HOST PREFERENCE AND DAMAGE OF CHEWING AND SUCKING INSECT PESTS OF STEM AMARANTH AND THEIR ECO-FRIENDLY MANAGEMENT

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CERTIFICATE

This is to certify that the thesis entitled **'HOST PREFERENCE AND DAMAGE OF CHEWING AND SUCKING INSECT PESTS OF STEM AMARANTH AND THEIR ECO-FRIENDLY MANAGEMENT'** 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 *bonafide* research work carried out by **Md. Raihan Kabir**, Registration number: **15-06906** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2016
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TO

MY BELOVED PARENTS

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HOST PREFERENCE AND DAMAGE BY CHEWING AND SUCKING PEST OF STEM AMARANTH AND THEIR ECO-FRIENDLY MANAGEMENT

ABSTRACT

The experiment was conducted at the research field, Sher-e-Bangla Agricultural University, Dhaka during the period of March 2016 to September 2016. Stem amaranth variety BARI datha 1 (V_1) and BARI datha 2 (V_2) were used as test crop in this experiment and consists of 6 treatments as Mechanical method + Cultural method at 7 days interval, Spraying of soap water @ 1.0 g detergent/L of water, Apply wood ash @ as per required with mixing inert materials (2:1), Spraying of neem oil @ 2.0 mg/L of water with mixing 10 ml detergent, Spraying of neem leaves extracts @ 20 gm/L of water at 7 days interval and untreated control. The experiment was laid out in Factorial Randomized Complete Block Design (RCBD) having two factors with three replications. Results showed, percent infestation due to grasshopper, green leaf eating caterpillar and amaranth stem weevil were decreased more in V_2T_4 (71.71); in V_2T_3 (77.51) and in V_2T_4 (83.69) treatments respectively; whereas less in V_2T_1 treatment (25.42, 59.45 and 22.83, respectively for those insects) compared to untreated control. But incase of leaf miner, percentage of infestation was decreased more in V_1T_4 (87.70) and less in V_2T_1 (49.92) compared to untreated control. Percent of infestation due to stink bug, jassid, white fly and aphid were decreased more in V_1T_4 treatment (77.51, 82.46, 84.60 and 87.70), respectively; whereas and less percent of infestation due to stink bug in V_1T_2 (55.27); jassid in V_1T_1 (52.26); white fly in V_2T_1 (50.64) and aphid in V_2T_1 (49.92) compared to untreated control. The highest plant height was observed both in V_1T_4 (109.50 cm) and V_2T_4 (108.47): on the other hand the lowest was in V_1T_0 (70.86 cm). The highest yield was observed both in V_1T_4 (36.56 t ha^{-1}) and V_2T_4 (34.57 t ha^{-1}): whereas the lowest was in V_2T_0 (21.78 t ha^{-1}). At last it was observed that, infestation was more in both varieties in untreated control (T_0) treatment but BARI datha-2 (V_2T_0) more infested than BARI datha-1 (V_1T_0). But yield was calculated more in both varieties in T_4 treatment but BARI datha-1 (V_1T_4) given more yield than BARI datha-2 (V_2T_4).

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CHAPTER I

INTRODUCTION

Stem amaranth (*Amaranthus oleraceus*) is an important herbaceous vegetable crop, which belongs to the family Amaranthaceae. Amaranthus species are important vegetable crops cultivated and consumed in Bangladesh and many countries of the world. Stem amaranth is a very promising crop. It is locally known as ‘Danta’. Among the leafy vegetables grown in Bangladesh, amaranth plays an important role in nutrition. The main reasons could be content of fat, protein and active substances. Among the tropics vegetables, stem amaranth is very easy to cultivate for its early growing habit and riches in vitamin and minerals (Shanmugavelu, 1989; Nath, 1976). Because of its adaptability to wide range of climate and soil, it can be cultivated in any season through all over the country (Islam and Hossain, 1992). Stem amaranth used for making stew and soup in the entire West African region. In the area of New Mexico, its seeds are used as fed to livestock (Auotundun *et al.*, I995). It ranks 5th among summer vegetables considering both in area and production and 13th among all vegetables (BBS, 2009). It contributes 5.42% in summer vegetable production (BBS, 2009). In Bangladesh, it is cultivated in an area of 24933 acre producing 61.48 thousand metric ton of fleshy edible part with per acre yield of 2.5 tons (BBS, 2009).

Unfortunately, insect pests are a major setback for commercial production and for the purpose of food security in the country. Approximately 60 species are recognized, with inflorescences and foliage ranging from purple and red to green or gold (Anon. 2013). Growing amaranth is possible all year round in the tropics. Amaranth consists of 60-70 species, 40 of which are considered native to the Americas. Over 400 varieties within these species around are found throughout the world in both temperate and tropical climates, and fall roughly into one of four categories: grain, vegetable, ornamental or weed (Anon. 2015). Many fall into more than one. Vegetable amaranth has been used in China for over 400 years. Amaranth is much closer genetically to its wild ancestors than our over developed and nutritionally depleted typical vegetables. Amaranth leaves are an excellent source of carotene, iron, calcium, protein, vitamin C and trace elements. Amaranth leaves are nutritionally similar to beets, swiss chard and spinach, but are much superior. For example amaranth leaves contain three times more calcium and three times more niacin (vitamin B_3) than spinach leaves. Amaranth seeds are also high in potassium, zinc, Vitamin B and E and can contain over 20% protein (depending on the variety). A lot of insects like chewing on amaranth leaves without it sustaining yield loss. A few insects however can inflict substantial damage. Amaranth can succumb to caterpillars, webworms, blister beetles, lygus bugs and stem borers.

The lygus bug, coffee bug or tarnished plant bug (*Lygus*spp.) is a brown, lady-bug sized sucking insect that attacks flowers and seeds. It can cause substantial damage both by preventing flowers from producing seeds and by reducing seed weight. Solutions made from pyrethrum or synthetic pyrethrins will help control lygus. Other insects that can injure the developing amaranth include fall armyworm (*Spodopter afrugiperda*), cabbage looper (*Trichoplusiani*), corn earworm (*Heliothiszea*) and the cowpea aphid (*Aphis craccavora*). The amaranth weevil (*Conotrachelus seniculus*) can damage roots, resulting in lodging or other root diseases. Cultural control of pest and judicious use or complete abstinence from persistent pesticides is the way forward in the management of insect pests (Losenge, 2005). The management of these insect pests has been through the use of insecticides. Dales (1996) noted that the use of synthetic insecticides pose health risk and result in environmental pollution. Also, Schmutterer (2002) reported that the World Health Organization (WHO) had reported the poisoning of at least 3 million agricultural workers from which 20,000 deaths are recorded annually due to pesticide usage. Wasthi (2001) also noted that consumers of vegetables may be at risk from pesticide residues. Thus, research has been geared towards identifying non-chemical methods of pest control, which are safe, cheap, easy toapply and accessible to farmers (Jilani and Su, 1983). In this regard botanicals from neem have shown considerable potential (Okunlola, 2008). The leaf and seed extracts of the neem tree, Azadirachta indica. Juss have been shown to affect over 200 insect species including some species of aphids, beetles, caterpillars, leafminers, mealybugs, scales, thrips, true bugs and whiteflies; it is also the most popular botanical pesticide against foliage feeding pests. The aqueous extract of A. indica bark has been shown to be as effective as a synthetic insecticide in controlling foliage feeders of vegetables. The aqueous extract of *A. indica* bark has been shown to be as effective as a synthetic insecticide (Cymbush) in controlling foliage feeders of vegetables (Okunlola, 2008). Meanwhile, Copping (2001) has earlier reported no known incompatibilities of neem extracts with other crops protection agents. There is evidence available for the synergistic action ofneem with microbial pesticides such as NPVs of tomato fruit worm (Senthikumar, 2008) and common armyworm (Nathanand Kalaivani, 2006), and entomopathogenic fungi (*Beauveria bassiana*) against common army worm (Mohan *et al*., 2007). Asian Vegetable Research and Development Centre (AVRDC) has developed IPM strategies for tomato and vegetable soybean involving neem as an integral component with microbial pesticides such as *Bacillus thuringiensis* and NPVs in managing phytophagous insects (Srinivasan *et al*., 2009). Therefore, the effective control of Chewing and Sucking insect pest in BARI Datha-1 and BARI Datha-2 deserves some new approaches which are eco-friendly, economically viable and socially acceptable.

Under the above perspective the present study has been undertaken with fulfilling the following objectives-

- To study the host preference and damages by chewing and sucking insect pest of stem amaranth (Datha), *Amaranthus oleraceus* during the growing season
- To find out efficacy of the management practices against sucking and chewing insect pest of stem amaranth, *A. oleraceus*

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Stem Amaranth (Datha Shak) is an important leafy vegetable in Bangladesh. Like many other vegetables, the growth and yield of stem amaranth are influenced by different factors like sowing time, temperature, soil moisture, plant spacing, organic and inorganic fertilizer etc. The crop has received less attention of the researchers on its various aspects because normally it grows with less care or management practices. For that a very few studies on insect attack and its control of stem amaranth have been carried out in our country as well as in many other countries of the world. Hence, the research work so far done in Bangladesh is not adequate and conclusive. Very few research work have been done relating Prevalence and management of sucking and chewing insect pest of stem amaranth in different parts of the world as well as in Bangladesh. An attempt has been made in this chapter to review literature available at home and abroad pertaining to the present research work under the following headings.

2.1 Insect Pest of Amaranth

Amaranths are susceptible to damage by foliar insect pests and diseases such as aphids (*Aphis* spp.), leaf worms (*Spodoptera spp*.), leaf rollers (*Sylepta derogota*), leaf miners (*Liriomyza spp*.), spider mites (*Tetranychus spp.),* stem boring weevils (*Hypolixus haereus*), bugs (*Asparia armigera*) and flea beetles (*Podagrica spp*.) (Richard, 1989; Okunlola *et al.*, 2008).

Leaf miner

Leaf miner larvae make long, slender, white mines (tunnels) in leaves. Severe mined leaves many turn yellow and drop. Severely attacked seedlings are stunted and may eventually die (Sorensen, 1995; Rodriquez, 1997; Sparles and Liu, 2001; Degri, *et al*., 2007; Degri *et al*., 2012).

Aphid

Aphids are major pest of Amaranths causing leaves to curl and become unattractive to consumers and customers. They feed by sucking plant sap. Small aphid population may be relatively harmless, but heavily infested Amaranth plants usually have wrinkled leaves, stunted growth and deformed seeds. Amaranth plants, particularly young plants, may dry out and die. Heavy attack on older Amaranth plants may cause crop loss by decreasing flower and seed viability (Okunlola *et al.,* 2008; Youdeowei, 2004).

Aphids are a major pest of vegetables including Amaranth (Picker *et al.*, 2004). Amaranth is majorly attacked by *Myzus persicae*. Aphids feed by sucking sap from plant tissues especially leaves causing the leaves to curl, wrinkle and discolour. They also result to overall slow and stunted growth of plant and under heavy infestation it may cause the plant to dry out. Seed production is also hampered by aphid infestation where it may lead to deformed seeds, decreased flower and seed formation or reduced seed viability (Picker *et al.*, 2004).

Bugs

Bugs can cause severe damage to flowering head and seeds and particularly damaging to grain Amaranth when present in large numbers during critical seed fill stage. They are usually of minor importance in vegetable Amaranth (Youdeowei, 2004).

Leaf worms

Leaf worms or cutworms attack young seedlings. The caterpillar emerges from the soil at night, encircle the plant with its body and cut through the stem of young plants just above ground level or below ground level causing plant wilt and death (Richard, 1989; Kirby and Dill, 2004). Leaf rollers larvae feed on the lower surface of the leaves folded and covered with webs or rolled and spun together (Booth, 1983; Imam *et al.*, 2010). Makwali (2002) in his research on grain amaranth reported that the most prevalent bugs infesting grain

Amaranth are *Cletus sp.* and *Cletomorpha sp*. whose population often reaches peak during the seed head: the critical milky seeds stage. This was supported by the research done by Oke and Ofuya (2011) which showed that this bugs feed on the seeds causing discoloration, shriveling and premature dying of seeds thereby reducing seed yield and viability.

Amaranthus weevil

Hypolixus spp is a major pest of cultivated amaranth (Tara *et al*., 2009). The eggs overwinter in the soil or inside the debris of harvested plants. Adults defoliate the plants while the larvae feed on the internal tissues of the stem and branches to form irregular zigzag tunnels resulting in galls. Females lay eggs 40 minutes after copulation singly in excavated holes in stems, branches, petiole or midrib of the leaves. Agarwal (1985) also reported, in his research the presence of adults in the field is noticed by the scratched stem, branches and eaten up tender margins of leaves. The weevil has a slow steady development with overlapping generations. Adults are dark brown, variegated with white hairs and several dark patches of dense pubescence. The body is medium sized 9 measuring 11.7 mm with females being slightly larger than males. They have chewing mouth parts with prominent mandibles that are used to borrow through the stem (Tara *et al.,* 2009).

Adults of amaranth weevils are all leaf and stem feeders. There were three significant species that included *Hypolixus nubilosus, Nematoceru sp*. and *Baris massaica*. They chew semi-circles out of the leaf edges and windows in the leaf lamina. They target mostly the soft stems and leaves. Adult defecation was visible all over the plants as small brown blotches. Their larvae on the other hand utilizes a number of feeding niches with *Nematoceru sp*. and *Baris massaica* boring endophytically in the above ground parts such as meristems and larger side stems and plant crowns, while *Hypolixus nubilosus* bore endophytically in stems and roots (Louw *et al*., 1994).

Spider mite

Spider mite feeding on Amaranth plants may cause reduction in plant growth, flowering and number of seeds. Damage is most severe when mites attack young plants particularly during the dry season (Richard, 1989; Okunlola *et al.,* 2008), stem boring weevils feed on the leaves but the larvae (grubs) bore into roots and stems, causing rotting, wilting, lodging and disposition to diseases thus increasing crop loss (Sorensen, 1995). Aderolu *et al.* (2013) reported *H. recurvalis* as the most abundant Lepidopteran pest of Amaranth in Nigeria while Akinlosotu (1977) reported that *Gasteroclisus rhomboidalis* as the major pest of Amaranthus cruentus in Nigeria. Kagali *et al.* (2013), in Kenya who reported that Cletus sp in the order Hemiptera was the insect with greatest number occurring surveyed with 100% infestation. Other pests with high infestations are *Zonocerus variegatus, Hymenia recurvalis, Gasteroclisus rhomboidalis* and *Liriomyza spp*.

2.2 Control Methods

In view of the fact that amaranth is consumed directly from the farm as a leafy vegetable or grain and sometimes consumed as a raw salad it is important then to develop pest control options that are safe, as well as cheap and simple to adopt (Sithanantham *et al.*, 2004). Some of the strategies used to control pests in other ALVs can also be employed in control of pests in Amaranth. These methods include:

2.2.1 Botanical pesticides

This are mainly extracts from plants or plant parts such as seeds, barks, leaves, roots. Seeds and leaves of neem (*Azadirachta indica*) and its relative Persian lilac (*Melia azedarach*) have been used widely in organic farming in Kenya to control insects (Sithanantham *et al.,* 2004). Another plant that has been used extensively is pyrethrum.

2.2.2 Microbial Bio-pesticides

The use of microbes to control insect pest and diseases is an area that has attracted a lot of attention from researchers throughout the world including Kenya in recent times. Several microbes including fungi, bacteria, viruses and entomopathogenic nematodes (EPN) have been employed to control insect pests. These include: Bacteria such as *Bacilus thuringensis (Bt), Agrobacterium sp.; Fungi: Trichoderma sp., Meterhizium sp., Beuveria sp.;* Nematodes*: Steinernerma sp.* and *Heterorhabditalis sp.* (Neuenschwender *et al*., 2003).

2.2.3 Cultural practices

Cultural controls employ practices that make the environment less attractive to pests and less favorable for their survival, dispersal, growth and reproduction, and that promote the pest's natural controls. The objective for this control strategy is to reduce pest numbers, either below economic injury levels, or sufficiently to allow natural or biological controls to take effect (Sithanantham *et al*., 2004).

Cultural control employs environmentally supportive and knowledge/skillintensive techniques, such as the optimal design and management of agro-ecosystems in time and space which include; management of adjacent environments, use of companion crops, rotations, timing of seeding, harvesting and field operations as well as more heavy-handed interventions like burning of crop residues, flooding and destruction of uncultivated areas containing alternative hosts of pests (Losenge, 2005).

2.2.4 Integrated Pest Management (IPM)

According to Agrios (2005) integrated pest management can be described as a pest management system that utilizes all suitable techniques in as compatible manner as possible and maintains the pest population levels below those causing economic injury. Integrated Pest Management relies on a combination of common-sense practices such as, the associated environment and the population dynamics of the pest species which are effective and environmentally sensitive (Mullen *et al.*, 1997).

The concept of IPM was first introduced in the mid-1970s to reduce the overdependence on pesticides that were used for reducing losses due to pests (Metcalf and Luckman, 1975). Integrated pest management programs utilize current comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with least possible hazard to people and the environment (Antle and Pingali, 1994). This strategy is knowledge-intensive and farmer-based decision making process and it encourages natural control of pests. It also prevents pest outbreaks and the development of pest resistance. The pesticide-free agricultural commodities from the IPM-practiced fields have a great scope to increase the income of farmers (Mullen *et al.*, 1997).

2.3 Factors on insect pest infestation

The highest insect pest populations recorded under Amaranths spaced at 20cm x 10cm and 20cm x 15cm could be due to the close canopy these spacing had, which encouraged the feeding activity of the insect pests (Makus, 1990). AVRDC (2003) reported that closely spaced vegetables and horticultural crops suffer more from insect pests attack due to the conductive environment which they provide for the insect and consequently a favorable and productive shelter for the insect pests and thus make it easier for the pest to find its food near on the host plant (Sorensen, 1995; Hein, 2003). There was no significant difference between insect pest population infestations on variety and spacing.

2.4 Methods of collecting insects

Slow moving and sedentary arthropods were collected by hand (Nderitu *et al.*, 2008). The plant was searched visually for possible insect pests which were then collected into vials, labeled and taken to the laboratory at NMK for identification, curation and archival. Healthy plants were also uprooted and stems and roots dissected to examine the presence of phytophagous insects that do not cause visible damage. A mild pesticide was sprayed on the plants to prevent the insect pests from escaping (Millar *et al.*, 2000). Beating sheets were used to collect well camouflaged or hidden insect pests on plants that were missed during sampling by hand picking (Millar *et al*., 2000). A small sheet was placed beneath the plants preferably a white sheet and the insect pests were knocked down from the plant onto the sheet by beating with a stick. The insects were then picked up from the sheet with aid of a hand lens and forceps and placed into vials. This method was employed to collect sessile and wingless insect pests (Millar *et al.*, 2000). Flying insects were collected using aerial nets (Nderitu *et al.*, 2008). Aerial net consist of a light weight frame made of soft durable material such as, aluminum with a net attached to it. Once the insect has been caught, the end of the net was flipped over to prevent it from escaping. Harmless insects were removed by hand, while harmful once were directed into a killing bottle (Millar *et al.*, 2000). Other insect pests that are ground dwelling such as, termites and weevils that attacked roots and stems of amaranth or those that moved to the ground to ovipositor spend one stage of their development cycle in the soil were collected using pitfall traps (Millar *et al.*, 2000). Cylindrical containers were placed in holes dug at random within the amaranth plot with the upper rim of the container being flush with the ground surface. A killing agent, ethylene glycol was added to the trap to kill the insect after entering the trap. The traps was inspected weekly for possible insect pests and if available collected using forceps and placed in vials. The holes were distributed evenly within the plots (Millar *et al.*, 2000).

2.5 Determining the yield loss due to insect pest damage

Naturally occurring infestations are often used to give a range of infestations or damage in a single plant, plot or field. The yield was determined per unit area in different plots with different degrees of pest infestation and correlation between the crop yield and degree of infestation was worked out to estimate crop yield loss (Odendo *et al.*, 2003). This was used to identify the pests of economic importance to amaranth and require control interventions.

2.6 Effects of various control strategies on insect pest population

The area to be used as a plot for planting amaranth was manured using farm yard manure before primary cultivation was done. The area was thoroughly ploughed ensuring that manure mixed evenly with the soil and was well distributed on the entire plot (Schippers, 2000). Thirty plots were prepared each measuring 3 meters in length and 1.5 meters wide. The depth of preparation was 30cm during primary plough. This was followed by harrowing which encompasses breaking up of large particles of soil as well as raising the beds to 30cms above the ground surface. The beds were raked flat on the top maintaining the dimensions (Schippers, 2000). Planting method was by direct seeding where seeds were mixed with sand, that is, 1g of seed mixed with 100 g of sand to ensure uniform stand. Seeds were sawn in rows by making furrows 0.5 to 1.0 cm deep using a stick or finger. Inter row spacing was 20 cm and thinning followed immediately after germination to achieve the desired within row spacing (Palada and Chang, 2003).

2.7 Diversity of insect pests

The results from this study show diversity in the number of insect species associated with cultivated amaranth in Meru County. These results concur with the findings from similar survey carried out in Puebla, Mexico (Lopez *et al.*, 2011). From the results Heteroptera is the order with greatest number of species, that is, 13 species, which causes significant damage to grains. The most significant genus in this Order was Cletus with four species. This genus was the most occurring with infestations of 100% in all plots. This may be as a result of amaranth being a suitable host for heteropterans. Other studies by Lopez *et al*. (2011) in Mexico and Aderolu *et al.* (2013) in Nigeria also recorded high number of heteroptera species attacking amaranth. The most abundant species were *Cletus sp.* (Heteroptera), *Eurystulus spp.* (Heteroptera), *Hypolixus nubilosus* (Coleoptera), *Microcentrum rhombifolium* (Orthoptera) and *Herpetogramma spp.* (Lepidoptera). Aderolu *et al.* (2013) reported *Hymenia recurvalis* and *Hypolixus truncatulus* as the most abundant pests in Nigeria. This shift in the species in the two studies may be due to geographical difference in the two study areas. From the results there was high diversity of amaranth pest species with a Shannon-Weaver index of 4.256 during the first growing season and 4.148 during the second growing season. This trend of insect species confirms the insect species previously reported on amaranth by López *et al*. (2011) and Torres *et al*. (2011).

2.8 Significance of pest species collected

Adults of amaranth weevils are all leaf and stem feeders. There were three significant species that included *Hypolixus nubilosus, Nematocerus sp*. and *Baris massaica*. They chew semi-circles out of the leaf edges and windows in the leaf lamina. They target mostly the soft stems and leaves. Adult defaecation was visible all over the plants as small brown blotches. Their larvae on the other hand utilizes a number of feeding niches with *Nematocerus sp.* and *Baris massaica* boring endophytically in the above ground parts such as meristems and larger side stems and plant crowns, while *Hypolixus nubilosus* bore endophytically in stems and roots (Louw *et al.*, 1994). The results of this study revealed that the infestation by the weevils took place throughout the growing period of the crop, with the number increasing gradually as the crop grew but began to drop as it matured. The females oviposited in the stems where eggs hatched into larvae which fed while tunneling through the stem. This pest resulted to significant crop loss especially through foliage damage. Other studies have also reported that this pest was found to cause considerable damage on amaranth leaves and stems (Torres *et al*., 2011 and López *et al*., 2011). All plants examined in the laboratory presented galleries throughout the main stem. The galleries had occasional interruptions, dark coloration and the presence of chewed plant material mixed with feces of *Herpetogramma spp*. larvae. This is consistent with reports from amaranth crop fields in Mexico where the pupae were observed in the soil nearby host plants (Torres *et al.,* 2011). *Herpetogramma bipunctalis* larvae have been observed feeding on several plant species (Solis, 2006; Oliveira *et al*., 2012). In Mexico this species was observed feeding on leaves and grains of *Amaranthus spp*. plant (Torres *et al*., 2011) as well as boring and building galleries inside the plant stems as observed in this study. The galleries and exit holes make the stem weak and if the weather is windy it causes lodging of the crop resulting to yield loss if the crop is not yet mature. If the weather is not windy the crop continues to grow without significant loss on yield. Oliveira *et al*. (2012) observed that 100% of the crop examined presented galleries of up to 5mm in diameter throughout the main stems which was an indication of the presence of *H. bipunctalis* larvae. This larvae was also observed feeding and building galleries in stems of amaranth in Puebla, Mexico (López *et al*., 2011).

In the present study Cletus sp. was observed and collected in all plots and farms visited. It was found to be a major grain pest of amaranth and in high infestation, caused total loss of yield. These insects are observed mostly at the beginning of milking stage and the population increases as the grain matures. This was also observed by Oke and Ofuya (2011) in their study on amaranth in Ibadan, Nigeria. They observed that the population of *Cletus sp.* increases gradually from the start of milking stage to maturity, with the highest population being recorded slightly before harvesting. Among the insects that damage the foliage we found grasshoppers which were observed in all the plots. The order Orthoptera was a significant order with four families and four species. This order consists of grasshoppers which is the only group of insects in this order collected during the research period. The most significant species was Microcentrum rhombifolium which infested the leaves of the crop especially during the early stages of crop development cutting the leaves and causing windowing. The number of species recorded in this study is higher compared to one species recorded by Gracia *et al*. (2012) in their study in Brazil and López *et al*. (2011) in their study in Mexico which recorded two species. Grasshoppers were using grass close to the amaranth plots as an alternative host and therefore were difficult to control. This has also been reported by Capinera *et al*. (2007) and Basset (1999) in USA and New Guinea respectively.

2.9 Diversity of potential natural enemies

Most hymenopterans and some coleopterans observed in this study were classified as natural enemies or parasitoids of amaranth pests. *Dentichamias busseolae* which was sampled during the second season of planting has been reported as a pupal parasitoid of lepidopterans. The female parasitoid oviposition only in a borer pupa without a cocoon in a stem (Mailu *et al*., 1984). Braconid parasite (*Bracon sp*.) was also observed occurring on amaranth during both the first and second season. Similarly, this insect was recorded in the survey conducted by López *et al*. (2011) in Mexico. Bracon sp. is a gregarious ectoparasitoid of weevils (Coleoptera) pest larvae (Dillon *et al*., 2008 and Evarard *et al*., 2009). Female braconid respond to the stimuli associated with the grab of the weevil actively feeding on or inside the stem of the crop (Faccoli and Henry, 2003). The female then inserts its ovipositor through the back of the stamp, to inject the larva with paralyzing venom prior to depositing a cluster of eggs on or near the body of the host (Evarard *et al*., 2009). This is the first study in Kenya which has reported the naturally occurring enemies and parasitoids of amaranth insect pest.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with a brief description on experimental period, experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses. Details of materials and methods used in this experiment are given below:

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Kharif-1 season of March 2016 to September 2016.

3.2 Description of the experimental site:

3.2.1 Geographical location

The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. The experimental field situated in the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.2 Climate

The experimental site is under the sub-tropical climate which is characterized by high humidity, heavy rainfall, high temperature and relatively long day during March to September. During the rest period of the year there is scanty rainfall, low humidity, low temperature and short day period. The first period that is long day period is favorable for stem amaranth cultivation. The weather data during the study period at the experimental site are shown in Appendix II.

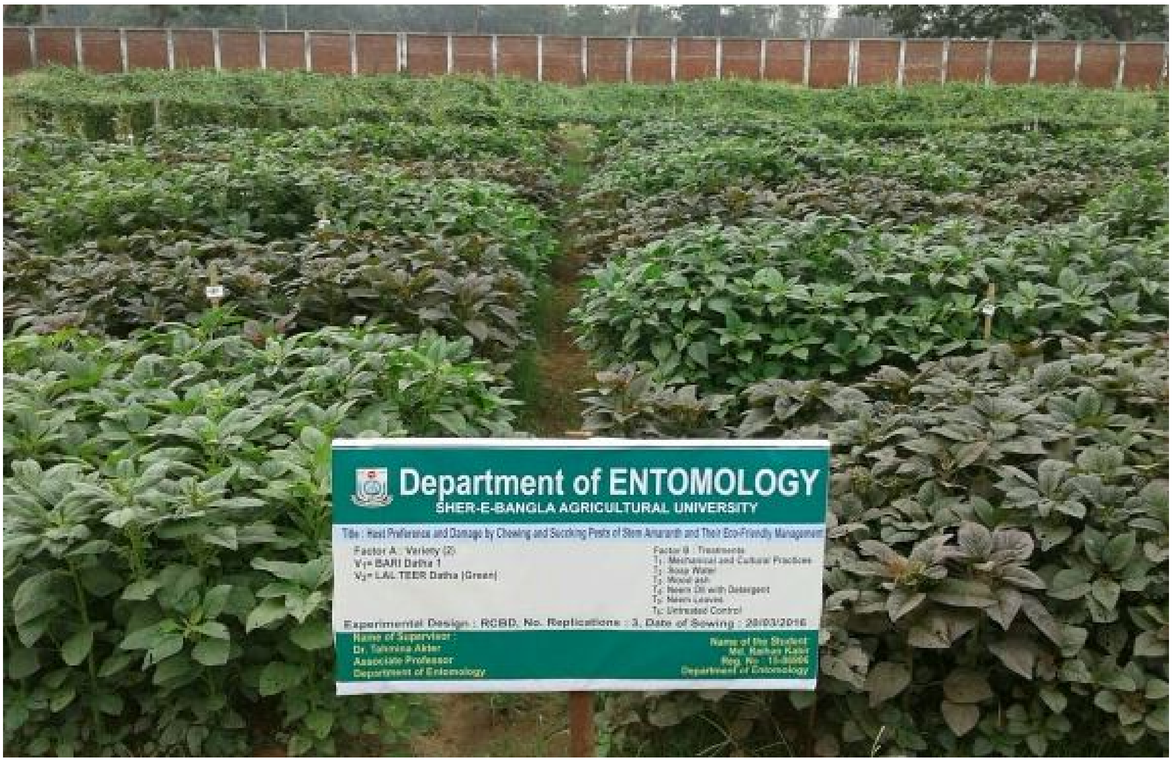


Plate no. 01: Experimental field of stem amaranth in the central farm of SAU

Plate no. 02: BARI datha 1 (**V_1**) and BARI datha 2 (**V_2**) of stem amaranth in the experimental field during the study

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Ranges of Soil P^H from 5.4-5.6. The land was situated above the flood level and during the experimental period there was available sufficient sunshine.

3.3 Experimental details

The experiment was laid out in factorial design having two factors with three replications, variety were considered as one factor and different management practices were considered as another factor.

3.3.1 Treatments and design

Two factors of treatments included in the experiment were as follows:

Factor A: Treatment combinations

T_0=Untreated control

T_1=Mechanical and cultural practices at the 7 days interval

T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval

T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval

T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval

T_5= Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval

Factor B: Variety – 2

- V_1 : BARI datha1
- V_2 : BRRI datha 2

Therefore, a total of 12 (2×6) treatments combinations V_1T_0, V_1T_1, V_1T_2, V_1T_3, V_1T_4, V_1T_5, V_2T_0, V_2T_1, V_2T_2, V_2T_3, V_2T_4, V_2T_5 and 36 (2×6×3) experimental units were used in this experiment. The experiment was laid out in randomized complete block design (RCBD) with three replications. There are total 36 numbers of unit plots. The size of unit plot was 6 m^2 (3m × 2m). Layout of the experiment was done

Plate no. 03: Amaranth stem weevil infested stem of BARI datha-2

Plate no. 04: Grasshopper infested leaves of stem Amaranth with the distances having 0.5 m between blocks and 0.5 m distances between plots maintained for proper drainage facility. For better understanding the layout of the experiment has been presented in Appendix III.

3.4 Crop/planting material

High yielding variety BARI datha1 and BARI datha2 of kharif season were used as test crop. The description of the variety is given below:

BARI datha1

BARI datha1, a high yielding variety was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. It can grows all year round but yield highest in summer season. From seedling to mature it takes about 40 to 45 days for consumption as shake and 65 to 70 days as stem. It attains at a plant height of 95-100 cm. The stems are strait with light violate color, less fiber and soft. The cultivar gives an average yield as shake 10-15 t/ha and as stem 45-50 t ha^{-1}.

BARI datha2

BARI datha2, a high yielding variety was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. It can grow all year round but yield highest in summer season. From seedling to mature it takes about 35 to 40 days for consumption as shake and 55 to 65 days as stem. It attains at a plant height of 80-90 cm. The stems are strait with light green color, more soft stem than BARI datha1. The cultivar gives an average yield as shake 10-12 t/ha and as stem 40-45 t/ ha.

3.5 Crop Management

3.5.1. Seed Collection

Healthy seeds of BARI datha1 and BARI datha2 were collected from the Breeding Division, BARI, Joydebpur, Gazipur.

3.5.2 Land preparation

The selected experimental plot was first plough by a power tiller and opened on the first week of March, 2016, to exposed insect like cutworm, field cricket, mole cricket etc. and to the sun for few days prior to next plough. After that, three ploughs and cross plough was done with power tiller followed by laddering up to a depth of 10 cm were done. During land preparation most of the plant debris of the previous crops and weeds were collected and removed from the plot. The corners of the experimental plot were trimmed.

The big clods were broken into fine soil particles by spade and the surface was leveled by ladder. Irrigation and drainage channels were prepared around the plots and the land was made ready. The plot was finally prepared by applying fertilizers and manures with proper basal dose.

3.5.3 Application of manures and fertilizers

Table 1: Doses of manures and fertilizers for stem amaranth applied to the plot as per recommended.

Manures and Fertilizers	Doses/ Decimal	During land preparation	After 20 days of seed sowing	After 40 days of seed sowing
Cow dung	40 kg	all	_	_
Urea	1 kg	400g	300g	300g
TSP	400g	all	_	_
MOP	600g	all	_	_
Gypsum	300g	all	_	_

3.5.4 Time and methods of planting

Seeds were sown uniformly in the line with a depth of 2-3 cm.

Date of planting: 20 March, 2016

Plant spacing: 25cm × 5cm

3.5.5 Intercultural operations

After sowing of stem amaranth seeds, the experimental area was taken under careful observation. All the necessary intercultural operations were done as and when necessary for proper growth and development of the plants.

Plate no. 05: Healthy plant (**A)** and infested plant due to leaf eating insects (**B**) of Stem Amaranth during the study period

3.5.6 Thinning

When the seeds were sown, spacing of plant was not maintained primarily. Thinning was done for maintain of optimum plant population in the plot. Thinning was done at 7 days after germination and continued up to 15 days for best plant spacing. Plant to plant spacing was maintaining about 8 cm for proper space. Thinning plant can be used as shakh.

3.5.7 Gap filling

Gap filling was done for desired plant population and maintain uniform spacing. Gap filling was done after 5 days of germination of seedling.

3.5.8 Weeding

For better growth and development, weeding is very essential for Stem amaranth to keep the plot free from weeds. Weeds compete with desired plants to take up nutrient, light, space and water. So, first weeding was done at l5 days aged of seedling by hoe. Subsequent weeding was done followed by irrigation up to the field condition.

3.5.9 Irrigation and drainage

For better growth watering is essential part. If there was scarcity of water in the field, the stem was turned into more fiber that reduces the quality of stem amaranth. Time of watering depends upon the moisture condition of the soil. In total 2 irrigations were provided at 15 and 25 days after sowing respectively. Proper drainage system was also developed for draining out excess water by preparing drainage channel.

3.5.10 Insect and pest management

A cover spray was given with soap water, neem oil with detergent; neem leaves extruct from 10, 17, 24, 31and 38 DAS respectively. At the same time wood ash & cultural and mechanical control was done. Botanical extract sprayed as water solution for 5 times at 7 days interval as per treatment from germination to harvest to control insect and pest.

3.5.11 Procedure of spray application

The actual amount of each botanical insecticide was taken in knapsack sprayer having pressure of 4-5 kg cm-2 and thoroughly mixed with water and sprayed in the relevant plot. The necessary amount of liquid insecticides was taken by measuring cylinder in the sprayer. Each treatment was repeated at 7 days interval and 5 sprays were applied in the field.

3.5.12 Procedure of wood ash application

The actual amount of each wood ash was taken in container and thoroughly mixed with inert materials and apply by disperse in the relevant plot.

Plate no. 06: Green leaf eating caterpillar infested leaves of stem Amaranth

Plate no. 07: Stink bug infested leaves of stem Amaranth (BARI datha-2)

3.5.13 Procedure of cultural and mechanical control

Cultural and mechanical control was done by maintaining proper spacing, weed control by hoe regularly, remove insect by hand picking etc.

3.6 Collection of data

Data were recorded on the following parameters from the sampled plants during the experimental plot was in the field. Ten plants were randomly selected from each plot to record data. Data were collected for the following parameters.

3.6.1 Number of sucking insects/plant

The population of sucking insects were counted before spraying of botanical insecticides, detergent water and cultural practice. Data on number of sucking insects were recorded at an interval of 7 days commencing from first incidence and continued up to the 5 weeks (5 times).

3.6.2 Number of chewing insects/plant

The population of sucking insects were counted before spraying of botanical insecticides, detergent water and cultural practice. Data on number of chewing insects were recorded at an interval of 7 days commencing from first incidence and continued up to the 5 weeks (5 times).

3.6.3 Number of infested leaves/plant

The population of sucking insects were counted before spraying of botanical insecticides, detergent water and cultural practice. Data on number of sucking insects were recorded at an interval of 7 days commencing from first incidence and continued up to the 5 weeks (5 times).

Plate no. 08: Aphid infested leaves of stem Amaranth (BARI datha-1)

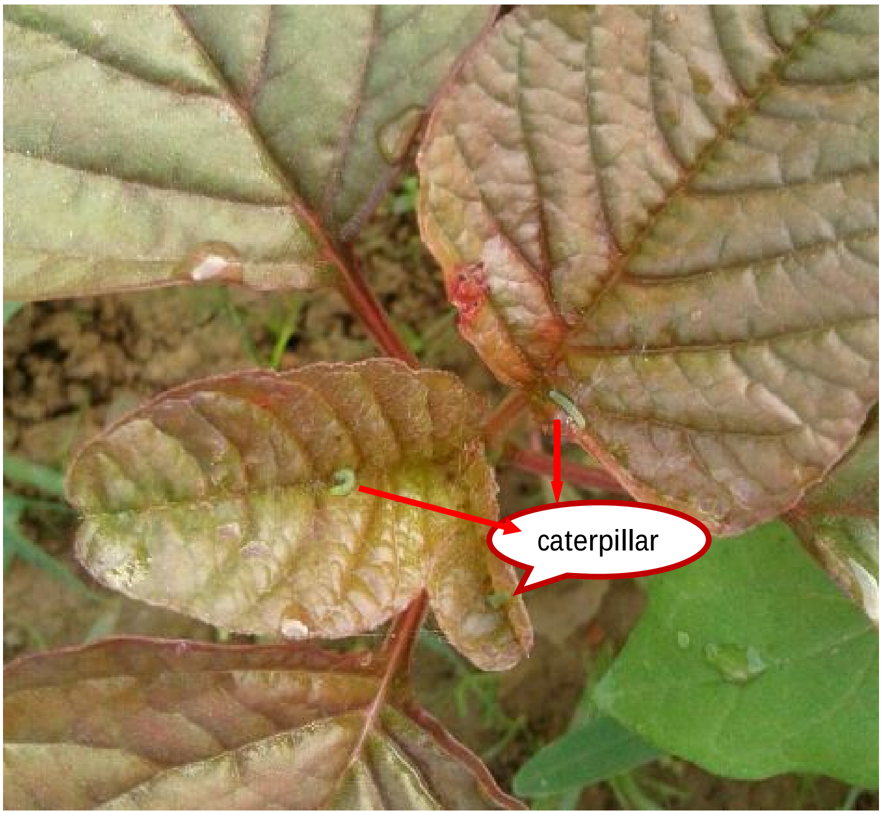


Plate no. 09: Tiny caterpillars on infested leaves of stem Amaranth (BARI datha-1)

3.6.4 Number of healthy leaves/plant

The population of sucking insects in the field was recorded on the ten randomly selected plants from each plot were counted before spraying of botanical insecticides, detergent water and cultural practice. Data on number of sucking insects were recorded at an interval of 7 days commencing from first incidence and continued up to the 5 weeks (5 times).

3.6.5 Determination of leaf infestation by number and infestation reduction over control

All the healthy and infested leaves were counted from 10 plants from middle rows of each plot and examined carefully. The healthy and infested leaves were counted at for different insect pests and converted into per plant and then the percent leaf infestation was calculated using the following formula:

$$\text{Leaf infestation (\%)} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves}} \times 100$$

3.7 Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT-C package programmers. The mean for all the treatments were calculated and analyzed and analyses of variance of all the characters were performed by F-variance test. The significance of differences between the pairs of treatment means was calculated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

Plate no. 10: Healthy stem Amaranth (BARI datha 1 and 2) after harvest

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the host preference and damage of chewing and sucking insect pests of stem amaranth and their eco-friendly management during the period of kharif-1 season March to July, 2016. Data was recorded on pest incidence, host preference and damage such as leaf infestation, stem infestation due to different insect pests. The results have been discussed and presented under the following headings and sub-headings:

4.1 Common insect pest of Stem amaranth vegetables found in the field

Under the present study, the insect pests of stem amaranth vegetables found in the experiment field are presented in Table 2.

Table 2. List of insect pest of stem amaranth vegetables with destructive stages of insect, site of infestation and nature of damage

Sl. No.	Common name of insect	Scientific name	Family & Order	Destructive Stage of insect
1.	Amaranth stem weevil	*Hypolixus truncatulus*	Curculionidae: Coleoptera	Larva, adult
2.	Leaf eating caterpillar	*Anticarsia gemmatalis* (Hübner)	Noctuidae: Lepidoptera	Caterpillar
3.	Leaf miner	*Acrocerphos phacospora*	Noctuidae: Lepidoptera	Caterpillar
4.	Grass hopper	*Atractomorpha crenulata*	Acrididae : Orthoptera	Nymph, adult
	White fly	*Bemisia tabaci*	Aleyrodidae: Homoptera	Nymph and adult
5.	Aphid	*Myzus persicae*	Aphidae: Homoptera	Nymph and adult
6.	Jassid	*Ambrasca Devastans*	Jassidae: Homoptera	Nymph and adult
7.	Stink bug	*Nezara viridula*	Pentatomidae: Hemiptera	Nymph and adult

4.2 Incidence of insect pests of stem amaranth

Insect populations for 20 selected plants/ plot were observed at 7 days interval with clean observation and amaranth stem weevil, green leaf eating caterpillar, leaf miner, grasshopper, white fly, aphid, jassid and stink bug was counted and converted in per plant and recorded. In was observed that for different management practices number of recorded different insect pests showed statistically significant variation under the present trial.

Incidence of chewing insect pests of stem amaranth

Name of the various insects (amaranth stem weevil, green leaf eating caterpillar, grass hopper and leaf miner) was significantly influenced by the interaction effect of treatment and amaranth varieties (Table 3).

4.2.1 Amaranth stem weevil

The highest number of amaranth stem weevil was observed in V_2T_0 treatment (5.31), which was significantly similar with V_1T_1 treatment (5.01). The lowest number of amaranth stem weevil was observed in V_2T_4 treatment (2.05), which was significantly similar with V_1T_4 treatment.

4.2.2 Green leaf eating caterpillar

The highest number of Green leaf eating caterpillar was observed in V_2T_0 treatment (3.87), which was significantly similar with V_2T_0 treatment (3.40) and V_2T_2 treatment (3.37). The lowest number of green leaf eating caterpillar was observed in V_2T_4 treatment (1.05), which was significantly similar with V_1T_4 treatment (1.13).

Table 3. Effect of different management practices on the incidence of chewing insect pests of stem amaranth (BARI Datha-1 and BARI Datha-2) during study

Treatments	**Number of insects/plot**			
	Amaranth stem weevil	**Green leaf eating caterpillar**	**Grass hopper**	**Leaf miner**
V_1T_0	5.01 a	3.40 a	3.85 a	5.89 a
V_1T_1	3.89 c	2.25 b	2.51 b	4.05 b
V_1T_2	4.25 b	2.87 b	2.91 b	4.56 ab
V_1T_3	3.24 c	2.01 c	2.09 c	3.80 bc
V_1T_4	2.17 e	1.13 e	1.23 e	2.74 d
V_1T_5	2.75 d	1.42 d	1.64 d	3.15 c
V_2T_0	5.31 a	3.87 a	4.15 a	6.09 a
V_2T_1	3.92 c	2.65 b	3.51 b	5.01 b
V_2T_2	4.41 b	3.37 ab	3.74 b	5.76 ab
V_2T_3	3.44 c	2.11 c	2.95 c	4.25 c
V_2T_4	2.05 e	1.05 e	1.73 e	3.04 d
V_2T_5	2.95 d	1.75 d	2.14 d	3.85 bc
$LSD_{(0.05)}$	0.127	0.484	0.319	0.412
Level of significance	*	**	**	**
CV (%)	6.44	7.23	8.17	9.17

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.2.3 Grasshopper

The highest number of grass hopper was observed in V_2T_0 treatment (4.15), which was significantly similar with V_1T_0 treatment (3.85). The lowest was observed in V_1T_4 treatment (1.13), which was significantly similar with V_2T_4 treatment (1.73).

4.2.4 Leaf miner

The highest number of leaf minor was observed in V_2T_0 a treatment (6.09), which was significantly similar with V_1T_0 treatment (5.89), V_2T_2 treatment (5.76) and V_1T_2 treatment (4.56), whereas the lowest was observed in V_1T_4 treatment (2.74), which was significantly similar with V_2T_4 treatments (3.04).

Incidence of sucking insect pests of stem amaranth

Name of the various insects (Aphid, Jassid, White fly and Stink bug) was significantly influenced by the interaction effect treatment and amaranth varieties (Table 4).

4.2.5 Aphid

The highest number of Aphid was observed in V_2T_0 treatment (4.65), which was significantly similar with V_1T_0 treatment (4.55) and V_2T_1 treatment (4.15), whereas the lowest was observed in V_2T_4 treatment (1.75), which was significantly similar with V_1T_4 treatment (1.98).

4.2.6 Jassid

The highest number of Jassid was observed in V_1T_0 treatment (4.85), which was significantly similar with V_2T_0 treatment (4.80), whereas the lowest was observed both in V_1T_4 (1.85) and V_2T_4 treatment (1.85), which was not significantly similar with other treatments combination.

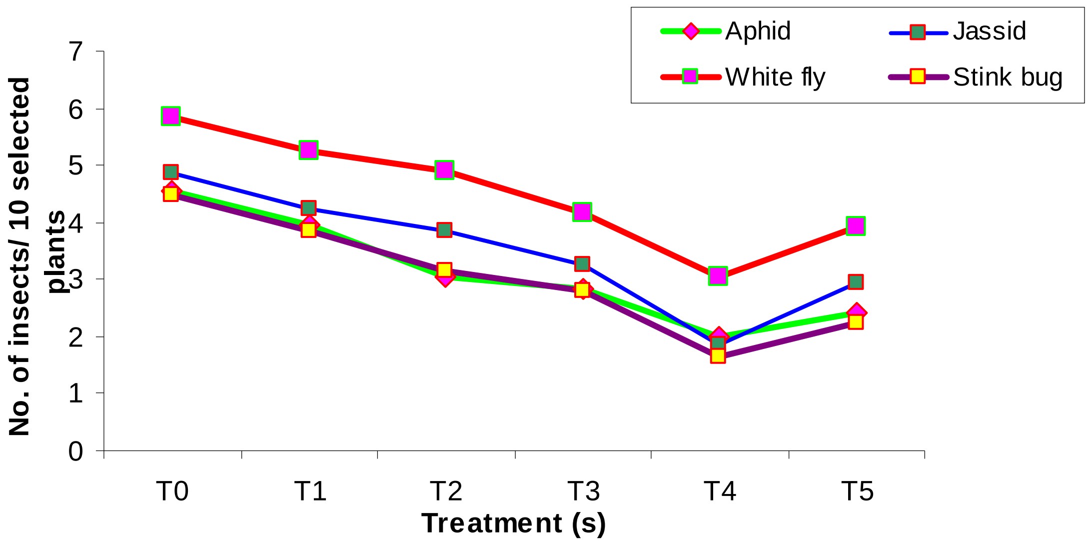


Figure 1: incidence of sucking insect pests on BARI datha-1 during the study period

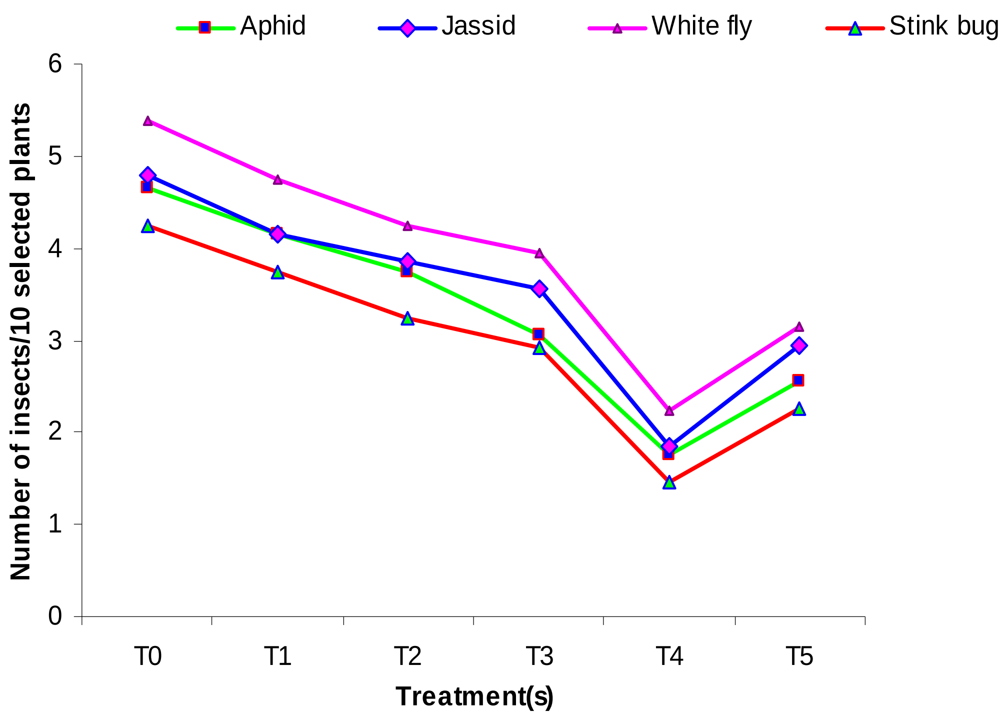


Figure 2: incidence of sucking insect pests on BARI datha-2 during the study period

Table 4. Effect of different management practices on the incidence of sucking insect pests of stem amaranth (BARI Datha-1 and BARI Datha-2) during study

Treatments	Number of insects/plot			
	Aphid	Jassid	White fly	Stink bug
V_1T_0	4.55 a	4.85 a	5.85 a	4.48 a
V_1T_1	3.95 b	4.25 b	5.25 ab	3.85 b
V_1T_2	3.05 c	3.84 b	4.91 b	3.15 c
V_1T_3	2.85 cd	3.25 c	4.15 c	2.80 d
V_1T_4	1.98 e	1.85 e	3.05 e	1.64 e
V_1T_5	2.43 d	2.95 d	3.92 d	2.25 d
V_2T_0	4.65 a	4.80 a	5.35 a	4.25 a
V_2T_1	4.15 ab	4.15 b	4.75 ab	3.75 b
V_2T_2	3.75 b	3.85c	4.25 b	3.25 bc
V_2T_3	3.05 c	3.55 c	3.95 c	2.93 c
V_2T_4	1.75 e	1.85 e	2.74 e	1.45 e
V_2T_5	2.56 d	2.95 d	3.15 d	2.25 d
$LSD_{(0.05)}$	0.412	0.455	0.624	0.705
Level of significance	*	**	*	**
CV (%)	6.74	7.05	8.47	8.16

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.2.7 White fly

The highest number of white fly was observed in V_1T_0 treatment (5.85), which was significantly similar with V_2T_0 treatment (5.35), V_1T_1 treatment (5.25) and V_2T_1 treatment (4.75), whereas the lowest value was observed in V_2T_4 treatment (2.74), which was significantly similar V_1T_4 treatment (3.05) in table 4.

4.2.8 Stink bug

The highest number of stink bug highest value was observed in V_1T_0 treatment (4.48), which was significantly similar with V_2T_0 treatment (4.25), whereas the lowest value was observed in V_2T_4 treatment (1.45), which was significantly similar V_1T_4 treatment (1.64).

4.3 Efficiency of different management practices against chewing insect pest of stem amaranth throughout the study period

4.3.1 Efficiency of different management practices against leaf infestation by grasshopper throughout the cropping season

Number of Leaves /plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (table 5).

In case of healthy leaves, the highest number of leaves /plant was observed in V_1T_4 treatment (27.60), which was significantly similar with V_2T_4 treatment (26.90) and V_1T_3 treatment (26.40). On the other hand, the lowest number of Leaves /plant was observed in V_2T_0 treatment (18.85), which was significantly similar V_2T_1 treatment (19.85), both in V_1T_0 (20.35) and V_1T_1 (21.50) treatments and V_2T_3 treatment (22.95).

Similar way, the highest number of infested leaves /plant was observed in V_2T_0 treatment (4.10), which was significantly similar with V_2T_5 treatment (3.75) and V_1T_0 treatment (3.40), and the lowest value was observed in V_1T_4 treatment (1.40), which were significantly similar V_2T_4 treatment (1.45) and V_1T_5 treatment (1.55) in table 5.

Table 5. Efficiency of different management practices against leaf infestation by grasshopper throughout the study period

Treatments	Number of leaves /plant			
	Healthy	**Infested**	**% infestation**	**Infestation decrease over control (%)**
V_1T_0	20.35 c	3.40 ab	14.32 a	-
V_1T_1	21.50 c	2.40 b	10.04 b	29.89
V_1T_2	25.10 b	2.85 b	10.20 b	28.77
V_1T_3	26.40 ab	2.10 bc	7.37 c	48.53
V_1T_4	27.60 a	1.40 c	4.83 e	66.27
V_1T_5	23.70 b	1.55 c	6.14 d	57.12
V_2T_0	18.85 c	4.10 a	17.86 a	-
V_2T_1	19.85 c	3.05 b	13.32 b	25.42
V_2T_2	24.50 b	2.45 b	9.09 bc	49.10
V_2T_3	22.95 bc	2.85 b	11.05 b	38.13
V_2T_4	26.90 a	1.45 c	5.11 e	71.71
V_2T_5	23.40 b	3.75 ab	13.81 b	22.68
$LSD_{(0.05)}$	0.712	1.45	0.724	1.24
Level of significance	*	**	*	*
CV (%)	6.74	7.15	8.37	9.45

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

In case of percent infestation of leaves, the highest percent of leaves infestation was observed in V_2T_0 treatment (17.86), which was significantly similar with V_1T_0 treatment (14.32). The lowest percent of leaves infestation was observed in V_1T_4 treatment (4.83), which was significantly similar V_2T_4 treatment (5.11).

Percent of Infestation was decreased more in V_2T_4 treatment (71.71) and less in V_2T_1 treatment (25.42) compare to controls.

4.3.2 Efficiency of different management practices against leaf infestation by Green leaf eating caterpillar throughout the cropping season

Leaves number/plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (table 6).

In V_2T_3 treatment (29.47), which was significantly similar with V_1T_3 treatment (28.35), V_2T_4 (27.60) and V_2T_5 (27.10) treatments and V_1T_4 (26.57) and V_1T_5 (26.72) treatments. Whereas, the lowest value was observed in V_2T_0 treatment (21.00), which was significantly similar in V_1T_0 treatment (21.10).

In the same way, the highest number of infested leaves /plant was observed in V_2T_0 treatment (3.87), which was significantly similar with V_1T_0 treatment (3.72). On the other hand, the lowest value was observed in V_2T_3 treatment (1.07), which was significantly similar V_1T_3 (1.10) and T_4 (1.58) treatments and V_2T_5 treatment (1.33).

In case of percent infestation of leaves, the highest percent of leaves infestation was observed in V_2T_0 treatment (15.56), which was significantly similar with BARI Datha-1 in $V1T_0$ treatment (14.99). The lowest value was observed in V_2T_3 treatment (3.50), which was significantly similar V_1T_3 treatment (3.74).

Percent of leaves infestation was decreased more in V_1T_3 treatments (77.51) and less in V_2T_1 treatment (59.45) compare to controls.

Table 6. Efficiency of different management practices against leaf infestation by Green leaf eating caterpillar throughout the study period

Treatments	No. of leaves /plot			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	21.10 d	3.72 a	14.99 a	-
V_1T_1	25.34 bc	1.49 c	5.55 cd	62.97
V_1T_2	25.73 bc	1.32 cd	4.88 d	67.44
V_1T_3	28.35 a	1.10 d	3.74 e	75.05
V_1T_4	26.57 ab	1.58 bc	5.61 cd	62.58
$V_{1S}T_5$	26.72 ab	1.62 bc	5.72 c	61.84
V_2T_0	21.00 d	3.87 a	15.56 a	--
V_2T_1	24.76 bc	1.67 bc	6.31 b	59.45
V_2T_2	25.47 bc	1.67 bc	6.15 b	60.48
V_2T_3	29.47 a	1.07 d	3.50 e	77.51
V_2T_4	27.60 ab	1.53 c	5.25 cd	62.26
V_2T_5	27.10 ab	1.33 cd	4.68 cd	69.92
$LSD_{(0.05)}$	1.013	2.746	0.394	1.493
Level of significance	*	*	*	*
CV (%)	6.74	9.09	7.88	8.55

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.3.3 Efficiency of different management practices against leaf infestation by Amaranth stem weevil throughout the cropping season

Number of healthy plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (table 7).

For healthy plant /plot, the highest number of healthy plant /plot was observed in V_1T_4 treatment (26.52), which was significantly similar with V_2T_4 treatment (25.27), V_1T_5 treatment (24.31) and V_2T_5 treatment (23.13). The lowest number of healthy plant /plot was recorded in V_1T_0 treatment (15.43), which was significantly similar V_2T_0 treatment (16.33).

In same way, the highest number of infested plants /plot was observed in V_1T_0 treatment (4.11), which was significantly similar with V_1T_1 treatment (3.51). The lowest number of infested plants /plot was observed in V_2T_4 treatment (0.67), which was significantly similar V_2T_5 treatment (0.80).

In case of percent infestation, the highest percent of plant infestation was recorded in V_1T_0 treatment (21.03), which was significantly similar with V_1T_1 treatment (16.23) and V_2T_0 treatment (15.82). Whereas, the lowest percent of plant infestation was observed in V_2T_4 treatment (2.58), which was significantly similar with V_2T_5 treatment (3.34).

Percent of Infestation was decreased more in V_2T_4 treatment (83.69) and less in V_1T_1 treatment compare to controls (22.83) in table no. 7.

Table 7. Efficiency of different management practices against leaf infestation by Amaranth stem weevil throughout the study period

Treatments	Number of plant /plot			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	15.43 e	4.11 a	21.03 a	-
V_1T_1	18.12 d	3.51 ab	16.23 ab	22.83
V_1T_2	19.23 cd	2.22 c	10.86 cd	48.36
V_1T_3	22.41bc	2.01 cd	8.23 d	60.87
V_1T_4	26.52 a	1.51 cd	5.39 d	74.37
V_1T_5	24.31 ab	1.77 d	6.79 cd	67.71
V_2T_0	16.33 e	3.07 b	15.82 ab	--
V_2T_1	19.27 cd	1.47 cd	7.09 cd	55.18
V_2T_2	20.80 cd	1.27 cd	5.75 d	63.65
V_2T_3	22.13 bc	1.07 d	4.61 d	70.86
V_2T_4	25.27 a	0.67 e	2.58 e	83.69
V_2T_5	23.13 ab	0.80 de	3.34 de	78.89
$LSD_{(0.05)}$	0.932	2.161	0.287	1.619
Level of significance	*	*	**	*
CV (%)	6.74	11.75	13.74	12.51

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.3.4 Efficiency of different management practices against leaf infestation by Leaf miner throughout the cropping season

Leaves number/plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (table 8).

In case of healthy leaves, the highest number of leaves /plant was observed both in V_1T_4 (29.67) and V_2T_4 treatment (29.67), which were significantly similar with V_2T_5 (29.33) and V_2T_3 treatments (28.33). The lowest number of leaves /plant was both in V_1T_0 and S T_0 treatment (25.01), which was not significantly similar V_1T_0 treatment (25.12).

In the same way, the highest number of infested leaves /plant was observed both in V_1T_0 and V_2T_0 treatment (4.67), having no significant difference among them. The lowest number of infested leaves /plant was observed both in V_1T_4 and V_2T_4 treatment (0.33), which was not significantly similar V_1T_4 treatment (0.33).

For % infestation leaves, the highest percent infestation of leaves was observed in V_2T_0 treatment (15.73), which was significantly similar with V_1T_0 treatment (15.68). The lowest value was observed both in V_1T_4 and with V_2T_4 treatment (1.1), which was significantly similar V_1T_3 treatment (4.08) and V_2T_5 treatment (5.08) in table 8.

Percent of Infestation was decreased more in V_2T_4 treatment (93.00) and less in V_1T_2 treatment (36.22) compare to controls.

Table 8. Efficiency of different management practices against leaf infestation by Leaf miner throughout the study period

Treatments	Number of leaves /plant			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	25.12 d	4.67 a	15.68 a	-
V_1T_1	26.05 c	2.67 bc	9.30 b	40.69
V_1T_2	27.00 bc	3.00 b	10.00 b	36.22
V_1T_3	27.53 b	1.17 cd	4.08 cd	73.98
V_1T_4	29.67 a	0.33 d	1.1 d	92.98
V_1T_5	28.33 b	1.97 c	6.50 c	58.55
V_2T_0	25.01 d	4.67 a	15.73 a	..
V_2T_1	26.15 c	1.87 bc	6.67 b	57.60
V_2T_2	27.17 b	2.67 b	8.95 bc	43.10
V_2T_3	28.33 ab	1.57 c	5.25 c	66.62
V_2T_4	29.67 a	0.33 d	1.1 d	93.00
V_2T_5	29.33 ab	1.57c	5.08 cd	67.71
$LSD_{(0.05)}$	1.012	0.927	0.927	2.07
Level of significance	*	*	*	*
CV (%)	6.74	8.56	7.66	8.12

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.4 Efficiency of different management practices against sucking insect pest of stem amaranth throughout the study period

4.4.1 Efficiency of different management practices against leaf infestation by Stink bug throughout the study period

Number of leaves /plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (table 9).

For healthy leaf, the highest number of healthy leaves /plant was observed both in V_1T_4 treatment (29.47), which was significantly similar with V_2T_5 (28.35), V_2T_4 (29.34), V_2T_3 (26.72) and V_2T_2 (26.57) treatments, respectively and V_1T_5 treatment (26.70). The lowest number of healthy leaves /plant was both in V_1T_0 treatment (21.00), which was significantly similar V_2T_0 treatment (21.10).

In the same way, the highest number of infested leaves /plant was observed in V_1T_0 treatment (3.87), which was significantly similar with V_2T_0 treatment (3.72). The lowest number of infested leaves /plant was observed in V_1T_4 treatment (1.07), which was significantly similar both in V_2T_4 (1.10) and V_2T_5 treatments and V_1T_5 treatment (1.33).

In case of % infestation leaves, the highest percent infestation of leaves was observed in V_1T_0 treatment (15.56), which was significantly similar with V_2T_0 treatment (14.99). The lowest percent infestation of leaves was observed in V_1T_4 treatment (3.50), which was significantly similar with V_2T_4 (3.61) and V_2T_5 (4.45) treatments and V_1T_5 treatment (4.74).

Percent of Infestation was decreased more in V_1T_4 treatment (77.51) and less in V_1T_2 treatment (55.27) compare to controls (Table 9).

Table 9. Efficiency of different management practices against leaf infestation by Stink bug throughout the study period

Treatments	Number of Leaves /plant			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	21.00 d	3.87 a	15.56 a	--
V_1T_1	25.37 bc	1.67 bc	6.18 b	60.28
V_1T_2	22.32c	1.67 bc	6.96 cd	55.27
V_1T_3	25.47 bc	1.53 c	5.67 cd	63.56
V_1T_4	29.47 a	1.07 d	3.50 e	77.51
V_1T_5	26.70 ab	1.33 cd	4.74 de	69.54
V_2T_0	21.10 d	3.72 a	14.99 a	--
V_2T_1	25.73 bc	1.58 bc	5.79 b	61.37
V_2T_2	26.57 ab	1.62 bc	5.75 cd	61.64
V_2T_3	26.72 ab	1.49 c	5.28 cd	64.78
V_2T_4	29.34 a	1.10 d	3.61 e	75.92
V_2T_5	28.35 a	1.32 cd	4.45 de	70.31
$LSD_{(0.05)}$	0.876	2.743	0.394	1.493
Level of significance	*	*	*	*
CV (%)	6.74	10.31	8.15	9.03

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.4.2 Efficiency of different management practices against leaf infestation by Jassid throughout the study period

Number of leaves /plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (Table 10).

For healthy leaves, the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.00), which was significantly similar with both in T_5 (28.67) and V_2T_3 (28.33) and BARI Datha-1 both in T_4 (28.12), T5 (27.56) and T_3 (27.12) treatments. The lowest number of healthy leaves /plant was V_1T_0 treatment (22.53), which was significantly similar V_2T_0 treatment (23.67).

Similarly, the highest number of infested leaves / plant was observed in V_1T_0 treatment (6.23), which was significantly similar with V_2T_0 treatment (6.33). The lowest number of infested leaves / plant was observed in V_2T_4 treatment (1.00), which were significantly similar both in V_2T_3 (1.67) and V_2T_5 (1.33) treatments and both in V_1T_5 (1.28), V_1T_4 (1.11) and V_1T_3 (1.56) treatments.

For % infestation leaf, the highest percent infestation of leaves was observed in V_1T_0 treatment (21.66), which was significantly similar with V_2T_0 treatment (21.10). The lowest percent infestation of leaves was observed in V_2T_4 treatment (3.33), which were significantly similar V_2T_3 (5.57) and V_2T_5 (4.43) treatments and both in V_1T_3 (5.44), V_1T_4 (3.80) and V_1T_5 (4.44) treatments.

Percent of Infestation was decreased more in V_1T_4 treatment (82.46) and less in V_1T_1 treatment (52.26) compare to controls (Table 10).

Table 10. Efficiency of different management practices against leaf infestation by Jassid throughout the study period

Treatments	Leaf number/plant			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	22.53 e	6.23 a	21.66 a	-
V_1T_1	26.11 d	3.01 b	10.34 b	52.26
V_1T_2	26.23 cd	2.43 bc	8.48 bc	60.85
V_1T_3	27.12 ac	1.56 ce	5.44 ce	74.88
V_1T_4	28.12 ac	1.11 e	3.80 e	82.46
V_1T_5	27.56 ab	1.28 de	4.44 de	79.50
V_2T_0	23.67 e	6.33 a	21.1 a	--
V_2T_1	27.00 d	3.00 b	10.00 b	52.61
V_2T_2	27.67 cd	2.33 bc	7.77 bc	63.18
V_2T_3	28.33 ac	1.67 ce	5.57 ce	73.60
V_2T_4	29.00 a	1.00 e	3.33 e	84.22
V_2T_5	28.67 ab	1.33 de	4.43 de	79.00
$LSD_{(0.05)}$	1.032	0.753	0.753	2.507
Level of significance	*	**	*	*
CV (%)	6.74	9.22	10.01	12.16

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.4.3 Efficiency of different management practices against leaf infestation by White fly throughout the study period

Number of leaves /plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (Table 11).

For Healthy leaf the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.00), which was significantly similar with both in V_2T_5 (28.67) and V_2T_3 (28.33) and both in V_1T_4 (29.12), V_1T_5 (28.56) and V_1T_3 (28.12) treatments. On the other hand, the lowest number of healthy leaves /plant was in V_1T_0 treatment (21.45), which was significantly different from V_2T_0 treatment (22.87).

Similarly, the highest number of infested leaves / plant was observed in V_1T_0 treatment (6.71), which was significantly similar with V_2T_0 treatment (5.81). The lowest number of infested leaves / plant was observed in V_2T_4 treatment (1.00), which were significantly similar both in V_2T_3 (1.67) and V_2T_5 (1.33) treatments and both in V_1T_5 (1.28), V_1T_4 (1.11) and V_1T_3 (1.56) treatments.

In case of % infestation leaf, the highest percent infestation of leaves was observed in V_1T_0 treatment (23.83), which was significantly similar with V_2T_0 treatment (20.26). The lowest percent infestation of leaves was observed in V_2T_4 treatment (3.33), which were significantly similar V_2T_3 (5.57) and V_2T_5 treatments (4.43) and both in V_1T_3 (5.26), V_1T_4 (3.67) and V_1T_5 (4.29) treatments.

Percent of Infestation was decreased more in V_1T_4 treatment (84.60) and less in V_2T_1 treatment (50.64) compare to controls (Table 11).

Table 11. Efficiency of different management practices against leaf infestation by White fly throughout the study period

Treatments	Number of leaves /plant			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	21.45 e	6.71 a	23.83 a	-
V_1T_1	27.11 d	3.01 b	10.00 b	58.04
V_1T_2	27.23 cd	2.43 bc	8.19 bc	65.63
V_1T_3	28.12 ac	1.56 ce	5.26 ce	77.93
V_1T_4	29.12 a	1.11 e	3.67 e	84.60
V_1T_5	28.56 ab	1.28 de	4.29 de	82.00
V_2T_0	22.87 e	5.81 a	20.26 a	--
V_2T_1	27.00 d	3.00 b	10.00 b	50.64
V_2T_2	27.67 cd	2.33 bc	7.77 bc	61.65
V_2T_3	28.33 ac	1.67 ce	5.57 ce	72.51
V_2T_4	29.00 a	1.00 e	3.33 e	83.56
V_2T_5	28.67 ab	1.33 de	4.43 de	78.13
$LSD_{(0.05)}$	0.512	1.753	0.953	2.507
Level of significance	*	*	**	*
CV (%)	6.74	9.22	10.01	12.16

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.4.4 Efficiency of different management practices against leaf infestation by Aphid throughout the study period

Number of leaves /plant (healthy, infested and % infestation) was significantly influenced by the interaction effect treatment and amaranth varieties (Table 12).

In case of healthy leaf the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.33), which was significantly similar with both in V_2T_5 (29.00) and V_2T_3 (28.67) and both in V_1T_4 (29.31), V_1T_5 (29.03) and V_1T_3 (28.52) treatments. The lowest number of healthy leaves/plant was in V_1T_0 treatment (24.56), which was significantly similar in V_2T_0 treatment (24.67).

Similarly, the highest number of infested leaves / plant was observed in V_2T_0 treatment (5.33), which was significantly similar with V_1T_0 treatment (5.26). The lowest number of infested leaves/plant was observed in V_2T_4 treatment (0.67), which was significantly similar both in V_2T_3 (1.33) and V_2T_5 (1.00) treatments and both in V_1T_5 (1.03), V_1T_4 (0.65) and V_1T_3 (1.30) treatments.

For % infestation leaf, the highest percent infestation of leaves was observed in V_2T_0 treatment (17.77), which was significantly similar with V_1T_0 treatment (17.64). The lowest percent infestation of leaves was observed in V_1T_4 treatment (2.17), which was significantly similar in V_2T_3 (4.43), V_2T_4 (2.23) and V_2T_5 (3.33) treatments and V_1T_5 treatment (3.43).

Percent of Infestation was decreased more in V_1T_4 treatment (87.70) and less in V_2T_1 treatment (49.92) compare to controls (Table 12).

Table 12. Efficiency of different management practices against leaf infestation by Aphid throughout the study period

Treatments	Number of leaves /plant			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
V_1T_0	24.56 e	5.26 a	17.64 a	-
V_1T_1	27.24 d	2.63 b	8.80 b	50.11
V_1T_2	27.71 cd	2.31 bc	7.69 bc	56.41
V_1T_3	28.52 ac	1.30 ce	4.36 bd	75.28
V_1T_4	29.31 a	0.65 e	2.17 e	87.70
V_1T_5	29.03 ab	1.03 de	3.43 de	80.56
V_2T_0	24.67 e	5.33 a	17.77 a	--
V_2T_1	27.33 d	2.67 b	8.9 b	49.92
V_2T_2	27.67 cd	2.33 bc	7.77 bc	56.27
V_2T_3	28.67 ac	1.33 ce	4.43 ce	75.07
V_2T_4	29.33 a	0.67 e	2.23 e	87.45
V_2T_5	29.00 ab	1.00 de	3.33 de	81.26
$LSD_{(0.05)}$	1.302	0.844	0.844	2.812
Level of significance	*	**	*	*
CV (%)	6.74	7.12	9.87	11.78

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.5 Efficiency of different management practices against plant height and yield at harvest period

4.5.1 Efficiency of different management practices against plant height at harvest period

Plant height (at harvest) was significantly influenced by the interaction effect of treatment and amaranth varieties (table 13). The highest value was observed both in V_1T_4 treatment (109.50 cm), which was significantly similar with both in V_2T_5 (106.47 cm), V_2T_4 (108.78 cm) and V_2T_3 (103.45 cm) and both in V_1T_5 (107.83 cm) and V_1T_3 (92.30 cm) treatments. The lowest value was in V_1T_0 treatment (70.86 cm), which was significantly similar V_2T_0 treatment (71.79 cm).

4.5.2 Efficiency of different management practices against yield (t ha^{-1}) at harvest period

Yield was significantly influenced by the interaction effect of treatment and amaranth varieties (table 13). The highest yield was observed both in V_1T_4 treatment (36.56 t ha^{-1}), which was significantly similar with both in V_2T_5 (32.56 t ha^{-1}), V_2T_4 (34.57 t ha^{-1}) and V_2T_3 (31.50 t ha^{-1}) and both in V_1T_5 (33.87 t ha^{-1}) and V_1T_3 (29.75 t ha^{-1}) treatments. The lowest yield was in V_2T_0 treatment (21.78 t ha^{-1}), which was significantly similar V_1T_0 treatment (22.32 t ha^{-1}).

Table 13. Efficiency of different management practices against plant height and yield at harvest period

Treatments	Plant Height (cm)	Yield (t ha^{-1})
V_1T_0	70.86 e	22.32 e
V_1T_1	90.26 d	26.90 d
V_1T_2	90.68 cd	26.98 cd
V_1T_3	92.30 ac	29.75 ac
V_1T_4	109.50 a	36.56 a
V_1T_5	107.83 ab	33.87 ab
V_2T_0	71.79 e	21.78 e
V_2T_1	90.67 d	26.79 d
V_2T_2	93.65 cd	30.57 cd
V_2T_3	103.45 ac	31.50 ac
V_2T_4	108.47 a	34.57 a
V_2T_5	106.78 ab	32.56 ab
$LSD_{(0.05)}$	0.912	0.844
Level of significance	*	**
CV (%)	11.74	9.12

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; Values are the means of three replications

[T_0=Untreated control; T_1=Mechanical and cultural practices at the 7 days interval;T_2=Spraying Soap water (Detergent) @ 2.0g/L of water at the 7 days interval;T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval; T_4=Spraying neem oil @ 2.0 ml/L of water with mixing 10 ml detergent at the 7 days interval and T_5=Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval]

4.6.1 Relationship between percent of infestation due to grasshopper and yield in both varieties (BARI Datha-1 and BARI Datha-2):

Correlation study was done to establish the relationship between percent of Grasshopper infestation and Yield in both varieties. From the Figure 3 and Figure-4, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = -1.461x +42.22 (figure 3) and y = -1.000x +40.33 (figure 4) gave a good fit to the data and the co-efficient of determination, R^2 =0.935 (figure 3) and R^2 =0.934 (figure 4) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure- 3 and Figure-4 that percent of grasshopper infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of grasshopper in both variety.

4.6.2 Relationship between percent of infestation due to Green leaf eating caterpillar and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between percent of caterpillar infestation and Yield in both varieties. From the Figure –5 and Figure-6, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = -0.717x +33.55 (figure 5) and y = -0.899x +35.65 (figure 6) gave a good fit to the data and the co-efficient of determination, R^2 =0.372 (figure 5) and R^2 =0.745 (figure 6) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure-5 and Figure-6 that percent of caterpillar infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of caterpillar in both variety.

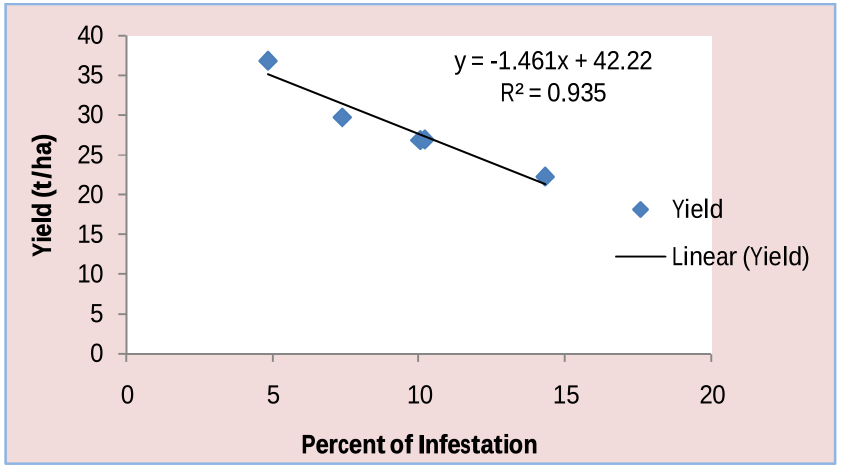


Figure: 3 Relationship between percent of infestation due to Grasshopper and Yield in BARI Datha-1

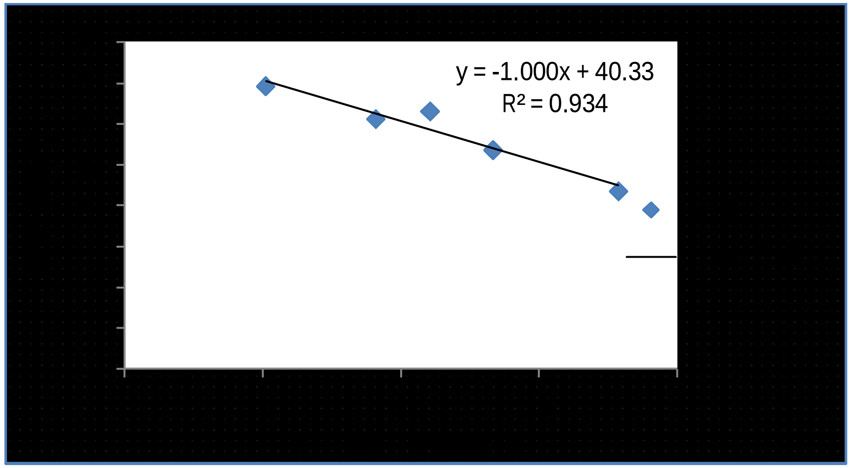


Figure 4: Relationship between percent of infestation due to Grasshopper and Yield in BARI Datha-2

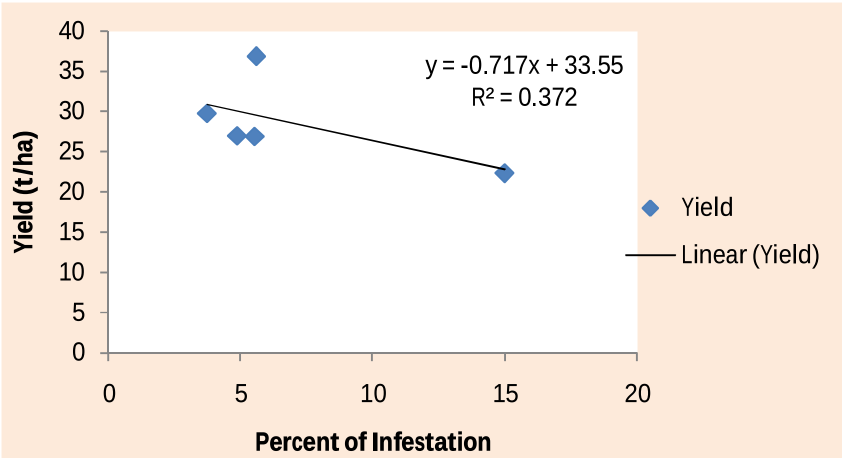


Figure 5: Relationship between percent of infestation due to Green leaf eating caterpillar and Yield in BARI Datha-1

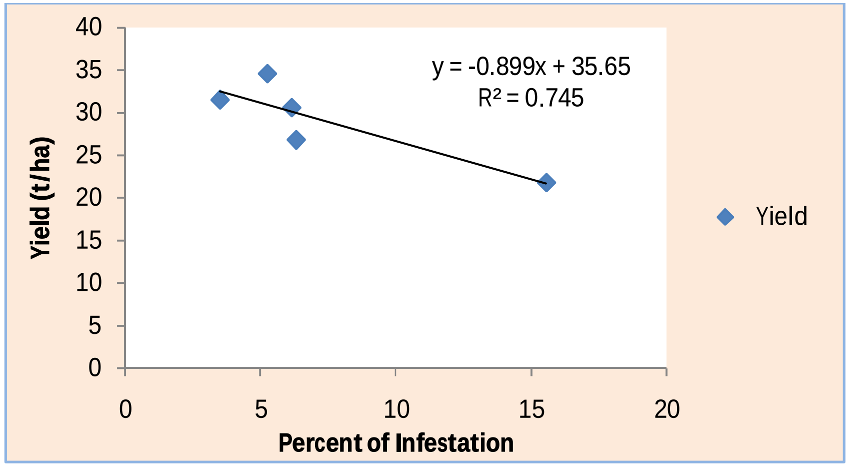


Figure 6: Relationship between percent of infestation due to Green leaf eating caterpillar and Yield in BARI Datha-2

4.6.3 Relationship between percent of infestation due to leaf miner and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between percent of infestation due to leaf miner and yield in both varieties. From the Figure-7 and Figure- 8, it was revealed that negative correlation was observed between the parameters. It was evident that the equation $y = -0.808x +35.13$ (figure 7) and $y = -0.802x +35.63$ (figure 8) gave a good fit to the data and the co-efficient of determination, $R^2 =0.801$ (figure 7) and $R^2 =0.945$ (figure 8) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure-7 and Figure- 8that percent of leaf miner infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of in both variety.

4.6.4 Relationship between percent of infestation due to white fly and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between percent of infestation due to white fly and yield in both varieties. From the Figure -9 and Figure-10, it was revealed that negative correlation was observed between the parameters. It was evident that the equation $y = -0.551x +34.18$ (figure 9) and $y = -0.728x +35.88$ (figure 10) gave a good fit to the data and the co-efficient of determination, $R^2 =0.681$ (figure 9) and $R^2 =0.946$ (figure 10) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure-9 and Figure- 10 that percent of white fly infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of in both variety.

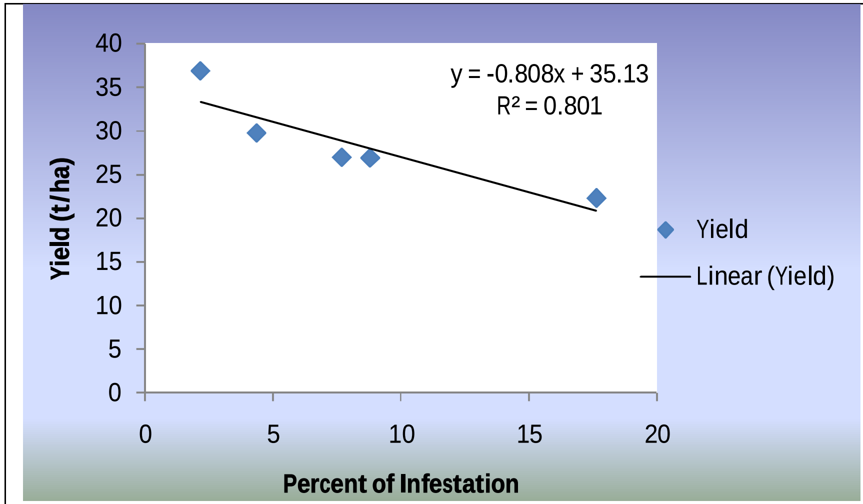


Figure 7: Relationship between percent of infestation due to leaf miner and Yield in BARI Datha-1

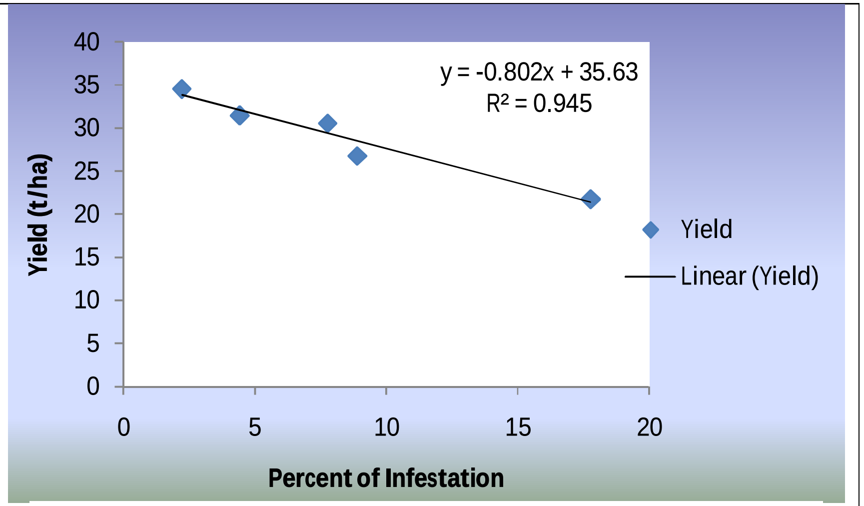


Figure 8: Relationship between percent of infestation due to leaf miner and Yield in BARI Datha-2

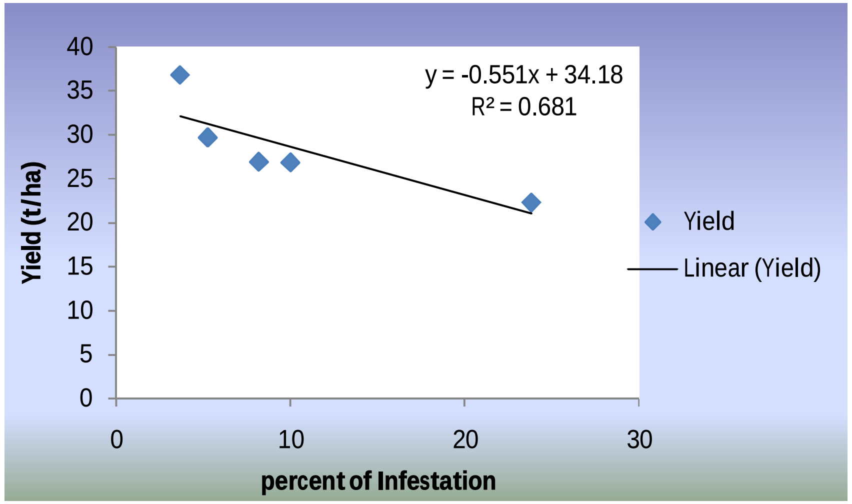


Figure 9: Relationship between percent of infestation due to white fly and Yield in BARI Datha-1

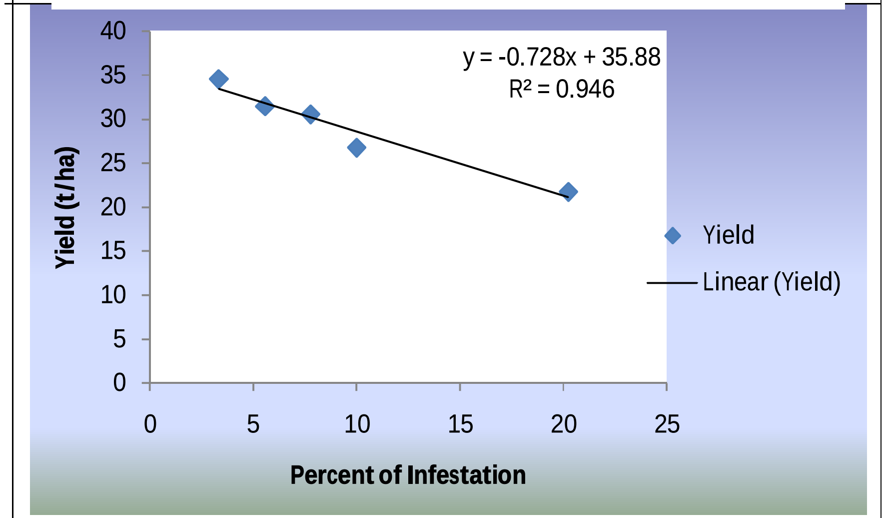


Figure 10: Relationship between percent of infestation due to white fly and Yield in BARI Datha-1

4.6.5 Relationship between percent of infestation due to jassid and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between percent of infestation due to jassid and yield in both varieties. From the Figure - 11 and Figure-12, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = -0.647x +34.99 (figure 11) and y = -0.688x +35.62 (figure 12) gave a good fit to the data and the co-efficient of determination, R^2 =0.721 (figure 11) and R^2 =0.938 (figure 12), respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure-11 and Figure-12 that percent of jassid infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of in both variety.

4.6.6 Relationship between percent of infestation due to aphid and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between percent of infestation due to aphid and yield in both varieties. From the Figure – 13 and Figure- 14, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = -1.417x +38.31 (figure 13) and y = -0.927x +36.14 (figure 14) gave a good fit to the data and the co-efficient of determination, R^2 =0.878 (figure 13) and R^2 =0.859 (figure 14) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure- 13 and Figure- 14 that percent of aphid infestation was strongly as well as negatively correlated with yield (t/ha). Yield (t/ha) was decreased due to increase percent infestation of in both variety.

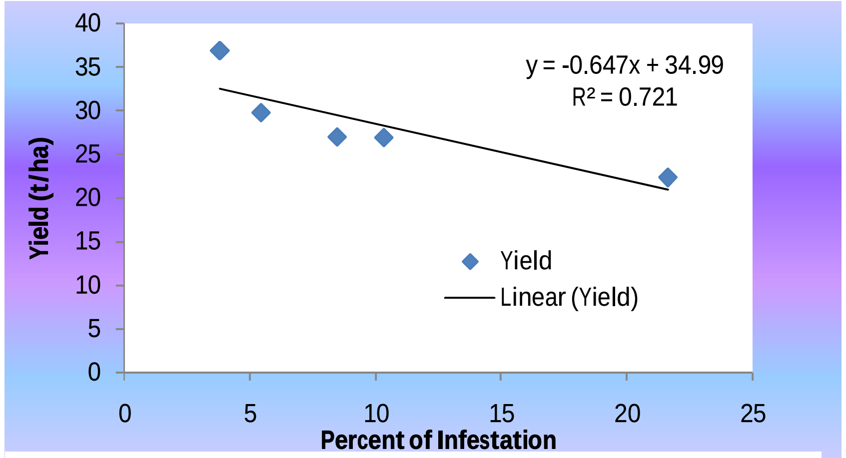


Figure 11: Relationship between percent of infestation due to jassid and Yield in BARI Datha-1

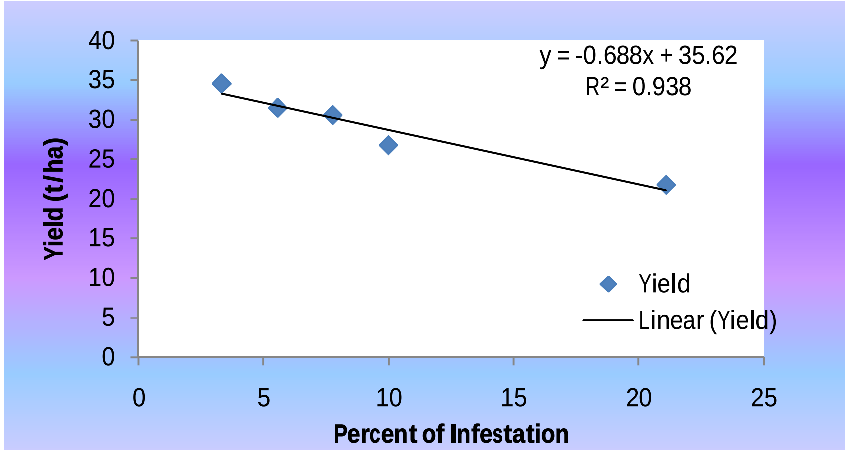


Figure 12: Relationship between percent of infestation due to jassid and Yield in BARI Datha-2

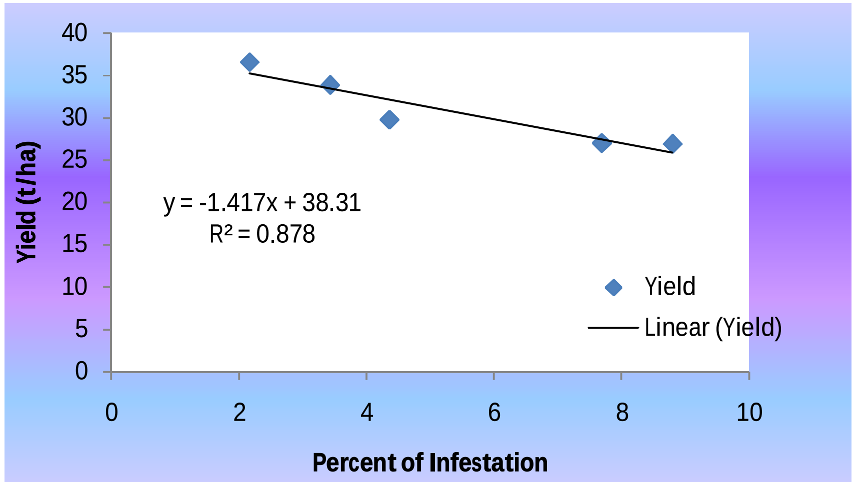


Figure 13: Relationship between percent of infestation due to Aphid and Yield in BARI Datha-1

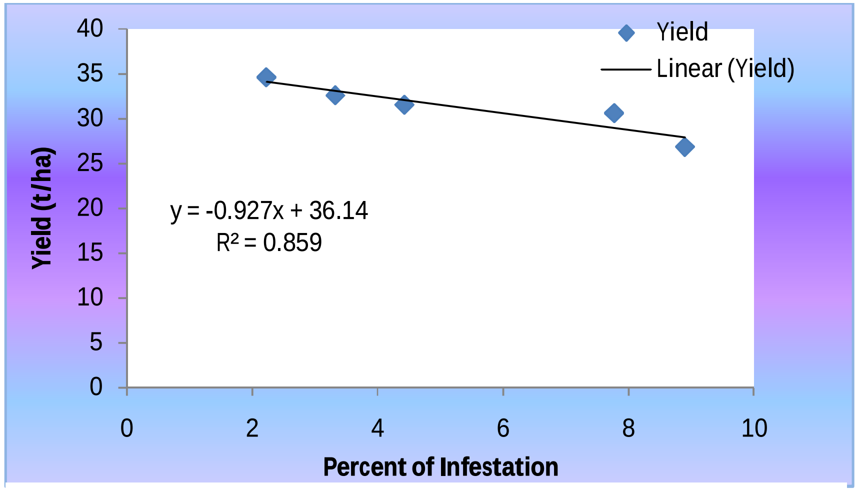


Figure 14: Relationship between percent of infestation due to Aphid and Yield in BARI Datha-2

4.6.7 Relationship between plant height and yield in both varieties (BARI Datha-1 and BARI Datha-2)

Correlation study was done to establish the relationship between plant height and yield of both varieties. From the Figure - 15 and Figure - 16, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 0.482x -17.83 (figure 15) and y = 0.496x -19.09 (figure 16) gave a good fit to the data and the co-efficient of determination, R^2 =0.852 (figure 15) and R^2 =0.854 (figure 16) respectively fitted regression line had a significant regression co-efficient. It may be concluded from the Figure-15 and Figure- 16 that plant height was strongly as well as positively correlated with yield (t/ha). Yield (t/ha) was increase due to increase percent infestation of caterpillar in both variety.

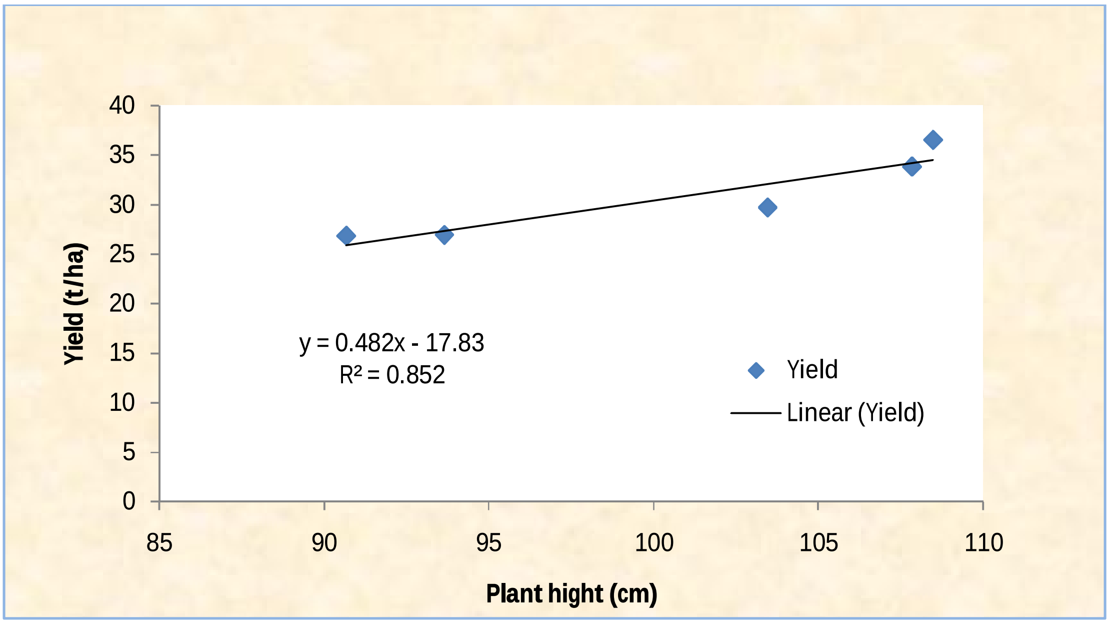


Figure 15: Relationship between plant height and yield in BARI Datha-1

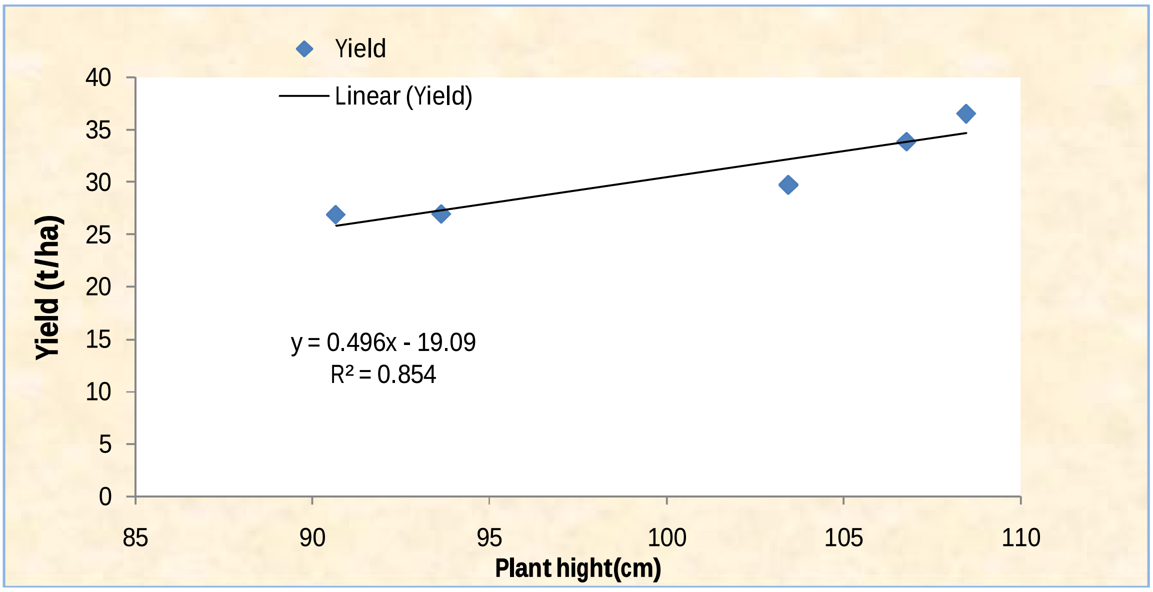


Figure 16: Relationship between plant height and yield in BARI Datha-2

Chapter V

Summary And Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Kharif-1 season of March 2016 to July 2016. The experiment was laid out in randomized complete block design (RCBD) with three replications where main plot was for variety (Factor B) v_1 : BARI datha-1, v_2 : BRRI datha -2 and sub-plot was for treatment (Factor A) T_0=Untreated control, T_1=Mechanical and cultural practices at the 7 days interval, T_2=Spraying Soap water (Detergent) @2.0g/L of water at the 7 days interval, T_3=Apply wood ash @ as per required with mixing inert materials (2:1) at the 7 days interval, T_4=Spraying neem oil @2.0 mg/L of water with mixing 10 ml detergent at the 7 days interval, T_5= Spraying neem leaves extracts @ 20 gm/L of water at the 7 days interval. There were 12 treatment combinations. There are total 36 numbers of unit plots. The size of unit plot was 6 m^2 (3m × 2m). Layout of the experiment was done with the distances having 0.5 m between blocks and 0.5 m distances between plot maintained for proper drainage facility.

The collected data on various parameters were statistically analyzed using MSTAT-C package programmers. The mean for all the treatments were calculated and analyzed and analyses of variance of all the characters were performed by F-variance test. The significance of differences between the pairs of treatment means was calculated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

The result of this study revealed that, the highest number of Amaranth stem weevil was observed in V_2T_0 treatment (5.31) and the lowest was observed in V_2T_4 treatment (2.05). In case of Green leaf eating caterpillar, the highest number of Green leaf eating caterpillar was observed in V_2T_0 treatment (3.87), which was significantly similar with V_1T_0 treatment (3.40) and V_2T_2 treatment (3.37), whereas the lowest number of green leaf eating caterpillar was observed in V_2T_4 treatment (1.05), which was significantly similar with V_1T_4 treatment (1.13).

The highest number of Grass hopper was observed in V_2T_0 treatment (4.15), which was significantly similar with V_1T_0 treatment (3.85). The lowest was observed in V_1T_4 treatment (1.13), which was significantly similar with V_2T_4 treatment (1.73).

The highest number of leaf minor was observed in V_2T_0 a treatment (6.09), which was significantly similar with V_1T_0 treatment (5.89), whereas the lowest was observed in V_1T_4 treatment (2.74), which was significantly similar with V_2T_4 treatment (3.04).

In case of sucking insect pest, the highest number of Aphid was observed in V_2T_0 treatment (4.65), which was significantly similar with V_1T_0 treatment (4.55) and V_2T_1 treatment (4.15), whereas the lowest was observed in V_2T_4 treatment (1.75), which was significantly similar with V_1T_4 treatment (1.98).

The highest number of Jassid was observed in V_1T_0 treatment (4.85), which was significantly similar with V_2T_0 treatment (4.80), whereas the lowest was observed both in V_1T_4 and V_2T_4 treatment (1.85), which was not significantly similar with other treatments combination.

The highest number of white fly was observed in V_1T_0 treatment (5.85), which was significantly similar with V_2T_0 treatment (5.35), V_1T_1 treatment (5.25) and V_2T_1 treatment (4.75), whereas the lowest value was observed in V_2T_4 treatment (2.74), which was significantly similar V_1T_4 treatment.

The highest number of stink bug was observed in V_1T_0 treatment (4.48), which was significantly similar with V_2T_0 treatment (4.25), whereas the lowest value was observed in V_2T_4 treatment (1.45).

In case of healthy leaves, the highest number of leaves /plant was observed in V_1T_4 treatment (27.60), On the other hand, the lowest number of Leaves /plant was observed in V_2T_0 treatment (18.85), which was significantly similar V_2T_1 treatment (19.85). The highest number of infested leaves /plant was observed in V_2T_0 treatment (4.10), which was significantly similar with V_2T_5 treatment (3.75) and V_1T_0 treatment (3.40), and the lowest value was observed in V_1T_4 treatment (1.40).

In case of percent infestation of leaves, the highest percent of leaves infestation was observed in V_2T_0 treatment (17.86), which was significantly similar with V_1T_0

treatment (14.32). The lowest percent of leaves infestation was observed in V_1T_4 treatment (4.83). Percent of Infestation was decreased more in V_2T_4 treatment (71.71) and less in V_2T_1 treatment (25.42) compare to controls.

In case of healthy leaves, the highest number of leaves /plant was observed in V_2T_3 treatment (29.47), which was significantly similar with V_1T_3 treatment (28.35), whereas, the lowest value was observed in V_2T_0 treatment (21.00), which was significantly similar V_1T_0 treatment (21.10). The highest number of infested leaves /plant was observed in V_2T_0 treatment (3.87), which was significantly similar with V_1T_0 treatment (3.72). On the other hand, the lowest value was observed in V_2T_3 treatment (1.07), which was significantly similar both in V_1T_3 (1.10) and V_1T_4 (1.58) treatments and V_2T_5 treatment (1.33). In case of percent infestation of leaves, the highest percent of leaves infestation was observed in V_2T_0 treatment (15.56), whereas the lowest value was observed in V_2T_3 treatment (3.50), Percent of leaves infestation was decreased more in V_2T_3 treatment (77.51) and less in V_2T_1 treatment (59.45) compare to controls.

In case of amaranth stem weevil, the highest number of healthy plant /plot was observed in V_1T_4 treatment (26.52), which were significantly similar with V_2T_4 treatment (25.27), V_1T_5 treatment (24.31) and V_2T_5 treatment (23.13). The lowest number of healthy plant /plot was recorded in V_1T_0 treatment (15.43), which was significantly similar V_2T_0 treatment (16.33). In same way, the highest number of infested plants /plot was observed in V_1T_0 treatment (4.11); whereas, the lowest number of infested plants /plot was observed V_2T_4 treatment (0.67), which was significantly similar V_2T_5 treatment (0.80). In case of percent infestation, the highest percent of plant infestation was recorded in V_1T_0 treatment (21.03); whereas, the lowest percent of plant infestation was observed in V_2T_4 treatment (2.58). Percent of Infestation was decreased more in V_2T_4 treatment (83.69) and less in V_1T_1 treatment compare to controls (22.83).

In case of leaf miner, the highest number of leaves /plant was observed both in V_1T_4 and V_2T_4 treatment (29.67), whereas the lowest number of leaves /plant was both in V_1T_0 and V_2T_0 treatment (25.01), which was not significantly similar with V_1T_0 treatment (25.12). In the same way, the highest number of infested leaves /plant was observed both V_1T_0 (4.67) and V_2T_0 treatment (4.67), having no significant difference among them. The lowest number of infested leaves /plant was observed both in V_1T_4 (0.33) and V_2 T_4 treatment (0.33). The highest percent infestation of leaves was observed in V_2T_0 treatments (15.73), and the lowest value was observed both in V_1T_4 (1.1) and with V_2T_4 treatment (1.1), which was significantly similar V_1T_3 treatment (4.08) and V_2T_5 treatment (5.08). Percent of Infestation was decreased more in V_2T_4 treatment (93.00) and less in V_1T_2 treatment (36.22) compare to controls.

In case of stink bug, the highest number of healthy leaves /plant was observed both in V_1T_4 treatment (29.47), whereas the lowest number of healthy leaves /plant was in V_1T_0 treatment (21.00), which was significantly similar V_2T_0 treatment (21.10). In the same way, the highest number of infested leaves /plant was observed in V_1T_0 treatment (3.87), and the lowest was observed in V_1T_4 treatment (1.07), which was significantly similar both in V_2T_4 (1.10) and V_2T_5 treatment (1.33) and V_1T_5 treatment (1.33). In case of % infestation leaves, the highest percent infestation of leaves was observed in V_1T_0 treatment (15.56), which was significantly similar with V_2T_0 treatment (14.99). The lowest percent infestation of leaves was observed in V_1T_4 treatment (3.50), which was significantly similar V_2T_4 (3.61) and V_2T_5 (4.45) treatment and V_1T_5 treatment (4.74). Percent of Infestation was decreased more in V_1T_4 treatment (77.51) and less in V_1T_2 treatment (55.27) compare to controls.

In case of jassid, the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.00), and the lowest number of healthy leaves /plant was in V_1T_0 treatment (22.53), which was significantly similar V_2T_0 treatment (23.67). Similarly, the highest number of infested leaves / plant was observed in V_1T_0 treatment (6.23), and the lowest number of infested leaves / plant was observed in V_2T_4 treatment (1.00). For % infestation leaf, the highest percent infestation of leaves was observed in V_1T_0 treatment (21.66), and the lowest percent infestation of leaves was observed in V_2T_4 treatment (3.33). Percent of Infestation was decreased more in V_1T_4 treatment (82.46) and less in V_1T_1 treatment (52.26) compare to controls.

Leaf infestation by White fly, the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.00), On the other hand, the lowest number of healthy leaves /plant was in V_1T_0 treatment (21.45), which was significantly different from V_2T_0 treatment (22.87). Similarly, the highest number of infested leaves / plant was observed in V_1T_0 treatment (6.71), and the lowest was observed in V_2T_4 treatment (1.00). In case of % infestation leaf, the highest percent infestation of leaves was observed in V_1T_0 treatment (23.83), and the lowest percent infestation of leaves was observed in V_2T_4 treatment (3.33). Percent of Infestation was decreased more in V_1T_4 treatment (84.60) and less in V_2T_1 treatment (50.64) compare to controls.

In case of aphid, the highest number of healthy leaves /plant was observed both in V_2T_4 treatment (29.33), and the lowest number of healthy leaves /plant was in V_1T_0 treatment (24.56), which was significantly similar V_2T_0 treatment (24.67). Similarly, the highest number of infested leaves / plant was observed in V_2T_0 treatment (5.33), and the lowest number of infested leaves / plant was observed in V_2T_4 treatment (0.67). The highest percent infestation of leaves was observed in V_2T_0 treatment (17.77), whereas the lowest percent infestation of leaves was observed in V_1T_4 treatment (2.17). Percent of Infestation was decreased more in V_1T_4 treatment (87.70) and less in V_2T_1 treatment (49.92) compare to controls.

Plant height (at harvest) was significantly influenced by the interaction effect of treatment and amaranth varieties. The highest plant height was observed both in V_1T_4 treatment (109.50 cm) and V_2T_4 treatment (108.47 cm) respectively. The lowest value was in V_1T_0 treatment (70.86 cm). Yield was significantly influenced by the interaction effect treatment and amaranth varieties. The highest yield was observed both in V_1T_4 treatment (36.56 t ha^{-1}) and V_2T_4 treatment (34.57), which was significantly similar with V_2T_5 treatment (32.56 t ha^{-1}), and the lowest yield was in V_2T_0 treatment (21.78 t ha^{-1}), which was significantly similar V_1T_0 treatment (22.32 t ha^{-1}).

Conclusion

From this study it was revealed that infestation was more in both varieties in T_0 treatment but BARI Datha-2 (V_2T_0) more infested than BARI Datha-1 (V_1T_0). BARI Datha-1 (V_1T_4) given more yield than BARI Datha-2 (V_2T_4).

Chapter VI

References

CHAPTER VI

REFERENCES

Abukutsa-Onyango, M. O., Tushabomwe-Kazoola, C., Wangari, M., Onyango, G. M. and Macha, E. S. (2006). Improved community Land use for sustainable production and utilization of African Indigenous Vegetables in the Lake Victoria Region. Proceedings of 6th Horticultural Seminar on Sustainable Horticultural production in the Tropics. Njoro, Kenya: *Horticultural Society of Kenya*. pp. 167-170.

Aderolu, A.I., Omooloye, A.A. and Okelana, A.F. (2013). Occurrence, Abundance and control of the major insect pests associated with amaranth in Ibadan, Nigeria. *J. Entom. Ornithol. Herpetol.* **2**: 112-118.

Agarwal, B.D.(1985). Biology of *Hypolixus truncatulus* (F) (Coleoptera: Curculionidae) forming galls on the stem of *Amaranthus spinosus* Lim. in India. *Cecidologia – International*, **6**(1/3): 83 -90.

Akinlosotu, T.A. (1977). A checklist of insects associated with local vegetables in Southwest Nigeria. Research Bulletin, IAR and T. Ife. **5**:18-23.

Alvarez-Jubete, L., Wijngaard, H., Arendt, E.K. and Gallagher, E. (2010). Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa, buckwheat and wheat as affected by sprouting and Baking. *Food Chemistry*. **119:** 770–778.

Anyango, J. J. (2006). Planning Integrated Pest Management for mites with emphasis on Roses. Proceedings of 6th Horticultural Seminar on Sustainable Horticultural production in the Tropics. Njoro, Kenya: *Horticultural Society of Kenya*. pp. 270-273.

Arivudainambi, S., Selvamuthukumaran, T. and Baskaran, P. (2010). Efficacy of Herbal extracts in the management of Amaranth Leaf Caterpillar. *International Journal of Vegetable Science*. **16:** 167 – 173.

Auotundun, J.S., Ajayi, J.O. and Bankole, M.H. (1995). Field evaluation of nitrogen availability in cattle, poultry and rabbit manure and concentration of N in the leaves of Amaranths. *Amaranths Newsletter*. **1**(l): 5-11.

AVRDC (2003). progress report 2003. Asian vegetable Research and Development centre, Shanhua, Tainan. pp. 80-90.

BBS. (2009). Year book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning, Dhaka. pp 201-223.

Becerra, R. (2000). Amaranth: new crop opportunity. **In:** *Janick Journal* (ed.): Progress in New Crops. Ashs Press, Alexandria. pp. 207-120.

Booth, S.A. (1983). Crop protection in vegetables production. In service Training papers by Agricultural Extension and Research Liaison services, ABU, Zaria, pp. 1-12.

Bose, T.K., Som, M.G. and Kabir, T. (1993). Vegetables Crops in India. Naya Prokash, Calcutta. pp. 11-16.

Capinera, J.L., Scott, R.D. and Walker, T.J. (2004). Field Guide to Grasshoppers, Katydids, and Crickets of the United States. Cornell University Press. pp. 31-34.

Cole, J. N. (1989). Amaranthus from the past for the future. The Vegetable Book. Rodale Press Eminaus Pennsy Wania, U.S.A. pp. 25-38.

Degri M.M., Ayuba, M.M. and Yoriyo, K.P. (2012). Bio-efficacy of some aqueous plant extracts and cyromazine (Trigard 169) in the management of leaf miner (Liriomyza sp.) on egg plant in the Northern Guinea Savanna of Nigeria. Niger. *J. Exp. Appl. Biol.* **13**(2): 125-130.

Degri, M.M. Onu, I.M.C. Dike and Ayuba, M.M. (2007). Host plants of the serpentine leaf miner, Liriomyza sativae Blanchard (Diptera: Agromyzidae) in Bauchi state, Nigeria. *Niger J. Entomol.* **24**(2007): 122-130.

Devdas, R.P. and Saroja, S. (2001). Availability of iron and b-carotene from Amaranthus to children. *Amaranthus Proceeding*. p. 15.

Dillon, A.B., Moore, C.P., Downes, M.J. and Graffin, C.T. (2008). Evict or infect? Managing populations of large pine weevil, Hylobius abietis using a bottom-up and top-down approach. Forest ecology and management, **225**: 2634 – 2642.

Drzewiecki, J., Delgado-Licon, E., Haruenkit, R., Pawelzik, E., Martin-Belloso, O., Park, Y.S., Jung, S.T., Trakhtenberg, S. and Gorinstein, S. (2003). Identification and Differences of Total Proteins and Their Soluble Fractions in Some Pseudocereals Based on Electrophoretic Patterns. *J. Agric. Food Chemistry*. **51**(26): 7798-7804.

Everard, A., Griffin, C.T. and Dillon, A.B. (2009). Competition and intraguild predation between the braconid parasitoid Bracon hylobii and entomopathogenic nematode *heterorhabditis downesi*, natural enemies of the large pine weevil, *Hylobius abietis*. Bulletin of Entomological Research. **99**: 151 – 161.

Faccoli, M. and Henry, C.J. (2003). Host location by chemical stimuli in *Bracon hylobii* (Ratzeburg) (Hymenoptera: Braconidae), a larval parasitoid of Hylobius abetis (L.) (Coleoptera: Curculionidae). *Annels Societe Entomologique de France.* **39**: 247 – 256.

Food and Agricultural Organisation. (1988). Traditional Food Plants: A resource book for promoting the exploitation and consumption in Arid, Semi - Arid and Semi – humid lands in Eastern Africa. Rome, Italy: FAO. p. 57.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure of Agricultural Research. 2ndEdition. John Willey and Sons Pub. Ltd., Singapore. pp. 27-91.

Granjerco, C., Taboada, A.E., Salgado, M. and Trujillo, T.R. (1994). Yield and quality of grain amaranth in Mexico. *J. Plant and Soil Environment.* **2:** 30.

Grubben, G.J.H., Van Sloten, D.H. (1981). Genetic Resources of Amaranths. International Board for plant Genetic Resources Secretariat, Rome. p. 57.

Hein, G. L. (2003). Insect management. USDA. Imam, T.S., Yusuf, A.U. and Mukthar, M.D. (2010). A survey of some insect pests of cultivated vegetables in three selection irrigation areas along Jakara river, Kano, Nigeria. *Int. J. Biol. Chem. Sci.,* **4**(20): 400-406.

Juan, M. (2007). Electrophoretic characterization of Amaranthus L. seed proteins and its systematic implication. *Botanical Journal of the Linnean society.* **3**: 57-63.

Judd, G. (2008). *Plant systematics: A phylogenetic approach.* Sunderland: MA: Sinauer Associates, Inc. pp. 57-62.

Kagali, R.N., Kioko, E.N, Osiemo, Z, Muya, S. and Catherine, W. (2013). Insect abundance and diversity on cultivated Amaranthus (*Amaranthadeae*) in Meru County Kenya. *American International Journal of Contemporary Research*, **3**:7-9.

Kigel, J. (1994). Development and eco-physiology of amaranth. In: Amaranth Biology, Chemistry and Technology (Paredez Lopz, ed.), **4**: 223.

Kirby, C.A. and Dill, J.F. (2004). Soil insect pests of vegetables. *Pest management fact sheet.* p. 5045.

Lopez-Olguin, J.F., Garcia, A.A. and Huato, M.A. (2011). Insect occurance and losses due to phytophagous species in the amaranth (*Amaranthus hypocondriacus* L.) in Puebla, Mexico. *African J. Agril. Res.* **6**(27):5924 - 5929.

Losenge, T. (2005). Insect pest management for plant health: Population dynamics of Thrips in pure and mixed cropping. Proceedings of 5th Horticultural

Seminar on Sustainable Horticultural production in the Tropics. Njoro, Kenya: Horticultural Association of Kenya. p. 35

Mailu, A.M., Kironji, C. and Ndungu, M. (1984). Ecology and Control of maize stem borers: Kenya Agricultural Information Network. Kenya Agriculture Research Institute. pp. 34-42.

Makus, D.J. (1990). Composition and nutritional value of vegetable Amaranth as affected by stage of growth, environment and method of preparation. Proceedings of the fourth Amaranth symposium. Minnesita Extension Services, Minnesita Agricultural University St Paul. pp.24-31.

Makwali, J.A. (2002). Pest of *Amaranthus sp*. and their effects on the consumer. Proceedings of 2nd Horticultural Seminar on Sustainable Horticultural production in the Tropics . Juja, Kenya: Horticultural Association of Kenya. pp. 113-118.

Maundu, P. M. (2004). Traditional African Leafy Vegetables. *From Despised to Prized, IPGRI, Geneflow.* Retrieved November 18, 2011, from http://news.biodiversityinternational.org/Geneflow.php?itemid=674.

Mbugua, G., Gitonga, L. N., Mureithi, E., Karoga, J. and Manyeki, L. (2006). Farmer-Participatory prioritization and development of agronomic practices for African Leafy Vegetables. *Proceedings of 6th Horticultural Seminar on Sustainable Horticultural production in the Tropics. Njoro, Kenya: Horticultural Association of Kenya*. pp. 152-16.

Metcalf, R.L. and Luckman, W.H. (1975). Introduction to Insect Pest Management. New York: John Wiley and Sons. pp.71-78.

Millar, I.M., Uys, V.M. and Urban, R.P. (2000). Collecting and Preserving Insects and Arachnids: A manual of Entomology and Arachnology. Johannesburg: Urban Ultra Litho (Pty) Ltd. pp.231-242.

Mullen, J.D., Norton, G.W. and Reaves, D.W. (1997). Economic analysis of environmental benefits of Integrated Pest Management. *Journal of Agriculture and applied Economics.* **29**: 243 - 253.

Nath, P. (1976). Vegetables for the Tropical Region, ICAR New Delhi Vegetable Crops in India. Naya Prokash, Calcutta, India. p. 670.

Nderitu, J.H., Nyamasyo, G.N. and Kasina, J.M. (2008). Agricultural Entomology: Practical Aspects of Agricultural Entomology. Nairobi: Equatops Trading. Neuenschwander, P., Langewald, J., Borgemeister, C. and James, B. (2003). Biological control for increased Agricultural Productivity, Poverty Reduction and Enviromental Protection in Africa. In P. Neueschwander, C.

Borgemeister , and J. Langewald, Biological control in IPM systems in Africa. CABI Publishing. pp. 377 – 407.

Odendo, M., Ouma, J., Wachira, S. and Wanyama, J. (2003). Economic assesssment of maize yield loss due to stem borer in major maize agroecological zones in Kenya. Africa crop science conference proceedings. Kampala, Uganda: African Crop Science Society. pp 683-687.

Oke, O.A. and Ofuya, T.I. (2011). Relationship between population of Cletus fuscescens (Walker) (Hemiptera: Coreidae); Planting dates, Lines and Grain Amaranth (*Amaranthus spp*.) Phenology. *Journal of Entomology,* **8**: 566-573.

Okunlola, A.I., Ofuya, T.I. and Aladesanwa, R.D. (2008). Efficacy of plant extracts on major insect pests of selected leaf vegetables in south western Nigeria. *Niger. Agric. J.* **3**:181-184.

Oliveira, C.M., Júnior, W.R., Camargo, A.A. and Frizzas, M.R. (2012). First record of damage by an insect pest in commercial amaranth crop in Brazil. *Scientia Agricola,* **69**(4): 271 -274.

Palada, M.C. and Chang, L.C. (2003). Gal practices for vegetable amaranthuide of suggested culture. Retrieved January 25, 2012, from AVRDC, International Cooperations: http://www.avrdc.org

Picker, M., Griffiths, C. and Weaving, A. (2004). Field guide to insects of South Africa. South Africa: Struik Publishers.

Prakash, O., Zaidi, P.H. (2000). Bio-availability of Iron from amaranthus (*Amaranthus spinosus* L.) supplemented maize diet. *J. Plant Bio.* **27:**133-138.

Richard, R.W. (1989). Studies of insects feeding on grain Amaranth in the mid west. *J. Kansas Entomol. Soc.* **62**(4): 440-448.

Rodriquez, C.L. (1997). The leaf miner (*Liriomyza spp*.) (Diptera Agromyzidae) a serious insect pest of vegetables and horticultural crops in the tropics. CAB Abstracts, **15**(1): 39-42.

Shanmugavelu, K.G. (1989). Production Technology of Vegetable Crops. Oxford and IBH Publishing Co. Pvt. Ltd., Oxford. p. 682.

Sithanantham, S., Matoka, C.M., Maundu, M., Jakari , M. and Agong, S.G. (2004). Integrated crop protection research for sustainable production of Indigenous vegetable crops in Eastern Africa. Proceedings of 4th Horticultural Seminar on Sustainable Horticultural production in the Tropics Njoro, Kenya: Horticultural Association of Kenya. pp. 152-166.

Solis, M.A. (2006). Key to selected Pyraloidea (Lepidoptera) larvae intercepted at U.S. ports of entry: Revision of Pyraloidea in “Keys to some frequently intercepted lepidopterous larvae” by Weisman 1986. . Lincoln, NE, USA: University of Nebraska.

Sorensen, K.A. (1995). Insect pest of vegetables. North Carolina Agricultural Extension service AG-404.

Sparle, A.N. and Liu, T.X. (2001). A key to common caterpillar pests of vegetables. Texas A and M University system. B-6110.

Tara, J.S. (2009). Bionomics of Hypolixus truncatulus (F) (Coleoptera: Curculionidae. Lixinae: Lixini) a major pest of *Amaranthus caudatus* L. Munis Entomology and Zoology, **4**(2): 510 -518.

Torres, B.P., García , A.A., Avilés , R.P., Hernández , L.R. and Lopez-Olguín, J. (2011). Entomofaunastic study in of the cultivation of Amaranth (*Amaranthus hypochondriacus*) in Puebla, Mexico. Revista Mexicana de Ciencias Agricolas, **2** (3): 359-371.

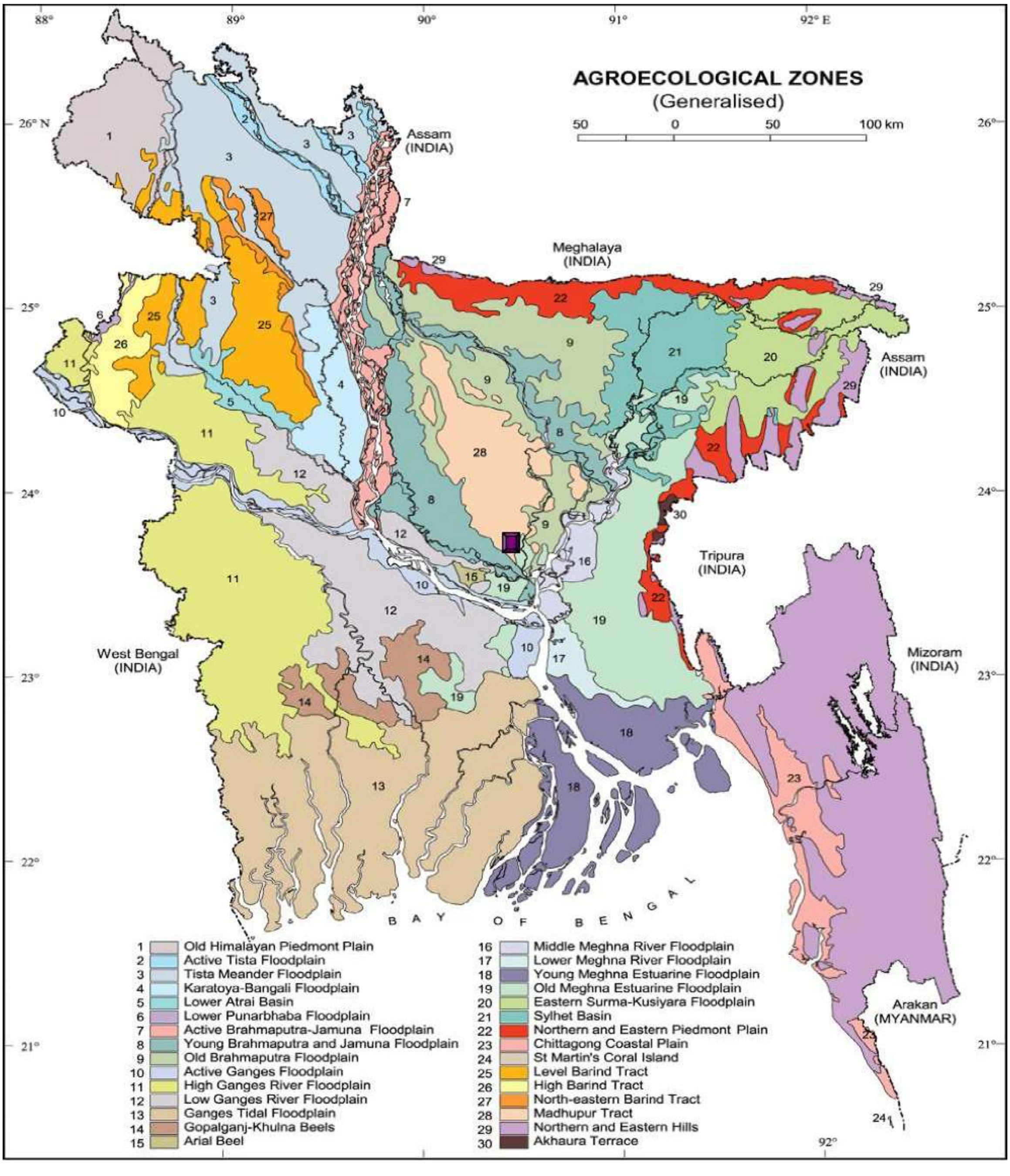
Youdeowei, A. (2004). Integrated pest management practices for the production of vegetables. *Ministry of Food and Agriculture*, Ghana. p. 49.

Chapter VII

Appendices

APPENDICES

Appendix l: Experimental site showing in the map under the present study



Map of Bangladesh remarked with study area

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from March 2016 to July 2016.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
2016	March	33.1	18.0	25.6	77	72	9.2
2016	April	32.0	15.0	23.5	67	98	10.1
2016	May	28.2	13.5	20.9	79	102	11.3
2016	June	24.5	11.5	18.0	72	143	12.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Layout of the experimental field.

R1	V_2T_2	V_1T_1	V_2T_5	V_1T_6	V_2T_3	V_1T_4
R2	V_1T_5	V_2T_4	V_1T_3	V_2T_3	V_1T_1	V_2T_6
R1	V_2T_1	V_1T_6	V_2T_3	V_1T_2	V_2T_4	V_1T_5
R3	V_1T_2	V_2T_6	V_1T_5	V_2T_1	V_1T_3	V_2T_4
R2	V_2T_5	V_1T_2	V_2T_1	V_1T_4	V_2T_5	V_1T_6
R3	V_1T_1	V_2T_6	V_1T_4	V_2T_2	V_1T_3	V_2T_5

Factor A: 6 Treatments
Factor B: 2 Varieties
Replication: 3
Total no. of unit plots: 36
Unit plot size: 6 m2
Unit plot length: 3 m
Unit plot width: 2 m
Plot to plot distance: 0.5 m
Replication to replication distance: 1 m