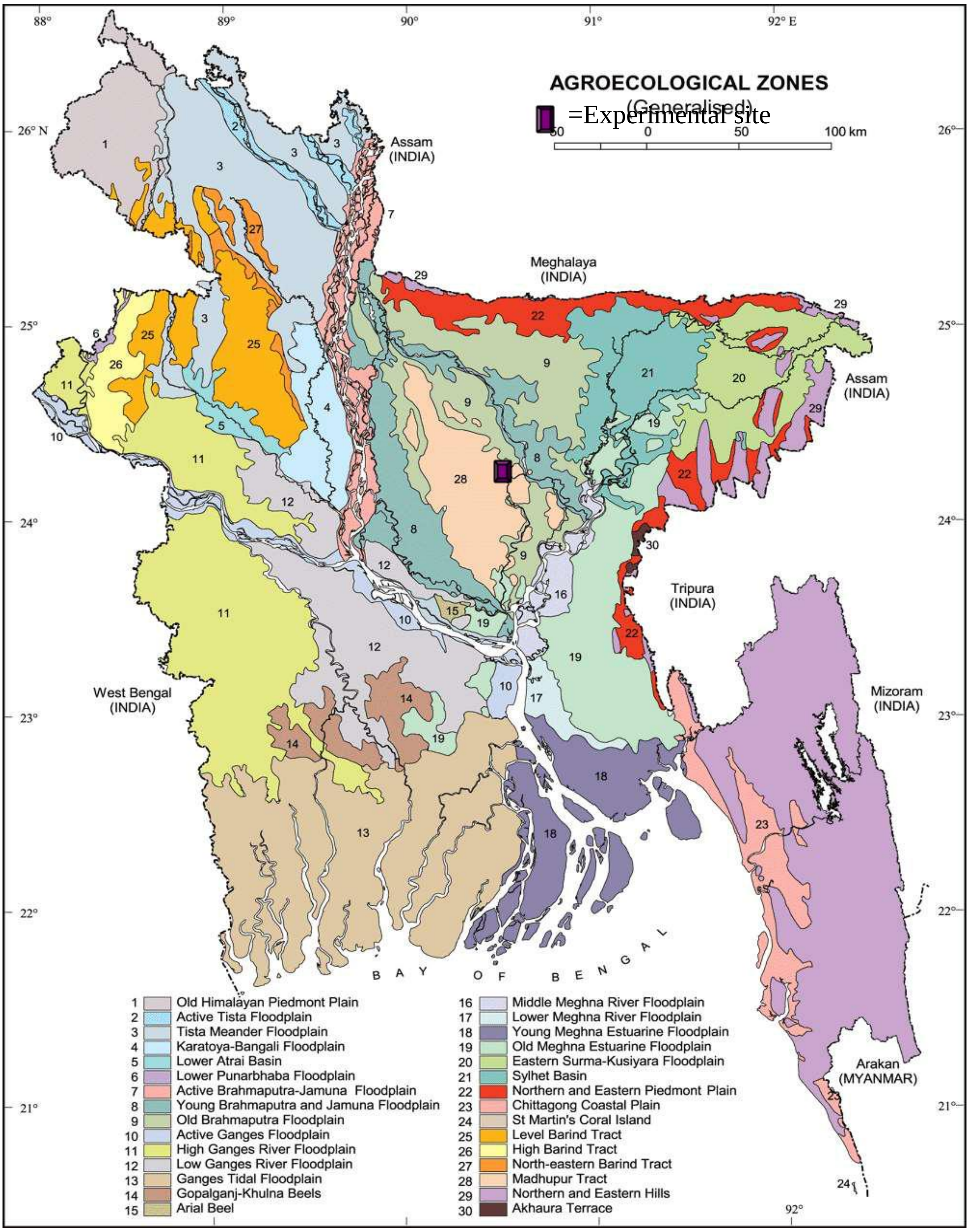
CHAPTER VII

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical coMoPosition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka