DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND OTHER ARTHROPOD PESTS OF CAPSICUM

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DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND OTHER ARTHROPOD PESTS OF CAPSICUM

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CERTIFICATE

*This is to certify that thesis entitled **"DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND OTHER ARTHROPOD PESTS OF CAPSICUM"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **NAJAT ALI, Registration no. 12-05623** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2020
Place: Dhaka, Bangladesh

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DEDICATED
TO
MY BELOVED
PARENTS

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to February, 2019 to evaluate the damage assessment and management of insect and other arthropod pests of capsicum. The experiment was laid out in RCBD 2 factor replicated with three times. For this study, factor A- V_1 (California wonder), V_2 (California hot pepper), V_3 (Bell pepper) and V_4 (Red army) and factor B- T_1: Botanical insecticide (Neem oil @ 3ml/L of water); T_2: Acaricide (Mitisol 5EC @ 2.50ml/L of water); T_3: Synthetic (Imidacloropid 200SL @ 2gm/L of water) and T_4: Control. In case of varietal performance, the number of insect pests like aphid, whitefly, thrips, gram pod borer and mite, insect pest infestation (i.e. leaves and plants) were low in California wonder and high in yield attributing characteristics (i.e. number of leaves, length of leaves, breadth of leaves, length of fruits, breadth of fruits, % fruit infestation by number, % fruit infestation by weight and yield) for California wonder. In case of different treatments, percent reducing the number of insect pests like aphid, whitefly, thrips, gram pod borer and mite, insect pest infestation (i.e. leaves and plants) over control were found in botanical insecticide (Neem oil) and high in yield attributing characteristics (i.e. number of leaves, length of leaves, breadth of leaves, length of fruits, breadth of fruits, % fruit infestation by number, % fruit infestation by weight and yield) and yield for botanical insecticide (Neem oil). Again in case of combinations of varieties and different treatments, the number of insect pests like aphid, whitefly, thrips, gram pod borer and mite, insect pest infestation (i.e. leaves and plants) were reduced in V_1T_1 and high in yield attributing characteristics and yield in combination with California wonder and botanical insecticide (Neem oil). The order of rank of efficacy of the combination of varieties and treatments was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$.

LIST OF ABBREVIATIONS AND ACRONYMS

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

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CHAPTER I

INTRODUCTION

Capsicum (*Capsicum annuum* L.), commonly known as sweet pepper, belongs to family Solanaceae, and is one of the most important economical and popular vegetable crops cultivated as an annual crop worldwide. While the species is not yet reported to be invasive, it is known to be a cultivation escape in Finland and Puerto Rico, and is labelled an agricultural weed in Portugal and western Europe (Liogier and Martorell 2000; Randall 2012). Then it was listed as a 'casual alien, cultivation escape, environmental weed, garden thug, naturalized, weed' in the Global Compendium of Weeds (Randall 2012). The species spreads by seed, which it produces profusely, and it has been transported through human and animal consumption as well as economic trade for hundreds of years (Basu and De 2003). It has been widely cultivated around the world as a valuable food and medicinal plant (Basu and De 2003; FAO EcoCrop 2014).

It is an important spice as well as vegetable crop, where both ripe and unripe fruits are used for culinary, salad and processing purposes. As a culinary commodity, *C. annuum* is known, in dried form, as both chilli pepper and paprika (Basu and De 2003), and fruits are used in salads, are stuffed or baked, added to soups and stews, dried and used as culinary seasoning, or pickled, while leaves make a good spinach dish (FAO EcoCrop 2014). Capsicum pepper is the most popular and most widely used condiment all over the world. In addition to uses as food and food additives, the fruits of *C. annuum* also have been grown on a large scale and used as medicine for the digestive system, blood system, muscular/skeletal, and skin applications (FAO EcoCrop 2014). It has also been reportedly used in arrow poisons by some tribal peoples, such as the Dyaks of Borneo and Youri Tabocas of Brazil (De 2003). The commercial use of the species in skin cosmetic products was recently reviewed in a toxicological risk assessment and found to be safe to humans within the ingredient formulae (Anon 2007).

It is one of the important cash crops grown in almost all parts of the country and is widely grown in the tropics and subtropics as also under glass houses in temperate regions. The fruits of capsicum have a variety of names like chilli pepper, red or green pepper, bell pepper miniature paprika, among others. It has both nutritive and medicinal value. Pepper is a largely widespread spice. China, Spain, Mexico, Romania, Yugoslavia, Bulgaria, USA, India, Europe and Central and South America are the major countries of capsicum production. (Roopa 2013).

The colour of the bell peppers can be green, red, yellow, orange, and more rarely white, purple, blue, brown and black, depending on time of harvest and the type of cultivar. It is broadly classified into sweet and hot pepper based on the level of pungency (Sunitha and Narasamma 2018). Nutritionally, it is rich in vitamins particularly, vitamins A and C. Hundred gram of edible portion of capsicum provides 24 k cal of energy, 1.3 g of protein, 4.3 g of carbohydrate and 0.3 g of fat (Kaur and Singh 2013).

The insect pests cause significant damage to the chilli crop. There are 39 genera and 51 species of insects and mites attacking chilli in the field, and in the storage which includes thrips, aphids, whiteflies, fruit borers, cutworms, plant bug, mites and other minor pests (Sorensen 2005). Aphids, thrips, and jassids are the major insect pest of chilli (Jadhav *et al*. 2014). Among thrips, *Scirtothrips dorsalis* (Thripidae: Thysanoptera) is one of the most destructive pest of chilli and under severe infestation 30 to 50 percent crop may be lost (Bhede *et al*. 2008; Krishna Kumar *et* al. 1996; Sanap and Nawale 1987; Ananthakrishnan 1971). Thrips alone is reported to be a major pest of chilli in sub-continent (Patel and Khakri 2012; Sumitha 2005; Eswara Reddy 2005; Vasicek *et al* 2001). Butani (1976) reported over 20 insect species on chillies

(*Capsicum* spp.) from India of which thrips (*Scirtothrips dorsalis*), aphids (*A. gossypii*) and *A. laburni* (Craccivora) are among the most damaging pests.

Farmers use chemical insecticides as an indiscreaminate rate for insect pest management in capsicum field. As a result, it become hazardous for human health, environment and other animals (Grainge and Ahmed 1988). Botanical pesticides are also special because they can be prodced easily by farmers for sustainable agriculture and small industries (Roy *et al.* 2005). About 413 different species/sub-species of insect pest have been listed by (Schmutterer, 1995) found to be susceptible to neem products. The listed species/sub-species belongs to different insect orders most of them were Lepidoptera (136) and Coleopteran (79). In Bangladesh, no works found on the efficacy of botanical insecticides in chilli field. There is a need to manage these pests effectively and economically in chilli. Therefore, the work aims to investigate following objectives:

Objectives:

- To find out the incidence of major insect and arthropod pests of capsicum in the field condition.
- To evaluate the damage caused by the major insect and arthropod pests of capsicum.
- To find out the effective management practice(s) against the major insect and arthropod pests of capsicum.

CHAPTER II

REVIEW OF LITERATURE

Capsicum is one of the most important vegetable crop and production is increasing day by day in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, thrips, aphids, whiteflies, fruit borers, cutworms, plant bug and mites are the major pests of capsicum. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings:

2.1. General review of insect pest of capsicum

2.1.1. Aphid

Nature of damage

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

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

2.1.2. Thrips

Thrips is an invasive pest insect in agriculture. This species of thrips belongs to the family Thripidae.

Nature of damage

The newly hatched nymph feeds on the plant for two of its instars, then falls off the plant to complete its other two instar stages. The insect damages the plant in several ways. The major damage is caused by the adult ovipositing in the plant tissue. The plant is also injured by feeding, which leaves holes and areas of silvery discoloration when the plant reacts to the insect's saliva. Nymphs feed heavily on new fruit just beginning to develop from the flower. The western flower thrips is also the major vector of tomato spotted wilt virus, a serious plant disease.

Thrips attack on the young leaves and flowers (Kalshoven 1981). Thrips attacks can cause chilli leaf curling to the upward. The attack of thrips on chilli plants starts from a mild attack to heavy. Mild attack begins from attack symptoms on leaves marked with silvery white color. Furthermore, the silvery color changed to be brown. Paroxysm attack occurs when thrips act as vectors of viruses that cause disease in chilli (Ananthakrishnan 1993).

Thrips attack can degrade the quality of agricultural products can reach the half. Thrips attack the buds so that the leaf buds die. Extreme damage can result in yield loss and can be exacerbated by cold weather which further slows plant growth (Williams *et al.* 2011).

2.1.3. Gram pod borer

Gram pod borer is a moth, the larvae of which feed on a wide range of plants, including many important cultivated crops.

Nature of damage

On Cotton, bore holes are visible at the base of flower buds, the latter being hollowed out. Bracteoles are spread out and curled downwards. Leaves and shoots may also be consumed by larvae. Larger larvae bore into maturing green bolls; young bolls fall after larval damage. Adults lay fewer eggs on smooth-leaved varieties.

On Tomatoes, young fruits are invaded and fall; larger larvae may bore into older fruits. Secondary infections by other organisms lead to rotting.

On Maize, eggs are laid on the silks, larvae invade the cobs and developing grain is consumed. Secondary bacterial infections are common.

On Sorghum, larvae feed on the developing grain, hiding inside the head during the daytime. Compact-headed varieties are preferred.

On Chickpea, foliage, sometimes entire small plants consumed; larger larvae bore into pods and consume developing seed. Resistant cultivars exist.

On Pigeon pea, flower buds and flowers bored by small larvae, may drop; larger larvae bore into locules of pods and consume developing seed. Short duration and determinate varieties are subject to greater damage. Less-preferred varieties exist.

On Groundnut, leaves, sometimes flowers attacked by larvae; severe infestations cause defoliation. Less preferred varieties exist, *H. armigera* has been reported causing serious losses throughout its range, in particular to cotton, tomatoes and maize. For example, on cotton, two to three larvae on a plant can destroy all the bolls within 15 days; on maize, they consume grains; and on tomatoes, they invade fruits, preventing development and causing falling.

Monetary losses result from the direct reduction of yields and from the cost of monitoring and control, particularly the cost of insecticides. In Australia, Wilson (1982) estimated total Australian losses at $A 23.5 million; with increases in the prices of insecticides and the replacement of the cheaper pyrethroids with more expensive alternatives to counter pyrethroid resistance, Twine (1989) has estimated that costs in Queensland alone would have increased to about $A 25 million annually.

In India, where *H. armigera* commonly destroys over half the yield of pulse crops, pigeon pea and chickpea, losses were estimated at over $US 300 million per annum (Reed and Pawar 1982), while in the late 1980s losses of both pulses and cotton were estimated to exceed $US 500 million, with an additional $US 127 million spent on insecticides on these two crops annually (KN Mehrotra, Indian Agricultural Research Institute, New Delhi, unpublished data, 1987/88). Following the rapid upsurge of pyrethroid resistance, and reduced effectiveness of other insecticide groups in *H. armigera* (Dhingra *et al.* 1988; McCaffery *et al.* 1989) these figures will certainly need to be revised upwards.

Cotton, Oerke *et al.* (1994) reported that *H. armigera* is an economically important pest or a key pest in Africa, Asia, Europe and the former USSR, and Oceania. Previously, Ridgway *et al.* (1984) had reported also that *H. armigera* was partly responsible for a major portion of cotton crop losses.

In Africa, *H. armigera* can reduce yields substantially. In the Côte d'Ivoire, between 1978 and 1983, cotton crop loses in the south of the country were primarily due to *H.*

armigera and were ca 60% (Moyal 1988). In Zimbabwe, potential crop losses due to *H. armigera* were 1175 kg/ha (Gledhill 1976). While *H. armigera* has now been contained as a pest on cotton in Zimbabwe, it is important in Tanzania where the economic loss of cotton was estimated at over $US 20 million (Reed and Pawar 1982). In Andhra Pradesh, India, problems in controlling *H. armigera* were first encountered in 1987. More than 30 insecticide treatments were applied, yet the average yield fell from 436 kg/ha in 1986/87 to 186 kg/ha in 1987/88. This was a reduction of 61% (Armes *et al*. 1992). In Thailand, *H. armigera* has been the principal cotton pest since the mid-1960s. Losses due to *H. armigera* were at least 31% in 1975-79 (Mabbett *et al*. 1980). In China, losses due to *H. armigera* larvae increased with plant age. Crop losses were substantial regardless of soil fertility (Sheng 1988). The damage threshold, 7.5 kg/ha, was reached at 35 egg clusters/100 plants. Integrated pest management reduced *H. armigera* infestations from 1.6 to 0.1% in Jiangsu between 1976 and 1982 (Jin 1986).

In the EPPO region, *H. armigera* is of great economic importance in Israel, Morocco, Portugal, former USSR and Spain, and of lesser importance in the other countries where it is established. Despite extensive spread in Greece, *H. armigera* only causes periodic damage to cotton.

Chickpeas and Other Crops, in India, chickpea is the most important pulse crop and is grown on 7.3 million hectares in various agro-climatic conditions. Although its yield potential is 2.5-3 t/ha, the average yield is only ca 0.8 t/ha. The extent of losses caused by *H. armigera* varies from region to region and depends upon climate and crop intensity. However, a monetary loss of 203 crore rupees annually is estimated.

Changes in sowing date have had a considerable influence on pod damage and seed yield of chickpea. Pod damage due to *H. armigera* increased as sowing dates grew later.

At five different sowing dates, % pod damage was 5.8, 8.1, 14.9, 18.2 and 26.2% while corresponding seed yields of 2452, 2409, 1859, 1439 and 1010 kg/ha, respectively, were recorded. The co-efficient of correlation between sowing date and pod damage and between pod damage and seed yield were significant (Saxena *et al.* 1998). The larval population of *H. armigera* on chickpea was ca four times higher at dense spacing (33 plants/m²) than at wide spacing (3 plants/m²).

Chickpea yields have been shown to increase following control treatments. The application of nuclear polyhedrosis virus reduced larval populations by 26.8% and pod damage by 36.6% and increased yields by 72% compared with untreated plots (Bhagwat and Wightman 1998).

Damage has been reported in India on potatoes, sunflowers, *Guizotia abyssinica*, pigeon peas and cotton. Crop losses of 10-100% have been estimated for potatoes in India. In studies over three seasons, between 1982 and 1985, on four varieties average losses of 0.34% were recorded. Based on the average potato yield for India of 15.8 t/ha, the loss rate was 2.1% (Parihar and Singh 1988).

An outbreak of this noctuid occurred on young *Pinus radiata* in New Zealand in 1969 and 1970, when the larvae consumed more than 50% foliage of about 60% of trees.

2.1.4. Cutworm

Cutworms are the larvae of several species of night-flying moths (Order- Lepidoptera, Family- Noctuidae).

Nature of damage

Cutworms are common pest of many vegetable crops including carrots, celery, lettuce, onion, tomato, pepper, eggplant, cole crops, rutabaga, beans, cucurbit crops, sweet corn and several others. Most species of cutworms are solitary feeders found in the soil;

however some species occasionally attack the foliage and/or fruit of some vegetable crops (Bentley *et al.* 1996).

All instars of *A. ipsilon* feed on the leaves of corn seedlings, but the most serious damage results from leaf and stem cutting by late instars (Clement and McCartney 1982).

Young larvae feed on the foliage or small roots of weeds or crops until they reach about 1/2 inch in length. At this stage, they can begin feeding on seedling stems, either cutting through them or burrowing into them. Corn, peppers, tomatoes, beans, and the crucifer family are common hosts, but they will attack many kinds of herbaceous plants (Hahn and Burkness 2015).

Cutworms feed at night causing serious damage to stems and foliage of young plants. Stalks of plants may be cut. The variegated cutworm climbs the plants to feed on foliage and the bud (Benssin 2011).

2.1.5. Broad mite

The broad mite, *Polyphagotarsonemus latus* (Acari: Tarsonemidae), is a microscopic species of mite found on many species of plants, including important agricultural species such as grapes, apples, and other fruits. Broad mites are also currently affecting cannabis plants, as the industry matures with legalization. The mites are found in many areas throughout the world and are major pests in greenhouses.

Nature of damage

P. latus symptoms vary on different plants (Gerson 1992). Edges of damaged young leaves usually curl. The foliage often becomes rigid and appears bronzed or scorched. Feeding of mites on the under surface of young leaves causes Gerbera to become rigid and rolled under at the edges. As leaves age, they may split, producing a ragged appearance of different shapes. Infested young potato leaves initially have oily black spots on the under surface, which later turn reddish. The plants become rosetted and then die back. Symptoms on red chilli pepper (*Capsicum* sp.) are similar. On lemons, this species produces multiple buds on citrus seedlings and discoloration on the skin of fruit. Damage on cucumber, aubergines and *Solanum laciniatum* includes crinkling, cracking, discoloration and malformations similar to those caused by a hormonal weedkiller. When grapevine is attacked, young leaf edges turn downwards, followed by browning and necrosis.

When chilli leaves are attacked, the leaf tissues disintegrate and the epidermal layer of the infested leaves thickens, with both the pallisade and spongy parenchymatous tissues becoming irregular and the cell nuclei enlarged in severely infested leaves (Karmakar 1997).

P. latus is a serious pest of tea, chilli pepper and aubergines in China (Li *et al*. 1985). It was reported to have destroyed 50% of the bean crop in New Guinea and of the lemon crop in parts of South Africa. It is a pest of cotton in tropical Africa and Brazil. It has a worldwide distribution on many crops (Gerson 1992).

Damage by *P. latus* was 100% on sweet peppers (*Capsicum* sp.) grown in a screenhouse in Taiwan, while aubergines, Datura, chilli pepper and Gerbera were severely damaged (Liu *et al*. 1991).

2.2. Management practices

2.2.1. Host plant resistance

The planting of crop varieties that are resistant or tolerant to *H. armigera* has received major attention, particularly for cotton, pigeon pea and chickpea. This is a tactic of considerable importance within IPM systems. Many crop species possess some genetic potential which can be exploited by breeders to produce varieties less subject to pest damage; this can take the form of antibiosis (un-palatability), antixenosis (non-preference) and tolerance. However, where there is a pest complex, interactions may not always be favorable. For example, fewer eggs were laid on plants having the glabrous leaf character in cotton, however both larval survival and susceptibility to jassid attack were higher. Varieties of chickpea, groundnut and pigeonpea showing varying degrees of resistance have been developed at ICRISAT in India, some of which have been successfully used by farmers.

In recent years, genetic engineering techniques have enabled genes carrying the toxic element of *Bacillus thuringiensis* to be introduced into crops such as cotton and tomato. Although the technique is still very much in its early stages, transgenic crop varieties offer considerable promise for use in IPM systems against *H. armigera*. As with the use of all resistant crop varieties, however, care still needs to be taken to avoid excessive selection pressure against the resistance factor, so that in such systems a mixture of both resistant and susceptible varieties is often recommended to lessen this (CABI 2020).

Plant resistance is not yet employed as a component in broad mite (*P. latus*) control, but there is some evidence that the potential exists (Gerson 1992). In Cuba, a double haploid of sweet pepper (*Capsicum* sp.) that has higher mean fruit weight and yield per plant was tolerant of *P. latus* (Depestre and Gomez 1995). Several chilli cultivars in India are resistant to *P. latus* (Rao and Ahmed 2001).

2.2.2. Cultural practices

Cultural manipulations of the crop or cropping system and land management have been tried as tactics to manage *H. armigera* populations. Trap cropping and planting diversionary hosts have been widely applied and recommended in the past, although with limited success. In the case of cotton, the diversionary hosts maize and sorghum had too short an attractive period to sustain populations; the tendency of these and earlier-planted crops to augment or create infestations were major disadvantages. The importance of ploughing cotton stubble to reduce overwintering populations of pyrethroid-resistant *H. armigera* was stressed by Fitt and Forrester (1987), and post-harvest cultivation to destroy pupae of bollworms has received considerable attention in the USA. However, all in situ cultural control tactics (including area-wide management of early season populations on wild hosts, as advocated by several workers in the USA for American species; Stadelbacher, 1982) and the concept of a close season during which food plants are denied for over one generation, would seem to be largely invalid where the immigration of adults into the protected habitats is the key consideration. One indirect cultural method which could be included under this heading is the regulation of crop agronomy, variety (such as the okra-leaved varieties of cotton), spacing and fertilizer regimes to render the crop, and thus target larvae, more accessible to insecticides or microbial formulations applied by conventional means.

Remove weeds and plant resi-due to help reduce egg-laying sites and seedling weeds that nourish small cutworms. Tilling land before planting, which helps expose and kill overwintering larvae. Tilling also removes plant residue, which helps to discourage egg laying. Avoid using green manure as this may encourage egg laying, instead use com-post. Tilling land in the fall; this helps destroy or expose overwintering larvae or pupae (Hahn and Burkness, 2015).

2.2.3. Mechanical practices

The importance of dispersive and migratory behaviour in the biology of *H. armigera* suggests that monitoring of these movements could provide an early warning of its invasion of an area or crop. Although work on long-distance movement using radar, backtracking and other techniques indicated that moths were able to (and often did) cover large distances, their occurrence in significant numbers at a particular location could seldom be predicted with any certainty. Changes in catch numbers in light and pheromone traps showed characteristic patterns of abundance for different locations in India (Srivastava *et al.* 1992), but the relationship between trap catch and subsequent egg or larval populations in a susceptible crop was usually variable to poor, with numbers captured differing markedly between traps separated by only a few tens of metres, although it was closest when moth densities were low and at the beginning of the seasonal cycle. Trapping *H. armigera* is thus only useful as a qualitative measure indicating the start of an infestation or a migratory 'wave front', indicating the need to begin scouting for immature stages in the crop.

Reddy *et al.* (2015) who reported that the pest control with LED lights could effectively reduce the dosage of pesticides as well as their pollution on the agricultural products, soil and water. The solar LED light is easy to use and can be applied to various crops. During the day, energy from the solar panels will be stored in the storage batteries at night, the electrical energy from the battery could drive circuit of LED light to control pests. Similarly Sunitha and Rajasekhar (2015) studied the effect of solar light trap in capsicum under net condition and reported that on an average number of insects trapped ranged between 600-700 /night which included whiteflies, thrips, hoppers, termites, cutworms and fruit borers and number of insecticides are reduced from 3 to 1/week and by 70.00%.

Cutworms can control by placing aluminum foil or cardboard collars around transplants. This creates a barrier that physically prevents cutworm larvae from feeding on plants. When placing these collars around plants, make sure one end is pushed a few inches into the soil, and the other end extends several inches above ground. This should prevent most species of cutworms from getting to plants (Hahn and Burkness, 2015).

2.2.4. Chemical practices

Most insecticide applications are targeted at the larval stages, but as these are only really effective when larvae are small, the need to scout for eggs and spray soon afterward is paramount. Young larvae are difficult to find, and older larvae soon burrow into the floral organs where they become less accessible to contact insecticides, require higher doses to kill and cause direct economic loss. Moreover, resistant larvae were still susceptible while less than 4 days old, so that targeting of neonates is essential in areas where resistant populations are present (Daly 1988).

The considerable selection pressure which *H. armigera* has experienced, particularly to the synthetic pyrethroids which were used predominantly in the early 1980s, has resulted in the development of resistance to the major classes of insecticides in many of the areas where these have been used. Field failures resulting from pyrethroid resistance have been reported from Australia, Thailand, Turkey, India, Indonesia and Pakistan. Insecticide resistance management strategies have been aimed either at preventing the development of resistance, or containing it. All rely on a strict temporal restriction in the use of pyrethroids and their alternation with other insecticide groups to minimize selection for resistance. And while the strong propensity of *H. armigera* to disperse confers the advantage of diluting resistant populations through the influx of susceptible insects from unsprayed hosts, the same tendency ensures that the genes for resistance are spread more widely than their area of origin (Forrester *et al.* 1993).

Pyrethroid resistance in *H. armigera* may be conferred through three separate mechanisms: detoxification by mixed-function oxidases (metabolic resistance), nerve insensitivity, and delayed penetration. Metabolic resistance may be inhibited by piperonyl butoxide and other synergists, providing a (costly) means whereby the use of pyrethroids might be prolonged in populations where this is the principal mechanism.

P. latus may be difficult to control on certain plants. On the curly leaves of *Psophocarpus tetragonolobus*, dicofol, bromopropylate, azocyclotin and abamectin were not effective (Heungen and Degheele 1986), presumably because the mites were protected in curly leaves; chinomethionat was more effective. On the more easily treated leaves of castor, all five pesticides tested virtually eliminated the mite population in 2 weeks, and abamectin remained effective for up to 3 weeks.

Dicofol and wettable sulphur were effective against all life stages of *P. latus* on chilli (Karmakar *et al*. 1996).

In Sao Paulo, Brazil, abamectin was the most efficient acaricide against *P. latus* in 12 applications at a range of rates and one application at a higher rate; the higher rate application maximized the production of beans (Scarpellini 1999). Chlorfenapyr is recommended for the control of *P. latus* on cotton in Sao Paulo (Santos *et al*. 1999).

Greenhouse tests in China showed that liuyangmycin (an antibiotic preparation from Streptomyces griseolus) gave the most effective and economical control of *P. latus* on green chilli peppers (Capsicum). Introduction of female adults or nymphs to plants 5 days after treatment with liuyangmycin resulted in 71.1 and 83% mortality, respectively. The effect declined after 7 days, but mite control for the 3 weeks after treatment remained >98%, which was equivalent to a control by dicofol (Xie *et al*. 1992). Three applications liuyangmycin to Capsicum in the greenhouse in September-April gave satisfactory control of the pest, with no side-effects.

In India, leaf extracts of *Lippia nodiflora* and *Aloe* sp. were shown to significantly reduce the population density of *P. latus* on chilli when sprayed as 5% aqueous extracts (Palaniswamy and Ragini 2000). In Brazil, Manipueira, a liquid extract from cassava roots, provided 100% control of *P. latus* on papaya plants when it was diluted in water (1:3) and sprayed three times at weekly intervals (Ponte 1996).

Roopa (2013) who reported that lowest populations, highest per cent reduction of *S. dorsalis* was recorded with the treatment Spinosad 45 SC @ 0.01% in capsicum and it also resulted in maximum fruit yield (30,050 kg/ha) followed by Fipronil (27750 kg/ha), Imidacloprid (27150 kg/ha) and Emamectin benzoate (27000 kg/ha). Similarly Vanisree *et al*. (2017) reported that Spinosad 0.015% was found most effective in reducing the population of *S. dorsalis* as well as in increasing yields in chilli and it attains highest cost benefit ratio.

For controlling cutworms several insecticides are effective. All of them are contact insecticide like Carbaryl, Cyfluthrin Permethrin etc. But carbaryl shows great result for controlling cutworms in the field condition (Hahn and Burkness, 2015).

2.2.5. Parasitoid

There have been attempts to enhance mortality due to natural enemies by the introduction of species that might complement existing natural enemies or be superior to them (Waterhouse 1993). Attempted introductions have included parasitoids of *Heliothis virescens* and *Helicoverpa zea* from the Americas as well as species from other parts of the range of *H. armigera*. Few of these have been successful. *Trichogramma pretiosum* and *T. perkinsi* from the USA are reported to have become established in Indonesia and South Africa, respectively. Other successful establishments are: India (*Chelonus blackburni*, *Eucelatoria bryani*, both from the USA, and *Bracon kirkpatricki* from Kenya); Fiji (*Cotesia marginiventris*, also from the USA); New Zealand (*Glabrobracon croceipes* from the USA); Western Australia (*Cotesia kazak* and *Hyposoter didymator*, both from Europe) (King and Jackson 1989). Records of nematode parasites, usually Mermithidae, are available from all regions where inventories of natural enemies are available, however high rates of parasitism occur only sporadically when conditions are favourable. There is some evidence that, in India, they may be important in suppressing early season populations on wild hosts (e.g. *Acanthospermum hispidum*) and low-growing crops such as groundnut on alfisols (Bhatnagar *et al*. 1985).

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

2.2.6. Botanicals

Johnson (2001) assigned that, mealybugs can be controlled using the biocontrol agent, e.g. Botanical pesticides are the most cost effective and environmentally safe inputs in Integrated Pest Management (IPM) strategies. There were about 3000 plants and trees with insecticidal and repellant properties in the world, and India was home to about 70 percent of this floral wealth (Narayanasamy, 2002). He stated the use of more than 450 botanical derivatives used in traditional agricultural system and neem was one of the well-documented trees, and almost all the parts of the tree had been found to have insecticidal value. The neem seed kernel extract, neem oil, extracts from the leaves and barks had all been used since ancient times to keep scores of insect pests away. A number of commercial neem based insecticides were now available and they had replaced several toxic chemical insecticides. The extracts were of particular value in controlling the sucking and chewing insect pests. The young caterpillars devouring the tender leaves were well managed by the botanical insecticides. The plant materials should be thoroughly washed before preparing the extract and the right quantity should be used. Pink mealybug infests the mulberry plants and cause Tukra diseases that leads to qualitative loss of leaves. Hence a study was carried out to evaluate the efficacy of various indigenous native plant extracts for their repellency property against pink mealybug, Maconellicoccus hirsutus (Green) at the Tamil Nadu Agricultural

University, Coimbatore. The native botanicals such as Andrographis leaf extract, Leucas leaf extract, Neem seed kernel extract, vitex leaf extract, fish oil rosin soap, ocimum leaf extract and lawsonia leaf extract at different dose levels viz., 1, 2, 4, 8 and 10 percent respectively. After 48 hours (Hour of release) the highest repellency was recorded in case of Andrographis leaf extract (99.0%) followed by Leucas leaf extract and NSKE (99.0%). Vitex leaf extract and FORS showed on par results among various treatments. The ocimum leaf extract (90.1%) also recorded a moderate repellent effect and the least repellency was recorded in case of Lawsonia leaf extract (81.3%). Similar trend was recorded during 24 hour of release also. As the dose increases the repellent effect also increased irrespective of the native botanical extracts against mealybugs (Sathyaseelan and Bhaskaran, 2010).

There are various insecticides that can be used to control aphids. Nowadays, there are many plant extracts and plant products that are eco-friendly and control aphids as effectively as chemical insecticides. Shrestha *et al*. (2010), suggested use of neem products and lantana products to protect plants against aphids (Chongtham *et al*., 2009). For small backyard infestations, simply spraying the plants thoroughly with a strong water jet every few days is sufficient protection for roses and other plants.

With the continued robust growth of the global bio-pesticide market, Azadirachtin is uniquely positioned to become a key insecticide to expand in this market segment. In the USA, actual or impending cancellation of some organophosphate and Carbamate insecticides that had either lost patent protection or were not being re-registered in many markets because of the food quality protection Act of 1996, had opened new opportunities for bio-pesticides and reduced risks of pesticides in general. The broad-spectrum activity of Azadirachtin at low use rates (125-140g a.i. ha-1) coupled with the insect growth regulator activity (in all larval /nymphal instars including the pupal stages) and unique mode of action (ecdysone disruptor) made Azadirachtin an ideal candidate for insecticide resistance, integrated pest control and organic pest control programs. The pest control potential demonstrated by various extracts and compounds isolated from the kernels and leaves of the neem plant (*Azadirachta indica*, (Meliaceae)) seem to be of tremendous importance for agriculture in developing countries. Laboratory and field trial data had revealed that neem extracts were toxic to over 400 species of insect pests; some of which had developed resistance to conventional pesticides, e.g. sweet potato whitefly (*Bemisia tabaci* Genn. Homoftera: Aleyrodidae), the diamond back moth (*Plutella xylostella* L. Lepidoptera: Plutellidae) and cattle ticks (*Amblyomma cajennense* F. Acarina: Ixodidae and *Tsoaphilus microplus* Canestrini. Acarina: Ixodidae). The compounds isolated from the neem plant manifested their effects on the test organisms in many ways, e.g. as antifeedants, growth regulators, repellents; toxicants and chemosterilants. This review strived to assess critically the pest control potential of neem extracts and compounds for their use in the tropics. This assessment was based on the formulation, stability and phytotoxicity information available on the wide range of pests against which neem extracts and compounds had proven to be toxic, toxicity to non-target organisms, e.g. parasitoids, pollinators, mammals and fish. (Lawrence *et al.*, 1996).

Azadirachtin had been exempted from residue tolerance requirements by the US environmental protection agency for food crop applications. It exhibited good 20 efficacy against key pests with minimal to no impact on non-target organisms. It was also compatible with other biological control agents and had a good fit into classical integrated pest management programs (John and Immaraju, 1997). Products derived from leaves and kernels of neem (*Azadirachta indica*) are becoming popular in plant protection programs for cotton, mainly because synthetic pesticides have several undesirable effects. Neem products acted both as systemic and as contact poisons and their effects were antifeedant, toxicological, repellent, sterility inducing or insect growth inhibiting. Furthermore, neem products appeared to be environmentally safe and IPM compatible and had the potential to be adopted on a broad scale, together with other measures, to provide a low cost management strategy (Hillocks, 1995; Gahukar, 2000). Indigenous plant materials were cheaper and hazard free in comparison to chemical insecticide (Saxena *et al*., 1992). These were also easily available in everywhere in our country. Ofori and Sackey (2003) reported that acetylic, aqueous neem seed extract reduced the *Amrasca biguttula* on okra. The biological control agents *Bacillus thuringiensis* (Bt; Delfin 85 WG) at 0.04% and *Trichograma chilonis* at 60000/ha and insecticides Azadirachtin (Econeem) at, 0.0006%, Lufenuron (Match 5EC) at 0.005%, Avermectin (Vertimec [Abamectin] at 0,0004%, Monocrotophos 36SL (Monocil) at 0.05%, Spark 36EC (Detramethrin lEC + Triazophos 35EC) at 0.05%, Bulldock star 262.5EC (Beta-cyfluthrin12.5EC + Chlorpyrifos 250 and Nurelle-D.505. 55EC Cypermethrin 5 + Chlorpyrifos 50) at 0.05% were tested in a field trial in Rahuri, Maharashtra, India, ;ring the kharif season of 2000 against pest complex of brinjal. Azadirachtin was moderately effective against the sucking pest including *Bemisia tabaci*, *Aphis gossypii*, *Amrasca biguttula biguttula* (Mote and Bhavikatti, 2003).

The joint action potential of methanoic extract of neem seed kernel (*Azadirachta indica*) in combination with methanolic extracts of two other botanical, viz. sweet flag (*Acorus calamus*) and *Pongamia glabra* (*P. pinnata*) against *Ammrasca devastans* at 1:1:1,2:1:1 and 3:1:1 (v/v) ratio were studied. This combination at 0.42% concentration gave superior control of *A. devastans* (Rao and Rajendran, 2002). An experiment was conducted with okra in India to determine the efficacy of neem based pesticide against the cotton jassid, *A. biguttula*. The treatments comprised Endosulfan at 0.07%, A Chook at 3% Neemarin at 0.7%, neem seed kernel extract (NSKE) at 1%, NSKE at 3% with an untreated control. Endosulfan followed by A Chook and NSKE (3%) were most effective in controlling the okra jassid. A Chook treated plots gave the highest yield of 50.06 q/ha and significantly superior to other treatments. However on the basis of cost benefit ratio NSKE (3%) ranked first (Singh and Kumar, 2003). Schneider and Madel (1992) reported that the treatments of neem seed kernel extract (NSKE) did not show a significant reduction in parasitization rate of fecundity of larval parasitoid, *Diadegma semiclausum*. The aqueous NSKE had no adverse effects on *D. semiclausum* following dfuect contact. Patel and Patel (1998) reported that application of Quinalphos and Triazophos resulted in a resurgence of *A. biguttuta* on okra and abergine (Brinjal), while Endosulfan at 0.07% and Repelin (based on *Azadirachta indica*) 1% were highly effective. Nandagopal and Soni (1992) observed that in India neem oil was least persistant insecticides and caused >50% mortality of jassid only up to 24 hours after application. Different concentrations of soap solution were applied against jassid of cotton. Soap powder (25gm/liter of water) predominantly reduced the pest population during the period and harvested the best yield than other treatments economic return is reasonably satisfied (Hossain *et al*., 2003).

2.2.7. IPM packages

In view of the need to make use of and exploit the existing spectra of natural enemies and to reduce excessive dependence on chemical control, particularly where there is resistance to insecticides, various IPM programmes have been developed in which different control tactics are combined to suppress pest numbers below a threshold. These vary from the judicious use of insecticides, based on economic thresholds and regular scouting to ascertain pest population levels, to sophisticated systems, almost exclusively for cotton, using computerized crop and population models to assess the need, optimum timing and product for pesticide application. The SIRATAC system, developed in Australia during the 1980s, and its subsequent derivatives fall into this category (Room 1979 & 1983, Hearn *et al.* 1981). A major constraint to the development of IPM for *H. armigera*, particularly on cotton, has been the need to deal with a complex of pests where control needs may be irreconcilable, as for example in the characteristics of the cotton plant which can either be unfavourable to *H. armigera* or to jassid pests in terms of leaf hairiness, and in the withholding of early season applications to encourage the build-up of natural enemies against the need to control sucking pests which can be severe on young plants.

Solar light traps can be used alone or integrated with other tools of IPM especially under protected conditions. The result of present experiments conclusively revealed that Solar light trap+ Spinosad 45SC@ 0.1ml/lit and Solar light trap+ Emamectin Benzoate@0.25gm/lit can be effectively used in the management of thrips in capsicum under protected conditions (Sunitha and Narasamma 2018).

CHAPTER III

MATERIALS AND METHODS

The present study regarding damage assessment and management of insect and other arthropod pests of capsicum particularly aphid (*Aphis fabae*), thrips (*Scirtothrips dorsalis*), gram pod borer (*Helicoverpa armigera*), cutworm (*Agrotis ipsilon*) and broad mite (*Polyphagotarsonemus latus*) has been conducted during October 2018 to February 2019 in the experimental fields of Sher-e-Bangla Agricultural University, Dhaka. Laboratory studies were also done in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University. Required materials and methodology are described below under the following sub-headings:

3.1. Location

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23.46 N and longitude 90.23E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of Entomology department, SAU.

3.2. Climate

The experimental area is characterized by subtropical rainfall during the month of May to September (Annon. 1988) and scattered rainfall during the rest of the year.

3.3. Soil

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.*, 1991).

3.4. Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The target land was divided into 27 equal plots (1m×1.5m) with plot to plot distance of 0.50 m and block to block distance is 0.75 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.5. Manure and fertilizer

Recommended fertilizers were applied at the rate of 60 kg urea, 70 kg triple super phosphate (TSP), 60 kg muriate of potash (MP), 25 kg Gypsum and 1.25 kg Zinc oxide per hectare were used as source of nitrogen, phosphorus, potassium, sulpher and zinc, respectively. Moreover, well-decomposed cow dung (CD) was also applied at the rate of 20 ton/ha to the field at the time of land preparation (Miah *et al.* 2005).

3.6. Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) two factors with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 16 unit plots. The size of the unit plot was 1 m×1.5 m. The block to block and plot-to-plot distance was .75m and 0.50m, respectively.

3.7. Collection of seed, seedling raising

The seeds of selected broccoli varieties i.e. California hot pepper, California wonder, Bell pepper and Red army were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Siddik Bazar, Gulistan, Dhaka. Before sowing, the germination test of seeds was done and on an average, 90% germination was found for these varieties. Seeds were then sown on the 10th October, 2018 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

3.8. Seedling transplanting

The 20 days old healthy and uniform sized seedlings of capsicum varieties were transferred in polybag on November 1st, 2018. Then 25 days old healthy transferred seedlings were transplanted in the main field on November 26th, 2018. Each plot contains 6 seedlings of capsicum with 50cm (plant to plant distance).

3.9. Cultural practices

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. Various intercultural operations like gap filling, weeding, earthen up, drainage, sticking, netting, fencing, binding etc. was done as and when necessary to cultivate capsicum.

Plate 1: Watering capsicum plants

Plate 2: Netting and sticking of capsicum field

3.10. Treatments

The experiment was evaluated to determine the damage assessment and management of insect and other arthropod pests of capsicum particularly aphid, thrips, cutworm, gram pod borer and broad mite. The treatments were used in this study are given follow:-

Factor A:

Different broccoli cultivar

V_1= California wonder

V_2= California hot pepper

V_3= Bell pepper

V_4= Red army

Plate 3: California wonder

Plate 4: California hot pepper

Plate 5: Red army

Plate 6: Bell pepper

Factor B:

Different insecticides

T_1= Botanical insecticide (Neem oil)

T_2= Acaricide (Mitisol 5EC)

T_3= Synthetic (Imidacloropid 200SL)

T_4= Control

3.11. Neem oil preparation

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. For neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture was sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant.

3.12. Treatment application

T_1: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15 ml /5L of water mixed with trix liquid detergent @

10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_2: Mitisol 5EC @ 2.50 ml/L of water was sprayed at 7 days interval. For this treatment 12.50 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_3: Imidacloropid 200SL @ 2.00 gm/L of water was sprayed at 7 days interval. For this treatment 10.0 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_4: Untreated control treatment. There was no any control measure was applied in capsicum field.

3.13. Data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage of capsicum plant. The data were recorded on number of aphid, number of thrips, number of gram pod borer, number of cutworm, number of broad mite, number of infested leaves by the insects and number of infested fruit by the insects. The following parameters were considered during data collection.

3.13.1. Number of insect pests of Capsicum and number of infested leaves caused by different insect pests

Data were collected on the number of aphid, thrips, gram pod borer, cutworm, broad mite and number of infested leaves and fruits caused by aphid, thrips, gram pod borer, cutworm and broad mite randomly selected 4 tagged plants per plot and counted separately for each treatment. Data were collected through visual observation in the morning.

3.13.2. Number of infested plants by cutworm

Data were collected on the number of infested plants by cutworms per plot and counted separately for each treatment.

3.13.3. Number and weight of the healthy and infested capsicum fruits

Data were collected on the number of healthy and infested capsicum fruits per plot which was harvested at fully mature stage of fruit and weighted separately for each treatment.

Plate 7: Bore on capsicum fruit

Plate 8: Gram pod borer larva on capsicum fruit

Plate 9: Infested capsicum fruit

Plate 10: Infested capsicum fruit

Plate 11: Thrips on capsicum leaf

Plate 12: Infested capsicum plant

3.14. Calculation

3.14.1. Percent of infested leaves by insect pests of capsicum

Number of infested leaves was counted from total leaves per five plants and percent leaf infestation by insect pests of capsicum were calculated as follows:

$$\text{\% Of infested leaves} = \frac{\text{Number of infested capsicum leaves}}{\text{Total number of capsicum leaves}} \times 100$$

3.14.2. Percent Cutworm infested plant

Number of infested plant was counted from total plants per plot and percent plant infestation by Cutworm was calculated as follows:

$$\text{\% Of infested plants} = \frac{\text{Number of infested capsicum plants}}{\text{Total number of capsicum plants}} \times 100$$

3.14.3. Percent fruit infestation by number

Infested fruits were counted from total harvested and the percent capsicum fruit infestation was calculated using the following formula:

$$\text{\% Fruit infestation (number)} = \frac{\text{Number of the infested fruit}}{\text{Total number of fruit}} \times 100$$

3.14.4. Percent fruit infestation by weight

Weight of the infested capsicum fruits were recorded from total weight of the harvested capsicum fruit and the percent capsicum fruit infestation by weight was calculated using the following formula:

$$\text{\% Fruit infestation (weight)} = \frac{\text{Weight of the infested fruit}}{\text{Total weight of fruit}} \times 100$$

3.14.5. Percent reduction of capsicum fruit infestation over control

The number and weight of infested capsicum fruit and total capsicum fruit for each treated plot and untreated control plot were recorded and the percent reduction of capsicum fruit infestation in number and weight was calculated using the following formula:

$$\% \text{ Fruit infestation reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.14.6. Percent yield loss

The weight of infested capsicum fruit was recorded from the total weight of the harvested capsicum fruit for each plot and the percent yield loss was calculated considering the following formula:

$$\% \text{ Yield loss} = \frac{\text{Avg. wt. of healthy fruit} - \text{Avg. wt. of whole plot}}{\text{Average weight of healthy fruit per plot}} \times 100$$

3.14.7. Statistical analysis

Data statistically analyzed by 2 factor randomized complete block design through MSTAT-C software and LSD range tests was used to determine the damage assessment and management of insect and other arthropod pests of capsicum with regards to study aphid, thrips, gram pod borer, cutworm and broad mite infestation.

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate damage assessment and management of insect and other arthropod pests of capsicum in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2018 to March, 2019. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1. In case of varietal performance of capsicum

4.1.1. Number of insect pests

The average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants was ranged from 2.35 to 3.48, 1.75 to 3.83, 1.57 to 2.78, 3.20 to 3.86 and 2.94 to 8.31, respectively. The lowest average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants were recorded in V_1 (2.35, 1.75, 1.57, 3.2 and 2.94, respectively). On the other hand, the highest average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants were recorded in V_2 (3.48, 3.83, 2.78, 3.86 and 8.31, respectively). But it observed that there was statistical variation among the different varieties of capsicum in terms of average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants (Figure 1).

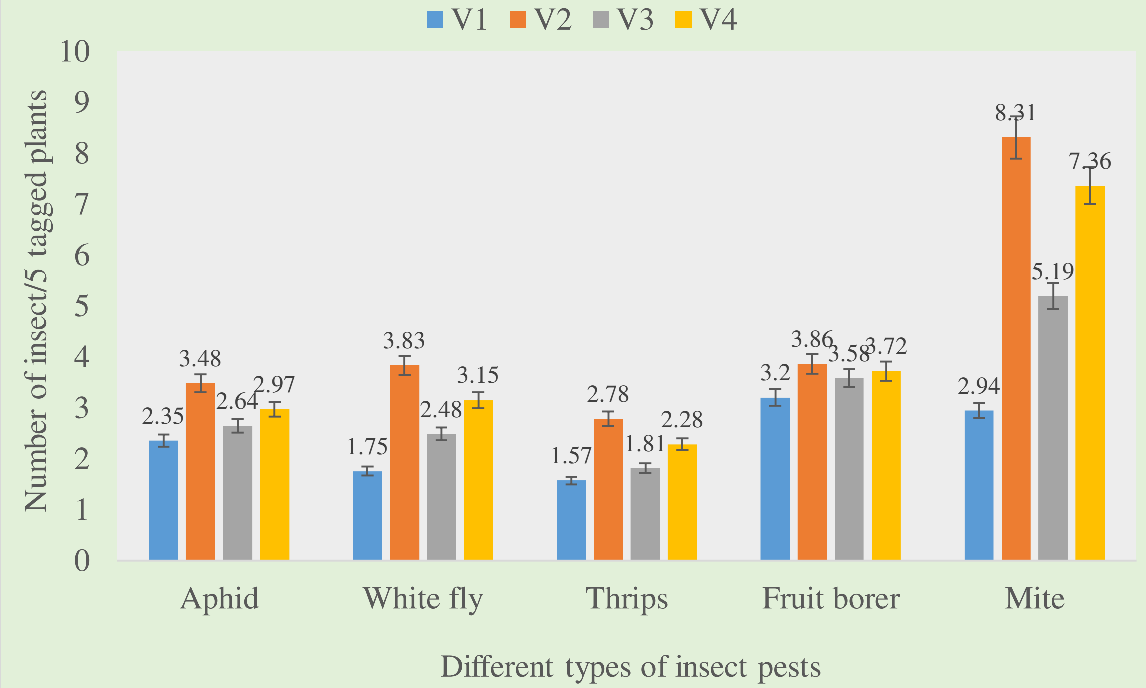

Figure 1: Effect of different varieties on the insect infestation of capsicum

From these above findings it was revealed that among the different Varieties, V_1 comprised with California wonder was more resistant variety for aphids, whitefly, thrips, fruit borer and mite infestation and V_2 comprised with California hot pepper was more susceptible variety for aphids, whitefly, thrips, fruit borer and mite infestation than other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants was $V_1 < V_3 < V_4 < V_2$. More or less similar research was also conducted by several researchers. Candole *et al.* (2012) evaluated the performance of California wonder variety was better than the other sweet pepper varieties.

4.1.2. Leaf infestation caused by insect pests

The average number of infested leaves caused by aphids, whitefly and mite per five tagged plants was ranged from 0.9 to 1.74, 1.03 to 2.75 and 5.3 to 11.08, respectively. The lowest average number of infested leaves caused by aphids, whitefly and mite per five tagged plants were recorded in V_1 (0.9, 1.03 and 5.3, respectively). On the other hand, the highest average number of infested leaves caused by aphids, whitefly and mite per five tagged plants were recorded in V_2 (1.74, 2.75 and 11.08, respectively). But it observed that there was statistical variation among the different varieties of capsicum in terms of average number of infested leaves caused by aphids, whitefly and mite per five tagged plants (Figure 2).

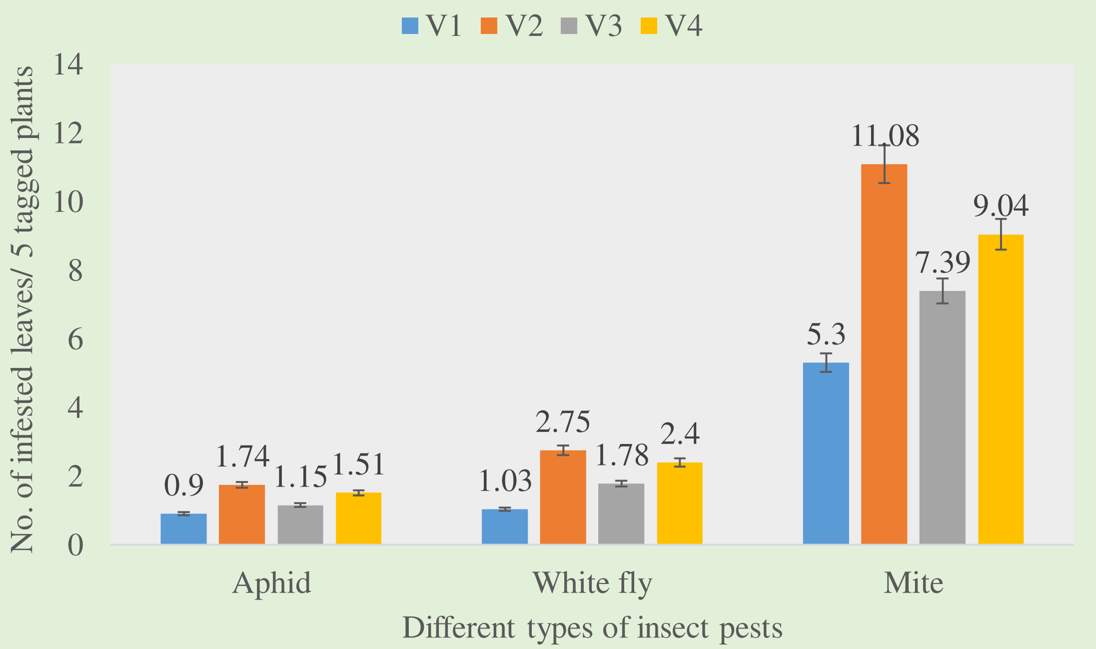

Figure 2: Effect of different varieties on the number of infested leaves by insect pests of capsicum

From these above findings it was revealed that among the different Varieties, V_1 comprised with California wonder was more resistant variety for leaf infestation caused by aphid, whitefly and mite and V_2 comprised with California hot pepper was susceptible variety for leaf infestation caused by aphid, whitefly and mite infestation than the other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of infested leaves caused by aphid, whitefly and mite per five tagged plants was $V_1 < V_3 < V_4 < V_2$. More or less similar research was also conducted by several researchers. Candole *et al.* (2012) evaluated the performance of California wonder variety was better than the other sweet pepper varieties.

4.1.3. Plant infestation caused by insect pests

The average number of infested plants caused by aphid and whitefly per plot was ranged from 1.43 to 2.12 and 0.9 to 1.93, respectively. The lowest average number of infested plants caused by aphids and whitefly per plot were recorded in V_1 (1.43 and 0.9, respectively). On the other hand, the highest average number of infested plants caused by aphid and whitefly per plot were recorded in V_2 (2.12 and 1.93, respectively). But it observed that there was statistical variation among the different varieties of capsicum in terms of average number of infested plants caused by aphid and whitefly per plot (Figure 3).

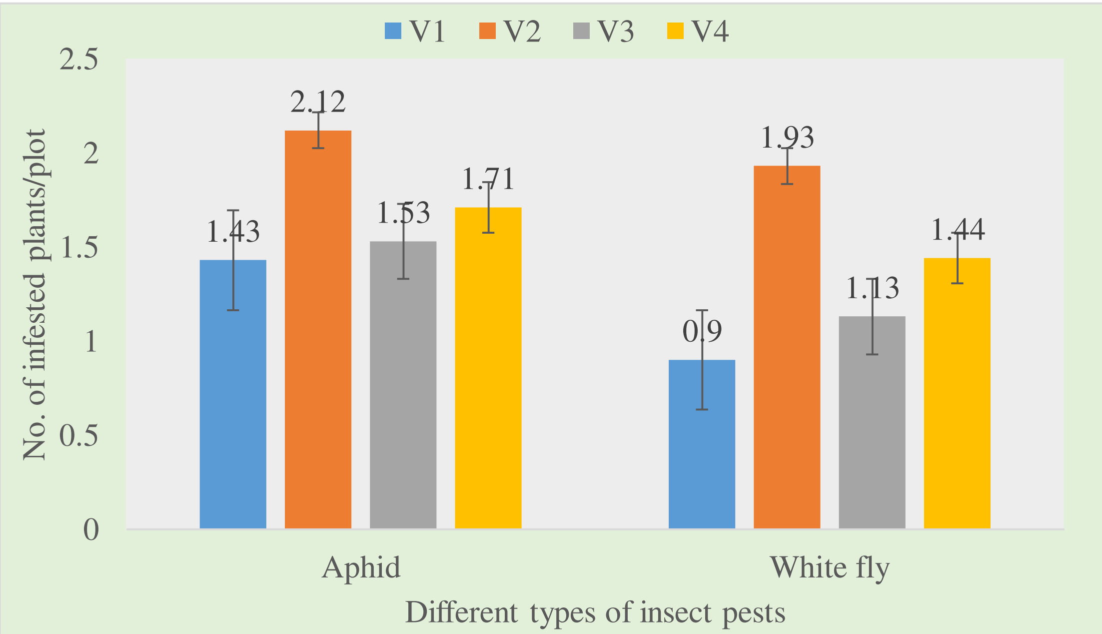

Figure 3: Effect of varieties on the number of infested plants by insect pests of capsicum

From these above findings it was revealed that among the different Varieties, V_1 comprised with California wonder was more resistant variety for plant infestation caused by aphid and whitefly and V_2 comprised with California hot pepper was more susceptible variety for plant infestation caused by aphid and whitefly than the other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of infested plants caused by aphid and whitefly per plot was $V_2 < V_3 < V_4 < V_1$.

More or less similar research was also conducted by several researchers. Candole *et al*. (2012) evaluated the performance of California wonder variety was better than the other sweet pepper varieties.

4.2. In case of different treatments against insect pests of capsicum

4.2.1. Number of insect pests

The average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants was ranged from 1.03 to 4.16, 1.12 to 3.82, 1.06 to 3.36, 1.49 to 3.99 and 4.65 to 7.94, respectively. The lowest average number of aphid, whitefly, thrips, fruit borer and mite per five tagged plants were recorded in T_1 (1.03, 1.12, 1.06, 1.49 and 4.65, respectively). On the other hand, the highest average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants were recorded in T_4 (4.16, 3.82, 3.36, 3.99 and 7.94, respectively). But it observed that there was statistical variation among the different treatments of capsicum in terms of average number of aphids, whitefly, thrips, fruit borer and mite per five tagged plants (Figure 4).

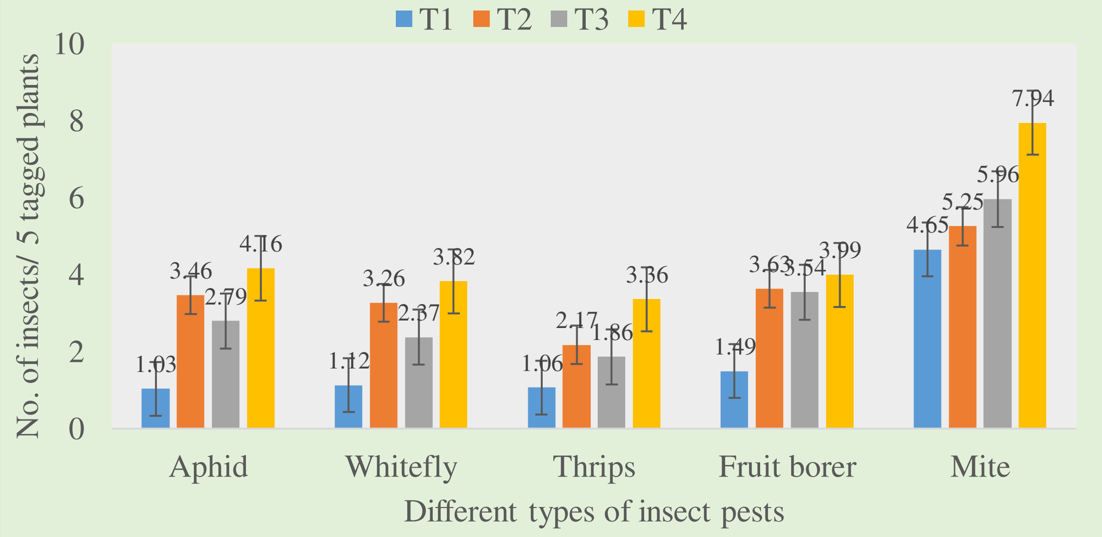

Figure 4: Effect of different treatments on the incidence of insect pests of capsicum

From these above findings it was revealed that among the different treatments, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of aphid, whitefly, thrips, fruit borer and mite per five tagged plants. As a result, the order of rank of efficacy of the treatments applied against the number of aphid, whitefly, thrips, fruit borer and mite per five tagged plants was $T_1 < T_3 < T_2 < T_4$. More or less similar research was also conducted by several researchers. Sathyaseelan and Bhaskaran (2010) evaluated the performance of botanical insecticide (Neem oil) was best than the other treatments.

4.2.2. Leaf infestation caused by insect pests

The average number of infested leaves caused by aphids, whitefly and mite per five tagged plants was ranged from 0.66 to 2.75, 1.07 to 4.2 and 5.61 to 11.54, respectively. The lowest average number of infested leaves caused by aphids, whitefly and mite per five tagged plants were recorded in V_1 (0.66, 1.07 and 5.61, respectively). On the other hand, the highest average number of infested leaves caused by aphids, whitefly and mite per five tagged plants were recorded in V_2 (2.75, 4.2 and 11.54, respectively). But it observed that there was statistical variation among the different treatments of capsicum in terms of average number of infested leaves caused by aphids, whitefly and mite per five tagged plants (Figure 5).

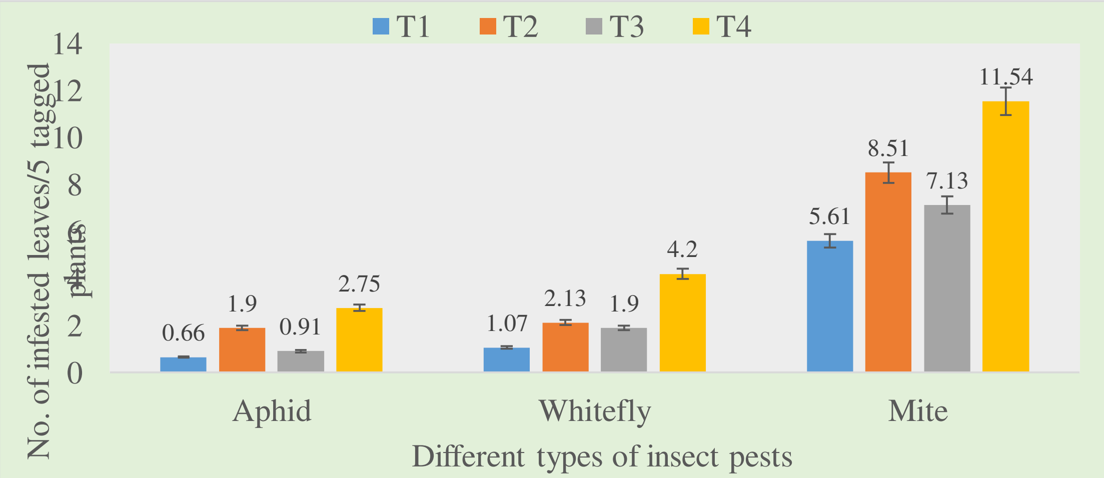

Figure 5: Effect of different treatments on the number of infested leaves by insect pests of capsicum

From these above findings it was revealed that among the different treatments, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants. As a result, the order of rank of efficacy of the treatments applied against aphid, whitefly and mite in terms of reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants was $T_1 < T_3 < T_2 < T_4$. More or less similar research was also conducted by several researchers. Sathyaseelan and Bhaskaran (2010) evaluated the performance of botanical insecticide (Neem oil) was best than the other treatments.

4.2.3. Plant infestation caused by insect pests

The average number of infested plants caused by aphid and whitefly per plot was ranged from 0.21 to 2.98 and 0.63 to 2.22, respectively. The lowest average number of infested plants caused by aphids and whitefly per plot were recorded in T_1 (0.21 and 0.63, respectively). On the other hand, the highest average number of infested plants caused by aphid and whitefly per plot were recorded in T_4 (2.98 and 2.22, respectively). But it observed that there was statistical variation among the different treatments of capsicum in terms of average number of infested plants caused by aphid and whitefly per plot (Figure 6).

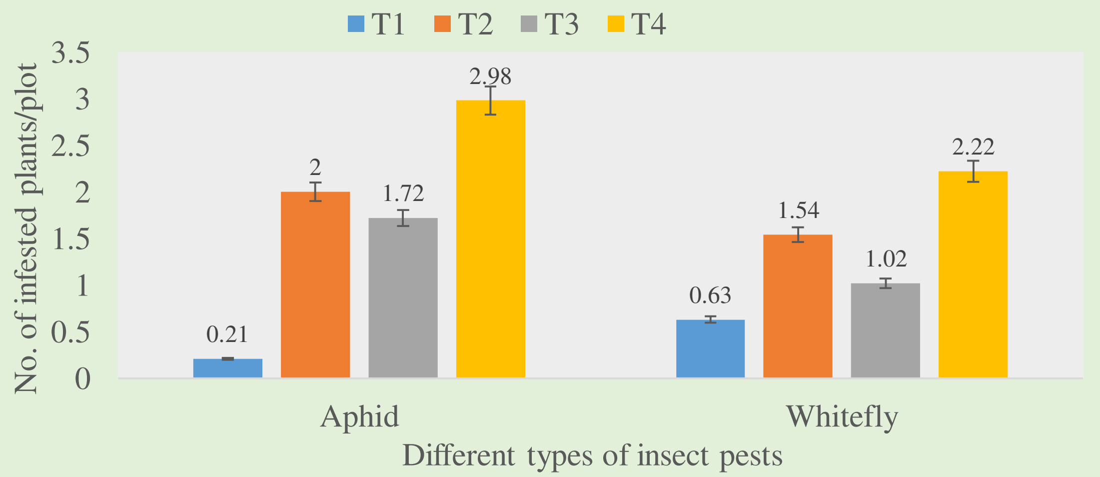

Figure 6: Effect of different treatments on the number of infested plants by insect pests of capsicum

From these above findings it was revealed that among the different treatments, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of infested plants caused by aphid and whitefly per plot. As a result, the order of rank of efficacy of the treatments applied against aphid and whitefly including untreated control in terms of reducing the number of infested plants caused by aphid and whitefly per plot was $T_1 < T_3 < T_2 < T_4$. More or less similar research was also conducted by several researchers. Sathyaseelan and Bhaskaran (2010) evaluated the performance of botanical insecticide (Neem oil) was best than the other treatments.

4.3. In case of combitions of varieties and treatments against different insect pest

4.3.1. Number of insect pests

The significant variations were observed among the combination of varieties and treatments in terms of the number of insect pests like aphid, whitefly, thrips, fruit borer and mite present per five tagged plants of capsicum. The lowest number of insect pest like aphid, whitefly, thrips, fruit borer and mite per five tagged plants was recorded in V_1T_1 (1.10 aphids, 0.58 whitefly, 1.00 thrips, 1.41 fruit borer and 1.16 mite, respectively), which was statistically different from others and followed by V_2T_1, V_1T_2, V_3T_1, V_2T_2, V_4T_1, V_1T_3, V_2T_3, V_4T_2 and V_3T_2. On the other hand, the highest number of insect pests like aphid, whitefly, thrips, fruit borer and mite per five tagged plants was recorded in V_4T_4 (5.81 aphid, 4.41 whitefly, 4.79 thrips, 5.21 fruit borer and 13.00 mite, respectively), which was significantly different from others and followed by V_3T_4, V_2T_4, V_1T_4, V_3T_3 and V_4T_3 (Table 1).

Table 1: Effect of different combination of varieties and treatments on the number of insect pests per five tagged plants of capsicum

Variety	Number of aphids per four tagged plants per plot				
	Aphid	Whitefly	Thrips	Fruit borer	Mite
V_1T_1	0.62 k	0.58 l	1.00 k	1.41 n	1.16 n
V_1T_2	1.41 i	1.10 jk	1.91 i	1.97 m	2.59 l
V_1T_3	2.49 f	2.12 h	2.89 f	2.80 j	5.54 h
V_1T_4	4.55 c	3.67 c	3.91 c	4.05 d	9.18 bc
V_2T_1	1.12 j	0.88 k	1.56 j	1.89 m	1.81 m
V_2T_2	1.99 g	1.54 i	2.30 h	2.39 l	4.09 ij
V_2T_3	2.69 e	2.74 f	3.16 e	3.28 h	7.19 f
V_2T_4	4.83 b	3.96 b	4.34 b	4.22 c	9.47b
V_3T_1	1.76 h	1.36 j	2.19 h	2.33 l	3.40 k
V_3T_2	3.34 d	3.31 d	3.62 d	3.67 f	8.29 d
V_3T_3	3.84 d	3.48 d	3.71 d	3.89 e	8.66 c
V_3T_4	4.98 b	4.27 ab	4.52 b	4.41 b	9.45 b
V_4T_1	2.07 fg	1.69 i	2.54 g	2.72 jk	4.67i
V_4T_2	2.75 e	2.46 g	2.96 f	3.10 i	6.14 g
V_4T_3	3.45 d	3.08 e	3.29 e	3.38 g	7.63 e
V_4T_4	5.31 a	4.41 a	4.79 a	5.21 a	13.00 a
LSD (0.05)	0.06	0.26	0.13	0.14	0.61
CV (%)	3.71	6.78	3.67	6.85	6.28

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of insect pests like aphid, whitefly, thrips, fruit borer and mite per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against the insect pests likr aphid, whitefly, thrips, fruit borer and mite in terms of reducing the number of aphid, whitefly, thrips, fruit borer and mite per five tagged plants was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 <$

$V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$. More or less similar research was also conducted by several researchers. Shrestha *et al.* (2010) and Frantz *et al.* (2004) evaluated the similar performance of Aqueous Neem Extract against the pests.

4.3.2. Leaf infestation caused by insect pests

The significant variations were observed among the combination of varieties and treatments in terms of the number of infested leaves caused by insect pests like aphid, whitefly and mite per five tagged plants of capsicum. The lowest number of infested leaves caused by insect pests like aphid, whitefly and mite per five tagged plants was recorded in V_1T_1 (0.40, 0.85 and 0.78 leaves, respectively), which was statistically different from others and followed by V_2T_1, V_1T_2, V_3T_1, V_2T_2, V_4T_1, V_1T_3, V_2T_3, V_4T_2 and V_3T_2. On the other hand, the highest number of infested leaves caused by insect pests like aphid, whitefly and mite per five tagged plants was recorded in V_4T_4 (3.11, 4.87 and 17.00 leaves, respectively), which was significantly different from others and followed by V_3T_4, V_2T_4, V_1T_4, V_3T_3 and V_4T_3 (Table 2).

Table 2: Effect of different combination of varieties and treatments on number of infested leaves caused by insect pests per five tagged plants of capsicum

Variety	No. of infested leaves caused by insect pests per five tagged plants per plot		
	Aphid	**Whitefly**	**Mite**
V_1T_1	0.40 i	0.85 n	0.78 n
V_1T_2	0.81 h	1.49 l	1.60 l
V_1T_3	1.25 f	2.69 hi	7.15 gh
V_1T_4	2.39 c	3.93 d	8.96 c
V_2T_1	0.61 h	1.16 m	1.30 m
V_2T_2	0.99 g	2.35 j	3.76 j
V_2T_3	1.72 e	2.98 g	7.48 f
V_2T_4	2.61 b	4.15 c	9.03 c
V_3T_1	0.87 h	2.14 k	3.16 k
V_3T_2	2.04 d	3.44 e	8.20 d
V_3T_3	2.26 c	3.54 e	8.32 d
V_3T_4	2.82 b	4.50 b	9.42 b
V_4T_1	1.20 f	2.56 i	6.27 i
V_4T_2	1.28 f	2.79 h	7.27 g
V_4T_3	1.91 d	3.28 f	7.81 e
V_4T_4	3.11 a	4.87 a	17.00 a
LSD (0.05)	0.12	0.16	0.14
CV (%)	5.48	4.84	1.02

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of infested leaves caused by insect pests like aphid, whitefly and mite per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of infested leaves caused by insect pests like aphid, whitefly and mite per five tagged plants was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 <$

$V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$. More or less similar research was also conducted by several researchers. Shrestha *et al.* (2010) and Frantz *et al.*, (2004) evaluated the similar performance of Aqueous Neem Extract against the pests.

4.3.3. Plant infestation caused by insect pests

The significant variations were observed among the combination of varieties and treatments in terms of the number of infested plants caused by insect pests like aphid and whitefly per plot of capsicum. The lowest number of infested plants caused by insect pests like aphid and whitefly per plot was recorded in V_1T_1 (0.88 and 0.43 plants, respectively), which was statistically different from others and followed by V_2T_1, V_1T_2, V_3T_1, V_2T_2, V_4T_1, V_1T_3, V_2T_3, V_4T_2 and V_3T_2. On the other hand, the highest number of infested plants caused by insect pests like aphid and whitefly per plot was recorded in V_4T_4 (4.00 and 3.28 plants, respectively), which was significantly different from others and followed by V_3T_4, V_2T_4, V_1T_4, V_3T_3 and V_4T_3 (Table 3).

Table 3: Effect of different combination of varieties and treatments against the number of infested plants caused by insect pests per plot of capsicum

Variety	**No. of infested plants caused by insect pests per plot**	
	Aphid	**Whitefly**
V_1T_1	0.88 n	0.43 i
V_1T_2	1.38 l	0.63 h
V_1T_3	2.24 h	1.19 f
V_1T_4	3.53 c	2.31 c
V_2T_1	1.19 m	0.56 h
V_2T_2	1.76 j	0.90 g
V_2T_3	2.70 g	1.61 e
V_2T_4	3.65 c	2.49 c
V_3T_1	1.54 k	0.79 g
V_3T_2	3.14 e	1.88 d
V_3T_3	3.34 d	2.13 cd
V_3T_4	3.85 b	2.76 b
V_4T_1	1.97 i	1.04 f
V_4T_2	2.58 g	1.55 e
V_4T_3	2.94 f	1.80 d
V_4T_4	4.00 a	3.28 a
LSD (0.05)	0.12	0.27
CV (%)	4.21	8.17

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of infested plants caused by aphid and whitefly per plot than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests like aphid and whitefly in terms of reducing the number of infested plants caused by aphid and whitefly per plot was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$. More or less similar research was also conducted by several researchers. Shrestha *et al.* (2010) and Frantz *et al.*, (2004) evaluated the similar performance of Aqueous Neem Extract against the pests.

4.4. Yield attribute characteristic

4.4.1. In case of varietal performance

Number of leaf: The significant variation was observed in the number of leaves of capsicum, whereas, the maximum average number of leaves was found in V_1 (46.76 leaves) which was significantly different from other varieties and followed by V_3 (42.97 leaves). On the other hand, the minimum average number of leaves was found in V_2 (41.18 leaves) which was significantly different from other varieties and followed by V_4 (42.59 leaves) (Table 4).

Length of leaf: The significant variation was observed in length of leaves of capsicum, whereas, the maximum average length of leaves was found in V_1 (11.50 cm) which was significantly different from other varieties and followed by V_3 (9.43 cm). On the other hand, the minimum average length of leaves was found in V_2 (7.97 cm) which was significantly different from other varieties and followed by V_4 (8.29 cm) (Table 4).

Breadth of leaf: The significant variation was observed in breadth of leaves of capsicum, whereas, the maximum average breadth of leaves was found in V_1 (3.92 cm) which was significantly different from other varieties and followed by V_3 (3.29 cm). On the other hand, the minimum average length of leaves was found in V_2 (2.74 cm) which was significantly different from other varieties and followed by V_4 (2.92 cm) (Table 4).

Length of fruit: The significant variation was observed in length of fruits of capsicum, whereas, the maximum average length of fruits was found in V_1 (13.02 cm) which was significantly different from other varieties. On the other hand, the minimum average length of fruits was found in V_2 (12.21 cm) which was statistically similar with V_4 (12.23 cm) and V_3 (12.58 cm) (Table 4).

Breadth of fruit: The significant variation was observed in breadth of fruits of capsicum, whereas, the maximum average breadth of fruits was found in V_1 (4.66 cm) which was statistically similar with V_3 (4.53 cm) and V_4 (4.50 cm). On the other hand, the minimum average breadth of fruit was found in V_2 (4.44 cm) which was significantly different from other varieties (Table 4).

Table 4: Effect of different varieties on number of leaves, leaf length, leaf breadth, fruit length and fruit breadth

Varieties	Number of leaf per plant	Leaf length (cm)	Leaf breadth (cm)	Fruit length (cm)	Fruit breadth (cm)
V_1	46.76 a	11.50 a	3.92 a	13.02 a	4.66 a
V_2	41.18 d	7.97 d	2.74 c	12.21 b	4.44 b
V_3	42.97 b	9.43 b	3.29 b	12.58 b	4.53 a
V_4	42.59 c	8.29 c	2.92 bc	12.23 b	4.50 a
LSD (0.05)	0.20	0.31	0.43	0.36	0.23
CV (%)	1.32	4.83	10.17	5.85	4.50

[V_1: California wonder; V_2: California hot pepper; V_3: Bell pepper; V_4: Red army.]

From these above findings it was revealed that among the different Varieties, V_1 comprised with California wonder showed the best performance in case of number of leaves, length of leaves, breadth of leaves, length of fruits and breadth of fruits than the others. As a result, the order of rank of varieties of capsicum in terms of number of leaves, length of leaves, breadth of leaves, length of fruits and breadth of fruits was V_1> V_3> V_4> V_2. More or less similar research was also conducted by several researchers. Boyhan *et al*. (2019) evaluated the performance of California wonder was higher than the other varieties.

Number of fruit: The significant variation was observed in the number of leaves of capsicum, whereas, the maximum average number of fruits was found in V_1 (14.22 fruits) which was significantly different from other varieties. On the other hand, the minimum average number of fruits was found in V_2 (12.21 fruits) statistically similar with V_4 (13.15 fruits) and V_3 (13.41 fruits) (Table 5).

Number of infested fruit: The significant variation was observed in the number of infested fruits of capsicum, whereas, the maximum average number of infested fruits was found in V_1 (1.92 fruits) which was significantly different from other varieties and followed by V_3 (2.53 fruits). On the other hand, the minimum average number of infested fruits was found in V_2 (4.08 fruits) which was statistically similar with V_4 (4.05 fruits) (Table 5).

Percent fruit infestation by number: The significant variation was observed in the percent fruit infestation by number of capsicum, whereas, the minimum percent fruit infestation by number was found in V_1 (13.50 %) which was significantly different from other varieties and followed by V_3 (18.87 %). On the other hand, the maximum percent fruit infestation by number was found in V_2 (33.42 %) which was significantly different from other varieties and followed by V_4 (30.80 %) (Table 5).

Total fruit weight: The significant variation was observed in total fruit weight of capsicum, whereas, the maximum average weight of fruits was found in V_1 (1.22 kg) which was statistically similar with V_3 (1.05 kg). On the other hand, the minimum average weight of fruits was found in V_2 (0.97 kg) which was statistically similar with V_4 (1.03 kg) (Table 5).

Infested fruit weight: The significant variation was observed in the weight of infested fruit of capsicum, whereas, the minimum average infested fruit weight was found in V_1 (0.25 kg) which was statistically similar with V_3 (0.31 kg). On the other hand, the maximum average infested fruit weight was found in V_2 (0.41 kg) which was statistically similar with V_4 (0.33 kg) (Table 5).

Percent infestation by weight: The significant variation was observed in the percent fruit infestation by weight of capsicum, whereas, the minimum percent fruit infestation by weight was found in V_1 (20.49 %) which was significantly different from other varieties and followed by V_3 (29.52 %). On the other hand, the maximum percent fruit infestation by number was found in V_2 (42.27 %) which was significantly different from other varieties and followed by V_4 (32.04 %) (Table 5).

Table 5: Effect of varieties on yield attributes and fruit infestation of capsicum

Varieties	Number of fruit per plot	Number of infested fruit per plot	% fruit infestation by number	Total fruit weight per plot(kg)	Infested fruit weight per plot (kg)	% fruit infestation by weight
V_1	14.22 a	1.92 c	13.50 a	1.22 a	0.25 c	20.49 d
V_2	12.21 b	4.08 a	33.42 d	0.97 b	0.41 a	42.27 a
V_3	13.41 b	2.53 b	18.87 b	1.05 ab	0.31 bc	29.52 c
V_4	13.15 b	4.05 a	30.80 c	1.03 b	0.33 b	32.04 b
LSD (0.05)	0.29	0.20	1.03	0.17	0.05	1.32
CV (%)	1.46	6.97	4.32	7.72	11.62	9.21

[V_1: California wonder; V_2: California hot pepper; V_3: Bell pepper; V_4: Red army.]

From these above findings it was revealed that, among the different Varieties, V_1 comprised with California wonder showed the best performance in case of number of fruits, number of infested fruits, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight than the others. As a result, the order of rank of varieties of capsicum in terms of number of fruits, number of infested fruits, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight was $V_1 > V_3 > V_4 > V_2$. More or less similar research was also conducted by several researchers. Boyhan *et al.* (2019) evaluated the performance of California wonder was higher than the other varieties.

4.4.2. In case of effect of different treatments

Number of leaf: The significant variation was observed in the number of leaves of capsicum, whereas, the maximum average number of leaves was found in T_1 (44.45 leaves) which was significantly different from other varieties and followed by T_3 (44.02 leaves). On the other hand, the minimum average number of leaves was found in T_4 (41.47 leaves) which was significantly different from other varieties and followed by T_2 (43.56 leaves) (Table 6).

Length of leaf: There was no significant variance between the effects of different treatments in case of length of leaves of capsicum, whereas, the average length of leaves was found in T_1 (9.44 cm), T_3 (9.41 cm), T_2 (9.31 cm) and T_4 (9.03 cm) (Table 6).

Breadth of leaf: There was no significant variance between the effects of different treatments in case of breadth of leaves of capsicum, whereas, the average breadth of leaves was found in T_1 (3.34 cm), T_3 (3.25 cm), T_2 (3.22 cm) and T_4 (3.07 cm) (Table 6).

Length of fruit: There was no significant variance between the effects of different treatments in case of length of fruits of capsicum, whereas, the average length of fruits was found in T_1 (12.86 cm), T_3 (12.62 cm), T_2 (12.61 cm) and T_4 (11.97 cm) (Table 6).

Breadth of fruit: There was no significant variance between the effects of different treatments in case of breadth of fruits of capsicum, whereas, the average breadth of fruits was found in T_1 (4.63 cm), T_3 (4.53 cm), T_2 (4.51 cm) and T_4 (4.45 cm) (Table 6).

Table 6: Effect of different treatments on number of leaf, leaf length, leaf breadth, fruit length and fruit girth of capsicum

Varieties	Number of leaf per plant	Leaf length (cm)	Leaf breadth (cm)	Fruit length (cm)	Fruit breadth (cm)
T_1	44.45 a	9.44 a	3.34 a	12.86 a	4.63 a
T_2	43.56 c	9.31 a	3.22 a	12.61 a	4.51 a
T_3	44.02 b	9.41 a	3.25 a	12.62 a	4.53 a
T_4	41.47 d	9.03 a	3.07 a	11.97 a	4.45 a
LSD (0.05)	0.23	0.74	0.54	1.20	0.34
CV (%)	1.32	4.83	10.17	5.85	4.50

[T_1: Botanical insecticide (Neem oil @ 3ml/L of water); T_2: Acaricide (Mitisol 5EC @ 2.50ml/L of water); T_3: Synthetic (Imidacloropid 200SL @ 2gm/L of water); T_4: Control.]

From these above findings it was revealed that among the different treatments, T_1 comprised with botanical insecticide (Neem oil) showed the best performance in case of number of leaves, length of leaves, breadth of leaves, length of fruits and breadth of fruits than the others. As a result, the order of rank of different treatments of capsicum in terms of number of leaves, length of leaves, breadth of leaves, length of fruits and breadth of fruits was $T_1 > T_3 > T_2 > T_4$. More or less similar research was also conducted by several researchers. Boyhan *et al.* (2019) evaluated the performance of California wonder was higher than the other varieties.

Number of fruit: The significant variation was observed in the number of leaves of capsicum, whereas, the maximum average number of fruits was found in T_1 (15.31 fruits) which was significantly different from other treatments and followed by T_3 (14.07 fruits). On the other hand, the minimum average number of fruits was found in T_4 (11.98 fruits) which was significantly different from other treatments and followed by T_2 (12.62 fruits) (Table 7).

Number of infested fruit: The significant variation was observed in the number of infested fruits of capsicum, whereas, the maximum average number of infested fruits was found in T_4 (3.93 fruits) which was significantly different from other treatments and followed by T_2 (3.40 fruits). On the other hand, the minimum average number of infested fruits was found in T_1 (2.40 fruits) which was significantly different from other treatments and followed by V_3 (2.85 fruits) (Table 7).

Percent fruit infestation by number: The significant variation was observed in the percent fruit infestation by number of capsicum, whereas, the minimum percent fruit infestation by number was found in T_1 (15.68 %) which was significantly different from other varieties and followed by T_3 (20.26 %). On the other hand, the maximum percent fruit infestation by number was found in T_4 (32.81 %) which was significantly different from other varieties and followed by T_2 (26.94 %) (Table 7).

Total fruit weight: The significant variation was observed in total fruit weight of capsicum, whereas, the maximum average weight of fruits was found in T_1 (1.20 kg) which was statistically similar with T_3 (1.16 kg). On the other hand, the minimum average weight of fruits was found in T_4 (0.90 kg) which was significantly different from other treatments and followed by V_2 (1.01 kg) (Table 7).

Infested fruit weight: The significant variation was observed in the weight of infested fruit of capsicum, whereas, the minimum average infested fruit weight was found in T_1 (0.26 kg) which was significantly different T_3 (0.16 kg). On the other hand, the maximum average infested fruit weight was found in T_4 (0.37 kg) which was statistically similar with T_2 (0.36 kg) (Table 7).

Percent infestation by weight: The significant variation was observed in the percent fruit infestation by weight of capsicum, whereas, the minimum percent fruit infestation by weight was found in T_1 (21.67 %) which was significantly different from other varieties and followed by T_3 (26.72 %). On the other hand, the maximum percent fruit infestation by number was found in T_4 (41.11 %) which was significantly different from other varieties and followed by T_2 (35.64 %) (Table 7).

Table 7: Effect of different treatments on yield attributes and fruit infestation of caapsicum

Varieties	Number of fruit per plot	Number of infested fruit per plot	% fruit infestation by number	Total fruit weight per plot (kg)	Infested fruit weight per plot(kg)	% fruit infestation by weight
T_1	14.07 b	2.85 c	20.26 c	1.16 a	0.31 b	26.72 c
T_2	12.62 c	3.40 b	26.94 b	1.01 b	0.36 ab	35.64 b
T_3	15.31 a	2.40 d	15.68 d	1.20 a	0.26 c	21.67 d
T_4	11.98 d	3.93 a	32.81 a	0.90 b	0.37 a	41.11 a
LSD (0.05)	0.32	0.36	0.29	0.14	0.05	0.56
CV (%)	1.46	6.97	4.32	7.72	11.62	9.21

[T_1: Botanical insecticide (Neem oil @ 3ml/L of water); T_2: Acaricide (Mitisol 5EC @ 2.50ml/L of water); T_3: Synthetic (Imidacloropid 200SL @ 2gm/L of water); T_4: Control.]

From these above findings it was revealed that among the different treatments, T_1 comprised with botanical insecticide (Neem oil) showed the best performance in case of number of fruits, number of infested fruits, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight than the others. As a result, the order of rank of treatments in terms of number of fruits, number of infested fruits, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight was $T_1 > T_3 > T_2 > T_4$. More or less similar research was also conducted by several researchers. Boyhan *et al.* (2019) evaluated the performance of California wonder was higher than the other varieties.

4.4.3. In case of effect of combinations of treatments and varieties

Number of leaf: The significant variation was observed in the number of leaves of capsicum per plant, whereas, the maximum average number of leaves was found in V_1T_1 (49.44 leaves) which was significantly different from others and followed by V_2T_1 (46.70 leaves), V_1T_2 (45.96 leaves), V_3T_1 (45.76 leaves), V_2T_2 (45.64 leaves), V_4T_1 (45.13 leaves) and V_1T_3 (44.70 leaves). On the other hand, the minimum average number of leaves was found in V_4T_4 (35.09 leaves) which was significantly different from other varieties and followed by V_3T_4 (38.76 leaves), V_2T_4 (39.95 leaves), V_1T_4 (41.61 leaves), V_3T_3 (41.68 leaves), V_3T_2 (42.48 leaves), V_4T_3 (42.61 leaves), V_2T_3 (44.03 leaves) and V_4T_2 (44.45 leaves) (Table 8).

Length of leaf: The significant variation was observed in the length of leaves of capsicum, whereas, the maximum average length of leaves was found in V_1T_1 (12.19 cm) which was significantly different from others and followed by V_2T_1 (11.37 cm), V_1T_2 (11.23 cm), V_3T_1 (11.21 cm), V_2T_2 (9.61 cm), V_4T_1 (9.51 cm) and V_1T_3 (9.46 cm). On the other hand, the minimum average length of leaves was found in V_4T_4 (7.47 cm) which was significantly different from other others and followed by V_3T_4 (7.70 cm), V_2T_4 (7.83 cm), V_1T_4 (7.91 cm), V_3T_3 (8.15 cm), V_3T_2 (8.24 cm), V_4T_3 (8.79 cm), V_2T_3 (8.95 cm) and V_4T_2 (9.14 cm) (Table 8).

Breadth of leaf: The significant variation was observed in the breadth of leaves of capsicum, whereas, the maximum average breadth of leaves was found in V_1T_1 (4.35 cm) which was statistically similar with V_2T_1 (3.83 cm), V_1T_2 (3.82 cm) and followed by V_3T_1 (3.67 cm), V_2T_2 (3.43 cm), V_4T_1 (3.33 cm) and V_1T_3 (3.32 cm). On the other hand, the minimum average length of leaves was found in V_4T_4 (2.50 cm) which was significantly different from other others and followed by V_3T_4 (2.66 cm), V_2T_4 (2.68 cm), V_1T_4 (2.84 cm), V_3T_3 (2.85 cm), V_3T_2 (2.86 cm), V_4T_3 (2.95 cm), V_2T_3 (3.22 cm) and V_4T_2 (3.24 cm) (Table 8).

Length of fruit: The significant variation was observed in the length of fruits of capsicum, whereas, the maximum average length of fruits was found in V_1T_1 (13.57 cm) which was statistically similar with V_2T_1 (13.11 cm), V_1T_2 (13.09 cm), V_3T_1 (13.04 cm), V_2T_2 (12.73 cm), V_4T_1 (12.63 cm) and V_1T_3 (12.55 cm). On the other hand, the minimum average length of fruits was found in V_4T_4 (11.55 cm) which was statistically similar with V_3T_4 (11.92 cm), V_2T_4 (12.07 cm), V_1T_4 (12.08 cm), V_3T_3 (12.27 cm), V_3T_2 (12.29 cm), V_4T_3 (12.33 cm), V_2T_3 (12.43 cm) and V_4T_2 (12.54 cm) (Table 8).

Breadth of fruit: The significant variation was observed in the breadth of fruits of capsicum, whereas, the maximum average breadth of fruits was found in V_1T_1 (4.80 cm) which was statistically similar with V_2T_1 (4.72 cm), V_1T_2 (4.67 cm), V_3T_1 (4.66 cm), V_2T_2 (4.62 cm), V_4T_1 (4.60 cm) and V_1T_3 (4.59 cm). On the other hand, the minimum average breadth of fruits was found in V_4T_4 (4.27 cm) which was statistically similar with V_3T_4 (4.28 cm), V_2T_4 (4.32 cm), V_1T_4 (4.37 cm), V_3T_3 (4.46 cm), V_3T_2 (4.51 cm), V_4T_3 (4.52 cm), V_2T_3 (4.55 cm) and V_4T_2 (4.56 cm) (Table 8).

Table 8: Effect of different combinations of treatments and varieties on number of leaf, leaf length, leaf breadth, fruit length and fruit girth of capsicum

Varieties	**Number of leaf per plant**	**Leaf length (cm)**	**Leaf breadth (cm)**	**Fruit length (cm)**	**Fruit breadth (cm)**
V_1T_1	49.44 a	12.19 a	4.35 a	13.57 a	4.80 a
V_1T_2	45.96 c	11.23 b	3.82 ab	13.09 ab	4.67 abc
V_1T_3	44.70 f	9.46 c	3.32 bc	12.55 abc	4.59 abc
V_1T_4	41.61 j	7.91 e	2.84 cde	12.08 bc	4.37 bc
V_2T_1	46.70 b	11.37 b	3.83 ab	13.11 ab	4.72 ab
V_2T_2	45.64 d	9.61 c	3.43 bc	12.73 abc	4.62 abc
V_2T_3	44.03 h	8.95 cd	3.22 bcd	12.43 abc	4.55 abc
V_2T_4	39.95 k	7.83 e	2.68 de	12.07 bc	4.32 bc
V_3T_1	45.76 cd	11.21 b	3.67 b	13.04 ab	4.66 abc
V_3T_2	42.48 i	8.24 de	2.86 cde	12.29 abc	4.51 abc
V_3T_3	41.68 j	8.15 de	2.85 cde	12.27 abc	4.46 abc
V_3T_4	38.76 l	7.70 e	2.66 de	11.92 bc	4.28 c
V_4T_1	45.13 e	9.51 c	3.33 bc	12.63 abc	4.60 abc
V_4T_2	44.45 g	9.14 c	3.24 bcd	12.54 abc	4.56 abc
V_4T_3	42.61 i	8.79 cd	2.95 cde	12.33 abc	4.52 abc
V_4T_4	35.09 m	7.47 e	2.50 e	11.55 c	4.27 c
LSD (0.05)	0.23	0.74	0.54	1.20	0.34
CV (%)	3.78	4.83	10.17	5.85	4.50

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in terms of number of leaf, leaf length, leaf breadth, fruit length and fruit breadth than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of number of leaf, leaf length, leaf breadth, fruit length and fruit breadth was V_1T_1> V_2T_1>

V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4. More or less similar research was also conducted by several researchers. Boyhan *et al*. (2019) evaluated the performance of California wonder was higher than the other varieties.

Number of fruit: The significant variation was observed in the number of fruits of capsicum, whereas, the maximum average number of fruits was found in V_1T_1 (17.33 fruits) which was significantly different from others and followed by V_2T_1 (16.58 fruits), V_1T_2 (15.78 fruits), V_2T_2 (14.50 fruits), V_4T_1 (14.47 fruits), V_3T_1 (14.31 fruits) and V_1T_3 (14.32 fruits). On the other hand, the minimum average number of fruits was found in V_4T_4 (9.60 fruits) which was significantly different from others and followed by V_3T_4 (10.67 fruits), V_2T_4 (11.67 fruits), V_1T_4 (11.79 fruits), V_3T_3 (12.09 fruits), V_3T_2 (12.30 fruits), V_4T_3 (12.53 fruits), V_2T_3 (13.32 fruits) and V_4T_2 (13.73 fruits) (Table 9).

Number of infested fruit: The significant variation was observed in the number of infested fruits of capsicum, whereas, the minimum average number of infested fruits was found in V_1T_1 (1.12 fruits) which was significantly different from others and followed by V_2T_1 (1.34 fruits), V_1T_2 (1.36 fruits), V_2T_2 (2.01 fruits), V_4T_1 (2.48 fruits), V_3T_1 (1.77 fruits) and V_1T_3 (2.69 fruits). On the other hand, the maximum average number of infested fruits was found in V_4T_4 (5.63 fruits) which was significantly different from others and followed by V_3T_4 (5.50 fruits), V_2T_4 (4.73 fruits), V_1T_4 (4.50 fruits), V_3T_3 (4.34 fruits), V_3T_2 (3.79 fruits), V_4T_3 (3.58 fruits), V_2T_3 (3.29 fruits) and V_4T_2 (3.28 fruits) (Table 9).

Percent fruit infestation by number: The significant variation was observed in the percent fruit infestation by number of capsicum, whereas, the minimum percent fruit infestation by number was found in V_1T_1 (6.46 %) which was significantly different from others and followed by V_2T_1 (8.08 %), V_1T_2 (8.62 %), V_2T_2 (13.86 %), V_4T_1 (17.14 %), V_3T_1 (12.37 %) and V_1T_3 (18.78 %). On the other hand, the maximum percent fruit infestation by number was found in V_4T_4 (58.65 %) which was significantly different from others and followed by V_3T_4 (51.55 %), V_2T_4 (40.53 %), V_1T_4 (38.17 %), V_3T_3 (35.89 %), V_3T_2 (30.81 %), V_4T_3 (28.57 %), V_2T_3 (24.70 %) and V_4T_2 (23.89 %) (Table 9).

Total fruit weight: The significant variation was observed in the weight of fruits of capsicum, whereas, the maximum average weight of fruits was found in V_1T_1 (2.04 kg) which was significantly different from others and followed by V_2T_1 (1.46 kg), V_1T_2 (1.44 kg), V_2T_2 (1.37 kg), V_4T_1 (1.17 kg), V_3T_1 (1.43 kg) and V_1T_3 (1.15 kg). On the other hand, the minimum average weight of fruits was found in V_4T_4 (0.54 kg) which was significantly different from others and followed by V_3T_4 (0.56 kg), V_2T_4 (0.60 kg), V_1T_4 (0.64 kg), V_3T_3 (0.82 kg), V_3T_2 (0.83 kg), V_4T_3 (0.92 kg), V_2T_3 (0.97 kg) and V_4T_2 (1.13 kg) (Table 9).

Infested fruit weight: The significant variation was observed in the weight of infested fruits of capsicum, whereas, the minimum average weight of infested fruits was found in V_1T_1 (0.12 kg) which was significantly different from others and followed by V_2T_1 (0.14 kg), V_1T_2 (0.16 kg), V_2T_2 (0.18 kg), V_4T_1 (0.22 kg), V_3T_1 (0.18 kg) and V_1T_3 (0.29 kg). On the other hand, the maximum average weight of infested fruits was found in V_4T_4 (0.33 kg) which was significantly different from others and followed by V_3T_4 (0.54 kg), V_2T_4 (0.24 kg), V_1T_4 (0.49 kg), V_3T_3 (0.41 kg), V_3T_2 (0.39 kg), V_4T_3 (0.35 kg), V_2T_3 (0.34 kg) and V_4T_2 (0.33 kg) (Table 9).

Percent infestation by weight: The significant variation was observed in the percent fruit infestation by weight of capsicum, whereas, the minimum percent fruit infestation by weight was found in V_1T_1 (5.88%) which was significantly different from others and followed by V_2T_1 (9.59 %), V_1T_2 (11.11 %), V_3T_1 (12.59 %), V_2T_2 (13.14 %), V_4T_1 (18.80 %) and V_1T_3 (25.22 %). On the other hand, the maximum percent fruit infestation by weight was found in V_3T_4 (96.43 %) which was significantly different from others and followed by V_1T_4 (76.56 %), V_4T_4 (61.11 %), V_3T_3 (50.00 %), V_3T_2 (46.99 %), V_2T_4 (40.00 %), V_4T_3 (38.04 %), V_2T_3 (35.05 %) and V_4T_2 (29.20 %) (Table 9).

Table 9: Effect of combinations of treatments and varieties on yield attributes and fruit infestation of capsicum

Varieties	Number of fruit per plot	Number of infested fruit per plot	% fruit infestation by number	Total fruit weight per plot(kg)	Infested fruit weight per plot (kg)	% fruit infestation by weight
V_1T_1	17.33 a	1.12 i	6.46 p	2.04 a	0.12 h	5.88 p
V_1T_2	15.78 c	1.36 h	8.62 n	1.44 b	0.16 h	11.11 n
V_1T_3	14.32 e	2.69 f	18.78 j	1.15 c	0.29 f	25.22 j
V_1T_4	11.79 jk	4.50 bc	38.17 d	0.64 e	0.49 b	76.56 b
V_2T_1	16.58 b	1.34 h	8.08 o	1.46 b	0.14 h	9.59 o
V_2T_2	14.50 e	2.01 g	13.86 l	1.37 b	0.18 gh	13.14 l
V_2T_3	13.32 g	3.29 e	24.70 h	0.97 d	0.34 def	35.05 h
V_2T_4	11.67 k	4.73 b	40.53 c	0.60 e	0.24 b	40.00 f
V_3T_1	14.31 d	1.77 g	12.37 m	1.43 b	0.18 gh	12.59 m
V_3T_2	12.30 hi	3.79 d	30.81 f	0.83 d	0.39 cd	46.99 e
V_3T_3	12.09 ij	4.34 c	35.89 e	0.82 d	0.41 c	50.00 d
V_3T_4	10.67 l	5.50 a	51.55 b	0.56 e	0.54 b	96.43 a
V_4T_1	14.47 e	2.48 f	17.14 k	1.17 c	0.22 g	18.80 k
V_4T_2	13.73 f	3.28 e	23.89 i	1.13 c	0.33 ef	29.20 i
V_4T_3	12.53 h	3.58 de	28.57 g	0.92 d	0.35 de	38.04 g
V_4T_4	9.60 m	5.63 a	58.65 a	0.54 e	0.33 a	61.11 c
LSD (0.05)	0.32	0.36	0.23	0.14	0.05	0.46
CV (%)	1.46	6.97	7.81	7.72	11.62	9.35

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in terms of number of fruit, number of infested fruits, percent infested fruit by number, total fruit weight, infested fruit weight and percent fruit infestation by weight than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of number of fruit, number of infested fruit, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight was V_1T_1> V_2T_1> V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4. More or less similar research was also conducted by several researchers. Boyhan *et al*. (2019) evaluated the performance of California wonder was higher than the other varieties.

4.5. Yield of capsicum

4.5.1. In case of varietal performance

The significant variation was observed in the yield of capsicum per hectare, whereas, the maximum average yield of capsicum per hectare was found in V_1 (8.12 ton/ha) which was statistically similar with V_3 (7.02 ton/ha). On the other hand, the minimum average yield of capsicum per hectare was found in V_2 (6.46 ton/ha) which was statistically similar with V_4 (6.85 ton/ha) (Table 10).

Table 10: Effect of different varieties on the yield of capsicum

Varieties	Yield (ton/ha)
V_1	8.12 a
V_2	6.46 b
V_3	7.02 ab
V_4	6.85 b
LSD (0.05)	1.13
CV (%)	7.68

[V_1: California wonder; V_2: California hot pepper; V_3: Bell pepper; V_4: Red army.]

From these above findings it was revealed that, among the different Varieties, V_1 comprised with California wonder showed the best performance in case of yield of capsicum per hectare than the others. As a result, the order of rank of varieties of capsicum in terms of yield of capsicum per hectare was $V_1 > V_3 > V_4 > V_2$. More or less similar research was also conducted by several researchers. Boyhan *et al*. (2019) evaluated the performance of California wonder was higher than the other varieties.

4.5.2. In case of effect of different treatments

The significant variation was observed in the yield of capsicum per hectare. The maximum average yield of capsicum per hectare was found in T_1 (7.97 ton) which was statistically similar with T_3 (7.72). On the other hand, the minimum average yield of capsicum per hectare was found in T_4 (6.01ton) which was statistically similar with T_2 (6.73) (Table 11).

Table 11: Effect of different treatments on yield of capsicum

Varieties	Yield (ton/ha)
T_1	7.97 a
T_2	6.73 b
T_3	7.72 a
T_4	6.01 b
LSD (0.05)	0.90
CV (%)	7.68

[T_1: Botanical insecticide (Neem oil @ 3ml/L of water); T_2: Acaricide (Mitisol 5EC @ 2.50ml/L of water); T_3: Synthetic (Imidacloropid 200SL @ 2gm/L of water); T_4: Control.]

From these above findings it was revealed that among the different treatments, T_1 comprised with botanical insecticide (Neem oil) showed the best performance in case yield of capsicum per hectare than the others. As a result, the order of rank of different treatments of capsicum in terms of yield of capsicum per hectare was $T_1 > T_3 > T_2 > T_4$. More or less similar research was also conducted by several researchers. Boyhan *et al.* (2019) evaluated the performance of California wonder was higher than the other varieties.

4.5.3. In case of effect of combinations of treatments and varieties

The significant variation was observed in the yield of capsicum per hectare. The maximum average yield of capsicum per hectare was found in V_1T_1 (13.59 ton/ha) which was significantly different from others and followed by V_2T_1 (9.75 ton/ha), V_1T_2 (9.57 ton/ha), V_3T_1 (9.54 ton/ha), V_2T_2 (9.10 ton/ha), V_4T_1 (7.69 ton/ha) and V_1T_3 (7.65 ton/ha). On the other hand, the minimum average yield of capsicum per hectare was found in V_4T_4 (3.61 ton/ha) which was significantly different from other varieties and followed by V_3T_4 (3.75 ton/ha), V_2T_4 (4.03 ton/ha), V_1T_4 (4.27 ton/ha), V_3T_3 (5.47 ton/ha), V_3T_2 (5.51 ton/ha), V_4T_3 (6.12 ton/ha), V_2T_3 (6.44 ton/ha) and V_4T_2 (7.57 ton/ha) (Table 12).

Table 12: Effect of different combinations of treatments and varieties on yield of capsicum

Varieties	Yield (ton/ha)
V_1T_1	13.59 a
V_1T_2	9.57 b
V_1T_3	7.65 c
V_1T_4	4.27 e
V_2T_1	9.75 b
V_2T_2	9.10 b
V_2T_3	6.44 d
V_2T_4	4.03 e
V_3T_1	9.54 b
V_3T_2	5.51 d
V_3T_3	5.47 d
V_3T_4	3.75 e
V_4T_1	7.69 c
V_4T_2	7.57 c
V_4T_3	6.12 d
V_4T_4	3.61 e
LSD (0.05)	0.90
CV (%)	7.68

[V_1T_1: California wonder + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_1T_2: California wonder + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_1T_3: California wonder + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_1T_4: California wonder + Control; V_2T_1: Bell pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_2T_2: Bell pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_2T_3: Bell pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_2T_4: Bell pepper + Control; V_3T_1: California hot pepper + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_3T_2: California hot pepper + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_3T_3: California hot pepper + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_3T_4: California hot pepper + Control; V_4T_1: Red army + Spraying synthetic insecticide (Imidacloropid 200SL @ 2gm/L of water); V_4T_2: Red army + Spraying acaricide (Mitisol 5EC @ 2.50ml/L of water); V_4T_3: Red army + Spraying botanical insecticide (Neem oil @ 3ml/L of water); V_4T_4: Red army + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in terms of yield of capsicum per hectare than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of yield of capsicum per hectare was V_1T_1> V_2T_1> V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4. More or less similar research was also conducted by several researchers. Boyhan *et al*. (2019) evaluated the performance of California wonder was higher than the other varieties.

4.6. Interaction with the number of bore and yield of capsicum

4.6.1. In case of varieties

Correlation study was done to establish the relationship between number of bore caused by gram pod borer per fruit and yield (t/ha) of capsicum in case of varietal performance. From the study it was revealed that significant correlation was observed between the number of bore caused by gram pod borer per fruit and yield of capsicum (Figure 7). It was evident from the Figure 7 that the egression equation y = -0.4675x + 8.4845 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9199) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of bore caused by gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of bore caused by gram pod borer per fruit of capsicum in case of varietal performance.

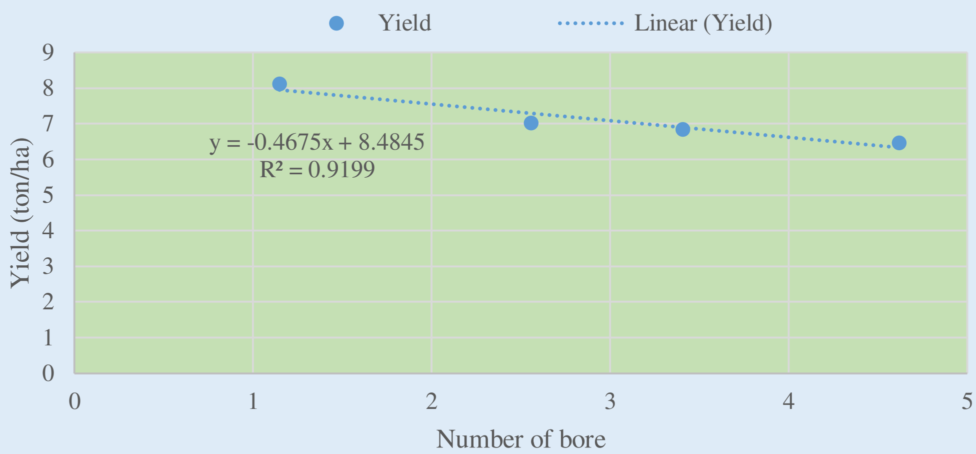

Figure 7: Interaction between number of bore and yield of capsicum in case of varietal performance

4.6.2. In case of different treatments

Correlation study was done to establish the relationship between number of bore per caused by gram pod borer fruit and yield (t/ha) of capsicum in case of the performance of different treatments. From the study it was revealed that significant correlation was observed between the number of bore caused by gram pod borer per fruit and yield of capsicum (Figure 8). It was evident from the Figure 8 that the regression equation y = -2.1923x + 13.657 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9434) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of bore caused by gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of bore caused by gram pod borer per fruit of capsicum in case of the performance of different treatments.

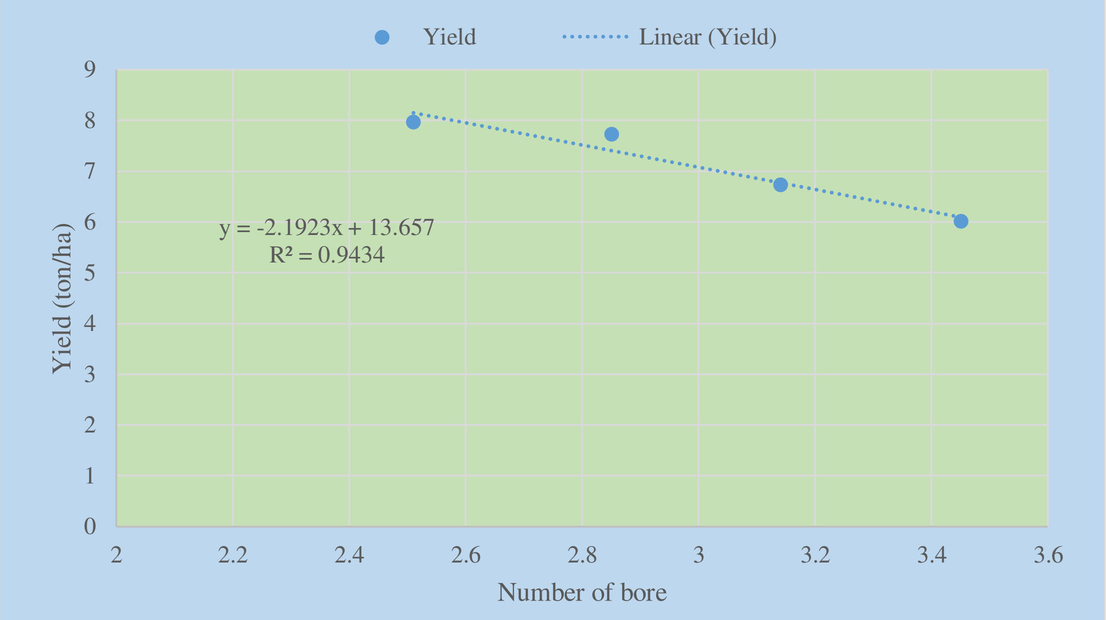

Figure 8: Interaction between number of bore and yield of capsicum in case of different treatments

4.6.3. In case of combination of varieties and treatments

Correlation study was done to establish the relationship between number of bore caused by gram pod borer per fruit and yield (t/ha) of capsicum in case of the combination of varieties and treatments. From the study it was revealed that significant correlation was observed between the number of bore caused by gram pod borer per fruit and yield of capsicum (Figure 9). It was evident from the Figure 9 that the regression equation $y = -1.9772x + 13.055$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9519$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of bore caused by gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of bore caused by gram pod borer per fruit of capsicum in case of the combination of varieties and treatments.

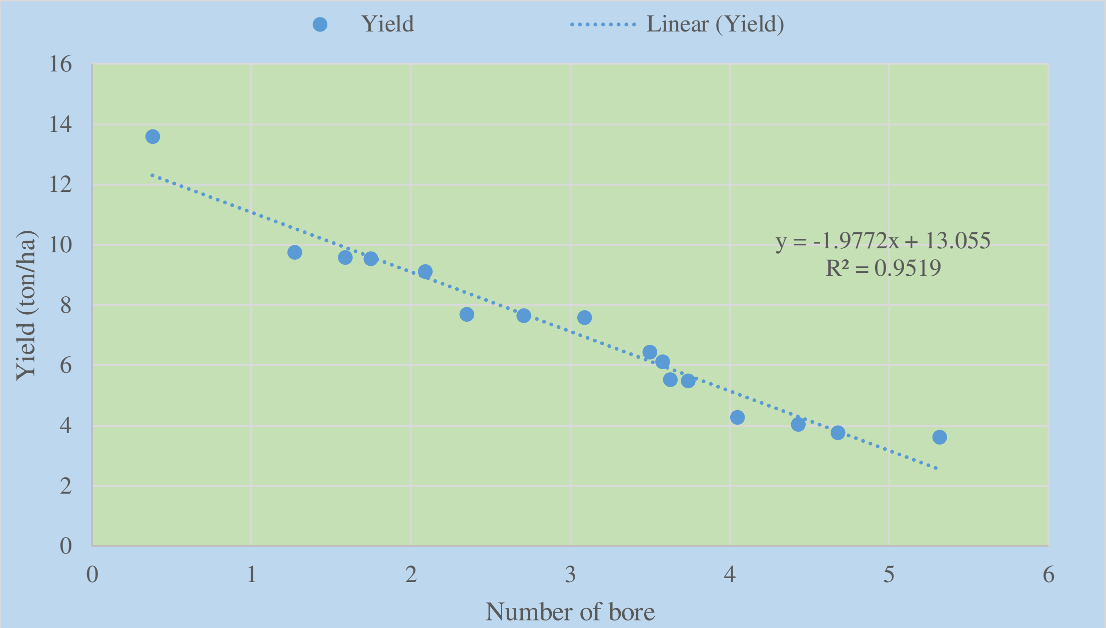

Figure 9: Interaction between number of bore and yield of capsicum in case of combination of treatments and varieties

4.7. Interaction with the number of spodoptera and yield of capsicum

4.7.1. In case of varieties

Correlation study was done to establish the relationship between number of spodoptera per fruit and yield (t/ha) of capsicum in case of varietal performance. From the study it was revealed that significant correlation was observed between the number of spodoptera per fruit and yield of capsicum (Figure 10). It was evident from the Figure 10 that the regression equation y = -1.6814x + 7.9154 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7367) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of spodoptera per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of spodoptera per fruit of capsicum in case of varietal performance.

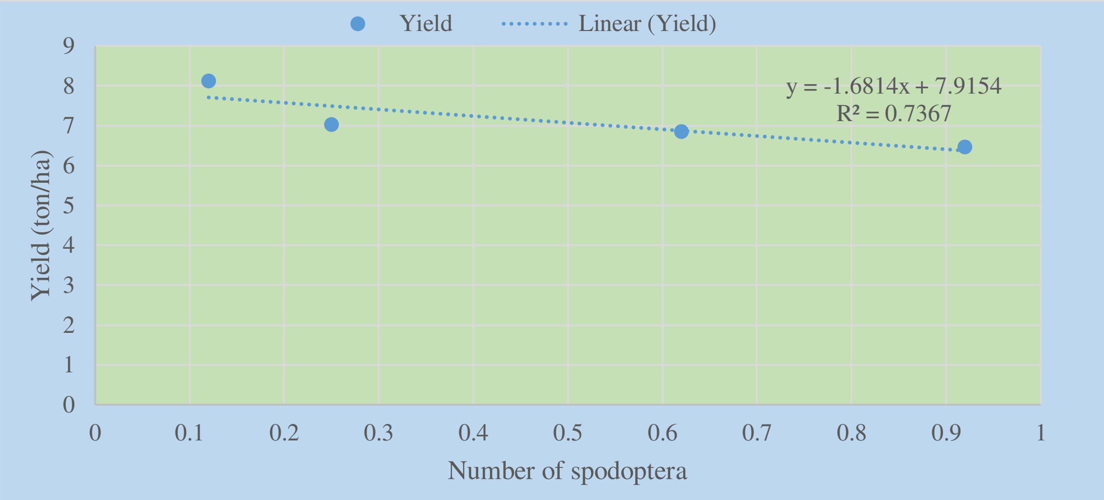

Figure 10: Interaction between the number of spodoptera and yield of capsicum in case of varietal performance

4.7.2. In case of different treatments

Correlation study was done to establish the relationship between number of spodoptera per fruit and yield (t/ha) of capsicum in case of the performance of different treatments. From the study it was revealed that significant correlation was observed between the number of spodoptera per fruit and yield of capsicum (Figure 11). It was evident from the Figure 11 that the regression equation y = -4.6296x + 8.9131 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9856) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of spodoptera per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of spodoptera per fruit of capsicum in case of the performance of different treatments.

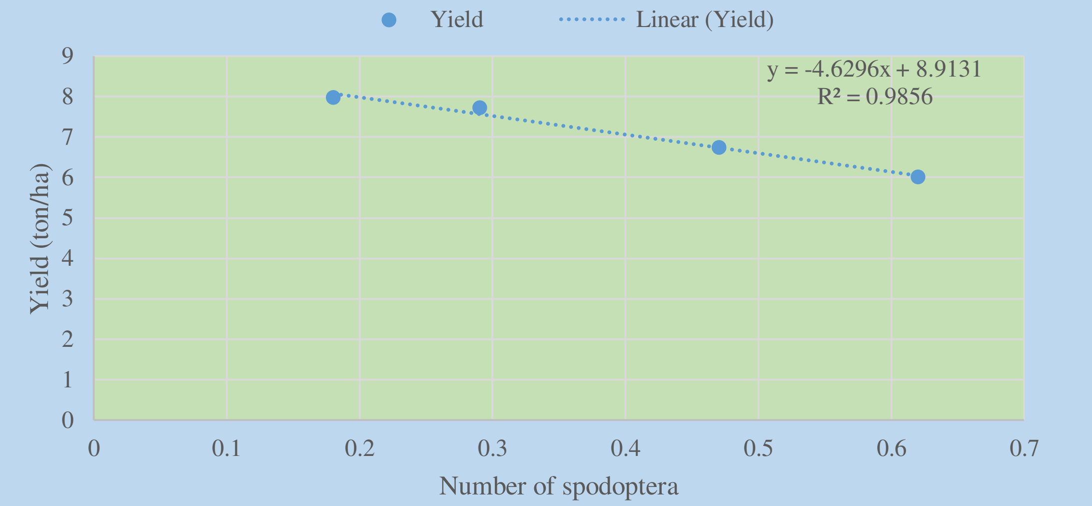

Figure 11: Interaction between the number of spodoptera and yield of capsicum in case of performance of different treatments

4.7.3. In case of combination of varieties and treatments

Correlation study was done to establish the relationship between number of spodoptera per fruit and yield (t/ha) of capsicum in case of the combination of varieties and treatments. From the study it was revealed that significant correlation was observed between the number of spodoptera per fruit and yield of capsicum (Figure 12). It was evident from the Figure 12 that the regression equation y = -9.007x + 12.176 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9095) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of spodoptera per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of spodoptera per fruit of capsicum in case of the combination of varieties and treatments.

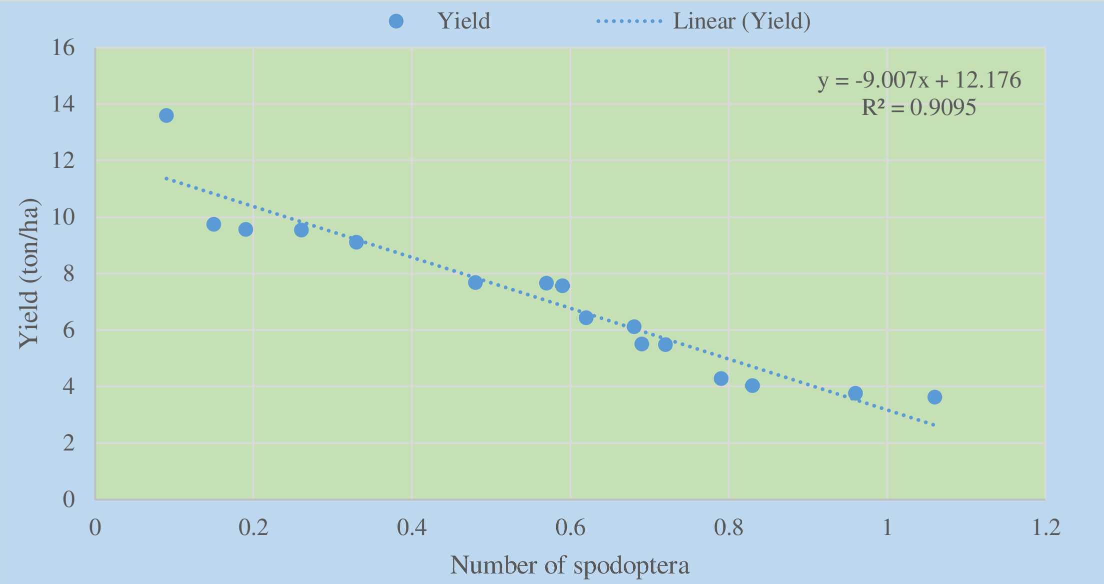

Figure 12: Interaction between number of spodoptera and yield of capsicum in case of combination of treatments and varieties

4.8. Interaction with the number of larvae of gram pod borer and yield of capsicum

4.8.1. In case of varieties

Correlation study was done to establish the relationship between number of larvae of gram pod borer per fruit and yield (t/ha) of capsicum in case of varietal performance. From the study it was revealed that significant correlation was observed between the number of larvae of gram pod borer per fruit and yield of capsicum (Figure 13). It was evident from the Figure 13 that the regression equation y = -0.5358x + 8.6637 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.979) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of larvae of gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of larvae of gram pod borer per fruit of capsicum in case of varietal performance.

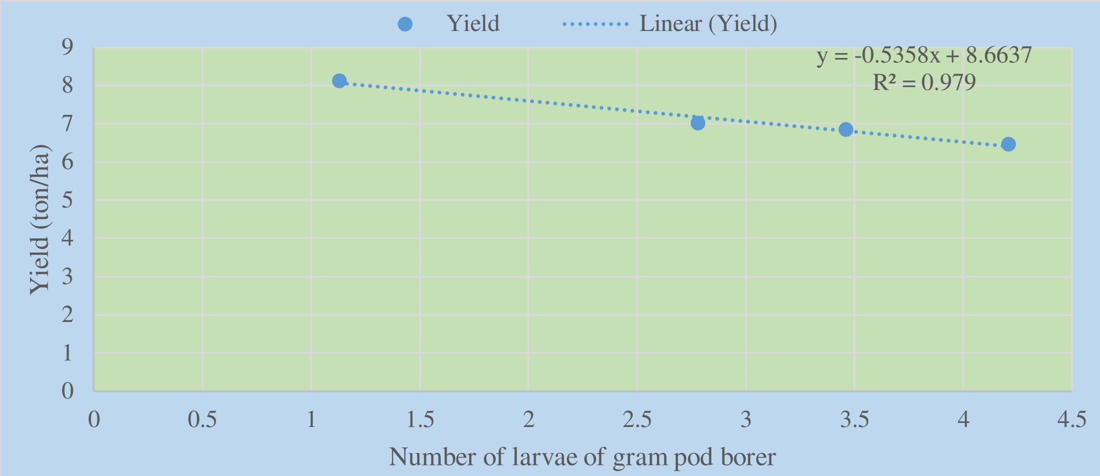

Figure 13: Interaction between the number of larvae of gram pod borer and yield of capsicum in case of varietal performance

4.8.2. In case of different treatments

Correlation study was done to establish the relationship between number of larvae of gram pod borer per fruit and yield (t/ha) of capsicum in case of the performance of different treatments. From the study it was revealed that significant correlation was observed between the number of larvae of gram pod borer per fruit and yield of capsicum (Figure 14). It was evident from the Figure 14 that the regression equation y = -0.7376x + 8.6326 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9772) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of larvae of gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of larvae of gram pod borer per fruit of capsicum in case of the performance of different treatments.

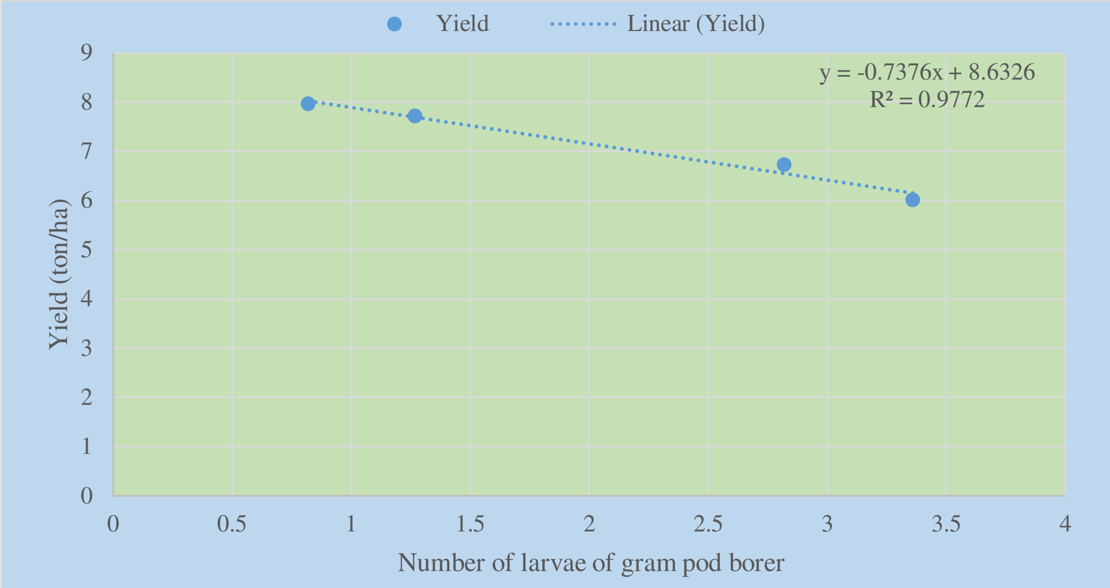

Figure 14: Interaction between the number of larvae of gram pod borer and yield of capsicum in case of varietal performance

4.8.3. In case of combination of varieties and treatments

Correlation study was done to establish the relationship between number of larvae of gram pod borer per fruit and yield (t/ha) of capsicum in case of the combination of varieties and treatments. From the study it was revealed that significant correlation was observed between the number of larvae of gram pod borer per fruit and yield of capsicum (Figure 15). It was evident from the Figure 15 that the regression equation $y = -2.044x + 12.189$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9116$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of larvae of gram pod borer per fruit and yield of capsicum, i.e., the yield decreased with the increase of the number of larvae of gram pod borer per fruit of capsicum in case of the combination of varieties and treatments.

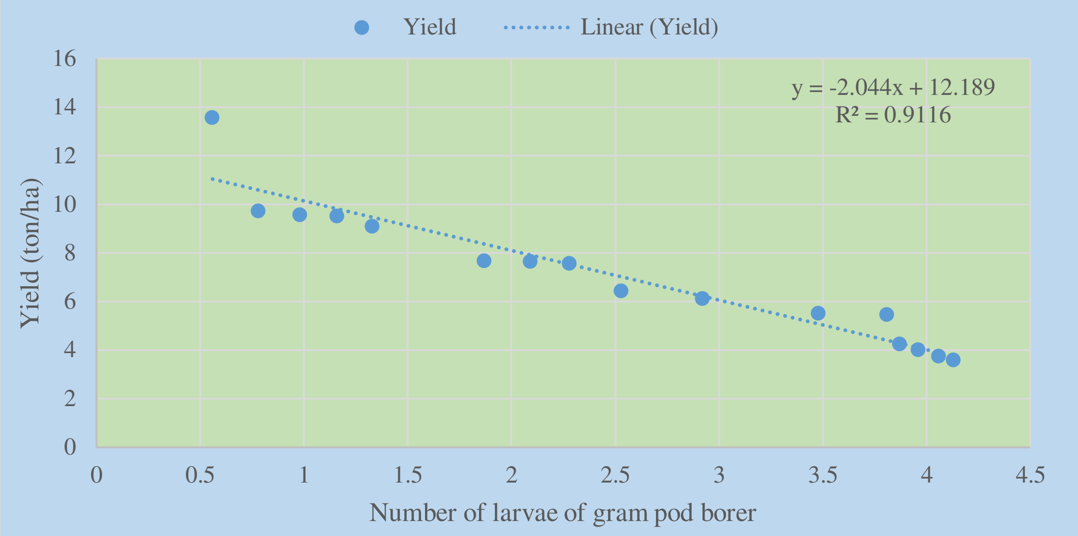

Figure 15: Interaction between number of larvae of gram pod borer and yield of capsicum in case of combination of treatments and varieties

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to February, 2019 to evaluate the damage assessment and management of insect and other arthropod pests of capsicum.

5.1. Summary

5.1.1. In case of varieties

Among the different Varieties, V_1 comprised with California wonder was more resistant variety for aphid, whitefly, jassid, fruit borer and mite infestation than the others varieties. V_2 comprised with California hot pepper was more susceptible variety for aphid infestation than other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of aphid per four tagged plants was $V_1 < V_3 < V_4 < V_2$.

In the term of leaf infestation by aphid, whitefly and mite per five tagged plants, V_1 comprised with California wonder was more resistant variety for leaf infestation then the others varieties and V_2 comprised with California hot pepper was more susceptible variety for leaf infestation than other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of infested leaves caused by insect pests per five tagged plants was $V_1 < V_3 < V_4 < V_2$.

In terms of plant infestation by aphid and whitefly per plot, V_1 comprised with California wonder was more resistant variety for plant infestation per plot caused by aphid and whitefly than the others and V_2 comprised with California hot pepper was more susceptible variety for aphid infestation than other varieties. As a result, the order of rank of resistant variety of capsicum in terms of number of infested plants caused by aphid per plot was $V_1 < V_3 < V_4 < V_2$.

5.1.2. In case of different treatments

Among the different treatments, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of insect pests like aphid, whitefly, jassid, fruit borer and mite per five tagged plants. As a result, the order of rank of efficacy of the treatments applied against insect pests including untreated control in terms of reducing the number of insect pests like aphid, whitefly, jassid, fruit borer and mite per five tagged plants was $T_1 < T_3 < T_2 < T_4$.

In the term of leaf infestation by aphid, whitefly and mite, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants. As a result, the order of rank of efficacy of the treatments applied against insect pests including untreated control in terms of reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants was $T_1 < T_3 < T_2 < T_4$.

In terms of plant infestation by aphid a nd whitefly, T_1 comprised with spraying of botanical insecticide (Neem oil) in reducing the number of infested leaves caused by aphid and whitefly per plot. As a result, the order of rank of efficacy of the treatments applied against insect pests including untreated control in terms of reducing the number of infested plants caused by aphid and whitefly per plot was $T_1 < T_3 < T_2 < T_4$.

5.1.3. In case of combination of varieties and treatments

Among the different combinations, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of insect pests like aphid, whitefly, jassid, fruit borer and mite per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of insect pests like aphid, whitefly, jassid, fruit borer and mite per five tagged plants was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$.

In the term of leaf infestation by aphid, whitefly and mite, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of infested leaves caused by aphid, whitefly and mite per five tagged plants was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$.

In terms of plant infestation by aphid and whitefly, V_1T_1 comprised with California wonder along with spraying botanical insecticide (Neem oil) showed the best performance in reducing the number of infested plants caused by aphid and whitefly per plot than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of infested plants caused by aphid and whitefly per plot was $V_1T_1 < V_2T_1 < V_1T_2 < V_3T_1 < V_2T_2 < V_4T_1 < V_1T_3 < V_2T_3 < V_4T_2 < V_3T_2 < V_4T_3 < V_3T_3 < V_1T_4 < V_2T_4 < V_3T_4 < V_4T_4$.

California wonder along with spraying botanical insecticide (Neem oil) (V_1T_1) showed the best performance in terms of number of leaf, leaf length and breadth, fruit length and fruit breadth (4.80 cm) than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of number of leaf, leaf length and breadth, fruit length and fruit breadth was V_1T_1> V_2T_1> V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4.

California wonder along with spraying botanical insecticide (V_1T_1) showed the best performance in terms of number of fruit, number of infested fruits, percent infested fruit by number, total fruit weight, infested fruit weight and percent fruit infestation by weight than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of number of fruit, number of infested fruit, percent fruit infestation by number, total fruit weight, infested fruit weight and percent fruit infestation by weight was V_1T_1> V_2T_1> V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4.

California wonder along with spraying botanical insecticide (Neem oil) (V_1T_1) showed the best performance in terms of yield of capsicum per hectare than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments in terms of yield of capsicum per hectare was V_1T_1> V_2T_1> V_1T_2> V_3T_1> V_2T_2> V_4T_1> V_1T_3> V_2T_3> V_4T_2> V_3T_2> V_3T_3> V_4T_3> V_1T_4> V_2T_4> V_3T_4> V_4T_4.

5.2. Conclusion

From the present study, it may be concluded that the California wonder variety of capsicum was the best variety among the other varieties in case of insect (like aphid, whitefly, thrips, gram pod borer and mite) infestation (e.g. leaves and plants) along with the other yield attributing characteristics and yield. Whereas, the botanical insecticide comprised with Neem oil was the best treatment among the other treatments in case of insect (like aphid, whitefly, thrips, gram pod borer and mite) infestation (e.g. leaves and plants) along with the other yield attributing characteristics and yield. And in case of the combination of varieties and treatments, California wonder along with botanical insecticide (Neem oil) showed the best performance for insect (like aphid, whitefly, thrips, gram pod borer and mite) infestation (e.g. leaves and plants) along with the other yield attributing characteristics and yield than the other combinations.

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

1. Though California wonder variety of capsicum was exotic variety for Bangladesh, so it should need more experiments.
2. Botanical insecticides should be more used to control the sucking insect pest in the capsicum field.
3. Further study should be needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

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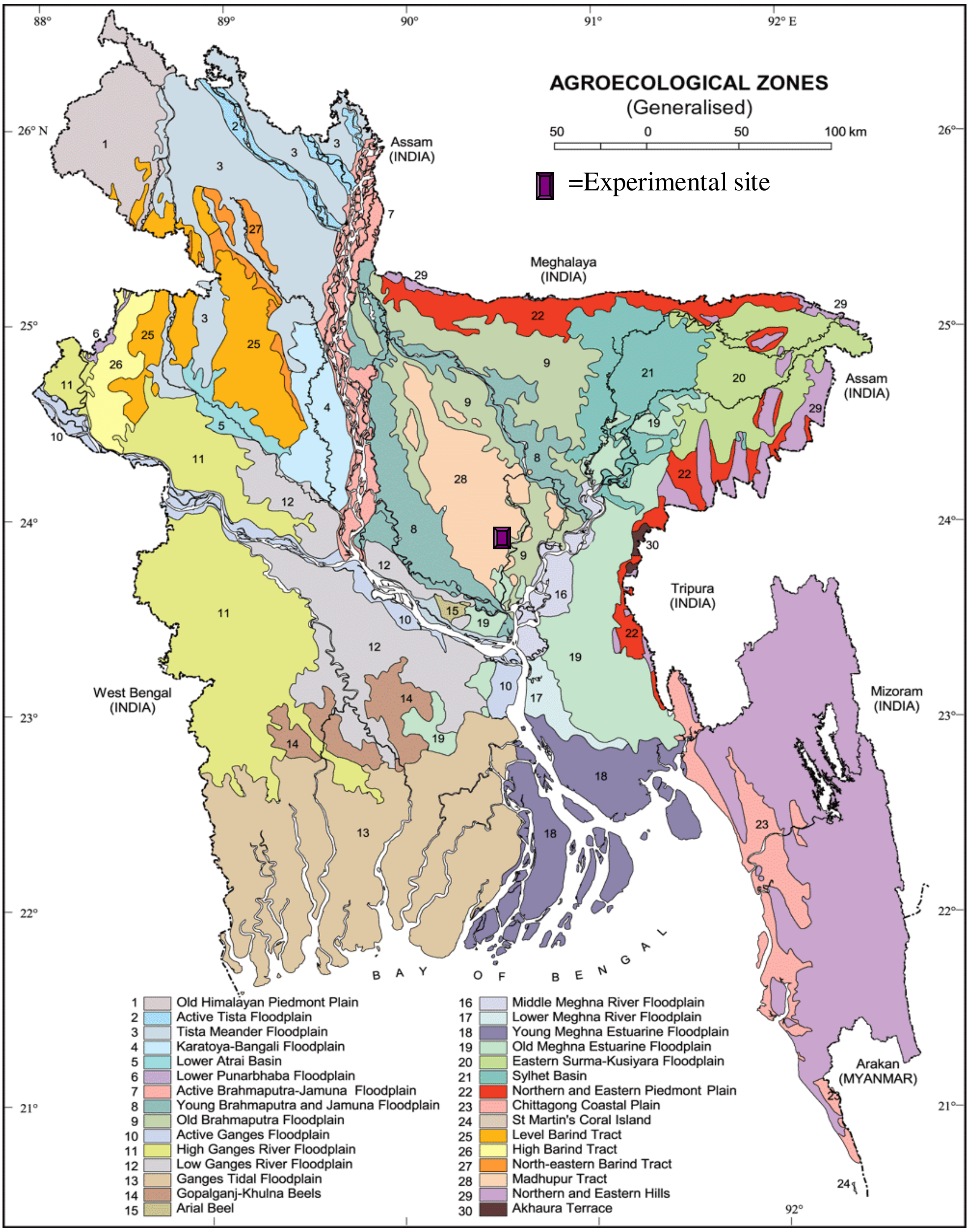
CHAPTER VII

APPENDICES

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



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

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

Chemical composition:

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

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