STUDY ON HOST PLANT PREFERENCE OF APHID (*Aphis gossypii*) IN DIFFERENT FIELD CROPS AND THE PREDATION EFFICACY BY LADYBIRD BEETLE (*Coccinella septempunctata)* ON APHID

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DHAKA-1207

JUNE, 2022

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REGISTRATION NO: 14-06147

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS) IN ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2022

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CERTIFICATE

This is to certify that thesis entitled, **"Study on host plant preference of aphid (*Aphis gossypii*) in different field crops and the predation efficacy by ladybird beetle (*Coccinella septempunctata*) on aphid"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **Entomology,** embodies the result of a piece of bonafede research work carried out by **Latifa Akter,** Registration No. **14-06147** 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.

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DEDICATED TO
MY
BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the "Almighty Allah" Who kindly enabled the author to complete the research work and the thesis leading to Master of Science.

The author would like to express her heartiest respect, her deep sense of gratitude and sincere, profound appreciation to her supervisor, **Prof. Dr. Md. Mizanur Rahman,** Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.

The author would like to express her heartiest respect and profound appreciation to her Co-supervisor, **Prof. Dr. Mohammed Sakhawat Hossain;** Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.

The author expresses her sincere respect to honorable chairman and all the teachers of Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.

Mere diction is not enough to express her profound gratitude and deepest appreciation to her father, mother, brother, sister, Tasnim Psyche, Antara Sarker and Shah Iftekhar Ahmed for their never-ending prayer, encouragement, sacrifice and dedicated efforts to educate to this level.

JUNE, 2022

SAU, Dhaka **The Author**

STUDY ON HOST PLANT PREFERENCE OF APHID (*Aphis gossypii*) IN DIFFERENT FIELD CROPS AND THE PREDATION EFFICACY BY LADYBIRD BEETLE (*Coccinella septempunctata*) ON APHID

ABSTRACT

The study on host plant preference of aphid and predation efficacy of ladybird beetles on aphid was conducted at Sher-e-Bangla Agricultural University central farm and the laboratory of the Department of Entomology, SAU during November 2020 to April 2021. Two experiments were conducted to explore the host plant preference of aphid and the predator efficiency of ladybird beetle. They were laid out in Randomized Complete Block Design (RCBD) for field condition and Complete Randomized Design (CRD) for laboratory condition with 3 replications. There are six different crops as treatment-wheat, brinjal, tomato, potato, country bean and mustard. The highest number of aphid (54.51 plant^{-1}) was recorded in Country bean at 7 DAS and the lowest (8.00 plant^{-1}) number of aphid was recorded in Brinjal plant at 35 DAS. The highest number of aphid (29.67 leaf^{-1}) was recorded in Country bean at 35 DAS and the lowest (8.00 leaf^{-1}) number of aphid was recorded in Wheat plant at 14 DAS. The highest number of aphid (9.67 inflorescence^{-1}) was recorded in Country bean at 14 DAS and the lowest (3.00 inflorescence^{-1}) number of aphid was recorded in Wheat plant at 14 DAS. The highest number of aphid (15.67 twig^{-1}) was recorded in Country bean at 7 DAS and the lowest (11.00 plant^{-1}) number of aphids was recorded in Brinjal plant at 35 DAS. The highest number of aphid (6.00 pod^{-1}) was recorded in Country bean and the lowest (5.94 pod^{-1}) number of aphids was recorded in Brinjal plant. The highest consumption of aphid (3.10 aphid) by Ladybird beetle was recorded in Country bean at 12 hours interval and the lowest consumption of aphid (1.10 aphid) by Ladybird beetle was recorded in Wheat at 6 hours interval. The adult ladybird beetles was more efficient in predating aphid and the highest consumption of aphid was recorded from adult ladybird beetles.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
et al.	=	And others
DAS	=	Days after Sowing
Mg	=	Milligram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
g	=	gram
cm	=	centimeter
wt	=	weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance
FY	=	Fiscal Year

CHAPTER I

INTRODUCTION

Oilseed crops have been grown all over the world and are considered important crops due to their economic value. Cereal crops provide essential nutrients and energy in the everyday human diet through direct human consumption and also via meat production since they comprise a major livestock feed. Aphid also called plant louse, greenfly, or ant cow, any of a group of sap-sucking, soft-bodied insects. Aphid is one of the most destructive pests and its distribution is worldwide (Begum *et al.,* 1991). Bean aphid, Aphids are almost always found on or near their food plants. they sometimes hide in the curls of leaves. Aphis attacks the crops attacked by the nymphs and the adults of aphid cause damage by sucking the sap from the flowers, buds, twigs, tender shoots and reduce the market value (Srivastava and Singh, 1986). At the time of infestation plant fails to give flowering and twigs setting resulting in 20-40% yield loss (Islam, 2007). Individual variation in species of host plants of the ladybird beetles was examined under laboratory conditions for their preference to plants as a host. Both the nymph and adult of the aphid suck sap from leaves, stems, inflorescences and twigs, as a result the plant show stunted growth, flowers wither and twig formation are hindered (Islam, 2007).

The host plant preferences of the study are; wheat, brinjal, tomato, potato, country been and mustard. Brinjal is a plant species in the family Solanaceae. It is grown worldwide for its edible fruit. The Indo-Burma zone or the Indian subcontinent itself are regions in which the brinjal eggplant, *Solanum melongena* L., may have originated (Samuels, 2011). The brinjal are grown throughout the year in Bangladesh. But its production is seriously impeded due to increasing threats from different sucking insect pests such as aphid (Dutta *et al.,* 2012). The adults and larvae of lady bird beetles attack aphids and many other soft bodied insects and found to be an effective predatory fauna in eggplant (Ali *et al.,* 2009). Tomato (*Solanum lycopersicum*) is one of the most important vegetables in the world. Tomato has been bred to improve productivity, fruit quality, and resistance to biotic and abiotic stresses. Tomato has been widely used not only as food, but also as research material

(Kimura and Sinha, 2008). The tomato is known to contain many compounds that play an important role in the prevention of cancer, heart disease, and many other common health problems. It is also rich source of several important nutrients. It is a good source of vitamins A, B, and C. (Saleem Shaikh., 2011). The major insect of tomato are jassids, aphid, white fly, thrips (Singh *et al.*, 2011). Similarly, a great diversity of natural enemies exists in tomato which can suppress pest population naturally, for example ladybird beetle controlling the aphid population, while the larvae of *Chrysoperla carnea* feed on all soft-bodied insects like aphids and the white fly *B. tabaci* (Webb *et al.,* 2001).

Potato is a starchy food, a tuber of the plant *Solanum tuberosum* and is a root vegetable native to the Americas. The plant is a perennial in the family Solanaceae. Potato consumed as vegetable in Bangladesh rather than staple food in other first world country (Hong *et al.*, 2017) and in relation to per capita consumption. Country bean (*Lablab purpureus* L.), which belongs to the Leguminosae family and is popularly known as “Sheem”, is a common and popular vegetable in Bangladesh, grown mainly during the winter (Rabi) season, and more recently also in the summer (Kharif) (Biswas, 2015). Bangladesh’s overall land area under bean cultivation is 61,628 acres, with a production of 169,735 metric tons in 2019-2020 (BBS). The green twig of the country bean contains approximately 5% protein, 0.1% fat, 0.75% lipids, 4.11% ash, and 10% carbohydrates. In addition, bean twigs provide vitamins (vit A, vit C, riboflavin, thiamine), and different minerals, i.e., magnesium, calcium, phosphorous, potassium, iron, sulfur, and sodium (Magalingam *et al.,* 2013). Despite being an important crop, the production of country bean in Bangladesh has dramatically reduced due to insect pests and diseases (Khan *et al.,* 2018). Approximately 55 species of insect pests and mites attack country bean from the seedling stage to harvest (Chopkar *et al.,* 2020). Among the insect pests, aphids, bean bugs, green semiloopers, hooded hoppers, leaf miners, leaf weevils, twig borers, shoot borers, shoot weevils, epilachna beetles and mitesly cause significant economic damage to country bean production (Chowdhury *et al.*, 2019). aphids is an emerging pest in this crop. The mustard plant is any one of several plant species in the genera Brassica, in the family Brassicaceae. Mustard seed is used as a spice. The seeds can also be pressed to make mustard oil, and the edible leaves can be eaten as mustard greens. Mustard aphid (Kaltenbach) recorded as a notorious pest of mustard throughout the globe. It causes damage directly by sucking cell sap and indirectly as vectors of certain plant viruses (Ali *et al.,* 2008). Ladybird beetles occupy a prominent position as predators of this aphid species all over the world (Ali *et al.,* 2008).

Among them, wheat (*Triticum spp*.) belongs to family Poaceae, and is an annual grass; culms simple, erect, hollow or pithy, glabrous, up to 1.2 m tall; with leaves flat, narrow, 20–38 cm long, about 1.3 cm broad; spikes long. It is a cereal grain, originally from the Levant region of the Near East but now cultivated worldwide. Wheat (*Triticum aestivum* L.) is one of the cereal food crops ranked third worldwide after maize and rice. In Bangladesh wheat is the second most important staple food after rice that accounts for about 12 percent of total cereal consumption. With the introduction of new wheat varieties developed by the Bangladesh Agricultural Research Institute (BARI), wheat yield per hectare has increased from 1.3 million tons in 2013-14 to 1.5 million tons in 2020-21 (FAO, 2022). For the control of insect pests of wheat naturally occurring carnivorous insects are responsible (Franco, *et al.,* 2002). Dangerously damaging pests of wheat crop are Aphids (Summers, 2006).

Most lady beetles found on crops and in vegetable fields are known as predators of aphids. Some species prefer only certain aphid species while others attack many aphid species on a variety of crops. Some prefer mite or scale species. If aphids are scarce, lady beetle adults and larvae may feed on the eggs of moths and beetles, and mites, thrips, and other small insects, as well as pollen and nectar. They may also be cannibalistic. Cannibalism of eggs, larvae and pupae are common, especially when prey is scarce. Because of their ability to survive on other prey when aphids are in short supply, lady beetles are particularly valuable natural enemies (Ghosh, 2022). Ladybird are insects thus has a place with the biggest request of living beings on the Earth, the coleoptera. Ladybird beetles, also known as ladybugs, are predatory insects that feed on aphids and other small insects (Hodek and Honěk, 1996). Ladybird is a name that has been used in England for more than 600 years for the European beetle (*Coccinella septempunctata* L.) As knowledge about insects increased, the name ladybird became extended to all its relatives, members of the beetle family Coccinellidae. The ladybird beetle, has been referred to worldwide as predator of various insect pest. This predatory beetle is common in all countries of Asia (Nasiruddin and Islam, 1979). It is exceptionally regular in the field. There are more than 6000 species of Coccinellids on the planet and of which more than 400 happen in the Indian sub-region (Vandenburg, 2000). About 36 species of *Coccinella septempunctata* L. are reported from Indian subcontinent (Baskaran and Subramanyan, 1992). Numerous species of ladybirds are major biological control agents of insect pests such as aphids, mealybugs, scale insects, thrips and mites in all parts of the globe (Moreton, 1969). Their life cycle is completed in three months depending upon location and temperature; two or three generations are generally produced in a year. Adults overwinter in sheltered locations such as tree holes and other natural hiding places (Majerus and Kearns, 1989). Therefore, the following study was done to ascertain the incidence of aphid in different host plants and predation of the of ladybird beetles against aphid. The present study was undertaken with the following objectives;

1. To know the incidence of aphid in different crops and
2. To study the predation efficacy of ladybird beetle against aphid.

CHAPTER II

REVIEW OF LITERATURE

The incidence of the pest occurs almost relevant information pertaining to origin, distribution and host preference of aphid and nature of predation of ladybird beetle over Aphid population due to the host preference are given below:

2.1 Taxonomic position of aphid

Taxonomic position of the aphid, *Lipaphis erysimi* (Kalt.) is given below:

Phylum: Arthrotwiga

Sub-phylum: Mandibulata

Class: Insecta

Sub-class: Apterygota

Order: Homoptera

Family: Aphididae

Sub-family: Aphidinae

Genus: *Lipaphis*

Species: *Lipaphis erysimi*

2.1.2. Geographical distribution of aphid

The mustard aphid, Lipaphis erysimi (Kalt.) is distributed worldwide (Pradhan, 1994). It is found in all tropical and subtropical countries (Schmutterer, 1978) and is recognized as a worldwide serious cruciferous pest (Atwal *et al.*, 1976).

2.1.3 Seasonal Abundance of aphid

Abiotic factors seem to influence the aphid infestation due to large variation in the date of aphid infestation and its progress. Under favourable weather conditions, mustard aphids spread very rapidly forcing the farmers to repeatedly use insecticides. However, need based application of the insecticides is desirable in order to avoid pollution related hazards. Several studies have been done to develop correlation between weather parameters and aphid population. They reported that the peak period of aphid activities on *B. juncea* varied from end of January to first week of March.

Based on simple linear regression analysis between aphid population and the corresponding weather for 3 years, Bishnoi *et al.* (1992) reported that the either mean temperature or saturation deficit contributes significantly to the buildup aphid population.

Samdur *et al.* (1997) from Delhi observed that average maximum and minimum relative humidity had positive relationship with mean aphid infestation index. A minimum relative humidity of 30 to 35% and average maximum relative humidity of 85 to 88% were found to be the most congenial conditions for increase in aphid population. Kulat *et al.* (1997) found that in Nagpur, a combination of ambient maximum temperature (26.4 to 29.0℃), minimum temperature (8.4 to 12.6℃) and high relative humidity ranging from 75 to 85 percent in the month of January favoured aphid multiplication, whereas the activity of the aphid ceased at relative humidity of 65 per cent and below. A lot of information is available about the relationship between various biotic and abiotic factors and incidence, multiplication and disappearance of mustard aphid. Based on the 13 understanding of the relationship between these factors and levels of aphid infestation, the correlation studies help in developing the regression models for forecasting the aphid infestation under existing condition.

Prasad and Phadke (1987) from their field studies at IARI, New Delhi, worked out semi logeX equation to be best fit for almost all the stages of the crop growth relating the yield with aphid population. Mishra and Singh (1986) observed similar type of relationships between the yield of mustard and aphid infestation levels. Based on field observation, Prasad *et al.* (1984) from IARI, New Delhi reported that maximum, minimum and mean temperatures existing one or two preceding weeks showed a significant and negative correlation with the prevailing population with a lower value of determination factor. From field studies conducted at IARI, New Delhi, (Samdur *et al.*, 1997) reported that the mean aphid infestation index was negatively correlated with maximum temperature, evaporation, sunshine and wind velocity and it was positively correlated with maximum relative humidity and minimum relative humidity in a significant way in case of timely sown crop.

Prabhakar and Roy (2008) at IARI, New Delhi, developed a typical model equation for forecasting the aphid population in Brassica crop, based on aphid population recorded at weekly intervals and the corresponding weather parameters viz. maximum, minimum and mean temperature, relative humidity, saturation deficit and the total rainfall. They also incorporated the aphid population at one week, two weeks and three weeks before the observation date. Development stage of the aphids can be effectively expressed as a temperature sum or degree-day (Chowdhury *et al.* 2008).

2.1.4. Damage caused by aphid

Rizkalla *et al.* (1994) conducted a four year investigation with six Brassica for their resistance to *Lipasphis erysimi* (Kalt.). The investigators used the yield loss as the criteria of resistance and reported the following decreasing order of resistance Erucs sativa t-27 (16.44 % yield loss), *B. juncea* parkesh (23.64 %), RH-30 (27.31 %), B. campestris brown sarson BSH-1 (32.73 %), yellow sarson YS-PB-24 (34.18 %) and B. napus HNS-3 (61.32 %). Sekhon and Ahman (1992) expressed that L. erysimi (Kalt.) is the most devastating insect pest in India where it can cause losses of up to 50 % in seed yield. Begum *et al.* (1995) conducted a research experiment with three varieties of mustard in 15 Joydebpur in the year 1993-1994 to assess the loss sue to aphid infestation. It was found that second highest losses occur in the flowering and twiging stages and the lowest losses occur in the twig formation and ripening stage. Begum *et al.* (1995) conducted another experiment at ARS rajbari, Dinajpur during radi season of 1994-1995 to find out the population activities of mustard aphid. She observed that aphid population increases gradually as sowing delayed. The highest aphid population was recorded 2879.12 per plant and the lowest aphid population 259.35 per plant. It was evident that the mustard yield decreased as the aphid population increased and the percent of twig infestation had positive correlation to aphid population. Bhadauria *et al.* (2001) evaluated thirty Indian mustard cultivars under field conditions against *L. erysimi* on the basis of mean aphid population, multiplication index and the susceptibility index. They suggested that low susceptibility index and higher grain yield (2060 kg ha^{-1}) in cv. RW-5453-B-2 seemed to be suitable for general cultivation. Anonymous (1995) conducted a field experiment with eleven varieties/mutant of mustard to measure the loss of yield due to aphid infestation. The mutant/varieties included in the test were Agrain, Safal, BINA-2, NAP-3, SS-75, Tori-7, Tori-68, Sangam and BS-5. The investigators reported that the mutant/ varieties were significantly different among themselves with respect to seed yield. The highest yield was obtained in NAP-3 and the lowest in BS-5. Srivastava *et al.* (1996) performed field trials in Himachal Pradesh, India during 1991-1994 to assess the yield loss of mustard due to infestation of *Myzus persicae* and *L. erysimi*. They observed that the yellow sarson cultivar (YST-8410) showed the maximum yield loss (46.12 %) and brown sarson BSH-1 showed (43.58 %), *B. juncea* (Varuna) and B. napus (HPS-1) showed lower susceptibility with yield loss 16 ranging from 30.90 % to 36.01 %.

2.2 Distribution of ladybird beetle

Coccinellidae are extremely diverse in their habits; they live in all terrestrial ecosystems (Skaife, 1979). They are distributed in many countries of Asia, including Bangladesh. These beetles often called ladybug or coccinellids. They are the most commonly known beneficial insects. In Europe these beetles are called Ladybirds (Williams, 2004). Lady bird beetle are more or less worldwide in distribution. About 6000 species of Coccinellidae are known worldwide (Vandenberg 2000) with over 300 species known from the Indo-Pakistan sub-continent (Rahatullah and Inayatullah 2010). Rahatullah and Inayatullah (2010) documented 4,000 predatory species of this family of which more than 300 species from Indo-Pak subcontinent. While 71 species are found only in Pakistan (Irshad, 2001).

2.2.1 Taxonomy of ladybird beetle

Kingdom: Animalia

Phylum: Arthrotwiga

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Epilachna*

Species: *Epilachna peniculata*

2.2.2 Origin and distribution of ladybird beetle

Species in this genus occur through much of Asia and Australasia, and species ladybird beetle has been accidentally introduced in other parts of the world (e.g., Brazil and Argentina).

2.2.3 Life cycle of ladybird beetle

ladybird beetle is a univoltine species. General life cycles of the beetles and their host-plants in Sapporo and vicinity were reported in Katakura (1981). Overwintered adults start to emerge in early May, most stocks of thistle sprout appear in late April, and those of blue cohosh in early May. Initially beetles mainly feed on young thistle leaves and eventually move to the blue cohosh leaves that unfold from mid to late May (Kimura and Katakura, 1986).

Beetles copulate on the host-plants repeatedly (Nakano, 1987), and egg clutches are usually oviposited on the underside of the host-plant leaves mainly from early June to early July. The emergence of a new generation of adult beetles starts from late July. The thistle stocks continue growing until July, and stems wither by mid-August, although they develop rosettes by early October.

On the other hand, blue cohosh stocks finish growing and bloom in early June. They retain their leaves until late September if not consumed by the beetles. More than half of newly emerging female mate before entering hibernation (Katakura, 1981). There has been no detailed investigation into the life cycles in Uryu, but they appear to have a delayed start and hibernate earlier due to a longer winter period.

2.3 Host Preference of aphid

2.3.1 Wheat

Plant architecture of wheat is important in the food choice of insect predators, particularly ladybirds, as their larvae crawl over and capture prey on the surfaces of plants (Reynolds, 2011). Plant structures, particularly, their morphological features like texture, shape and size have a great effect on the foraging success of ladybirds. Plant architecture has a direct effect on the walking speed and attack rate. This also affects the host preference of ovipositing ladybirds. However, increase in the heterogeneity of plant structures decreases the foraging capacity of ladybirds. For example, larvae of the ladybird *C. septempunctata* forage less successfully for pea aphids, *A. pisum*, on highly branched varieties than on normal varieties of peas (Legrand and Barbosa, 2003). Even the surface texture of plants, i.e. hairiness or slipperiness of wheat plants, affect the foraging ability of ladybird larvae. Trichomes reduce the foraging and walking speed of predators (Riddick and Simmons, 2014). Similarly, waxy plants reduce the foraging success of ladybirds, for instance, larvae of wheat are more successful foraging for aphids (Chang *et al.*, 2006).

The effect of leaf waxes is however largely ignored in the literature. In addition, larvae of *C. septempunctata* are less effective in foraging and killing prey on foliage, which has more junctions (Legrand and Barbosa, 2003). Presence of wax on the surface of wheat plants, especially leaves, plays a significant role in the foraging ability of ladybird larvae. Increase in surface wax reduces the walking speed and searching efficacy of coccinellid larvae, and also tends to result in the larvae loosing adhesion and falling from leaves (Rutledge *et al.*, 2008). The adhesion of foraging larvae depends on the texture and surface wax on leaves, for instance, the presence of crystalline epicuticular wax on the wheat plant, *Triticum spp.* (Eigenbrode *et al.*, 2008). A morphological study of the way Cryptolaemus montrouzieri Mulsant adheres to plants surfaces combined with measurements of the forces that keeps beetles attached to plant surfaces is reported by Gorb *et al.*, (2008).

2.3.2 Brinjal

Adults and larvae of ladybirds leave trails or footprints on Solanaceae plants (Kumar *et al.*, 2014) in the form of non-volatile hydrocarbons (Magro *et al.*, 2007), which deter other foraging ladybirds. These chemicals may be referred to as deterrent pheromones as they inhibit foraging activity (Moser *et al.*, 2010). The first instar larva of an aphidophagous ladybird, Cycloneda limbifer Say respond to conspecific larval tracks by avoiding or leaving such microhabitats (Ruzicka and Zemek, 2008). This probably indicates that foraging larvae balance the spatial variation in the concentration of larval tracks by shifting from microhabitats with high to lower concentrations of larval tracks.

Thus, in field condition, it is likely that the regulation of prey-location might be driven by the ratio between attractant and deterrent pheromone-cues. Active foraging of early instars in uninvaded or less contaminated aphid colonies reduces the risk of cannibalism or intraguild predation. In contrast, older instars search more effectively for better aphid colonies because they are less at risk. It seems that ladybird larvae optimize their distribution between aphid colonies according to the densities of both prey and larval tracks (Dixon *et al.*, 1997). In predatory guilds, small ladybirds are more easily deterred from foraging possibly because they are more vulnerable to intraguild predation (Kumar *et al.*, 2014).

The fitness parameters, particularly growth-rate and conversion-efficacy, of small ladybirds even declines due to reduced foraging in habitats previously visited by other predators (Kumar *et al.*, 2014). In addition to deterring foraging, ladybirds' footprints also reduce the settling of herbivores, like aphids (Ninkovic *et al.*, 2013) and psyllids (Seo *et al.*, 2018), thereby resulting in declines in pest populations.

2.3.3 Potato

honeydew secreted by aphids, acts as a secondary olfactory cue in attracting predators, particularly ladybirds, to aphid prey. Artificial spraying of honeydew attracts ladybirds, e.g. Hiptwigamia sp. to aphid habitats, thereby making it useful in integrated pest management (IPM) programmes (Evans and Richards, 1997). Larvae of the ladybird, *H. convergens* stay longer in patches contaminated with honeydew compared to clean patches (Purandare and Tenhumberg, 2012). In addition, these larvae are unable to distinguish between high and low-quality aphid honeydew. However, it also acts as an arrestant for certain predators and prolongs their searching time (Ide *et al.*, 2007).

2.3.4 Country bean

It is an established fact that chemical cues help in locating the habitat of the prey. Further, other cues and signals are also perceived by foraging ladybirds. Amongst these cues, visual cues are considered to be the major ones. However, they are rarely mentioned in the literature where more importance is given to chemical cues. (Bahlai *et al.*, 2008) suggest that adult *H. axyridis* depend upon long-range visual cues to locate host habitats. Adult ladybirds tend to be attracted by silhouetted shapes and foliage of host plants regardless of olfactory cues. Adults of *Chilocorus nigritus* (Fabricius) prefer to forage near horizons that simulate treelines over flat horizons (Hattingh and Samways, 1995). Most ladybirds prefer to forage during daytime, as they can use visual cues for finding prey. This is evident from the increased aphid consumption in daytime compared to that at night (Harmon *et al.*, 1998). In addition, ladybirds, for instance, *C. septempunctata* consume a greater number of *A. pisum* that contrast in colour with the background. Certain ladybirds, viz. *H. convergens*, *Coleomegilla maculata* (deGeer), *H. axyridis* and *C. septempunctata*, consume more red individuals of *A. pisum* than green ones (Harmon *et al.*, 1998). Similarly, naive adults of *H. axyridis* are more attracted to yellow than green pillars (Mondor and Warren, 2000), as yellow pillars resemble stressed or young plants that are more likely to be infested with aphids (Lorenzetti *et al.*, 1997).

Most of the foraging activity of the ladybird *Propylea dissecta* (Mulsant) occurs in daytime (Mishra and Omkar, 2004). However, the major life events such as mating, oviposition, hatching and moulting occur at night, which indicate the importance of visual cues that are needed for the ladybird to forage. Heit *et al.*, (2008) did not find any difference in the foraging behaviour of adult male and female *C. sanguinea* during the morning and afternoon. However, as the day progressed, they noticed a decline in foraging probably due the fact that other activities, such as mating, are more likely to occur later in the day. Ferran and Dixon (1993) suggest that conditioning in ladybirds affects their foraging ability. Learning from previous experience helps them to switch from extensive to intensive search. For instance, laboratory-reared *H. axyridis* have a strong affinity for pea aphids (*A. pisum*) and any sign or smell of this prey enables the predator to switch to intensive search (Ettifouri and Ferran, 1993).

2.3.5 Mustard

Prey-preference studies indicate that ladybirds have an affinity and preference for certain prey over others (Pervez and Kumar, 2017). In addition, this prey-preference depends largely on the host plant, as aphids sequester host plant allelochemicals and use them as a defence against ladybirds. For instance, *Acyrthosiphon nipponicus*

(Aphididae), feeds on *Paederia scandens* (Lour.) Merr. (Rubiaceae) and secretes paederoside, an iridoid glycoside and lipids from its cornicles that helps it to defend itself from *H. axyridis,* as these chemical forces the ladybird to release the aphid and flee from the aphid colony (Nishida, 2014). Thus, aphids sequestering such allelochemicals become toxic and unpalatable for ladybirds, which then avoid further attacking and consuming these aphids. Hence, despite this aphid being highly preferred when raised on suitable host plants, it is avoided when raised on a toxic host. Thus, we can manage the prey preference capabilities of ladybirds by providing aphids raised on suitable and nutritious hosts rather than toxic host plants.

2.4 Predation rate of ladybird beetle

Hameed *et al.,* (2013) found that, eleven spotted ladybird beetle (*Coccinela undecimpunctata* Linnaeus) proved to be the best predator against aphid. 1st instar larvae of eleven spotted beetle is an effective bio control agent which consumed on an average 91.99 1st instar cotton mealybug whereas 2nd, 3rd instar and adult consumed 45.00, 44.00, 5.44 aphid, respectively. The *C. undecimpunctata* L. at 2nd instar devoured 97 1st instar, 35.66 2nd instar and 45.00 3rd instar aphid and 7.11 adult stage aphid. Whereas 3rd instar beetle took in 121.66 1st instar, 51.66 2nd instar and 54.33 3rd instar aphid and 8.21 adult stage aphid respectively. The larvae of 4th instar *C. undecimpunctata* preyed 93.00 1st instar, 35.00 2nd instar and 33 3rd instar aphids. and 7.33 adult stage aphid respectively. Adult female of this beetle consumed higher number of mealybugs than adult male during its whole life. Hoy and Nguyen (2012) studied that both predators *Chrysoperla carnea* and *Cryptolaemus montrouzieri* larvae had high consumption rates in cotton field, *C. montrouzeiri* being the most voracious feeder. In the no choice feeding tests, third instar larvae of *C. montrouzeiri* devoured the highest mean number of first instar *P. solenopsis* (439.38). In the choice feeding tests, a similar number of first instar nymphs (410) were consumed. In 15 both feeding tests, *C. carnea* devoured relatively fewer number of *P. solenopsis* than *C. montrouzeiri*.

Franco (2009) reported that apart from health and environmental hazards caused by chemical pesticides, pesticide applications do not generally provide adequate control for mealybugs in the long-term owing to their cryptic behaviour, their typical waxy body cover and clumped spatial distribution pattern. About 90% of coccinellid species are considered beneficial because of their predatory activity, mainly against homopteran insects and phytophagous mites injurious to various agricultural and forest plants. Since prey is the main limiting factor for ladybird beetle reproduction (Dixon, 2000, Hodek and Honek, 1996) adults tend to synchronize their life cycle with that of their prey (Dixon, 2000). Life cycle synchronization may be achieved through dormancy, migration or reproductive diapause (Hodek and Honek, 1996). In many studies it is known that *Coccinella septempunctata* L. commonly called lady bird beetle is a capable predator and can be used for the biological control of *T. tabaci* and *T.vaporariorum* in a greenhouse (Soloman, 1949). Victor, (1997) reported that *Coccinella septempunctata* is considered to be an important bio control agent for soft bodied insects such as aphids, white flies, jassids and lepidopterous larvae which are among the first to be used in this fashion.

Mani and Thontadarya (1987) observed that *Cryptolaemus montrouzieri* Muls (Coleoptera: Coccinellidae) is a aphid predator, both larvae and adults attack all stages of aphid, *Planococcus citri* (Risso). This predator is most effective in high infestations, but with the scarcity of food, it feeds on soft scale insects and aphids. Mani (1988) reported that *C. montrouzieri* succeeded to suppress the population of the grape vine mealybug, *Maconellico cushirsutus;* the release of 1000-1500 adult's predator/acre gave an effective control within two months. Srinivasan and Babo (1989) in India found that maximum effect of this predator against the mealybug, *Macunillicocus hirsutuson* Grapes was observed at six weeks after the initial release, with 64.3% reduction when 10 predators were per vine. In India, Mani *et al.* (1990) reported that the population of the aphid *Ferrisia virginata* in guava orchards was controlled within 50 days after releasing *Cryptolaemus montrouzieri.*

Nathapol and Pensook (1991) found that the average predation capacities of *M. sexmaculatus* (F.) in 1st, 2nd, 3rd and 4th larval instars and adult stage of male were 8.35, 20.60, 36.05, 44.65 and 1012.7 aphids (*A. glycines*), respectively. The average predation capacity in the larval instars and adult stage of female were 9.3, 22.25, 36.15, 48.25 and 1106.9 aphids respectively. Das (1994) found that the feeding rate of larvae of *M. sexmaculatus* (F.) during the 1st day after hatching ranged between

9.0 to 13 adults of *A. craccivora* from the 2nd day the rate of consumption gradually increased and reached an average of 53.05 ± 0.93 aphids on the 8th day after which feeding rate fall down sharply. It was also reported that a single larva consumed 270.0 to 367.0 aphids prior to pupation.

CHAPTER III

MATERIALS AND METHODS

Two experiments were conducted at the Sher-e-Bangla Agricultural University (SAU) central farm and the laboratory of the Entomology department from November 2020 to April 2021. The objective of the study was to explore the host preference of aphids in different field crops and to find out the predation of ladybird beetle on aphids under laboratory conditions. The materials and methods followed are described under the following sub-headings:

3.1 Location of the experimental field

3.1.1 Location and time

The present research was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2020 to April 2021. The experimental area is located at 23.74º N latitude and 90.35º E longitude with an elevation of 8.2 m from the sea level (Khan, 1997).

3.1.2 Soil

The soil of the experimental area was general soil type series of shallow red brown terrace soils under Tejgaon series. Upper-level soils were clay loam in texture, olive-gray through common fine to medium distinct dark yellowish-brown mottles under the Agroecological Zone (AEZ- 28) and belonged to the Madhupur Tract (UNDP, 1988; FAO, 1988). The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land, fertile, well drained and having pH 5.8. The physicochemical property and nutrient status of soil of the experimental plots are given in Appendix 1.

3.2 Climate of the experimental area

The experimental area is situated in the sub-tropical climatic zone and the Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February. The detailed meteorological data in respect of temperature, relative humidity and total rainfall recorded by the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka during the period of study have been presented in Appendix II.

3.3 Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) 3 replications for host plant preference experiment. The size of the experimental plot were 3×1 m^2 with plot-to-plot distance 1m and row to row distance 1m. Complete Randomized Design (CRD) with 10 replications was followed for lab experiment on predation efficacy of ladybird beetle.

3.4 Preparation of the experimental field

3.4.1 Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field.

3.4.2 Fertilizers

The fertilizers were applied as per fertilizers recommendation guide (BARI, 2006). The applied manures were mixed properly with the soil in the plot using a spade.

3.4.3 Sowing of seeds

Seeds were sown on 17 November, 2020 at the recommended rate for all six (wheat, brinjal, tomato, potato, country bean and mustard) crops selected under the study in the furrow and the furrows are were covered with soils soon after seeding. The line to line (furrow to furrow) distance was maintained treatment arrangements with continuous sowing of seeds in the line.BAR seeds were procured from the seed wing of the Bangladesh Agricultural Research Institute at Gazipur, Dhaka.

3.4.4 Intercultural operations

The seedlings were constantly being watched carefully. To ensure that the plants grew and developed properly throughout the cropping season, necessary intercultural activities were carried out.

3.4.4.1 Thinning

When the seedlings became established, one healthy seedling was kept in each location, and the other seedlings were removed.

3.4.4.2 Gap filling

The gaps were filled in within two weeks after germination of seeds.

3.4.4.3 Weeding

There were some common weeds found in the country bean field. First weeding was done at 30 DAS and then once a week to keep the plots free from weeds and to keep the soil loose and aerated.

3.4.4.4 Irrigation and drainage

The irrigation was done at after first weeding. Irrigation was used as and when irrigation needed. Proper drainage system was also developed for draining out excess water.

3.5 Preparation of lab experiment

3.5.1 Net house management

A net house was established for ensure the adequate number of aphids and ladybird beetles. The size of the net house was 3×2×2 m and the divided into two chambers by a dividing net. Four sided and top portion of the net house was covered with fine mesh net. Twelve plants leaves from 6 different host plants were placed inside the net house. In both the chambers aphid and ladybird beetles were released for providing adequate supply for these two insects.

3.5.2. Mass culture of Ladybird beetle

Mass production of ladybird beetle (*Epilachna paniculata*) was done for this lab experiment. Some adult ladybird beetles were collected from different host plants from the field experiment plots. Bean aphid (*Lipaphis erysimi*) were provided as food for mass culture of the predator. The ladybird beetles were kept as single pair of male and female in several petridishes (9×2 cm) for mating. Every day field collected aphid from the field experiment plots infested in host plants leaf, inflorescence, twig and pods were supplied in the petridishs as food for the ladybird beetles. The observations were made at several times with regular interval daily. Females laid yellow spindle shaped eggs in masses in the supplied host plants leaf, inflorescence, twig and pods and on the side of the petridishes. The eggs were kept undisturbed in the petridishes for hatching. After hatching eggs, newly emerged larvae were transferred to several petridishes with the help of a brush and reared till adult emergence. Each petrishes contained 10-15 larvae of ladybird beetles. Aphid were supplied at this stage too. The newly emerged adults were placed in other petridishes of same size having one male and female with the adequate supply of aphid as food for measure the consumption rate. Both the larvae and adult ladybird beetles consumption were subsequently recorded.

3.6 Data collection

Data were collected from Wheat, Brinjal, Tomato, Potato, Bean, Mustard as host plant at five (5) intervals available in Sher-e-Bangla Agricultural University experimental field during the study December 2021 to June 2022.

Data will be collected on the following parameters:

1. Total number of Aphid leaf^{-1}
2. Total number of Aphid inflorescence^{-1}
3. Total number of Aphid twig^{-1}
4. Total number of Aphid on pod^{-1}
5. Total number of ladybird beetle leaf^{-1}
6. Total number of ladybird beetle inflorescence^{-1}

7. Total number of ladybird beetle twig^{-1}
8. Total number of ladybird beetle on pod^{-1}
9. Predation efficacy of ladybird beetle on aphid at DAS

3.6.1 Incidence of aphid in different crops

Incidence of aphid was recorded from wheat, brinjal, tomato, potato, country bean and mustard field of experimental field of Sher- e-Bangla Agricultural University, Dhaka by visual observation. For each location 3m^2 area (each plot) was taken for the counting of aphid incidence. 1m^2 stick was used for measuring area. The point where a centre position was taken and from the centre position 1m^2 land was taken from in front side, left and right side. Number of aphids were recorded at reproductive stage randomly 5 (five) plants were selected to collect the data for aphid per leaf inflorescence, twig and pod.

3.6.2 Incidence of ladybird beetle in the field conditions

Incidence of ladybird beetle was recorded from wheat, brinjal, tomato, potato, country bean and mustard field of experimental field of Sher- e-Bangla Agricultural University, Dhaka by visual observation. For each location 3m^2 area (each plot) was taken for the counting of ladybird beetle incidence. 1m^2 stick was used for measuring area. The point where a centre position was taken and from the centre position 1m^2 land was taken from in front side, left and right side. Then incidence of beetle was counted at the time of early morning and data was recorded for per leaf, twig, inflorescence and pod.

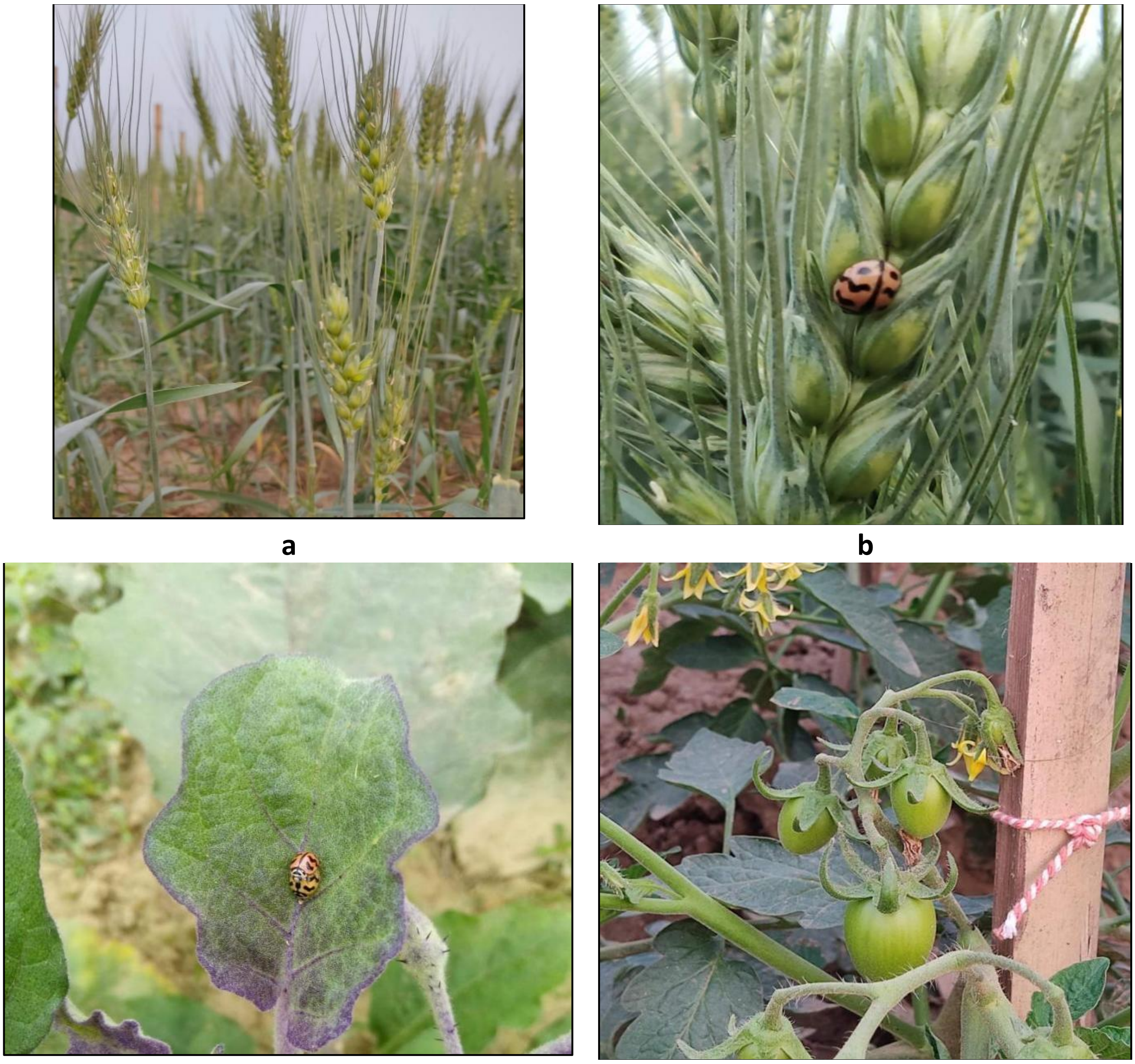
a

b

Plate 01. a (Mustard), b (Country bean) Selected crops for the measurement of host preference.

a b

Plate 02. a (Wheat), b (Potato) Selected crops for the measurement of host preference.



a b

c d

Plate 03. a and b (Wheat), c (Brinjal) and d (Tomato) shows presence of ladybird beetle in different host.

3.6.3 Predation efficacy of ladybird beetle on aphid

For the determination of predation of adult beetle, pair of (2) adult beetles were transferred to individual petridishes and cultured individually. 50 aphids were placed in each plant and after 24 hours new aphid was introduced. Aphids were counted under magnifying glass. This process was continued till the death and consumption of aphid were recorded. Number of aphids consumed by ladybird beetle were recorded.

a

b

Plate 05. a, b Showing predatory efficacy of ladybird beetles larvae.

3.7 Data analysis

The data obtained from experiment on various parameters were statistically analysed in MSTAT-C computer program (Russell, 1986). The mean values for all the parameters were calculated and the significance of difference between pair of means was tested by the Least Significant Differences (LSD) test at 5 % levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present research work was carried out to investigate the host plant preference of aphids and their predation by ladybird beetles at Sher-e-Bangla Agricultural University campus. The data have been presented and discusssed and possible interactions are made under the following sub-headings:

4.1 Host preference of aphid in different field crops

4.1.1 Incidence of aphid on leaf in different crops at 7, 14, 21, 28 and 35 DAS

Incidence of the aphid on leaf were recorded at different growth stages of six host plants evaluated in field condition. The highest number (33.10 aphid/leaf) of aphid was recorded in Country bean plant at 7 DAS, and then 23.67, 25.67, 28.30 and 29.67 at 14 DAS, 21 DAS, 28 DAS, and 35 DAS respectively. The lowest (8.00 aphid/leaf) aphid were recorded in Wheat plant at 14 DAS, and then 8.30, 9.00, 14.66 and 19.67 aphid/leaf at 7, 21, 28, and 35 DAS respectively (Table 1). aphid often have a low mobility in their immature stages, and thus have little opportunity to change the location of their development. Similar observation was also obtained by Hassan *et al.* (2012) who also found that aphid highly preferred country bean.

Table 1. Incidence of aphid leaf^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of aphid leaf^{-1}				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Wheat	8.30 cd	8.00 d	9.00 d	14.66 d	19.67 bc
Brinjal	13.30 bc	15.66 c	16.67 c	21.30 b	25.90 b
Tomato	15.67 ab	18.30 b	18.67 b	20.10 cd	28.67 ab
Potato	13.33 bc	15.67 c	16.20 c	19.66 cd	23.66 bc
Country bean	19.33 a	23.67 a	25.67 a	28.30 a	29.67 a
Mustard	10.66 c	15.67 c	18.33 c	20.67 bc	21.30 bc
LSD (0.05)	4.29	2.06	3.61	2.69	4.70
CV%	18.14	10.19	6.87	5.14	7.26

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.1.2 Incidence of aphid inflorescence^{-1} in different crops at 7, 14, 21, 28 and 35 DAS

Incidence of aphid inflorescence^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at inflorescence of six host plants evaluated in field condition. The highest number (9.67 aphid/inflorescence)of aphids were recorded in Country bean plant at 28 DAS while, 9.60 aphid/inflorescence at 21 DAS, 9.56 aphid/inflorescence at 35 DAS, 9.30 aphid/inflorescence at 28 DAS and 9.00 aphid/inflorescence at 7 DAS. The lowest (3.00 aphid/inflorescence) aphids were recorded in Wheat plant at 14 DAS while, 3.33 aphid/inflorescence at 7 DAS, 4.66 aphid/inflorescence at 21 DAS, 5.33 aphid/inflorescence at 28 DAS and 6.30 aphid/inflorescence at 35 DAS, (Table 2).

Table 2. Incidence of aphid inflorescence^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of aphid inflorecence^{-1}				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Wheat	3.33 e	3.00 e	4.66 e	5.33 e	6.30 c
Brinjal	7.67 b	5.00 c	9.00 b	8.00 b	9.33 ab
Tomato	5.33 c	5.50 b	8.30 c	8.67 c	9.66 ab
Potato	5.00 d	4.33 d	6.00 d	6.30 d	9.66 ab
Country bean	9.00 a	9.67 a	9.60 a	9.30 a	9.56 a
Mustard	5.00 c	5.33 bc	8.33 c	8.00 b	8.67 b
LSD (0.05)	0.36	0.40	0.46	0.21	0.41
CV%	8.30	9.79	6.10	8.30	5.41

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.1.3 Incidence of aphid twig^{-1} in different crops at 7, 14, 21, 28 and 35 DAS

Incidence of aphid twig^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of five host plants evaluated in natural field condition. Table 3 revealed that the highest number (15.67 aphid/twig) of aphids were recorded in Country bean plant at 7 DAS, whereas, 15.15 aphid/twig, 14.30 aphid/twig, 13.98 aphid/twig and 13.30 aphid/twig at 14 DAS, 21 DAS, 28 DAS, 35 DAS respectively. At 7 DAS, the lowest number (8.00 aphid/twig) were recorded in Potato plant 9.33 aphid/twig at 14 DAS, 10.33 aphid/twig at 28 DAS and 11 aphid/twig at 35 DAS in potato plant and 12.10 aphid/twig at 21 DAS in brinjal plant (Table 3).

Table 3. Incidence of aphid twig^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of aphid twig^{-1}				
	7 DAS	**14 DAS**	**21 DAS**	**28 DAS**	**35 DAS**
Brinjal	13.10 bc	13.00 b	12.10 c	11.98 bc	11.00 e
Tomato	12.60 bc	13.25 ab	12.50 ab	11.50 bc	11.33 d
Potato	8.00 c	9.33 c	12.35 ab	10.33 c	11.00 e
Country bean	15.67 a	15.15 a	14.30 a	13.94 a	13.30 a
Mustard	15.00 ab	13.25 ab	14.00 ab	13.50 ab	12.90 b
LSD (0.05)	1.53	1.03	0.95	0.48	0.37
CV%	7.81	9.55	8.60	7.05	6.82

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.1.4 Incidence of aphid on pod^{-1} of different crops at 7, 14, 21, 28 and 35 DAS

Incidence of aphid on pod^{-1} of different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of two host plants evaluated in field condition. Table 4 revealed that the highest number (6.00 pod^{-1})of aphids were recorded in mustard and the lowest (5.94 pod^{-1}) aphids were recorded in country bean plant which was statistically similar at 7 DAS. The highest (5.01 pod^{-1}) aphids were recorded in mustard and the lowest (5.25 pod^{-1}) aphids were recorded in country bean plant which was statistically similar at 14 DAS. The highest (4.30 pod^{-1}) aphids were recorded in country bean and the lowest (4.00 pod^{-1}) aphids were recorded in mustard statistically similar at 21 DAS. The highest (4.50 pod^{-1}) aphids were recorded in mustard and the lowest (3.10 pod^{-1}) aphids were recorded in country bean at 28 DAS. The highest (2.36 pod^{-1}) aphids were recorded in Country bean plant and the lowest (2.30 pod^{-1}) aphids were recorded in mustard at 35 DAS.

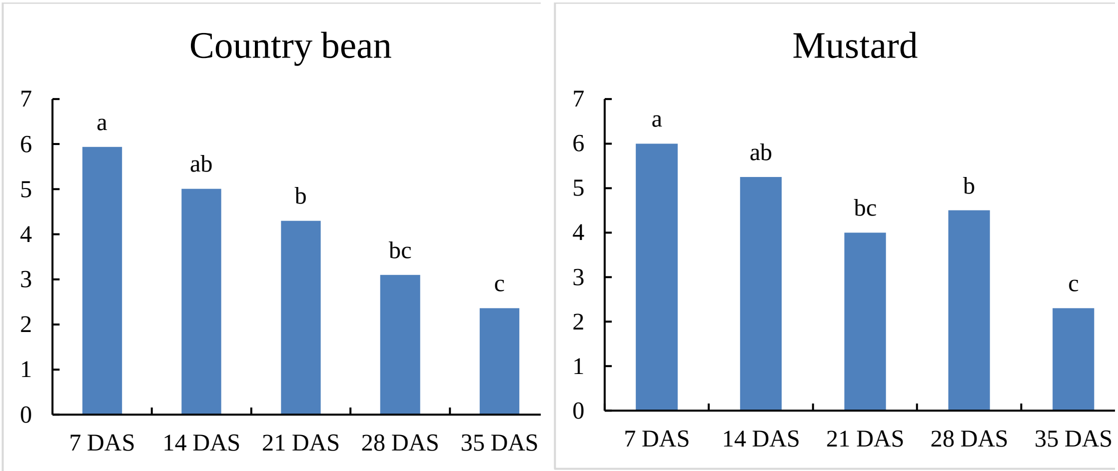


Figure 1. Incidence of aphid on pod^{-1} of different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

4.1.5 Incidence of aphid plant^{-1} in different crops at 7, 14, 21, 28 and 35 DAS

Incidence of aphid plant^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of six host plants evaluated in natural field condition. Table 4 revealed that the highest number (54.51 aphid/plant) of aphids were recorded in Country bean plant at 7 DAS, whereas, 50.01 aphid/plant, 43.30 aphid/plant, 32.10 aphid/plant and 21.36 aphid/plant at 14 DAS, 21 DAS, 28 DAS, 35 DAS respectively. At 7 DAS, the lowest (31.20 aphid/plant) aphids were recorded 25.01 aphid/plant at 14 DAS in Potato plant and 16.10 aphid/plant at 21 DAS, 11.87 aphid/plant at 28 DAS and 8 aphid/plant at 35 DAS in Brinjal plant (Table 4). Wheat lacks phytohormone concentrations to defend itself from insect's pests (Sadeghi *et al.* 2021). In addition, the high host fidelity of wheat also ensures female oviposition on the original host plant. A higher number of aphids toward infested wheat as host plant are confirmation with the investigations of Dicke (2009), Francis *et al.* (2014)

they found that, the aphid are known to be associated with odour of infested host plants and volatile cues released by plants in response to feeding by their herbivore prey.

Table 4. Incidence of aphid plant^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of aphid plant^{-1}				
	7 DAS	**14 DAS**	**21 DAS**	**28 DAS**	**35 DAS**
Wheat	43.23 b	40.01 b	27.56 b	22.40 b	15.98 b
Brinjal	33.21 c	30.00 c	16.10 d	11.87 c	8.00 d
Tomato	36.60 c	30.24 c	25.38 c	19.50 b	14.29 b
Potato	31.20 c	25.01d	24.35 c	15.00 bc	10.00 cd
Country bean	54.51 a	50.01 a	43.30 a	32.10 a	21.36 a
Mustard	36.00 c	31.20 c	24.00 c	18.50 b	12.30 c
LSD (0.05)	7.67	5.02	3.29	4.41	2.10
CV%	12.40	12.12	9.87	10.16	8.57

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.2 Incidence of ladybird beetle in different field crops

4.2.1 Incidence of ladybird beetle leaf^{-1} in different crops at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Incidence of ladybird beetle leaf^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of six host plants evaluated in field condition. The highest number (2.66 ladybird beetle/leaf) of ladybird beetles were recorded in Country bean plant at 7 DAS, and then 2.66, 2.67, 2.10, 2.30 and 2.67 ladybird beetle/leaf at 14, 21, 28, and 35 DAS respectively. The lowest (0.67 ladybird beetle/leaf) ladybird beetles were recorded in Wheat plant at 35 DAS (Figure 1). These results were agreed with those of Khan (2012).

Table 5. Incidence of ladybird beetle leaf^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of ladybird beetle leaf^{-1}				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Wheat	1.30 c	1.00 c	1.00 d	0.66 d	0.67 c
Brinjal	1.30 c	1.66 ab	1.67 ab	1.30 b	1.90 ab
Tomato	1.67 ab	1.30 b	1.67 ab	1.10 cd	1.67 ab
Potato	1.33 bc	1.67 ab	1.20 c	0.67 cd	1.03 bc
Country bean	2.66 a	2.67 a	2.10 a	2.30 a	2.67 a
Mustard	2.33 ab	2.67 a	1.98 ab	1.77 ab	2.30 ab
LSD (0.05)	0.20	1.06	1.61	1.19	1.70
CV%	1.14	1.19	1.80	2.15	2.83

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.2.2 Incidence of ladybird beetle inflorescence^{-1} in different crops at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Incidence of ladybird beetle inflorescence^{-1} in different crops at DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at inflorescence of six host plants evaluated in field condition. The highest number(1.67 ladybird beetle/inflorescence) of ladybird beetles were recorded in Country bean plant at 14 DAS. The lowest (0.00 ladybird beetle/inflorescence) ladybird beetles were recorded in brinjal plant at 14 DAS which is statistically identical with potato plant at 7 DAS, wheat plant at 14 DAS, brinjal plant at 21 DAS, potato plant at 21 DAS and brinjal plant at 28 DAS (Table 6). Similar observation was also reported by Hassan *et al.* (2012).

Table 6. Incidence of ladybird beetle inflorescence^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of ladybird beetle inflorecence^{-1}				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Wheat	0.33 c	0.00 c	0.66 e	0.33 bc	0.30 c
Brinjal	0.67 b	0.00 c	0.00 b	0.00 c	0.33 b
Tomato	0.33 c	0.50 b	0.30 c	0.67 b	0.66 ab
Potato	0.00 d	0.33 d	0.00 d	0.30 bc	0.67 ab
Country bean	1.00 a	1.67 a	0.67 a	0.80 ab	0.75 a
Mustard	1.00 a	1.33 ab	0.60 ab	1.00 a	0.67 ab
LSD (0.05)	0.36	0.40	0.35	0.21	0.41
CV%	1.30	1.70	2.10	2.30	4.41

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.2.3 Incidence of ladybird beetle twig^{-1} in different crops at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Incidence of ladybird beetle twig^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of five host plants evaluated in natural field condition. Table 7 revealed that the highest number (2.67 per twig) of ladybird beetles was recorded in Country bean plant at 7 DAS. At 14 DAS, the lowest (1 ladybird beetle/twig) ladybird beetles were recorded in brinjal plant (Table 7).

Table 7. Incidence of ladybird beetle twig^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of ladybird beetle twig^{-1}				
	7 DAS	**14 DAS**	**21 DAS**	**28 DAS**	**35 DAS**
Brinjal	1.10 d	1.00 c	1.10 b	1.98 bc	1.00 d
Tomato	1.60 bc	1.25 bc	1.50 ab	1.50 bc	1.33 c
Potato	1.33 cd	1.33 bc	1.35 ab	1.00 c	1.00 d
Country bean	2.67 a	2.15 ab	2.30 a	2.33 ab	2.30 a
Mustard	2.00 ab	2.25 a	2.00 ab	2.50 a	1.90 b
LSD (0.05)	0.70	0.71	0.92	0.73	.31
CV%	6.38	7.26	6.71	9.10	9.77

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.2.4 Incidence of ladybird beetle on pod^{-1} of different crops at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Incidence of ladybird beetle on pod^{-1} of different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of two host plants evaluated in laboratory condition. Table7 revealed that the highest number (1.51 pod^{-1}) of ladybird beetles were recorded in Country bean plant and the lowest (1.00 pod^{-1}) ladybird beetles were recorded in mustard at 7 DAS. The highest (0.67 pod^{-1}) ladybird beetles were recorded in mustard and the lowest (0.51 pod^{-1}) ladybird beetles were recorded in country bean at 14 DAS. The highest (0.67 pod^{-1}) ladybird beetles were recorded in mustard and the lowest (0.30 pod^{-1}) ladybird beetles were recorded in country bean at 21 DAS. The highest (0.50 pod^{-1}) ladybird beetles were recorded in mustard and the lowest (0.33 pod^{-1}) ladybird beetle was recorded in country bean at 28 DAS. The highest (0.36 pod^{-1}) ladybird beetles were recorded in Country bean plant and the lowest (0.30 pod^{-1}) ladybird beetles were recorded in mustard at 35 DAS.

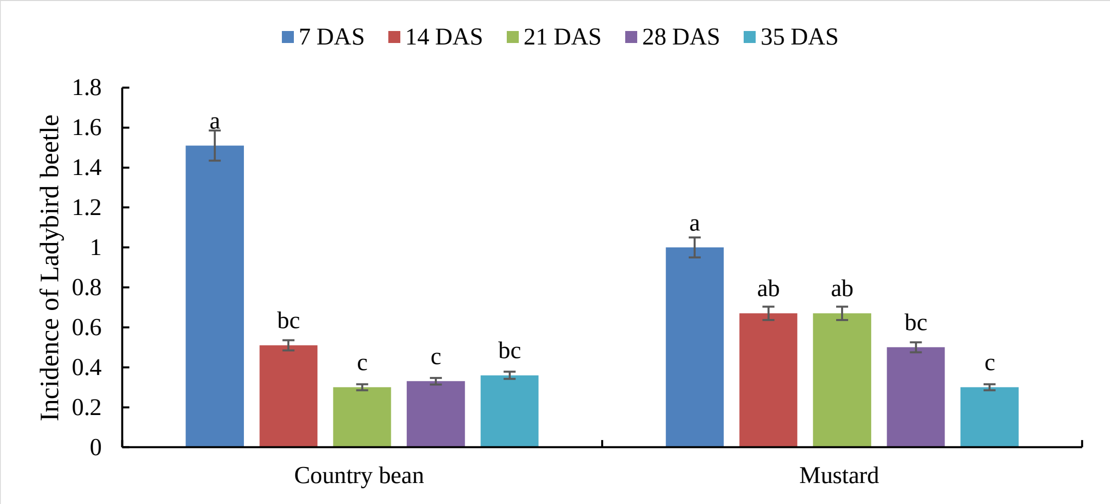


Figure 2. Incidence of ladybird beetle on pod^{-1} of different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

4.2.5 Incidence of ladybird beetle plant^{-1} in different crops at 7, 14, 21, 28 and 35 DAS

Incidence of ladybird beetle plant^{-1} in different crops at 7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS were recorded at different growth stages of six host plant evaluated in natural field condition. Table 8 revealed that the highest ladybird beetles was recorded in Country bean plant 6.00 ladybird beetle/plant at 7 DAS, whereas, 5.67 ladybird beetle/plant, 4.30 ladybird beetle/plant, 3.95 ladybird beetle/plant and 3.36 ladybird beetle/plant at 14DAS, 21DAS, 28DAS, 35 DAS, respectively. At 7 DAS, the lowest (3.20 ladybird beetle/plant) ladybird beetles were recorded in Potato plant whereas, 2.01 ladybird beetle/plant,1.00 ladybird beetle/plant and 1.00 ladybird beetle/plant at 14DAS, 28DAS, 35 DAS, respectively and 1.10 ladybird beetle/plant at 21 DAS in brinjal (Table 8). These results were agreed with those of Khan (2012).

Table 8. Incidence of ladybird beetle plant^{-1} on different host plants at different DAS (7 DAS, 14 DAS, 21 DAS, 28 DAS, 35 DAS)

Host plants	Incidence of ladybird beetle plant^{-1}				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Wheat	4.23 c	4.01 c	2.56 bc	2.40 bc	1.98 b
Brinjal	3.21 cd	3.00 cd	1.10 d	1.87 bc	1.00 d
Tomato	3.60 c	3.24 cd	2.38 bc	1.50 cd	1.29 c
Potato	3.20 d	2.01 d	2.35 bc	1.00 d	1.00 d
Country bean	6.00 a	5.67 a	4.30 a	3.95 a	3.36 a
Mustard	5.51 b	5.20 b	4.00 ab	3.50 ab	3.30 ab
LSD (0.05)	0.58	1.02	1.29	1.41	0.30
CV%	1.40	2.15	2.73	1.16	2.50

[DAS= Days after sowing; In a column, means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability]

4.3 Relationship between the Incidence of aphid with incidence of ladybird beetle on different host plants

4.3.1 Relationship between the incidence of aphid with incidence of ladybird beetle on wheat

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on wheat, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on wheat. It was recorded that the equation y=0.087x + 0.45 considered as good fit and co-efficient value R^2=0.974 considered as significant regression co-efficient expressing 97% positive correlation between the incidence of aphid with incidence of ladybird beetle on wheat. Divergent host preference (i.e., host fidelity) plays a significant role in the speciation process in aphid. Highest number aphid was found (43.23) on wheat plant with the positive correlation with the highest number of ladybird beetle (4.23). So, it may be concluded from figure 6 number of aphids was positively correlated with the number of ladybird beetle on wheat as host plant.

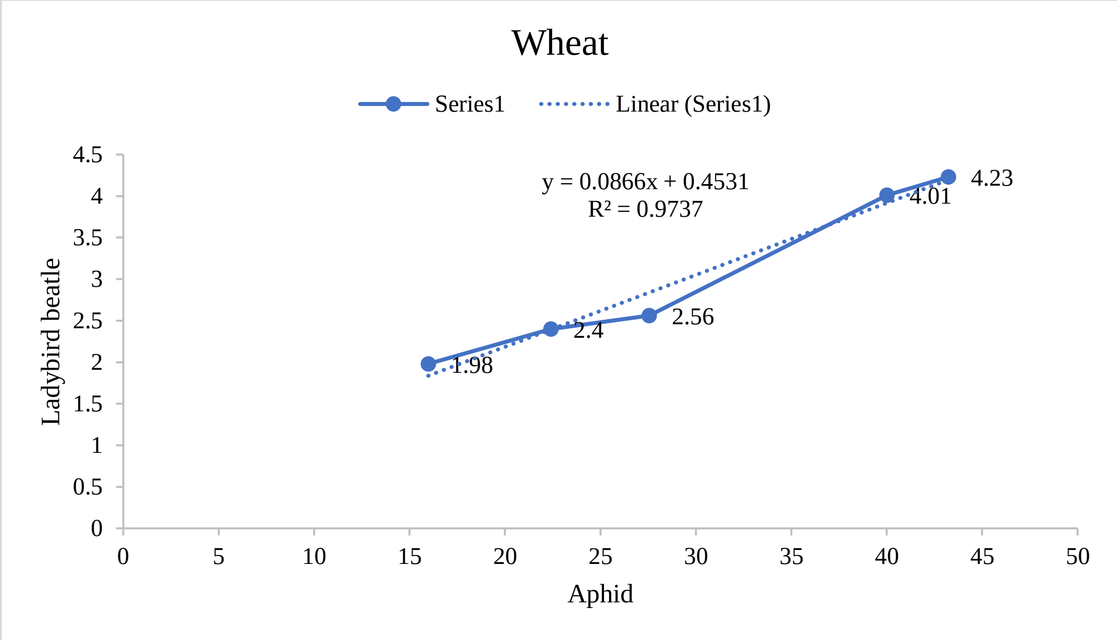


Figure 3. Relationship between the incidence of aphid with incidence of ladybird beetle on wheat

4.3.2 Relationship between the incidence of aphid with incidence of ladybird beetle on brinjal

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on brinjal, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on brinjal. It was recorded that the equation $y=0.085x + 0.35$ considered as good fit and co-efficient value $R^2=0.847$ considered as significant regression co-efficient expressing 85% positive correlation between the incidence of aphid with incidence of ladybird beetle on brinjal. Highest number aphid was found (33.21) on brinjal plant with the positive correlation with the highest number of ladybird beetle (3.21) and also lowest number of aphid (8) also correlate with the lowest number of ladybird beetle (1). So, it may be concluded from Figure 7 number of aphids were positively correlated with the number of ladybird beetle on brinjal as host plant.

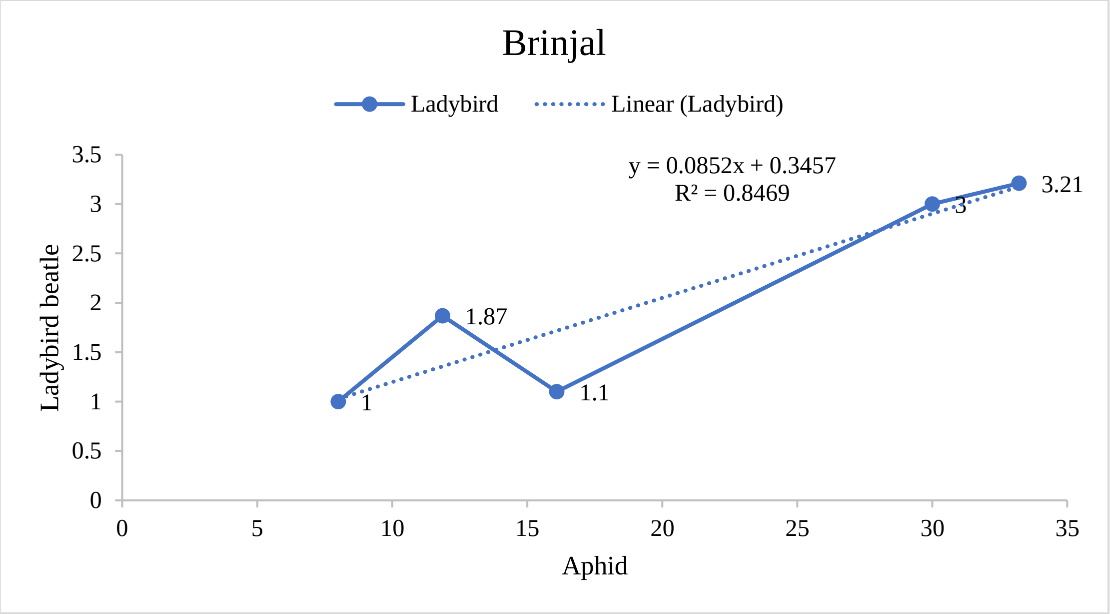


Figure 4. Relationship between the incidence of aphid with incidence of ladybird beetle on brinjal

4.3.3 Relationship between the incidence of aphid with incidence of ladybird beetle on tomato

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on tomato, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on tomato. It was recorded that the equation y=0.115x + 0.48 considered as good fit and co-efficient value R^2=0.961 considered as significant regression co-efficient expressing 96% positive correlation between the incidence of aphid with incidence of ladybird beetle on tomato. Highest number aphid was found (36.60) on tomato plant with the positive correlation with the highest number of ladybird beetle (3.67) and also lowest number of aphid (14.29) also correlate with the lowest number of ladybird beetle (1.29). So, it may be concluded from Figure 8 number of aphid was positively correlated with the number of ladybird beetle on tomato as host plant.

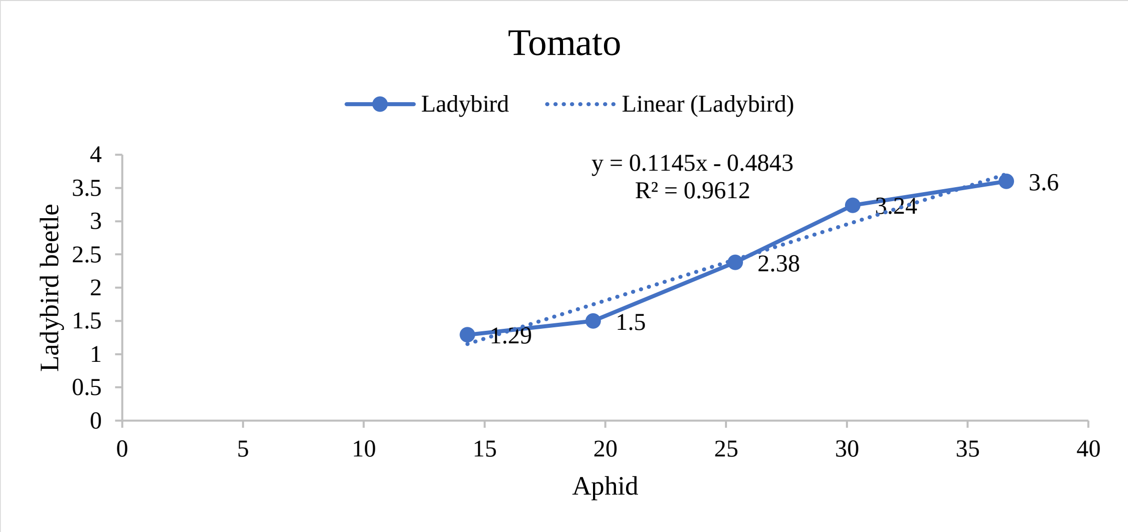


Figure 5. Relationship between the incidence of aphid with incidence of ladybird beetle on tomato

4.3.4 Relationship between the incidence of aphid with incidence of ladybird beetle on potato

Relationship between the incidence of aphid with incidence of ladybird beetle on potato, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on potato. It was recorded that the equation y=0.106x + 0.32 considered as good fit and co-efficient value R^2=0.916 considered as significant regression co-efficient expressing 92% positive correlation between the incidence of aphid with incidence of ladybird beetle on potato. Alos, negative correlation was observed between the incidence of aphid with incidence of ladybird beetle on potato. The number of ladybird beetles decreased (1, 15) when there were aphids. Highest number aphid was found (31.2) on potato plant with the positive correlation with the highest number of ladybird beetle (3.2) and also lowest number of aphid (10) also correlate with the lowest number of ladybird beetle (1). So, it may be concluded from Figure 6 number of aphids were positively correlated with some abnormalities with the number of ladybird beetle on potato as host plant.

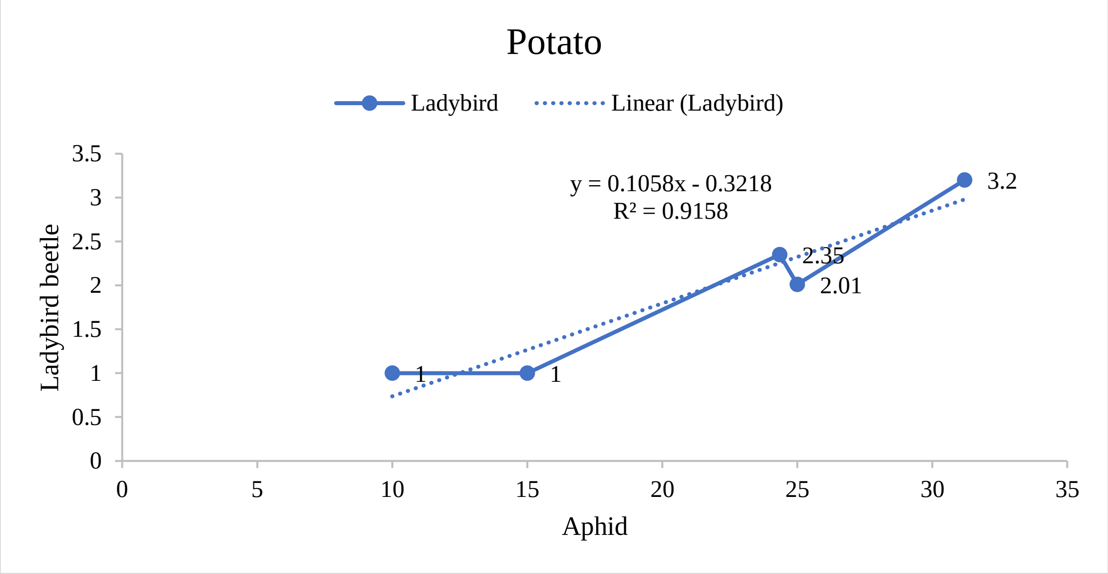


Figure 6. Relationship between the incidence of aphid with incidence of ladybird beetle on potato

4.3.5 Relationship between the incidence of aphid with incidence of ladybird beetle on country bean

Relationship between the incidence of aphid with incidence of ladybird beetle on country bean, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on country bean. It was recorded that the equation y=0.0796x + 1.45 considered as good fit and co-efficient value R^2=0.902 considered as significant regression co-efficient expressing 90% positive correlation between the incidence of aphid with incidence of ladybird beetle on country bean. Highest number aphid was found (54.51) on country bean plant with the positive correlation with the highest number of ladybird beetle (6) and also lowest number of aphid (21.36) also correlate with the lowest number of ladybird beetle (3.36). So, it may be concluded from Figure 7 number of aphid was positively correlated with the number of ladybird beetle on country bean as host plant. But the presence of ladybird beetle against the number of aphid was relatively low compared to other host plants.

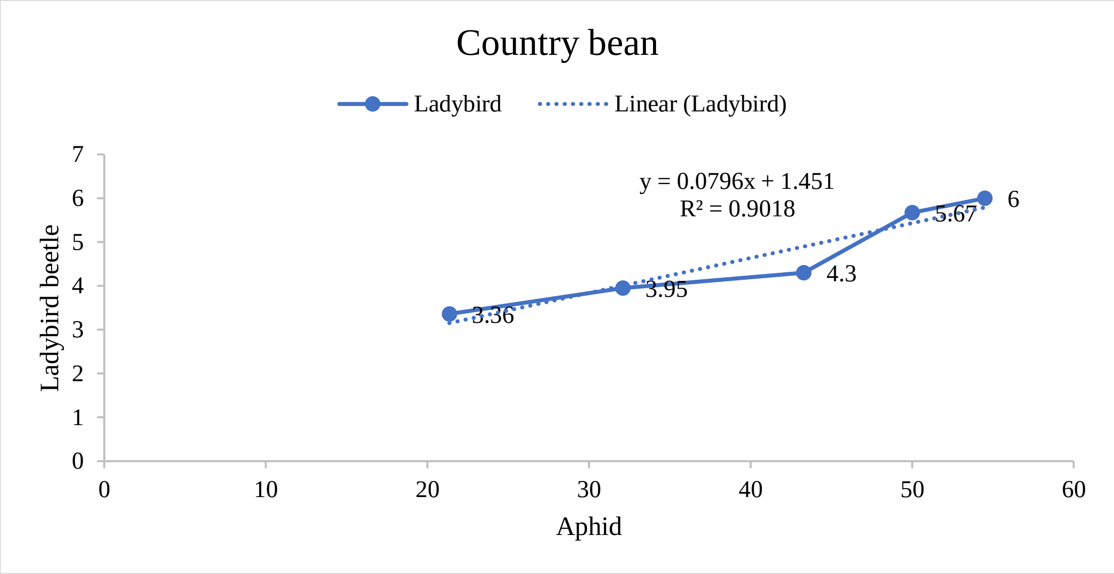


Figure 7. Relationship between the incidence of aphid with incidence of ladybird beetle on country bean

4.3.6 Relationship between the incidence of aphid with incidence of ladybird beetle on mustard

Relationship between the incidence of aphid with incidence of ladybird beetle on mustard, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Positive correlation was observed between the incidence of aphid with incidence of ladybird beetle on mustard. It was recorded that the equation y=0.177x + 0.496 considered as good fit and co-efficient value R^2=0.885 considered as significant regression co-efficient expressing 89% positive correlation between the incidence of aphid with incidence of ladybird beetle on mustard. Highest number aphid was found (36) on mustard plant with the positive correlation with the highest number of ladybird beetle (5.51) and also lowest number of aphid (14.29) also correlate with the lowest number of ladybird beetle (1.29). So, it may be concluded from Figure 8 number of aphid was positively correlated with some abnormalities, the number of ladybird beetle on mustard as host plant. But the presence of ladybird beetle against the number of aphid was relatively low compared to other host plants.

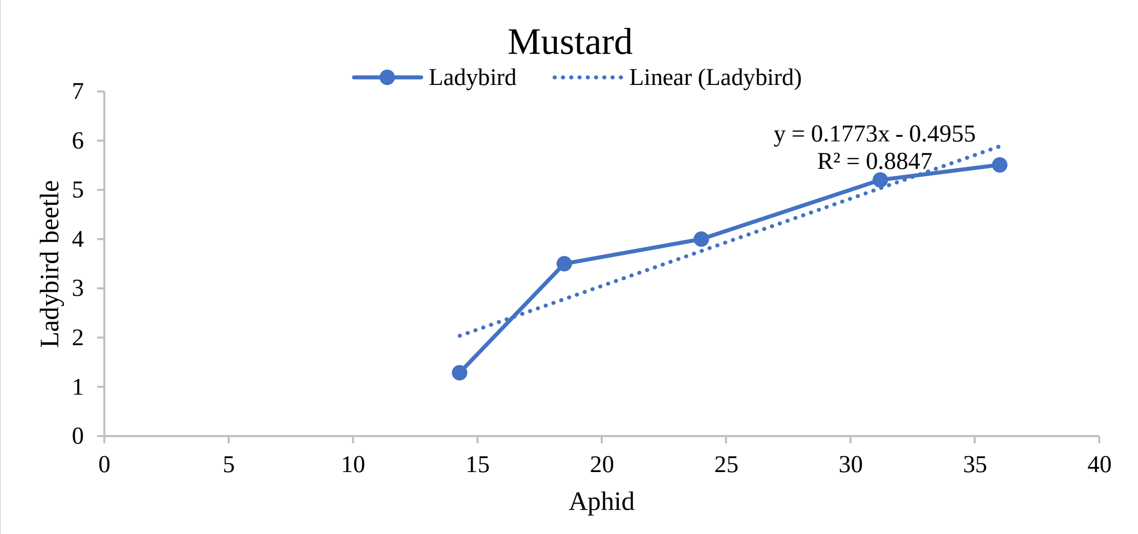


Figure 8. Relationship between the incidence of aphid with incidence of ladybird beetle on mustard

4.4. ladybird beetle predation efficacy on Aphid

4.4.1 Consumption of aphid by larvae of ladybird beetle on different host plants

The consumption of aphid was statistically significant at each time in every measured on different host plants. The highest consumption of aphid per host plant by larvae of ladybird beetles released in different host plants was on average 4.34 aphids were consumed at 2 hours intervals, 4.13 aphids at 12 hours intervals, 4.10 aphids at 4 hours intervals, 3.56 aphids at 6 hours intervals, 3.48 aphids at 10 hours intervals, and 3.31 aphids at 8 hours intervals. The lowest consumption of aphid per host plant by larvae of ladybird beetles released of host plants 1.10 aphids at 8 hours intervals, 1.20 aphids at 10 hours intervals, 1.21 aphids at 6 hours intervals, 2.10 aphids at 4 hours intervals, 2.15 aphids at 12 hours intervals, and 2.31 aphids at 2 hours intervals. (Table 9). The ladybird beetle responded positively to volatiles from the aphid. Ladybird beetles (Coccinellids) are ancient and very successful group of predatory insects belonging to order Coleoptera. Lady beetles can be mass-reared for use against aphids or other pests. The olfactory learning by a predatory coccinellids beetle is very effective. Predatory coccinellids can learn to associate the odour of aphid infested plants due to the presence of volatile cues released by plants in response to feeding by their herbivores (Dicke, 2009). Ladybird foraging involves navigation through a complex landscape in which suitable high quality food sources are found and exploited when they are available (Pettersson *et al.*, 2005).

Table 9. Consumption of aphid by larvae of ladybird beetle at different time intervals.

Host plants	Mean number of aphids consumed per predator at different time (hours) intervals					
	2	**4**	**6**	**8**	**10**	**12**
Wheat	2.31 b	2.10 b	1.21 c	1.10 c	1.20 c	2.15 b
Brinjal	2.45 ab	2.40 ab	1.43 bc	1.32 bc	1.41 bc	2.50 ab
Tomato	2.89 ab	2.60 ab	1.85 ab	1.62 ab	1.82 ab	2.58 ab
Potato	3.10 ab	3.40 ab	2.10 ab	2.02 ab	2.06 ab	3.42 ab
Country bean	4.34 a	4.10 a	3.56 a	3.31 a	3.48 a	4.13 a
Mustard	4.30 ab	4.00 ab	3.33 ab	3.00 ab	3.33 ab	4.00 ab
LSD (0.05)	1.31	1.38	1.28	1.41	1.21	1.63
CV%	5.68	7.42	4.80	6.55	9.73	7.02

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).]

4.4.2 Consumption of aphid by adult ladybird beetles on different host plants

Table 10 revealed that the highest consumption of aphid per host plant by adult ladybird beetles released in host plants was on average 3.10 aphids were consumed at 12 hours intervals, 2.80 aphid at 2 hours intervals, 2.20 aphid at 10 hours intervals, 2.10 aphids at 4 hours and 8 hours intervals, 2.03 aphids at 6 hours intervals. The lowest consumption of aphid per host plant by adult ladybird beetles released of host plants 1.10 aphids at 6 hours intervals, 1.20 aphids at 8 hours intervals, 1.30 aphids at 4 hours intervals, 1.40 aphids at 2 hours, 1.60 aphids at 10 hours intervals, and 1.70 aphids at 12 hours intervals. The results of another study also indicate that the starved adult beetles consumed a greater number of aphids than well-fed adults (Sharma and Joshi, 2010).

Table 10. Consumption of aphid by adult ladybird beetles at different time intervals.

Host plants	Mean number of aphids consumed per predator at different time (hours) intervals					
	2	**4**	**6**	**8**	**10**	**12**
Wheat	1.40 b	1.30 c	1.10 b	1.20 b	1.60 b	1.70 b
Brinjal	2.10 ab	1.60 b	1.20 b	1.30 b	1.80 a b	2.30 ab
Tomato	2.70 ab	1.60 b	1.60 ab	1.73 ab	1.80 ab	2.70 ab
Potato	2.55 ab	2.05 ab	1.68 ab	1.70 ab	2.10 ab	2.50 ab
Country bean	2.80 ab	2.10 ab	2.03 ab	2.10 ab	2.20 ab	3.10 ab
Mustard	2.87 a	2.15 a	2.53 a	2.10 a	2.25 a	3.33 a
LSD (0.05)	0.45	0.71	0.48	0.43	0.71	1.07
CV%	8.69	10.32	5.78	7.81	6.93	8.34

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT)]

4.4.3 Predation efficacy of ladybird beetle

Predation efficacy of ladybird beetle depends on the searching behaviour, size as well as on the surrounding nature of environment. The predation efficacy of grub and adult was ascertained by counting the total number of aphids engrossed by each instar of grub and adult within 24 hours. Both the grub and adult fed on aphid voraciously but their rate of feeding varied. They feed intermittently both day and night, but mainly in day time. The rate of consumption aphid was increased with time. Adult of ladybird beetle were consumed aphid voraciously and the rate become very high. Adult male consumed 680-785 aphids on an average 750.33 aphids while adult female consumed 875-950 aphids on an average 875.15 aphids respectively (Table 11). Some author also observed the same result (Islam, 2006).

Table 11. Predatory efficacy of lady bird beetle on aphid

Stages	Minimum	Maximum	Average
Total larval predation	71	125	100.04
Adult male predation	680	785	750.33
Adult female predation	875	950	875.15

CHAPTER V

SUMMARY AND CONCLUSION

The study on host plant preference of aphid and predation of ladybird beetles was conducted at Sher-e-Bangla Agricultural University campus. The experiment included field study of aphids host preference and predation was conducted during December, 2021 to April, 2022. The research consists of six different crop fields like Wheat, Brinjal, Tomato, Potato, Country bean and Mustard fields.

Significant percentage of incidence of the aphid on plant were recorded at different growth stages of six host plant varieties evaluated in natural field condition. Table 1 revealed that the highest (54.51 per plant) aphid was recorded in Country bean plant at 7 DAS whereas 50.01 aphid/plant, 43.30 aphid/plant, 32.10 aphid/plant and 21.36 aphid/plant at 14, 21, 28, 35 DAS respectively. At 7 DAS, the lowest (31.20 aphid/plant) aphids was recorded in Potato plant; in Brinjal plant 30 aphid/plant (at 14 DAS), 16.10 aphid/plant (at 21 DAS), 11.87 aphid/plant at 28 DAS and 8 aphid/plant at 35 DAS (Table 1).

Significant percentage of incidence of the aphid on leaf were recorded at different growth stages of six host plant varieties evaluated in field condition. The highest (33.10 aphid/leaf) aphid was recorded in Country bean plant at 7 DAS, and then 23.67, 25.67, 28.30 and 29.67 at 14, 21, 28, and 35 DAS respectively. The lowest (8.00 aphid/leaf) aphid were recorded in Wheat plant at 14 DAS, and then 8.30, 9.00, 14.66 and 19.67 aphid/leaf at 7, 21, 28, and 35 DAS respectively. Significant number of the aphid were recorded at inflorescence of six host plant varieties evaluated in field condition. The highest (9.67 aphid/inflorescence) ladybird beetles were recorded in Country bean plant at 28 DAS while, 9.60 aphid/inflorescence at 21 DS, 9.56 aphid/inflorescence at 35 DAS, 9.30 aphid/inflorescence at 28 DAS and 9.00 aphid/inflorescence at 7 DAS. The lowest (3.00 aphid/inflorescence) aphids was recorded in Wheat plant at 14 DAS while, 3.33 aphid/inflorescence at 7 DAS, 4.66 aphid/inflorescence at 15 DAS, 5.33 aphid/inflorescence at 28 DAS and 6.30 aphid/inflorescence at 35 DAS.

Significant percentage of incidence of the aphid on twigs were recorded at different growth stages of six host plant varieties evaluated in natural field condition. Table 4 revealed that the highest (5.67 per twig) aphids was recorded in Country bean plant at 7 DAS whereas 5.15 aphid/twig, 4.30 aphid/twig, 3.98 aphid/twig and 3.30 aphid/twig at 14, 21, 28, 35 DAS respectively. At 7 DAS, the lowest (1.33 aphid/twig) aphids was recorded in Potato plant; in potato plant 1.33 aphid/twig at 21 DAS 1 aphid/twig at 28 DAS and 1 aphid/twig at 35 DAS. Significant percentage of incidence of the aphid on pod^{-1} were recorded at different growth stages of six host plant varieties evaluated in field condition. Table 5 revealed that the highest (6 per pod^{-1}) aphid was recorded in mustard plant at 7 DAS whereas 5.25 aphid/ pod^{-1} 4 pod^{-1}, 4.50 aphid/ pod^{-1}and 2.3 aphid/ pod^{-1} 14, 21, 28, 35 DAS respectively.

Significant percentage of incidence of the ladybird beetle on plant were recorded at different growth stages of six host plant varieties evaluated in natural field condition. Table 6 revealed that the highest (6 per plant) ladybird beetles was recorded in Country bean plant at 7 DAS whereas 5.67 ladybird beetle/plant, 4.30 ladybird beetle/plant, 3.95 ladybird beetle/plant and 3.36 ladybird beetle/plant at 14, 21, 28, 35 DAS respectively. At 7 DAS, the lowest (3.20 ladybird beetle/plant) ladybird beetles was recorded in Potato plant. Significant percentage of incidence of the ladybird beetle on leaf were recorded at different growth stages of six host plant varieties evaluated in field condition. The highest (2.66 ladybird beetle/leaf) ladybird beetle was recorded in Country bean plant at 7 DAS, and then 2.66, 2.67, 2.10, 2.30 and 2.67 ladybird beetle/leaf at 14, 21, 28, and 35 DAS respectively. The lowest (0.67 ladybird beetle/leaf) ladybird beetle were recorded in Wheat plant at 35 DAS.

Significant number of the ladybird beetle were recorded at inflorescence of six host plant varieties evaluated in field condition. The highest (1.67 ladybird beetle/inflorescence) ladybird beetles were recorded in Country bean plant at 14 DAS. The lowest (0.00 ladybird beetle/inflorescence) ladybird beetles was recorded in brinjal plant at 14 DAS. Significant percentage of incidence of the ladybird beetle on twigs were recorded at different growth stages of six host plant varieties evaluated in natural field condition. Table 9 revealed that the highest (1.67 per twig) ladybird beetles was recorded in Country bean plant at 7 DAS. At 14 DAS, the lowest (0 ladybird beetle/twig) ladybird beetles was recorded in brinjal plant

Significant percentage of incidence of the aphid on pod^{-1} were recorded at different growth stages of six host plant varieties evaluated in laboratory condition. Table 10 revealed that the highest (1.51 per pod^{-1}) ladybird beetles was recorded in Country bean plant at 7 DAS and 0.51 ladybird beetle/ pod^{-1}, 0.30 ladybird beetle/ pod^{-1}, 0.33 ladybird beetle/ pod^{-1} and 0.36 ladybird beetle/ pod^{-1} at 14, 21, 28, 35 DAS respectively.

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on wheat, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Divergent host preference (i.e. host fidelity) plays a significant role in the speciation process in aphid. Highest number aphid was found (43.23) on wheat plant with the positive correlation with the highest number of ladybird beetle (4.23). So, it may be concluded from figure 6 number of aphid was positively correlated with the number of ladybird beetle on wheat as host plant.

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on brinjal, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Highest number aphid was found (33.21) on brinjal plant with the positive correlation with the highest number of ladybird beetle (3.21) and also lowest number of aphid (8) also correlate with the lowest number of ladybird beetle (1). So, it may be concluded from Figure 7 number of aphid was positively correlated with the number of ladybird beetle on brinjal as host plant.

Considering the relationship between the incidence of aphid with incidence of ladybird beetle on tomato, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Highest number aphid was found (36.60) on tomato plant with the positive correlation with the highest number of ladybird beetle (3.67) and also lowest number of aphid (14.29) also correlate with the lowest number of ladybird beetle (1.29). So, it may be concluded from Figure 8 number of aphid was positively correlated with the number of ladybird beetle on tomato as host plant.

Relationship between the incidence of aphid with incidence of ladybird beetle on potato, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Highest number aphid was found (36.60) on potato plant with the positive correlation with the highest number of ladybird beetle (3.67) and also lowest number of aphid (14.29) also correlate with the lowest number of ladybird beetle (1.29). So, it may be concluded from Figure 9 number of aphid was positively correlated with the number of ladybird beetle on potato as host plant.

Relationship between the incidence of aphid with incidence of ladybird beetle on country bean, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Highest number aphid was found (54.51) on country bean plant with the positive correlation with the highest number of ladybird beetle (6) and also lowest number of aphid (21.36) also correlate with the lowest number of ladybird beetle (3.36). So, it may be concluded from Figure 10 number of aphid was positively correlated with the number of ladybird beetle on country bean as host plant. But the presence of ladybird beetle against the number of aphid was relatively low compared to other host plants.

Relationship between the incidence of aphid with incidence of ladybird beetle on mustard, a positive trend can be followed where the number of ladybird beetle increased where the presence of aphid was higher. Highest number aphid was found (36) on mustard plant with the positive correlation with the highest number of ladybird beetle (5.51) and also lowest number of aphid (14.29) also correlate with the lowest number of ladybird beetle (1.29). So, it may be concluded from Figure 11 number of aphid was positively correlated with the number of ladybird beetle on mustard as host plant. But the presence of ladybird beetle against the number of aphid was relatively low compared to other host plants.

The consumption of aphid was statistically significant at each time in every measured on different host plants. The highest consumption of aphid per host plant by larvae of ladybird beetles released in different host plants was on average 4.34 aphids were consumed at 2 hours intervals, 4.13 aphids at 12 hours intervals, 4.10 aphids at 4 hours intervals, 3.56 aphids at 6 hours intervals, 3.48 aphids at 10 hours intervals, and 3.31 aphids at 8 hours intervals. The lowest consumption of aphid per host plant by larvae of ladybird beetles released of host plants 1.10 aphids at 8 hours intervals, 1.20 aphids at 10 hours intervals, 1.21 aphids at 6 hours intervals, 2.10 aphids at 4 hours intervals, 2.15 aphids at 12 hours intervals, and 2.31 aphids at 2 hours intervals.

Table 12 revealed that the highest consumption of aphid per host plant by adult ladybird beetles released in host plants was on average 3.10 aphids were consumed at 12 hours intervals, 2.80 aphid at 2 hours intervals, 2.20 aphid at 10 hours intervals, 2.10 aphids at 4 hours and 8 hours intervals, 2.03 aphids at 6 hours intervals. The lowest consumption of aphid per host plant by adult ladybird beetles released of host plants 1.10 aphids at 6 hours intervals, 1.20 aphids at 8 hours intervals, 1.30 aphids at 4 hours intervals, 1.40 aphids at 2 hours, 1.60 aphids at 10 hours intervals, and 1.70 aphids at 12 hours intervals.

Predation efficacy of ladybird beetle depends on the searching behaviour, size as well as on the surrounding nature of environment. The predation efficacy of grub and adult was ascertained by counting the total number of aphids engrossed by each instar of grub and adult within 24 hours. Both the grub and adult fed on aphid voraciously but their rate of feeding varied. They feed intermittently both day and night, but mainly in day time. The rate of consumption aphid was increased with time. Adult of ladybird beetle were consumed aphid voraciously and the rate become very high. Adult consumed 875-950 aphids on an average 875.15 aphids respectively.

Conclusions

Based on above findings it can be concluded that, the research consists of six different crop fields like Wheat, Brinjal, Tomato, Potato, Country bean and Mustard fields. Significant percentage of incidence of the aphid on plant were recorded at different growth stages of six host plant varieties evaluated in natural field condition.

1. The highest (54.51 per plant) ladybird beetles was recorded in Country bean plant at 7 DAS, whereas, 50.01 aphid/plant, 43.30 aphid/plant, 32.10

aphid/plant, 21.36 aphid/plant, and 14.47 aphid/plant at 14, 21, 28 and 35 DAS respectively.

2. Aphid were found in different crop fields the highest (54.51 aphid per plant) aphid was recorded in Country bean plant at 15 DAS whereas 50.01 aphid/plant.
3. Statistically adult of ladybird beetles was more efficient in predating aphid and the highest consumption of aphid was recorded by adult ladybird beetles.

Recommendations

From this study it may be recommended that

- Aphid were found in different crop fields like Wheat, Brinjal, Tomato, Potato, Country bean and Mustard fields and the highest (54.51 aphid per plant) aphid was recorded in Country bean plant at 15 DAS whereas 50.01 aphid/plant.
- However, further study of this experiment is needed in different crops and different locations of Bangladesh for accuracy of the results obtained from the present experiment.

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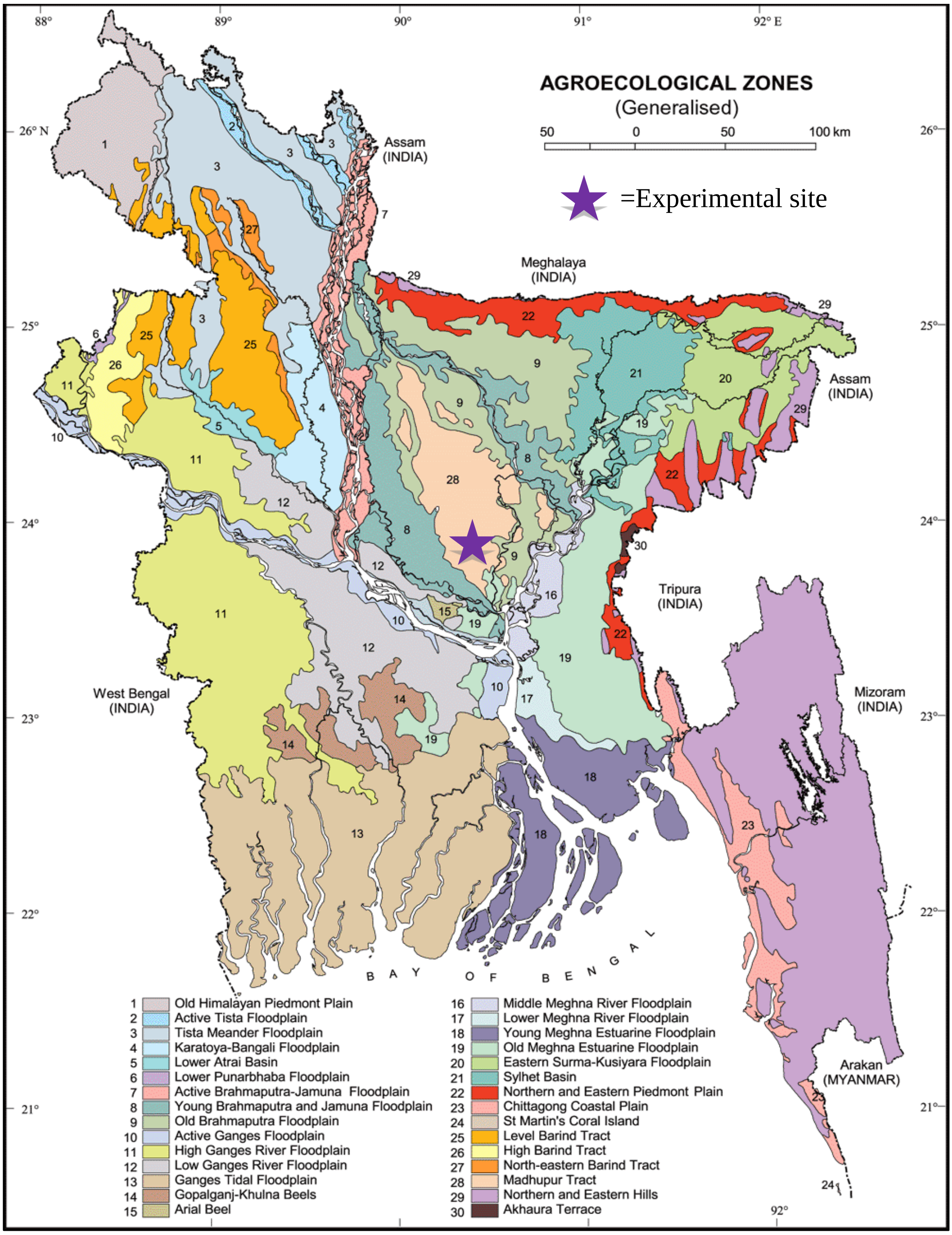
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	Value
pH	5.9
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from November, 2020 to April, 2021

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2021	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	33.50	25.90	64.50	119

Source : Meterological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance on Incidence of aphid and ladybird beetle plant^{-1} on different host plants at different DAS

Source of variation	D.F.	Mean square				
		7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Replications	2	0.055	1.808	4.287	2.139	3.471
Factor A	1	4.866**	5.537**	635.449**	17.554**	132.494**
Factor B	5	2.500**	19.969**	771.077**	63.643**	778.678**
Error	10	0.055	1.808	4.287	2.139	3.471

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance on Incidence of aphid and ladybird beetle leaf^{-1} on different host plants at different DAS

Source of variation	D.F.	Mean square				
		7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Replications	2	0.351	0.190	0.702	1.502	2.472
Factor A	1	3.046*	0.865**	2.432**	0.491*	212.019**
Factor B	5	8.253**	2.789**	1.536**	1.159**	276.727**
Error	10	0.351	0.190	0.702	1.502	2.472

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance on Incidence of aphid and ladybird beetle inflorescence^{-1} on different host plants at different DAS

Source of variation	D.F.	Mean square				
		7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Replications	2	0.013	0.013	0.007	0.102	0.500
Factor A	1	95.404**	95.404**	0.000^{NS}	1.130**	9.389**
Factor B	5	1.844NS	1.844*	0.071**	0.946**	1.167*
Error	10	0.013	0.013	0.007	0.102	0.500

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance on consumption of aphid by larvae of ladybird beetle at different time intervals.

Source of variation	D.F.	Mean square					
		2	4	6	8	10	12
Replications	2	2.11	0.69	36.11	16.12	14.00	1.16
Factor B	5	38.80*	16.31**	485.82**	79.77**	111.37**	12,88**
Error	10	17.93**	7.45**	166.62**	18.12*	16.01NS	0.48NS

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance on consumption of aphid by adult ladybird beetle at different time intervals.

Source of variation	D.F.	Mean square					
		2	4	6	8	10	12
Replications	2	0.84	1.07	3.71	1.87	4.23	4.89
Factor B	5	84.68**	212.82*	426.15*	391.06**	393.18**	405.46**
Error	10	80.34**	188.67**	401.59**	327.41**	329.02**	336.52**

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance