EFFICACY OF SOME SELECTED BOTANICALS FOR THE MANAGEMENT OF MAJOR INSECT PESTS OF SQUASH

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EFFICACY OF SOME SELECTED BOTANICALS FOR THE MANAGEMENT OF MAJOR INSECT PESTS OF SQUASH

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CERTIFICATE

*This is to certify that the thesis entitled, '**Efficacy of Some Selected Botanicals for the Management of Major Insect Pests of Squash'** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of bona fide research work carried out by **Sarothi Sarker,** Registration number: 14-05975 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June 2021
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Dedicated to…

My beloved Parents and the farmers who feed the nation

ABBREVIATIONS

Elaborated Form	Abbreviated Form
And others (Co-workers)	*et al.*
Gram	G
Coefficient of Variation	CV
Degree centigrade	^{O}c
Example	viz.
Least significant difference	LSD
Million tons	Mt
Non-significant	NS
Per Hectare	ha^{-1}
Percentage	%
Nitrogen	N
Phosphorus	P
Potassium	K
Randomized Complete Block Design	RCBD
Standard Week	SW
Sher-e-Bangla Agricultural University	SAU
Standard Error	SE
that is	i.e.
Tons	T

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The Author

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EFFICACY OF SOME SELECTED BOTANICALS FOR THE MANAGEMENT OF MAJOR INSECT PESTS OF SQUASH

ABSTRACT

Experiment was conducted in research field of the department of entomology, Sher- e-Bangla Agricultural University, Dhaka in order to evaluate the efficacy of some botanicals against major insect pests of squash. The experiment was laid out seven treatments and three replications in a randomized complete block design (RCBD). The treatments were neem oil, neem seed kernel extract, datura seed extract, garlic bulb extract, mehagany seed extract, black pepper seed extract and control. In context of controlling fruit fly infestation in squash, lowest fruit infestation in terms of percent fruit infested (6.17%@1 day after first spray, 9.09%@7 days after first spray, 14.90%@7 days after second spray, 24.33%@7 days after second spray) obtained from neem oil treated plots. Similarly, lowest population of aphids (6.54 aphids per leaf and 4.23 aphids per leaf during vegetative and fruiting stage respectively), red pumpkin beetle (0.18 per plot and 0.69 per plot during vegetative and fruiting stage respectively) and epilachna beetle (0.02 per plot and 0.29 per plot respectively) obtained from neem oil treated plots. Moreover, the lowest leaf damage (5.66% damaged leaves per plant) obtained from neem oil also. However, highest yield of squash in terms of fruit length (37.48 cm) and yield (38.64 ton/ha) was obtained from neem oil treatment. Among the botanicals neem oil was the best for control of major insect pests of squash.

CHAPTER I

INTRODUCTION

Squash (*Cucurbita pepo*) commonly known as Zucchini squash, one of the most economically important vegetable crops grown in many tropical and subtropical regions of the world (Paris 1996). It is a quick-growing early yielding cucurbit cultivated throughout Bangladesh (Mohammad *et al.* 2011). It is popular and grown worldwide particularly for oil and medical purposes as it possesses several pharmacological effects as antidiabetic, antihypertensive, antitumor, antimutagenic, immunomodulating, antibacterial, antihypercholesterolemic, intestinal antiparasitic, antalgic, and antiinflammation effects (Bannayan *et al.* 2011 and Caili *et al*. 2006). Although it offers great importance, the production of summer squash is particularly hampered by the incidence of various insect pests (Sarwar 2014). This might be one of the reasons for the lower yield of summer squash compared to its attainable yield as farmers are discouraged to cultivate this crop.

Squash is susceptible to several chewing and sucking insect pests as, Red pumpkin beetle, melon fruit fly, flea beetle, squash bug, whitefly, melon aphid, squash lady beetles which are being the most troublesome one leading to great loss in quality and yield (Kaiser and Ernst 2018). Some insect pests may infest the crop during the whole cultivation period and may cause damage up to 80% (Rahman and Uddin 2016). About 50 percent of cucurbits are partially or completely damaged by those problematic insect pests (Dhilon *et al*. 2005). The average economic loss caused by these insect's pests in cucurbits is around 40% (Sharma *et al*. 2016). Among these pests Cucurbit fruit fly viz., *Bactrocera cucurbitae*, Melon aphid viz., *Aphis gossypii*, Red pumpkin beetle *Aulacophora foveicollis* L. and Epilachna beetle *Hemisepilachna vigintioctopunctata* are the most damaging insect pest causing the yield losses up to 30-100% depending on the cucurbit species and season (Hassan *et al.* 2012; Dhillon *et al*. 2005).

Bactrocera cucurbitae (Coquillett) is a major threat to cucurbits (Shah *et al*. 1948). Senior-White (1924) listed 87 species of Tephritidae in India. Amongst these, the genus, *Bactrocera* (Dacus) causes heavy damage to fruits and vegetables in Asia (Nagappan *et al*. 1971). Melon fruit fly damages over 81 plant species. Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred most. Young maggot move to healthy tissue of the fruit, where they often introduce various pathogens, secondary infections and initiate decomposition.

Aphis gossypii Glover is an important agricultural pest because it has a broad host range, and transmits many agriculturally important plant viruses. Damage is direct through feeding which can kill the host, but also productivity is reduced long before plant death. Damage is indirect through contamination with aphid honeydew and by vectoring viral pathogens. Honey dew causes economic loss through physical contamination and through providing a nutrient source for fungi that contaminate produce and reduce photosynthesis rates by blocking sunlight (Kamal *et al*. 2014)

Red pumpkin beetle (*Aulacophora foevicoliis*) is most serious pest of cucurbitaceous vegetable crops. *Aulacophora* is Polyphagous and attacks more than 81 plant species and prefers cucurbit vegetable causing great loss in cucurbits production in Bangladesh. It causes damage from seedling stage up to harvesting stage. Both grub and adult are harmful to the crop. Grub feeds on root tissue and cause direct damage to the seedlings. Adult cause damage by feeding leaves, flower buds and flowers (Hassan *et al*. 2012).

The epilachna beetle has been recorded on the hosts as brinjal, squash, tomato, tobacco, pumpkin, bitter gourds and other cucurbitaceous plant (Azam *et al*. 1974). Both adults and larvae feed voraciously by scrapping the chlorophyll of the leaves causing characteristic skeletonization of leaf lamina, leaving a fine net of veins. The affected leaves gradually dry and drop down. A severe infestation kills the young plants overnight.

Farmers are using chemical pesticides and in a desperate to save their crop sometimes apply more than the required number of sprays survey conducted in Bangladesh reported excessive use of pesticides on summer squash. This overuse of pesticides leads to the problem of the pest developing resistance against the recommended pesticides, insecticides-induced resurgence of insect pest, adverse effect on non-target organism and pesticide Residue in food commodities and environment which leads to health problems as well as environmental pollution.

Pesticide is a key component of integrated pest management (IPM), help out an important role in increasing agricultural production. The sole use of older chemicals has led to the problem of residues as farmer is dependent on the broad spectrum insecticide which has higher persistency. To overcome this problem a newer group of insecticides has been introduced.

Keeping above-mentioned information in view, the present study was undertaken to-

- ❖ To evaluate the efficacy of botanical insecticides against major insect pests of squash and
- ❖ To determine the yield and yield attributes of squash influenced by different treatments.

CHAPTER II

REVIEW OF LITERATURE

2.1. Origin, distribution and systematic of Squash, *Cucurbita pepo*

Squash is the edible young (several days past anthesis) fruit of *Cucurbita pepo*, a highly diverse species. An easy to grow, short-season crop, squash is adapted to temperate and subtropical climates and is grown in many regions. More recent figures from a variety of regional and local reports indicate that production and per capita consumption of squash have risen sharply during the past decade. Not only has the cultivation of squash expanded markedly in countries in which the crop is familiar, it also has spread to regions where heretofore squash was either a minor crop or not grown. While the United States and Mexico, the two countries to which *C. pepo* is native, are two of the largest producers of squash, the countries of the Mediterranean and Middle East, led by Turkey, Italy, and Egypt, are responsible for one-third of the world's production

A conservative estimate of the worldwide value of the squash crop is several billion dollars annually; therefore, squash ranks high in economic importance among vegetable crops. *Cucurbita*, new world genus (Whitaker 1947) of the gourd family, Cucurbitaceae, contains five cultivated species. *Cucurbita pepo* is the most diverse of these species, consisting of wild forms in the United States and Mexico previously classified as separate species, *C. texana* Gray and *C. fraterna* Bailey, respectively, as well as many of the pumpkins and ornamental gourds, the acorn squash, and summer squash. Various terms have been used interchangeably for the many forms of *C. pepo*, but the uses of these terms often have not been faithful to the original meanings.

The term pumpkin is rooted in a Greek and Latin word for a large, round fruit, whereas squash comes from the plural form of a native North American word for something immature or incomplete. Therefore, the term pumpkin is to be

Figure 1. Squash, *Cucurbita pepo* fruit

edible *Cucurbita* fruit that are round or nearly round (spherical, oval, obovate, globe, flat globe, oblate, flat oblate, etc.), whereas the term squash should be applied to edible *Cucurbita* fruit deviating greatly from roundness. With the exceptions described later, pumpkins almost always are consumed when mature. All *C. pepo* squash, except for acorn squash and a few unique cultivars such as ‘Delicata,’ are consumed when immature.

Perhaps in the Cucurbitaceae in general, more so in the genus *Cucurbita*, and very definitely so in *C. pepo*, there is an association between the length-to-width ratio and the stage of development at which the fruit is used for culinary purposes (Paris 1989). Pumpkins as well as acorn squash have a near 1:1 length-to-width ratio and, with certain exceptions, are consumed when mature. Summer squash deviate from this ratio, originally being used when about half-grown. Zucchini, which deviate more, are used only when young. Cocozelles, which deviate even more, are used when young or very young, with the corolla still attached. Similarly, straightneck, crookneck, and scallop squash, which also deviate noticeably from the 1:1 ratio, are used only when young.

Apparently, this trend toward deviation from the 1:1 ratio stem from the desire for more of the colored exocarp and firm mesocarp tissue and less of the soft, pulpy interior of developing seeds and placenta.

On the basis of genetic relationships, *C. pepo* has been subdivided into two subspecies, *pepo* and *ovifera*, the former appearing to be associated with a Mexican origin and the latter with an origin in the eastern half of the United States (Decker 1988). Six extant horticultural groups of squash have been recognized on the basis of fruit shape (Paris 1986). Of these six, the vegetable marrow, cocozelle, and zucchini groups can be assigned to subspecies pepo and the scallop, crookneck, and straightneck groups to subspecies ovifera.

Their distinct fruit shapes allow the squash groups to be identified easily in even some of the earliest illustrated botanical works. Much of the early historical record of *Cucurbita* is indeed from botanical herbals (Paris 1989). One of the most noteworthy of these tomes, because of the abundance of realistic, quality illustrations of various forms and therefore perhaps best summarizing the Renaissance depictions of *C. pepo*, is the compilation of (Chabrey 1666). As all forms of *C. pepo* are pollinated by bees, cross with one another freely, and produce fully fertile offspring, it is amazing that most of the squash groups have maintained their identity for hundreds of years.

2.1. Scientific Classification of Squash

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Cucurbitales

Family: Cucuritaceae

Genus: *Cucurbita*

Species : *Cucurbita pepo*

2.2. Botanical description of Squash, *Cucurbita pepo*

C. pepo is an annual creeping or climbing plant with 5-angled stems up to 15 m long. The shallow root system is branched, growing from a well-developed taproot. The stems are rugged and bristle, branching 6-24 cm long, often rooting at the nodes. The plant bears tendrils at 90 degrees to the leaf insertion, which are coiled and 1-6-branched. On bushy plants, tendrils may be poorly developed. The leaves are simple, alternate, broadly ovate to deltoid, basally cordate, apically acute, palmately lobed with 5-7 lobes, marginally toothed, scabrous, palmately veined, 20-30 cm long, and 10-35 cm broad leaves with 5 to 25 cm petioles that are ovate–cordate to suborbicular–cordate, with or without white spots on the surface and have three to five rounded or obtuse, apiculate lobules, the central one bigger than lateral ones.

Squash is monoecious (unisexual flowers, with male and female on the same plant) and bears solitary actinomorphic flowers (~ 10 cm across) that produce nectar. Male flowers are long and pedicellate and have a campanulate calyx that is 5 to 10mm long and almost as wide 5-15mm, 1-2mm linear sepals and a tubular campanulate corolla that is rather broader towards the base, 6 to 12 cm long and yellow to pale orange. Flower has three stamens. Female flowers have thick peduncles, 3 to 5 cm long, an ovoid to elliptical, multilocular ovary, sepals that are occasionally foliaceous and a corolla is somewhat larger than that of the male flowers. They have a thickened style and three lobate stigmas (Ratnam *et al*. 2017).

Fruits are variable in shape, color, and size. It can be oval, cylindrical, flattened, globular, scalloped, fusiform, and/or tapering to a curved or straight neck on one or both ends. There is more than one color to the soft to hard skin: white, yellow, light to dark green, nearly black, cream, and/or orange. The flesh is also variable in color (white, yellow, orange) and thickness (Yadav *et al*. 2017).

2.3. Health benefits of squash, *Cucurbita pepo*

Cucurbita pepo is traditionally used in many countries to treat several diseases e.g., as an anti-inflammatory, antiviral, analgesic urinary disorders, antiulcer, antidiabetic and antioxidant (Perez 2016). Traditional medicine, particularly ayurvedic systems, and Chinese have used different parts of the plant.

2.3.1. Phytochemistry

Squash has been considered as beneficial to health because it contains various biologically active components such as polysaccharides, para-aminobenzoic acid, fixed oils, sterols, proteins and peptides (Murkovic *et al*. 2002).

2.3.2. Fruits

These are depicted by a low content of fat (2.3% squash pulp is not a rich source of oil), carbohydrates (66%), proteins (3%), and by high carotenoids content with values of 171.9 to μg/g (Elinge *et al*. 2012). Food value per 100 g is: Calories 80 kcal, crude fibre 11.46%, ash 16%. The mineral analysis indicated that squash pulp contained high levels of Mn (0.5 mg/kg), Fe (1.37 mg/kg), Cu (mg/kg), Pb (0.29 g/kg), P (11.38 mg/kg), Ni (0.5 mg/kg), Ca (179 mg/kg), Mg (190 mg/kg), Na (159 mg/kg) and K (160 mg/kg) (11). The level of Pb (0.210.25 mg/kg), and Cu (25 mg/kg) are within acceptable range (Perez 2016).

2.3.3. Seeds

Seed and seed oil are an ample natural source of phytosterols, proteins, polyunsaturated fatty acids, antioxidant vitamins, carotenoids and tocopherols and various elements (Glew *et al*. 2006). Due to these, components are attributed providing many health benefits. It contains main fatty acid components being palmitic (10.68%), palmitoleic (0.58%), stearic (8.67%) oleic (38.42%) linolic (39.84%), linolenic (0.68%), gadoleic (1.14%), total saturated fatty acids (19.35%), and total unsaturated fatty acids (80.65%).

Various components such as p-aminobenzoic acid, γ-aminobutic acid, polysaccharides, peptides, proteins, carotenoids as lutein, lutein epoxide, 15-cis-lutein (central-cis)-lutein, 9(9')-cis-lutein, 13(13')-cislutein, α-carotene, β-carotene violaxanthin, auroxanthin, epimers, flavoxanthi, chrysanthemaxanthin, luteoxanthin, α-cryptoxanthin, β- cryptoxanthin.

Stigmastatrienol has been abundantly isolated from the seed sterols with values of 18.8 to 35.1 g/100 g of the total sterol content, followed by the sterol spinasterol with values of 18.2-23.3 g/100 g of the total sterol content. B-sitosterol and spinasterol represented 41.1-53.6 g/100 g of total sterol content. The third most abundant is the stigmasterol and stigmastadienol.

In seeds, the greatest concentrations of squalene were found ranged 583.2 to 747 mg/100 g. Squalene is a triterpene produced by humans, animals and plants. It is a precursor of steroid hormones, cholesterol, and vitamins D in their biosynthesis in the human body. Squalene also has positive effects in the treatment of certain kinds of cancer (Perez 2016). In addition, the seeds contain cucurbitosides which are acylated phenolic glycosides as well as Cucurbitosides F-M.

2.3.4. Leaves

Study suggests that leaves contain secondary metabolites i.e., alkaloids, flavonoids, carbohydrate, phytosterol, tannin, saponin, steroid, gums and mucilage, fixed oils and fats, proteins and amino acids (Kalaiselvi and Selvi 2016).

2.3.5. Flowers

With a rich source of vitamins B9, squash flowers are known to be full of health benefits. Vitamin C present in squash flower help to enhance the immune system of our body, which protects us from colds and coughs making strong bones and improving vision. Major nutrients are presented vitamin C (10.22%), vitamin B9(4.75%), vitamins A (4.57%), iron (2.88%) and phosphorus (2.29%).

2.3.6. Biological activity

2.3.6.1. Antioxidant Activity

Oxidative stress has been considered as a sure sign of various chronic diseases and their complications such as diabetes, obesity, CVD and cancer (Yadav *et al.* 2017). Several experimental studies showed the antioxidant activity3. Tocopherols (non-glycoside) are compounds of vegetable oil and are natural antioxidants. Seeds oil of the pumpkin containing a mixture of isomers β and δ-tocopherol in range 29.92 to 53.60 mg/100 g making 79% and 84% respectively of the total tocopherol content. Methanolic extract of squash seeds contain higher amount of phenolic compounds (Perez 2016). Radical scavenging effect depends on their total phenolic content. It is reported that squash extract administration significantly increased the serious and hepatic activities of superoxide dismutase and glutathione peroxidase in mice, and reduced the concentration of malonaldehyde. It has also been found that pumpkin polysaccharide could increase the superoxide dismutase and glutathione peroxidase activity and reduce the malondialdehyde content in tumour-containing mice serum.

2.3.6.2. Antidiabetic Activity

Diabetes, a metabolic disease, is a serious problem of modern society due to the severe health complications linked with it5. Many several other studies have been recently carried out to recognize the anti-diabetic potential of herbal formulations; squash is one of them, its fruits are used for human consumption in diabetic conditions (Xia and Wang 2007). In various other reports, the squash exhibited acute hypoglycemic activity (blood sugar lowering) like a standard drug (tolbutamide) in temporarily hyperglycemic animals, in alloxan-induced diabetic animals but not in severe diabetic animals (Acosta-Patino *et al*. 2001).

Protein-bound polysaccharide (PBPP) is isolated from aqueous extract of squash fruits which consist of 10.13% protein and 41.21% polysaccharides. Administration of these protein-bound polysaccharides to alloxan-induced diabetic rat model reduced significantly glucose levels. *C. pepo* might so be use hindrance of complications associated with diabetes, conjointly since its ancient use in diabetes is well established.

2.5. **Major insect pests of Squash, *Cucurbita pepo***

2.5.1. **Melon fruit fly**, ***Bactrocera cucurbitae***

The dipteran family Tephritidae consists of over 4000 species, of which nearly 700 species belong to Dacine fruit flies (Fletcher 1987). Nearly 250 species are of economic importance, and are distributed widely in temperate, sub-tropical, and tropical regions of the world (Christenson and Foote 1960). Amongst these, *Bactrocera cucurbitae* (Coquillett) is a major threat to cucurbits (Shah *et al.* 1948). Senior-White (1924) listed 87 species of Tephritidae in India. Amongst these, the genus, *Bactrocera* (Dacus) causes heavy damage to fruits and vegetables in Asia (Nagappan *et al*. 1971).

2.5.1.1. **Host distribution of Melon fruit fly, *Bactrocera cucurbitae***

Melon fruit fly damages over 81 plant species. Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred most. Doharey (1983) reported that it infests over 70 host plants, amongst which, fruits of Summer Squash, *Cucurbita pepo,* bitter gourd (*Momordica charantia*), muskmelon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*) and snake gourd (*Trichosanthes anguin*a and *T. cucumeria*) are the most preferred hosts. However, White and Elson-Harris (1994) stated that many of the host records might be based on casual observations of adults resting on plants or caught in traps set in non-host plant species. In the Hawaiian Islands, melon fruit fly has been observed feeding on the flowers of the sunflower, Chinease bananas and the juice exuding from sweet corn. Under induced oviposition, McBride and Tanda (1949) reported that broccoli (*Brassica oleracea* var. *capitata*), dry onion (*Allium cepa*), blue field banana (*Musa paradisiaca* sp. *sapientum*), tangerine (*Citrus reticulata*) and longan (*Euphoria longan*) are doubtful hosts of *B. cucurbitae*. The melon fly has a mutually beneficial association with the Orchid, *Bulbophyllum patens*.

Which produce xigerone doubtful hosts of *B. cucurbitae*. The melon fly has a mutually beneficial association with the Orchid, *Bulbophyllum patens*, which produces zingerone. The males pollinate the flowers and acquire the floral essence and store it in the pheromone glands to attract con-specific females.

2.5.1.2. **Nature of damage by melon fruit fly *B. cucurbitae***

Young maggot moves to healthy tissue of the fruit, where they often introduce various pathogens, secondary infections and initiate decomposition. One of the most prominent scavengers, the vinegar fly, *Drosophilla melanogaster* has also been observed to lay eggs on the fruits infested by melon fly (Dhillon *et al*. 2005). As a result of this type of infestation, premature drop of fruits and decay of fruits occur due to the bacterial infections. Depending on the cucurbit species and season of infestation, the extent of losses varies between 30 to 100%. Fruit infestation by melon fruit fly in squash has been reported to vary from 41 to 89% (Dhillon *et al*. 2005; Gupta and Verma 1978). It has been reported that melon fruit fly causes 31.27% damage on squash and 28.55% on watermelon in India (Gupta and Verma 1978).

2.5.1.3. **Life cycle of Melon fruit fly, *B. cucurbiate***

The melon fruit fly remains active throughout the year however, they hide and huddle together under dried leaves of bushes and trees during the severe winter months. During the hot and dry season, the flies feed on honeydew of aphids infesting the fruit trees (Dhillon *et al*. 2005). Generally, the females prefer to lay the eggs in soft tender tissues on the fruit surface by piercing with the ovipositor. Sometimes, the eggs are also laid into unopened flowers (Sohrab *et al*. 2018). The eggs are laid shiny to creamy white, slightly curved, nearly 1.3 mm in length, oblong, bananas shaped and tapering at one end while rounded at the other end (Sohrab *et al*. 2018; Narayanan and Batra 1960). The eggs are fixed vertically or slightly at an angle and touching each other.

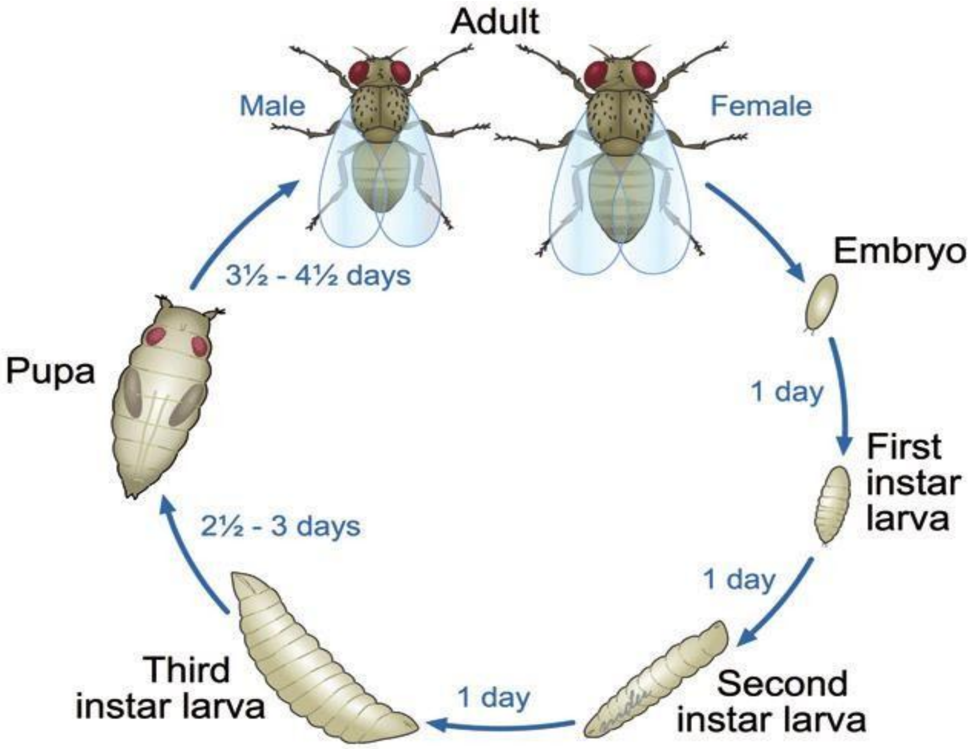


Figure 2. Life cycle of Melon fruit fly, *Bactrocera cucurbitae*

The eggs are laid singly or in clusters of into flowers or tender fruits (Sohrab *et al*. 2018). The egg incubation period on pumpkin, bitter gourd and squash has been found to be longer (4.0 to 4.2 days) (Doharey *et al*. 1983) than on cucumber and sponge gourd (1.1 to 1.8 days) (Gupta and Verma 1978). The maggots, after hatching of eggs, bore into the pulp tissue and make the feeding galleries. The full- grown maggot comes out of the fruit by making one or two exit holes, hops out of the fruit to pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae move in the soil for pupation, and survival depend on soil texture and moisture (Jackson *et al*. 1998; Pandey and Misra 1999).

In general, it has been observed that the pupal period lasts for 6 to 9 days during the rainy season and 15 days during the winter. After the stipulated time period, the adults come out from the soil. The males mate with females for 10 or more hours, and sperm transfer increases with the increase in copulation time. It has been observed that hatchability is not influenced by mating duration

(Tsubaki and Sokei 1988). It has been reported that the males and females survived for 65 to 249 days and 27.5 to133.5 days respectively (Khan *et al*. 1993).

2.5.1.4. Chemical control of Melon fruit fly, *B. cucurbiate*

The continuous feeding with extract of *Acorus calamus* (0.15%) mixed with sugar (at 1 mL/g sugar) reduced the adult longevity from 119.2 to 26.6 days (Nair and Thomas 1999). (Ranganath *et al*. 1997) reported neem oil (1.2%) and neem cake (4%) for its effective control. The use of chemicals to manage fruit fly is relatively ineffective. Apply malathion (0.05%) as cover spray to kill the insects on contact or a bait spray by adding 50 g gur + 10 mL malathion in 10 L water that attract and kill the adults. The application of malathion + molasses + water in the ratio of 1:0.1:100 provides good control of fruit fly (Akhtaruzzaman *et al*. 2000). This technique is economical and there is very low contamination of fruits from insecticides. Gupta and Verma (1982) reported that fenitrothion (0.025%) in combination with protein hydrolysate (0.25%) reduced fruit fly damage to 8.7% compared to 43.3% damage in non-treated control. Reddy (1997) reported triazophos as the most effective insecticide to manage it on bitter gourd. On the other hand, Borah (1998) obtained the highest yield and minimum damage in pumpkins when treated with carbofuran at 1.5 kg a.i./ha at 15 days after germination. Lambda-cyhalothrin reduced in more number of fruit fly pupae and increased the quality of harvested cucumber fruits in relation to the infestation of fruits with ovipositor marks.

2.5.2. Melon Aphid, *Aphis gossypii* Glover

Aphis gossypii Glover is an important agricultural pest because it has a broad host range, and transmits many agriculturally important plant viruses. Damage is direct through feeding which can kill the host, but also productivity is reduced long before plant death. Damage is indirect through contamination with aphid honeydew productivity is reduced long before plant death. Damage is indirect through contamination with aphid honeydew and by vectoring viral pathogens. Honeydew causes economic loss through physical contamination and through providing a nutrient source for fungi that contaminate produce and reduce photosynthesis rates by blocking sunlight.

2.5.2.1. Host range of Melon Aphid, *Aphis gossypii* Glover

Melon aphid has a very wide host range. At least 60 host plants are known in USA, and perhaps 700 host plants world-wide. However, the taxonomy of this species is uncertain, so some records may be incorrect. Among cucurbit vegetables, it can be a serious pest on squash, watermelons, cucumbers, and cantaloupes, and to a lesser degree in pumpkin. This is the basis for the common name "melon aphid." Other vegetable crops seriously affected are asparagus, pepper, eggplant, and okra. Some other important crops injured regularly are citrus, cotton, and hibiscus. In the south, cotton is an important host, which explains the second common name, "cotton aphid."

The overwintering, or primary, host in cold climates was long thought to be limited to live forever, *Sedum purpureum*. However, *Sedum* is not a host of melon aphid, but a closely related species. Rather, catalpa, *Catalpa bignonioides*, and rose of sharon, *Hibiscus syriacus*, were the overwintering hosts in some locations. In the other locations, overwintering eggs are not commonly produced and overwintering hosts are more numerous, including dock, *Rumex crispus*; *Lamium amphlexicaule*; boneset, *Eupatorium petaloiduem*; and citrus, *Citrus* spp. Several researchers have noted the existence of host races; for example, aphids reared on cotton could be transferred successfully to okra but not to cucurbit.

2.5.2.2. Nature of damage by Melon Aphid, *Aphis gossypii* Glover

Downward curling and crinkling of leaves are the first symptom of the aphid infestation. A variety of symptoms including reduced plant growth and vigour, mottling, yellowing, browning, curling or wilting of leaves, which result in lower yields and sometimes death of plants are noticed in field condition.

Salivary toxins infected by the aphids cause the puckering and curling of leaves that help them to protect themselves from natural enemies and insecticides (Sharma *et al*. 2009).

Aphids damage plants in three major ways. First, they remove plant sap from phloem sieve elements, which weaken the plants resulting in lower quality and quantity of fruit. Heavy infestations can result in plant death. Second, due to the fact that phloem is an amino acid poor substrate, aphids must process a large quantity of phloem to gain the products necessary for protein synthesis which they use to produce offspring. With a modification of their gut into a filter chamber, aphids are able to shunt large quantities of phloem which is excreted in a carbohydrate-rich exudate that is termed "honeydew." Aphids produce large quantities of honeydew which can cover the leaves and fruit. The sugary substrate provides a suitable medium for the growth of black sooty mold fungi (from the genera *Capnodium*, *Fumago*, *Scorias*, *Antennariella*, *Aureobasidium*, and *Limacinula*. On the foliage this sooty mold can become so thick that it reduces photosynthetic activity on the leaves resulting in poor quality and quantity of fruit. On the fruit, the honeydew and sooty mold must be removed prior to processing the tomatoes or packaging them for fresh market. This is an added cost for squash producers. The third, and perhaps most costly type of aphid damage, is as efficient vectors of a number of plant viruses.

2.5.2.3. Life cycle of Melon Aphid, *Aphis gossypii* Glover

Female nymphs hatch from eggs in the spring on the primary hosts. They may feed, mature, and reproduce parthenogenetically (viviparously) on this host all summer, or they may produce winged females that disperse to secondary hosts.

The dispersants typically select new growth to feed upon, and may produce both winged (alate) and wingless (apterous) female offspring. Under high density conditions, deterioration of the host plant, or upon arrival of autumn, production of winged forms predominates during period stressful to the hostplant, small yellow or white forms of the aphid are also produced.

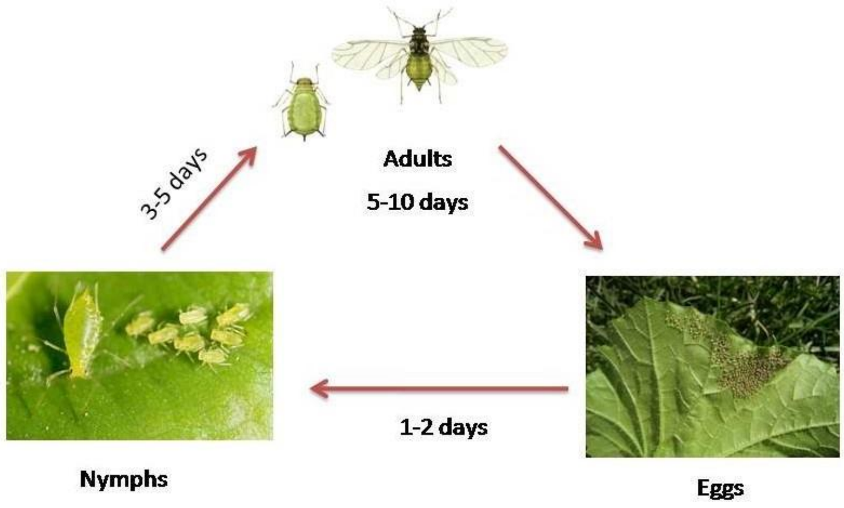


Figure 3. Life cycle of Aphid, *Aphis gossypii*

Late in the season, winged females apparently seek primary hosts, and eventually both males and egg-laying (oviparous) females are produced. They mate and females deposit yellow eggs: eggs are the only overwintering form under cold conditions. Under warm conditions, a generation can be completed parthenogenetically in about seven days.

When first deposited, the eggs are yellow, but they soon become shiny black in color. The nymphs vary in color from tan to gray or green, and often are marked with dark head, thorax and wing pads, and with the distal portion of the abdomen dark green. The body is dull in color because it is dusted with wax secretions. The nymphal period averages about seven days.The wingless (apterous) parthenogenetic females are 1 to 2 mm in length. The body is quite Variable in color light green mottled with dark green is most common, but also occurring are whitish, yellow, pale green, and dark green forms.

The legs are pale with the tips of the tibiae and tarsi black. The cornicles also are black. Small yellow forms apparently are produced in response to crowding or plant stress. Winged (alate) parthenogenetic females measure 1.1 to 1.7 mm in length. The head and thorax are black, and the abdomen yellowish green except for the tip of the abdomen, which is darker. The wing veins are brown. The egg-laying (oviparous) female is dark purplish green; the male is similar.

The duration of the adult's reproductive period is about 15 days, and the post-reproductive period five days. These values vary considerably, mostly as a function of temperature. The optimal temperature for reproduction is reported to be about 21 to 27 degrees. *C. viviparous* females produce a total of about 70 to 80 offspring at a rate of 4.3 per day.

2.5.2.4. Chemical control of Melon Aphid, *Aphis gossypii* Glover

Organic chemical controls include potassium soap and petroleum oil or primicarb. Endosulfan, Dimethoate, Lannate, Fulfill, and Actara are recommended for aphid control. Kill aphids using a detergent and vegetable oil solution before destroying old crops to avoid winged virus-infected aphids from getting to nearby crops. Cypermethrin (0.01%) or acetamiprid (0.01%) or bifenthrin (0.01%) or malathion (0.05%) can be used to control aphids.

2.5.3. Red pumpkin beetle, *Aulacophora foevicoliis*

Red pumpkin beetle (*Aulacophora foevicoliis*) is most serious pest of cucurbitaceous vegetable crops. *Aulacophora* is Polyphagous and attacks more than 81 plant species and prefers cucurbit vegetable causing great loss in cucurbits production in Bangladesh. It causes damage from seedling stage up to harvesting stage. Both grub and adult are harmful to the crop. Grub feeds on root tissue and cause direct damage to the seedlings. Adult cause damage by feeding leaves, flower buds and flowers.

2.5.3.1. Host range of Red pumpkin beetle

Aulacophora foevicolii is polyphagous insect and prefers cucurbit vegetables (Butani 1984; Khan *et al.* 2011). It is a major pest and cause considerable damage on almost all cucurbits. Originally, it is a pest of pumpkin, Bottle gourd, Muskmelon, but it feeds other cucurbitaceous vegetables as well (Annadurai *et al.* 1985). In literature significant variation for host preference of red pumpkin beetle among different cucurbits has been reported.

Field trials of 10 cucurbits against red pumpkin beetle in relation to the preference shows the order as muskmelon> sweet gourd> cucumber > sqaush > ash gourd > bottle gourd > sponge gourd ≥ ribbed gourd ≥ snake gourd > bitter gourd (Khan 2012). The study on food preference of RPB in 11 cucurbitaceous crops showed that muskmelon as most preferred, snake gourd as least preferred while bitter gourd was not preferred (Rajak 2001). Apart from the preference among cucurbits, Red pumpkin beetle shows variable infestation within a crop. Sinha and Krishna reported the differential preference of red pumpkin beetle within cucurbitaceous crop (Sinha and Krishna 1970). It has been demonstrated that polyphagous insects strongly prefer less nutritious mature leaf tissues (Khan 2013; Evans 1984).

Raman and Annadurai in 1985 also reported that higher and strong preference for mature leaves and flower compared to young and senescent leaves. There is positive correlation between RPB populations per leaf with the % nitrogen, total and reducing sugar content of the mature leaves of cucurbits (Khan 2013). Also the pattern of food consumption on a mature and senescent leaves shows a direct relationship of leaf nitrogen, protein content, carbohydrate and total phenolic contents (Annadurai *et al*. 1985). Thus the differential preference of RPB among and within cucurbits could be due to the distribution and varied concentration of such biochemical.

2.5.3.2. Nature of damage by Red pumpkin beetle,

Aulacophora foevicoliis *Aulacophora* is a serious pest of cucurbits (Atwal 1993). It is polyphagous and attack more than 81 plant species (Doharey 1983). Losses by the attack of this pest are obvious which ranges from 35-75% at seedling stage and it declines as canopy increases (Kamal *et al*. 2014; Saljoqi and Khan 2007). Beetle starts to attack the plant right after the germination and slows down the growth due to severe damage (Yamaguchi 1983). In some cases it cause 30-100% yield loss in cucurbits (Atwal 1993). *Aulacophora* is one of the important constraints as it attacks every stages causing great loss in cucurbit production.

Sometime, these beetles damage to such an extent that the crop needs to be re-sown 3 to 4 times causing great loss in seed, labor and delay in crop production (Khan, 2005).

Severity of damage is more on cotyledons and young leaves, but they also feed readily on flowers and mature leaves. The destruction is very high particularly during March-April when the creepers are young (Dhilon *et al*. 2005). Activity of both larva and adult is responsible for the damage. Larvae feed on the root tissue, underground parts of the plant and cause direct damage to the newly developed seedling. Also, larva feeds on rind of the fruit touching the soil surface making it unfit for consumption (Pradhan 1969). The adult feed voraciously on leaves making irregular holes, cotyledons, flower buds and flowers. It may cause up to 70% damage on leaves and 60% damage on flowers while 100% fruit damage is also reported in most of cucurbits (Khan *et al*. 2010).

The damage done by the grub may attract rot infection by the saprophytic fungi in the under-ground root and stem of the plant. Adult beetles cause the net-like appearance on the leaves by feeding voraciously on the leaf lamina and by scrapping off the chlorophyll. They attack the plant mostly at the cotyledon stage. The beetles may kill seedlings and sometimes the farmer has to re-sow the crop for 3-4 times more than the normal**.** As a result of such attack, the young and smaller fruits of the infested plants may dry up and the bigger and mature fruits become unfit for human consumption. They are so serious pest that their damage may reach up to a loss of 35-75% at seedling stage and 30-40 % at the field condition**.** Sweet gourd was the most suitable and bitter gourd was the least suitable for red pumpkin beetles.

2.5.3.3. Life cycle of Red pumpkin beetle, *Aulacophora foevicoliis*

It is a major pest of almost all the cucurbits and is polyphagous in nature. The female lays eggs in the moist soil near fallen dead leaves or at the base of the host plant in clusters of 8-9 that hatch into larvae in 6-15 days. The eggs are brown and elongated in shape. Generally, beetle starts lying after 7 days of emergence and complete about 5 generations before October. The grubs are 10-

12 mm long; possess creamy-white body with conspicuous brown heads which feed on the basal part of the host touching the soil. Adult beetles are deep orange with black colored back. It is oblong with oblong about 5-8 mm length, 3.5-3.75 mm width and bears soft white hairs on the posterior part of the abdomen.

2.5.3.4. Chemical control of Red pumpkin beetle, *Aulacophora foevicoliis*

Use of neem oil cake in the soil is effective in killing the pest larvae. Vishwakarma *et al*. (2011) observed that treatment with entomopathogenic fungi *B. bassiana* resulted in maximum reduction of beetle infestation along with the highest fruit yield in bottle gourd. Khan and Wasim (2001) observed maximum repellency against beetles in treatment comprising of neem extracts mixed with benzene. The application of plant extract of *Parthenium* spp. was found to be highly effective in controlling the red pumpkin beetle (Ali *et al.*, 2011). These beetles especially attack the crop at the cotyledonary stage when adults skeletonize the young leaves. During initial infestation, applications of carbaryl (0.1%) or malathion (0.5%) suppress the damage successfully (Hasan *et al*. 2011). Mahmood *et al*. (2010) reported that permethrin dust (0.5%) alone and ash + permethrin dust (2000:1 a.i. w/w) effectively control beetles on the cucumber crop, with no mortality of plants. Synthetic pyrethroids (deltamethrin 0.004%, cypermethrin 0.012%, and fenvalerate 0.01%) were effective in controlling the beetle for about a week (Thapa and Neupane 1992).

2.5.4. Epilachna beetle, *Epilachna vigintioctopunctata*

The beetles belonging to the Epilachninae, constitute one sixth of the known species of the Coccinellidae. The genus Epilachna has nearly 500 species, which are phytophagous. Among different species, *Epilachna vigintioctopunctata* is widely distributed in South East Asia, Australia, Sri Lanka, Malaya, East Indies, China and India, America and Siberia. In India, the beetle is present in the higher hills of Jammu and Kashmir, Punjab, Himachal Pradesh and Bengal and also in the plains. In Bangladesh, the pest occurs in the squash and pumpkin growing areas.

The beetles that attack cucurbitaceous plants are *E. vigintioctopunctata* (Syn: *E. dodecastigma*: *E.* 12 *stigma* and *E.* 28 *punctata*) *E. ocellata* Redt. and *Henosepilachna sparsa* Herbst. (Syn: *E. sparsa*).

2.5.4.1. Host distribution of Epilachna beetle, *Epilachna vigintioctopunctata*

The pest has been recorded on many plants. The epilachna beetle has been recorded on the hosts as brinjal, tomato, tobacco, pumpkin, bitter gourds and other cucurbitaceous plant (Azam *et al*. 1974). It also occurs on some medicinal plants like *Datura stramonium* Linn., *D. metel* Linn., *D. innoxia* Mill., *D. quercifolia* H.B.R., *Solanum aviculare* Forst. *S. surratensis* Burm., *S. nigrum* Linn, and *Withania somnifera* Dunal. (Mathur and Srivastava, 1964), *Physalis minima* Linn., *P. peruvianum*, *P. ixocarpa*, wild species of *Amaranthus caudatus* L. (Hameed and Adlakha 1973) and *Datura fastuosa* (Edona and Soans 1971). This species will not feed on cucurbits. In a survey, in Andhara Pradesh, of the beetles reared on potato, brinjal tomato and snakegourd, the snake gourd was least preferred, with a marked retarding effect on the growth rate and a prolonged larval and pupal stage.

2.5.4.2. Nature of damage by Epilachna Beetle, *Epilachna vigintioctopunctata*

Both adults and larvae feed voraciously by scrapping the chlorophyll of the leaves causing characteristic skeletonization of leaf lamina, leaving a fine net of veins. The affected leaves gradually dry and drop down. A severe infestation kills the young plants overnight. The adult beetles are medium-sized (6-8 mm long), yellowish-brown, and globular, bearing 12-28 black spots on the elytra. The eggs are laid in clusters on the undersurface of the leaves that hatch into yellowish larvae. The female may lay 300-400 eggs. The larva (7-9 mm long) is found on the underside of leaves and is yellow with branched black spines covering the body. Full-grown larvae pupate below the leaf or at the base of the stems. The pupa hangs from the leaf, is yellow in color, and lacks spines. The development stages are completed in 4-6 weeks under optimal conditions.

Scrapping of the epidermis indicates the feeding manner of the grubs, while adults make semicircular cuts in rows. Young plants can be entirely destroyed, while older plants can tolerate considerable leaf damage. Adults overwinter under loose tree bark or under leaf litter near the edge of fields.

2.5.4.3. Life cycle of Epilachna beetle, *Epilachna vigintioctopunctata*

It is an occasional pest of cucurbits but, attacks seriously on bitter gourd, pumpkin and squash. The females lay eggs up to 300-400 in number in clusters on the under-surface of the leaves that hatch into yellowish larvae. The larva is of 7–9 mm long. Full-grown larvae pupate below the leaf or at the base of the stems by hanging from the leaf. Pupa is yellow in color and lacks spines. The adult beetles are yellowish-brown, medium-sized (6–8 mm long) and globular. Adults bear 12– 28 black spots on the elytra.

2.5.4.4. Chemical control Epilachna beetle, *Epilachna vigintioctopunctata*

The weekly foliar sprays of aqueous neem kernel extracts at concentrations of 25, 50, and 100 g/L and neem oil applied with an ultralow-volume sprayer at 10 and 20 L/ha significantly reduced feeding by Epilachna beetles in squash and cucumber (Ostermann and Dreyer 1995). Mondal and Ghatak (2009) reported that the seed extracts of *Annona squamosal* (3 Ml/L of water) as botanical pesticide help in reducing population buildup to the extent of 76%, followed by 64% and 57% through Neem Azal (5 mL/L of water) and petroleum ether extracts of rhizome of *A. calamus* (2 mL/L of water), respectively. *Tephrosia* leaf extract (20 g/100 mL water) effectively controls Epilachna beetle by killing adults and inhibiting pupae formation along with the highest yield and is an environment friendly pest control method (Rahaman *et al.* 2008). Swaminathan *et al*. (2010) have demonstrated the antifeedant and lethal effects of *Azadirachta indica*, *P. glabra*, and *Madhuca latifolia* on this beetle.

Larvicidal bioassays with crude aqueous leaf extracts of three plants, namely, *Ricinus communis*, *Calotropis procera*, and *Datura metel* showed significant toxicity against the experimental Epilachna beetles by adversely affecting both oviposition and egg hatching besides prolonged larval duration, pupae formation, and adult emergence (Islam *et al*. 2011).

2.5. Potential of botanicals against insects

Today, Botanicals insecticide has to face up to the economic and ecological consequences of the use of pest control measures. Fifty years of sustained struggle against harmful insects using synthetic and oil-derivative molecules has produced perverse secondary effects (mammalian toxicity, insect resistance and ecological hazards). The diversification of the approaches inherent in IPM is necessary for better environmental protection. Among the alternative strategies, the use of plants, insecticidal allelochemicals appears to be promising. Aromatic plants, and their essential oils, are among the most efficient botanicals. Their activities are manifold. They induce fumigant and topical toxicity as well as antifeedant or repellent effects. They are toxic to adults but also inhibit reproduction. Although mechanisms depend on phytochemical patterns and are not yet well known, this widespread range of activities is more and more being considered for both industrial and household uses essential oils are present.

CHAPTER III

MATERIALS AND METHODOLOGY

Current study was carried out in the research field of department of entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during September 2019 to February 2020 i.e., in the rabi season with a view to assess the efficacy of some botanicals against major insect pests of squash. The materials and methods used for conducting the experiment presented in this chapter under the following headings-

3.1. Description of experimental site

The experiment was conducted during the period from September 2019 to February 2020. Field work was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated at 23.074^0/N latitude and 90.0035^0/E longitude with an altitude of 8.2 meter from sea level. In terms of climate, the experimental site is under the subtropical climate and its climatic conditions are characterized by low temperature and scanty rainfall during the winter i.e., rabi season. Soil of the experimental site belongs to “The Modhupur Tract”, AEZ-28. However, the experimental site was flat having a provision of available irrigation and an ample drainage system.

3.2. Planting materials

In order to conduct the current experiment, BARI Squash-1 was used as planting materials. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. This variety is temperature tolerant, whitish light yellow flesh color, less bitterness in taste. Deep green leaves with whitish strip. It has long cylindrical and deep green colored fruit with light green color spot at edible green stage. Average fruit weight 1.05kg.

3.3. Treatments of the experiment

There are seven treatments including control (absolute) used in this experiment. Followings are the name of the treatments and respective doses.

Table 1. Treatments of the experiment

Treatment No.	Name of the Treatment	Dose
T_1	Neem oil	5ml/L of water
T_2	Neem seed kernel extract	5ml/L of water
T_3	Datura seed extract	5ml/L of water
T_4	Garlic bulb extract	5ml/L of water
T_5	Mehagany seed extract	5ml/L of water
T_6	Black pepper seed extract	5ml/L of water
T_7	Control	

3.3.1. Neem oil

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazar, Dhaka. All sprays were made according to the methods described earlier. For each neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e., 0.3% per 5 liters of water was used. The mixture within the spray machine (knapsack sprayer) was shacked well and sprayed on the upper and lower surface of the plants until the drop run off from the plant. Three liters spray material was required to spray in three plots at each replication.

3.3.2. Neem seed kernel extract

The mature and dried neem seeds were collected from the neem tree found in the Horticulture Garden of SAU. Then seeds were roasted at 60ºC to

80ºC for 1 to 2 days by electric oven. The seed kernel was separated and taken into the electric blender for blending. Then 250 gm of this powder was taken into a beaker and 250 ml water was added into it. The beaker was shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatman no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4^0c for future experimental use.

3.3.3. Datura seed extract

Extraction of D. stramonium seeds were collected from rural area. All seeds were washed with tap water and dried in shade and powdered in grinder. Each powder was packed in filter paper and extract was extracted in Soxhlet's apparatus in 1:10 ratio i.e., 20 g powder in 200 ml of solvent. After eight hrs. of continuous extraction, the final extract was filtered by Whatman filter paper no. 1 and the filtrate was collected and kept open to evaporate the solvent. Extract of plant materials was extracted in chloroform, acetone, methanol, ethanol and n-hexane and were stored after evaporation of solvent in refrigerator.

3.3.4. Garlic bulb extract

Fresh garlic bulbs were collected from the local market and chopped the bulbs in small size by sharp knife. Then 250 gm chopped garlic bulbs were taken into electric blender for blending. Then the blended garlic was taken into the beaker and 250 ml water was added with the garlic extract. The beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of garlic. The aqueous extract then filtered using Whatman no.1 paper filter and preserved the aqueous extracts of garlic in the refrigerator at 4^0c for experimental use.

3.3.5. Mahogany seed kernel

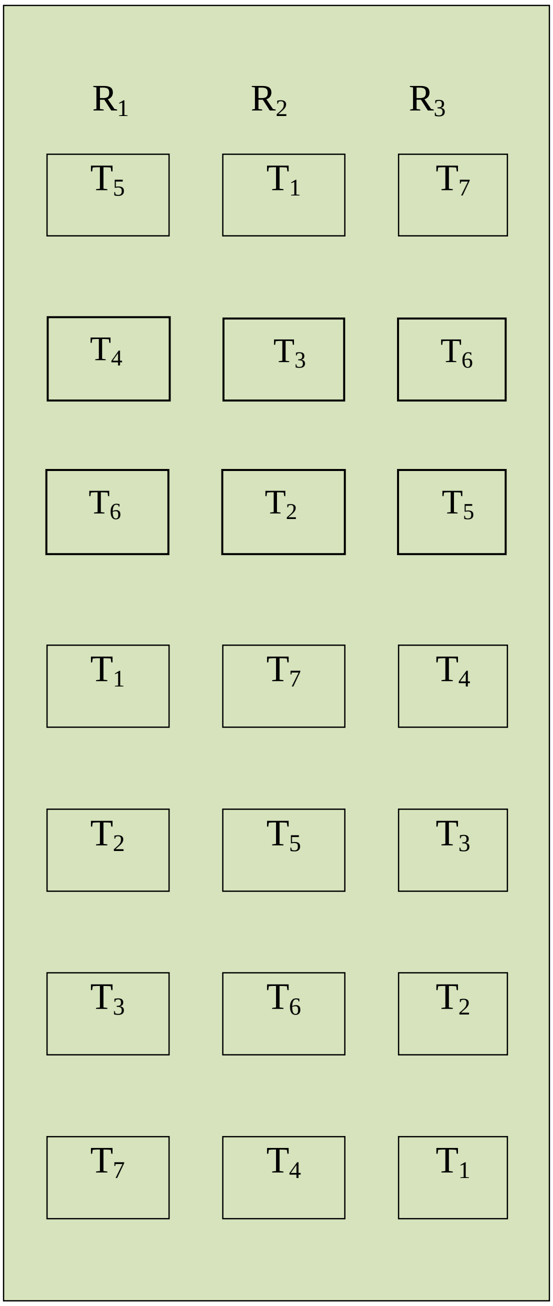
The mature and dried mahogany seeds were collected from the mahogany tree found in the campus of SAU. Then seeds were roasted at 60ºC to 80ºC for 1 to 2 days by electric oven. The seed kernel was then separated and taken into the electric blender for blending. Then 250 gm of this powder was taken into a beaker and 250 ml water was added into it. The mixture in the beaker was then shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatman no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4^0c for future experimental use.

3.3.6. Black pepper seed extract

Black pepper (Piper nigrum L.) (Piperaceae) seed contains between 4.6 to 9.7% pioerine by mass that powders were used in this investigation. They were selected based on assumption of absence of mammalian toxicity owing to its use as a popular spice in several diets. Extract from black pepper discourage insect pests from laying eggs on leaves. Half of a teaspoon of black pepper in warm water and place into a spray. Wheat grains were disinfested by keeping them in a freezer at -18°C for a day and subsequently in room temperature.

3.4. Experimental design and layout

The experimental field was designed in a single factor randomized complete block design (RCBD) with three replications, where the experimental site was divided into three blocks allocating the replications to assemble homogeneous soil conditions. Every block was divided into seven-unit plots as treatments. Raised bunds were used as identifiers for treatment demarcation. However, the total numbers of experimental plots were 7X3=21. Each plot size was 3.6 m × 1.6 m. Subsequently, 0.5 m and 0.5 m distance were maintained between two blocks and two plots respectively.



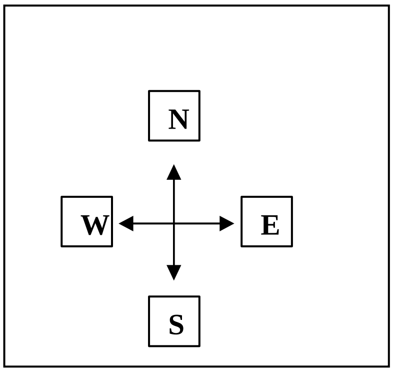


Figure 4: Layout of the experiment plots

3.5. Seedbed preparation and seed sowing

Squash are normally transplanted because much better results are gained when seedlings are raised in a seedbed. The seedbed was 60-120 cm wide and 20- 25 cm high. Initially, the clods of earth and stubble were removed. Then well composted farmyard manure and fine sand were added. Eventually, the seedbed was brought to fine tilth. Lines were drawn 10-15 cm apart, over the length of the seedbed. The seeds were sown thinly spaced on the lines and pressed gently. The seeds were covered with fine sand and straw. The seedbeds were watered twice a day to ensure sufficient moisture for germination. After germination the straw was removed.

3.6. Main field preparation and seedling transplanting

The seedlings were transplanted to the field 3 to 6 weeks after sowing. A week before transplanting, seedlings were hardened by reducing the application of water, further 12-14 hours before they were taken out of the seedbed were thoroughly watered again to avoid excessive damage to the roots. Transplanting was done in the afternoon to reduce the transplanting shock. The plants were watered immediately once they had been transplanted. Spacing between plants and rows was maintained as per recommendation of Bangladesh Agricultural Research Institute (BARI). The common spacing is 50 cm between plants and 75 - 100 cm between rows. The holes for the plants were made deep enough so that the lowest leaves were at ground level. The soil was pressed firmly around the root, and watered around the base of the plant to settle the soil.

3.7. Manure and fertilizer

To get high yields, tomatoes need to be fertilized. There are two groups of crop nutrients: organic manures and chemical fertilizers.Well decomposed cow dung was applied at the time of final land preparation. As suggested by the Bangladesh Agricultural Research Institute, fertilizers N, P, K in the form of Urea, TSP, MoP and S, Zn, and B in the form of gypsum, zinc sulphate and borax were applied (Mondal *et al.* 2011).

Table 2. Fertilizer and manure used in the experiment

Name of Fertilizer and manure	Total Amount (Kg/dec.)	Last plough (Kg/dec.)	Before transplanting (Kg/dec.)	10-15 DAT	30-35 DAT	50-55 DAT	70-75 DAT
Cow dung/ FYM	80	80	-	-	-		
Urea	0.7	-		0.2	0.2	0.2	0.1
TSP	0.7	0.35	0.06	0.25	-		
MoP	0.6	0.2	-	0.2	0.2		
Gypsum	0.4	0.4	-	-	-		
Boric Acid	0.04	0.04	-	-	-		
Zinc Sulphate	0.05	0.05	-	-	-		

Source: Mondal *et al.* 2011

Figure 5. Experimental plots

3.8. Intercultural operation

Squash is very sensitive to water. Therefore, regular watering was done as per necessity by the irrigation channels. Field was never flooded with water. In dry periods, watering was done at 5-7 days interval. Soon after every irrigation, mulching was done by breaking the soil clots. Weeds are the principal competitor of crops regarding soil nutrients. Moreover, weeds act as reservoir of pest and diseases in the crop field. Hence, squash field was kept weed free throughout the growing period. Usually, 16-25^0 C temperature is conducive for squash production. If night temperature falls below 17-21^0 C, growth and development of squash plant retarded. Since, our crop was planted in October polythene shade was used to protect plants for smooth growing.

3.9. Data collection

3.9.1. Data recording on the fruit infestation by melon fruit fly

Total number of fruits and infested fruits of five randomly selected plants per plot were recorded at each harvest and continued up to the last harvest. Infested fruits recorded at each observation were pooled and finally expressed in percentage. The damaged fruits were spotted out by the presence of holes opening made by the fruit fly.In the similar way, the number of healthy fruits per plot were selected. In order to determine the weight of healthy fruits, collected healthy fruits were measured by a weighing machine in the laboratory.

3.9.2. Data recording on the leaf infestation by melon aphid

The population of adult and nymph of aphid were recorded randomly from five leaves of each plots in the experiment. Counting was done after 10 days of transplanting and once in a week upto final harvesting. Upper and lower surface of sqaush leaves were carefully observed to count the number of aphids.

3.9.3. Data recording on the infestation by Red pumpkin beetle (RPB)

The number of red pumpkin beetle was counted carefully by observing randomly selected plants and then made it average. The percent reduction of red pumpkin beetle and other insect's population for each treatment was calculated by the formula

$$\% \text{ Reduction} = \frac{P_r - P_o}{P_o} \times 100$$

Where,
Pr= count in respective treatment and
Po= count in control treatment

Figure 6: Red pumpkin beetle infestation

3.9.4. Data recording on the infestation by Epilachna beetle (EB)

The number of Epilachna beetle was counted carefully by manually observing randomly selected plants and then made it average.

3.9.5. Data recording on the leaf infestation caused by defoliators (red pumpkin beetle and epilachna beetle)

The infested area on the individual damaged leaves was recorded and expressed in percentage.

3.10. Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance for different treatments. The analysis of variance was performed by using the STAT-10 Program. The significance of the difference among the treatment combinations was estimated by Tukey's HSD Test at 5% level of probability.

CHAPTER IV

RESULT AND DISCUSSION

4.1. Effect of treatments on the fruit infestation caused by fruit fly

4.1.1. Effect of treatments on the fruit infestation during one day after first spray caused by fruit fly

Table 3. Effect of treatments on the fruit infestation during one day after first spray caused by fruit fly

Treatment No.	Treatment name	% fruit infestation per plot	Decrease over control (%)
T_1	Neem oil	6.17 f	43.18
T_2	Neem seed kernel	6.88 e	36.64
T_3	Datura seed extract	8.93 c	17.77
T_4	Garlic bulb extract	7.91 d	27.16
T_5	Mehagany seed extract	7.31 e	32.68
T_6	Black pepper seed Extract	9.62 b	11.41
T_7	Control	10.86 a	-
	$LSD_{0.05}$	**0.57**	-
	CV (%)	**12.46**	-

It is evident (Table 3) that there was varying degree of fruit fly infestation in terms of fruit infestation percentage in the experimental field during first day after first spray of the rabi season of 2019-20. Percentage of fruit infestation amid the treatment regime ranged from 6.17 percent infested fruits per plot to 10.86 percent of infested fruits per plot which showed decrease over control. The lowest fruit infestataion (6.17% infested fruit per plot) obtained from T_1 (neem oil).

Treatments showed 11.41% to 43.18% decrease over control. The lowest fruit infestation (6.17% infested fruits per plot) obtained from T_1 (Neem oil). This treatment showed significant variation i.e., statistical difference from any other treatments used in the experiment and also exhibited 43.18% decrease of fruit infestation over control treatment. Later on, the fruit infestation percentage (6.88% infested fruits per plot) was followed by T_2 (Neem seed kernel) which was statistically different from any other treatments of the experiment except T_5. It showed 36.64% decrease of fruit infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 7.31% infested fruits per plot which was statistically different from other treatments of the experiment except T_2. It showed 32.68% decrease over the untreated plot. After that the infested fruits percentage was followed by T_4 (garlic bulb extract) and observed infested fruit was 7.91 percent per plot. This treatment also differed significantly from other treatments of the experiment and showed a 27.16 decrease over control treatment of the current study. This was followed by T_3 (datura seed extract) where the percentage of fruit infestation was observed 8.93 per plot. It was significantly different from other treatments of the experiment and showed 17.77% decrease over control treatment. Later on, the percent infested fruit induced by melon fruit fly (9.62% per plot) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment. It exhibited 11.41% decrease over the control treatment. However, the highest fruit infestation (10.86% infested fruits per plot) which was statistically different from any other treatments used in the current experiment.

It is found that all the treatments tested of the selected insecticides were significantly effective in reducing percent fruit infestation compared to the control, although the efficacy of the tested insecticides varied according to their types. The resultant high efficacy of neem oil against the *B. cucurbitae* could be due to its anti-ovipositional and reproductive inhibitory effect as suggested by our previous observation. Further experiment are required to determine the exact cause of efficacy against the cucurbit fruit fly by neem oil application (Ali *et al* 2011).

Ranganath *et al*. (1997) reported that Neem oil (1.2 %) and neem cake (4.0 %) is effective against melon fruit fly.

4.1.2. Effect of treatments on the fruit infestation during seven days after first spray caused by fruit fly

Table 4. Effect of treatments on the fruit infestation during seven days after first spray caused by fruit fly

Treatment No.	Treatment name	% fruit infestation per plot	Decrease over control (%)
T_1	Neem oil	9.09 d	42.02
T_2	Neem seed kernel	9.68 d	38.26
T_3	Datura seed extract	12.26 b	21.56
T_4	Garlic bulb extract	11.97 bc	23.66
T_5	Mehagany seed extract	10.55 cd	32.71
T_6	Black pepper seed extract	13.53 b	13.71
T_7	Control	15.68 a	-
	$LSD_{0.05}$	**1.57**	-
	CV (%)	**14.68**	-

It is evident (Table 4) that there was varying degree of fruit fly infestation in terms of fruit infestation percentage in the experimental field during seventh days after first spray in the rabi season of 2019-20. Percentage of fruit infestation amid the treatment regime ranged from 9.09 percent infested fruits per plot to 15.68 percent infested fruits per plot. Treatments showed 13.71% to 42.02% decrease over control. The lowest fruit infestation (9.09% infested fruits per plot) obtained from T_1 (Neem oil). This treatment showed statistical similarity i.e., no significant difference with T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) used in the experiment and also exhibited a 42.02% decrease of fruit infestation over the control treatment.

Later on, the fruit infestation percentage (9.68% infested fruits per plot) was obtained from T_2 (Neem seed kernel) which was statistically different from any other treatments of the experiment except T_1 (Neem oil) and T_5 (Mehagany seed extract). It showed 38.26% decrease of fruit infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 10.55% infested fruits per plot which was statistically different from other treatments of the experiment except T_4 (Garlic bulb extract). It showed 32.71% decrease over the untreated plot. After that the infested fruits percentage was followed by T_4 (garlic bulb extract) and observed infested fruit was 11.97 percent per plot. This treatment also differed significantly from other treatments of the experiment except T_3 (Datura seed extract) and T_5 (Mehagany seed extract) and showed a 23.66% decrease over control treatment of the current study. This was followed by T_3 (datura seed extract) where the percentage of fruit infestation was observed 12.26% per plot. It was significantly different from other treatments of the experiment except T_4 (garlic bulb extract) and T_6 (black pepper seed extract), and showed 21.56% decrease over control treatment. Later on, the percent infested fruit induced by melon fruit fly (13.53% per plot) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment except T_3 (datura seed extract). However, the highest fruit infestation (15.68% infested fruits per plot) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

It is found that all the treatments tested of the selected insecticides were significantly effective in reducing percent fruit infestation compared to the control, although the efficacy of the tested insecticides varied according to their types. Surprisingly it is evident that after the first spray the fruit infestation was reduced initially. However, during seventh days counting, fruit infestation percentage increased. Though the efficacy of treatment was around similar than that of first day of first spray that the minimum percent damage of crops.

Ali*et al*. (2011) reported that the minimum percent damage of a cucurbitaceous crop (41.94%) was found in Neem seed extract treated plots. They argued that the results of the experiment revealed that botanicals can be replaced for the management of melon fruit flies instead of using the synthetic pesticides in order to save the environment from their hazards. Mahfuza *et al*. (2007) found that Neem leaf dust and commercial formulation of Neem can easily control the population of *Bactrocera cucurbitae* and *Bactrocera dorsalis*. They also found that Neem blocks the ovarian development and can be used as safe alternative of insecticides for the control of *Bactrocera* Species.

4.1.3. Effect of treatments on the fruit infestation during one day after second spray caused by fruit fly

Table 5. Effect of treatments on the fruit infestation during one day after second spray caused by fruit fly

Treatment No.	Treatment name	% fruit infestation per plot	Decrease over control (%)
T_1	Neem oil	14.90 d	51.61
T_2	Neem seed kernel	16.36 cd	46.86
T_3	Datura seed extract	18.23 bc	40.79
T_4	Garlic bulb extract	17.47 c	43.26
T_5	Mehagany seed extract	16.73 cd	45.66
T_6	Black pepper seed extract	20.35 b	33.91
T_7	Control	30.79 a	-
	$LSD_{0.05}$	**2.28**	-
	CV (%)	**14.16**	-

It is evident (Table 5) that there was varying degree of fruit fly infestation in terms of fruit infestation percentage in the experimental field during first day after second spray of the rabi season of 2019-20. Percentage of fruit infestation amid the treatment regime ranged from 14.90 percent infested fruits per plot to 30.79 percent infested fruits per plot which decrease over control of insect infestation.

Treatments showed 33.91% to 51.61% decrease over control. The lowest fruit infestation (14.90% infested fruits per plot) obtained from T_1 (Neem oil). This treatment showed statistical similarity i.e., no significant difference with T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) used in the experiment and also exhibited a 51.61% decrease (the highest control) of fruit infestation over the control treatment.

Later on, the fruit infestation percentage (16.36% infested fruits per plot) was obtained from T_2 (Neem seed kernel) which was statistically similar with other treatments of the experiment except T_6 (Black pepper seed extract) and T_7 (Control). It showed a 46.86% decrease of fruit infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 16.73% infested fruits per plot which showed statistical similarity with other treatments of the experiment except T_6 (Black pepper seed extract) and T_7 (Control). It showed a 45.66% decrease over the untreated plot. After that the infested fruits percentage was followed by T_4 (garlic bulb extract) and observed infested fruit was 17.47 percent per plot. This treatment also showed statistical similarity with other treatments of the experiment except T_1 (Neem oil), T_6 (Black pepper seed extract) and T_7 (Control) and showed a 43.26% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the percentage of fruit infestation was observed 18.23% per plot. This treatment also showed statistical similarity with other treatments of the experiment except T_1 (Neem oil) and T_7 (Control) and showed a 40.79% decrease over control treatment of the current study.

The percent infested fruit induced by melon fruit fly (20.35% per plot) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment except T_3 (datura seed extract). It showed 33.91% (the lowest control) decrease of fruit infestation over the control treatment. However, the highest fruit infestation (30.79% infested fruits per plot) obtained from T7 (control) which was statistically different from any other treatments used in the current experiment of squash.

The present studies conclude that the cucurbit fruit fly causes significant damage in squash preferably in young and immature stages. The cucurbit fruit fly causes huge losses in squash yield under farmers' field conditions in uncontrolled situations. Application of locally made botanical pesticide offers superior yield in terms of fruit size and quality, and reduced fruit fly infestation in squash. Although, botanicals are easy to prepare locally and is effective for the management of fruit fly, it requires more frequent applications owing to more labor cost.

In the current experiment, all the botanical insecticides evaluated were effective against the major fruit fly infesting summer squash to some extent but Neem products were superior in terms of infestation reduction. Botanicals have been proved effective against fruit fly previously. An extract of *Acorus calamus* (0.15%) reduced the adult longevity from 119.2 days to 26.6 days when fed continuously with sugar mixed with extract (at 1 ml/g sugar) (Nair and Thomas, 1999). Neem oil (1.2%) and neem cake (4.0 %) have also been reported to be as effective as dichlorvos (0.2 %) (Ranganath *et al.* 1997).

4.1.4. Effect of treatments on the fruit infestation during seven days after second spray caused by fruit fly

Table 6. Effect of treatments on the fruit infestation during seven days after second spray caused by fruit fly

Treatment No.	Treatment name	% fruit infestation per plot	Decrease over control (%)
T_1	Neem oil	21.33 e	63.56
T_2	Neem seed kernel	25.38 d	56.65
T_3	Datura seed extract	31.56 c	46.09
T_4	Garlic bulb extract	28.20 cd	51.83
T_5	Mehagany seed extract	26.43 d	54.85
T_6	Black pepper seed extract	37.36 b	36.19
T_7	Control	58.55 a	-
	$LSD_{0.05}$	**3.48**	-
	CV (%)	**13.73**	-

It is evident (Table 6) that there was varying degree of fruit fly infestation in terms of fruit infestation percentage in the experimental field during seventh day after second spray of the rabi season of 2019-20. Percentage of fruit infestation amid the treatment regime ranged from 21.33 percent infested fruits per plot to 58.55 percent infested fruits per plot. Treatments showed 36.19% to 63.56% decrease over control. The lowest fruit infestation (21.33 infested fruits per plot) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment and also exhibited a 63.56% decrease (the highest control) of fruit infestation over the control treatment. Later on, the fruit infestation percentage (25.38% infested fruits per plot) was obtained from T_2 (Neem seed kernel) which different from other treatment compare to other treatments.

T_2 which was statistically different from other treatments of the experiment except T_4 (Garlic bulb extract) and T_5 (Mehagany seed extract). It showed a 56.65% decrease of fruit infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 26.43% infested fruits per plot which showed statistical dissimilarity with other treatments of the experiment except T_4 (Garlic bulb extract). It showed a 54.85% decrease over the untreated plot. After that the infested fruits percentage was followed by T_4 (garlic bulb extract) and observed infested fruit was 28.20 percent per plot. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_3 (Datura seed extract) and showed a 51.83% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the percentage of fruit infestation was observed 31.56% per plot. This treatment also showed statistical variation with other treatments of the experiment except T_4 (Garlic bulb extract) and showed a 46.09% decrease over control treatment of the current study. Later on, the percent infested fruit induced by melon fruit fly (37.36% per plot) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment except T_3. It showed 36.19% (the lowest control) decrease of fruit infestation over the control treatment. However, the highest fruit infestation (58.55% infested fruits per plot) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Plants rich in bioactive chemicals may provide potential alternatives to currently used insect controlling agents. These plants carry thousand of compounds which are virtually an untapped reservoir of pesticides that can be used directly or as templates for synthetic ticides. Homemade or commercial formulation of neem products can minimize the population and damage of fruit fly species. It also blocks the ovary development (Mahfuza *et al.* 2007). It has been seen that fruit infestation gradually increased throughout the growing period of crop under the current experiment based on studies it was found.

Based on studies, it was found that the dry periods and adequate rainfall have a direct impact on the increase and reduction of the fruit fly population. The population expands with adequate rainfall and contracts during dry periods (Nishida 1963).

4.2. Effect of treatments against melon aphid

4.2.1. Effect of treatments against melon aphid during vegetative

Table 7. Effect of treatments on the number of aphid during vegetative stage

Treatment No.	Treatment name	Number of aphid per leaf	Decrease over control (%)
T_1	Neem oil	6.54 f	83.03
T_2	Neem seed kernel	9.87 ef	74.41
T_3	Datura seed extract	17.54 bc	54.51
T_4	Garlic bulb extract	15.27 cd	60.39
T_5	Mehagany seed extract	12.31 de	68.07
T_6	Black pepper seed extract	20.46 b	46.93
T_7	Control	38.56 a	-
	$LSD_{0.05}$	**4.01**	-
	CV (%)	**8.14**	-

It is evident (Table 7) that there was varying degree of aphid infestation in terms of number of nymphs and adult aphis in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of aphids amid the treatment regime ranged from 6.54 per leaf to 38.56 per leaf. Treatments showed 46.93% to 83.03% decrease over control. The lowest aphid infestation (6.54 aphids per leaf) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment except T2 (Neem seed kernel) and exhibited an 83.03% decrease (the highest control) of aphid infestation over the control treatment.

This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment except T_2 (Neem seed kernel) and exhibited an 83.03% decrease (the highest control) of aphid infestation over the control treatment. Later on, the aphid infestation (9.87 aphids per leaf) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatments of the experiment except T_5 (Mehagany seed extract). It showed a 74.41% decrease of infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 12.31 aphids per leaf which showed statistical dissimilarity with other treatments of the experiment except T_4 (Garlic bulb extract). It showed a 68.07% decrease over the untreated plot. After that the aphid infestation was followed by T_4 (garlic bulb extract) and obtained number of aphid was 15.27 per leaf. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_3 (Datura seed extract) and showed a 17.54% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the aphid infestation was observed 31.56% per plot. This treatment also showed statistical variation with other treatments of the experiment except T_4 (Garlic bulb extract) and showed a 54.51% decrease over control treatment of the current study. Later on, the infestation induced by melon aphid (20.46 aphids per leaf) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment except T_3 (Datura seed extract). It showed 46.93% (the lowest control) decrease of fruit infestation over the control treatment. However, the highest aphid infestation (38.56 aphids per leaf) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Aphids are one of the most destructive pests of almost all cultivated crops. Given their short life cycle, aphids can have as many as 40 generations or more annually under optimal conditions, which means that theoretically, one female can produce billions of descendants annually, if there is no mortality. The most widely represented major compounds efficacy derived from botanicals, with respect to acute toxicity in insects, were oxidized monoterpenes such as carvacrol, thymol, trans-anethole, methyl chavicol, menthone, pulegone, menthol, caryophyllene oxide, spathulenol, anisaldehyde, anisketone, and α-terpineol. As already established, oxidized monoterpenes provide better efficacy as regards acute toxicity for insects compared to non-oxidized monoterpenes, which is most likely associated with their better lipophilic properties that support better penetration of the insect cuticle (Pavela 2015).

4.2.2. Effect of treatments against melon aphid during fruiting stage

Table 8. Effect of treatments on the number of aphid during fruiting stage

Treatment No.	Treatment name	Number of aphid per leaf	Decrease over control (%)
T_1	Neem oil	4.23 g	83.45
T_2	Neem seed kernel	6.99 f	72.66
T_3	Datura seed extract	16.13 c	36.91
T_4	Garlic bulb extract	12.88 d	49.62
T_5	Mehagany seed extract	9.93 e	61.16
T_6	Black pepper seed extract	19.17 b	25.02
T_7	Control	25.57 a	-
	$LSD_{0.05}$	**2.35**	-
	CV (%)	**6.09**	-

It is evident (Table: 8) that there was varying degree of aphid infestation in terms of number of nymphs and adult aphids in the experimental field during the fruiting stage of grown crop in the rabi season of 2019-20. Number of aphids amid the treatment regime ranged from 4.23 per leaf to 25.57 per leaf. Treatments showed 25.02% to 83.45% decrease over control. The lowest aphid infestation (4.23 aphids per leaf) was obtained from T_1 (Neem oil).

This treatment showed no statistical similarity i.e., significant variation with any other treatments used in experiment and exhibited an 83.45% decrease over control. Later on, the aphid infestation percentage (6.99 aphids per leaf) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatments of the experiment except. It showed a 72.66% decrease of fruit infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 9.93 aphids per leaf which showed statistical dissimilarity with other treatments of the experiment. It showed a 61.16% decrease over the untreated plot. After that the aphid infestation was followed by T_4 (garlic bulb extract) and obtained number of aphid was 12.88 per leaf. This treatment also showed statistical dissimilarity with other treatments of the experiment and showed a 49.62% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the aphid infestation was observed 316.13% per plot. This treatment also showed statistical variation with other treatments of the experiment and showed a 36.91% decrease over control treatment of the current study. Later on, the infestation induced by melon aphid (19.17 aphids per leaf) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment. It showed 25.02% (the lowest control) decrease of fruit infestation over the control treatment. However, the highest aphid infestation in fruiting stage of crop (25.57 aphids per leaf) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Neem products have diverse pest control properties, affecting insect growth, fertility, and metamorphosis in addition to direct toxicity and antifeedant and oviposition-deterrent effects (Naqvi 1996). Coventry and Allan (2001) revealed that exposure of adult aphids to neem seed oil and azadirachtin had a significant influence on the survival of offspring produced by treated adults, whereas the survival of adults remained unaffected. Direct toxicity, these authors declared that adults successfully emerging from aphid nymph treated with neem oil were undersized with abnormal wings, legs and stylet.

Previous research has indicated that neem-based pesticides could control a number of other aphid species infesting plants under laboratory and field circumstances. However, there were differences in the insecticidal activity among commercially available products of which the majority showed to be toxic to aphids, including those on many different crops.

4.3. Effect of treatments on the number of red pumpkin beetle

4.3.1. Effect of treatments on the number of red pumpkin beetle during vegetative stage

Table 9. Effect of treatments on the number of red pumpkin beetle during vegetative stage

Treatment No.	Treatment name	Number of RPB per plant	Decrease over control (%)
T_1	Neem oil	0.18 e	94.88
T_2	Neem seed kernel	0.68 de	80.68
T_3	Datura seed extract	2.14 b	39.20
T_4	Garlic bulb extract	1.54 c	56.25
T_5	Mehagany seed extract	1.16 cd	67.04
T_6	Black pepper seed extract	2.52 b	28.24
T_7	Control	3.52 a	-
	$LSD_{0.05}$	**0.56**	-
	CV (%)	**11.69**	-

It is evident (Table 9) that there was varying degree of red pumpkin beetle (RPB) infestation in terms of number of adult RPB in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of RPB amid the treatment regime ranged from 0.18 per leaf to 3.53 per plant.

Treatments showed 28.24% to 94.88% decrease over control. The lowest RPB infestation (0.18 RPB per plant) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment except T_2 (Neem seed kernel) and exhibited a 94.88% decrease (the highest control) of RPB infestation over the control treatment. Later on, the RPB infestation (0.68 RPB per plant) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatments of the experiment except T_5 (Mehagany seed extract). It showed a 80.68% decrease of RPB infestation over control treatment.

Subsequently, T_5 (Mehagany seed extract) showed 1.16 RPB per plant which showed statistical dissimilarity with other treatments of the experiment except T_4 (Garlic bulb extract). It showed a 67.04% decrease over the untreated plot. After that the RPB infestation was followed by T_4 (garlic bulb extract) and obtained number of RPB was 1.54 per plant. This treatment also showed statistical dissimilarity with other treatments of the experiment and showed a 56.25% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the RPB infestation was observed 2.14 per plant. This treatment also showed statistical variation with other treatments of the experiment except T_4 (Garlic bulb extract) and showed a 39.20% decrease over control treatment of the current study.

Later on, the infestation induced by RPB (2.52 RPB per plant) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment except T_3 (Datura seed extract). It showed 28.24% (the lowest control) decrease of RPB infestation over the control treatment. However, the highest RPB infestation (3.52 RPB per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Red pumpkin beetle is the most serious and destructive polyphagous pest of cucurbitaceous vegetables especially cucumber, white gourd, water melon, muskmelon and sweet gourd in India (Varavdekar and Dumbre 1992). It causes about 35 to 75 per cent damage to all cucurbits, except bitter gourd at seedling stage which needs to be re-sowing of crop. Both the adults and the grubs of red pumpkin beetle causing considerable damage to cucurbit plants during all stages of plant development (Atwal and Dhaliwal 2002).

Chemical insecticides are used as the frontline defense sources against insect pests in India. However, their indiscriminate use creates a number of problems such as development of resistance against insecticides, pest resurgence and environmental hazards including residue in soil, water, vegetables and fruits. The concept of pest control with botanicals is emerging worldwide as it is eco-friendly and cost effective. Botanical pesticides are environmentally safer, unique with novel mode of action and rich source of biologically active compounds.

4.3.2. Effect of treatments on the number of red pumpkin beetle during fruiting stage

Table 10. Effect of treatments on the number of red pumpkin beetle during fruiting stage

Treatment No.	Treatment name	Number of RPB per plant	Decrease over control (%)
T_1	Neem oil	0.69 e	82.48
T_2	Neem seed kernel	1.23 d	68.78
T_3	Datura seed extract	2.29 c	41.87
T_4	Garlic bulb extract	1.64 d	58.37
T_5	Mehagany seed extract	1.45 d	63.19
T_6	Black pepper seed extract	2.96 b	24.87
T_7	Control	3.94 a	-
	$LSD_{0.05}$	**0.47**	-
	CV (%)	**8.19**	-

It is evident (Table 10) that there was varying degree of red pumpkin beetle (RPB) infestation in terms of number of adult RPB in the experimental field during the fruiting stage of grown crop in the rabi season of 2019-20. Number of RPB amid the treatment regime ranged from 0.69 per leaf to 3.94 per plant. Treatments showed 24.87% to 82.48% decrease over control. The lowest RPB infestation (0.69 RPB per plant) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment and exhibited a 82.48% decrease (the highest control) of RPB infestation over the control treatment. Later on, the RPB infestation (1.23 RPB per plant) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatment of the experiment except T_4.

T_4 (garlic bulb extract) and T_5 (Mehagany seed extract). It showed a 68.78% decrease of RPB infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 1.45 RPB per plant which showed statistical dissimilarity with other treatments of the experiment except T_2 (Neem seed kernel) and T_4 (Garlic bulb extract). It showed a 63.19% decrease over the untreated plot. After that the RPB infestation was followed by T_4 (garlic bulb extract) and obtained number of RPB was 1.64 per plant. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) eventually showed a 58.37% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the RPB infestation was observed 2.29 per plant. This treatment also showed statistical variation with other treatments of the experiment and showed a 41.87% decrease over control treatment of the current study. Later on, the infestation induced by RPB (2.96 RPB per plant) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment. It showed 24.87% (the lowest control) decrease of RPB infestation over the control treatment. However, the highest RPB infestation (3.94 RPB per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Gujar and Mehrotra (1988) reported that NSKE 0.01 per cent and neem oil 0.4 per cent reduced the feeding activity of red pumpkin beetle upto 50 per cent. Rajak and Singh (2002) reported that leaf powder of neem (*Azadirachta indica*) was most effective against the red pumpkin beetle followed by balcayen (*Melia azadirach*). Lakshmi *et al*. (2005) revealed that spray of nimbecidine (28.66 %) was found most effective in reducing the beetle population as well as in reducing the leaf damage.

Rashid *et al*. (2016) who noted that spraying with NSKE 5% recorded the minimum (4.31 beetles/plant) population followed by *Moringa olefera* (4.89 beetles/plant). Chowdhury and Talukder (2019) revealed that spray of neem oil and malathion recorded the minimum (1.26 and 1.30 beetles/plant, respectively) number of beetle population followed by mahogoni seeds (1.80 beetles/plant) and pyrethrum flower (2.12 beetles/plant).

4.4. Effect of treatments on the number of Epilachna beetle

4.4.1. Effect of treatments on the number of Epilachna beetle during vegetative stage

Table 11. Effect of treatments on the number of Epilachna beetle during vegetative stage

Treatment No.	Treatment name	Number of EB per plant	Decrease over control (%)
T_1	Neem oil	0.02 e	99.35
T_2	Neem seed kernel	0.13 de	95.83
T_3	Datura seed extract	0.75 c	75.96
T_4	Garlic bulb extract	0.42 d	86.53
T_5	Mehagany seed extract	0.20 de	93.58
T_6	Black pepper seed extract	1.46 b	53.20
T_7	Control	3.12 a	-
	$LSD_{0.05}$	**0.32**	-
	CV (%)	**12.70**	-

It is evident (Table 11) that there was varying degree of epilachna beetle (EB) infestation in terms of number of adult EB in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of EB amid the treatment regime ranged from 0.02 per leaf to 3.12 per plant. Treatments showed 53.20% to 99.35% decrease over control.

The lowest EB infestation (0.02 EB per plant) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment except T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) and exhibited a 99.35% decrease (the highest control) of EB infestation over the control treatment. Later on, the EB infestation (0.13 EB per plant) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatments of the experiment except T_1 (Neem oil), T_4 (Garlic bulb extract) and T_5 (Mehagany seed extract). It showed a 95.83% decrease of EB infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 0.2 EB per plant which showed statistical dissimilarity with other treatments of the experiment except T_1 (Neem oil), T_2 (Neem seed kernel) and T_4 (Garlic bulb extract). It showed a 93.58% decrease over the untreated plot.

After that the EB infestation was followed by T_4 (garlic bulb extract) and obtained number of EB was 0.42 per plant. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) which showed a 86.53% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the EB infestation was observed 0.75 per plant. This treatment also showed statistical variation with other treatments of the experiment and showed a 75.96% decrease over control treatment of the current study. Later on, the infestation induced by EB (1.46 RPB per plant) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment and showed 53.20% (the lowest control) decrease of EB infestation over the control treatment. However, the highest EB infestation (3.12 EB per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Venkataramireddy *et al*. (1993) studied the The efficacy of petroleum ether extracts of *Eucalyptus globulus*, *Calotropis gigantia*, *Pongamia glabra, Annona squamosa*, *Azadirachta indica* and *Lantana camara* against larvae of *Henosepilachna vigintioctopunctata* (*Epilachna vigintioctopunctata*) was studied on aubergine plants in the greenhouse. Extracts of neem and *Annona squamosa* were the most effective and reduced the larval population by 94.77 and 91.94%, respectively. Petroleum ether (40-60 degrees C) extracts of leaves of 4 selected plants were tested in the laboratory for their antifeedant and insecticidal properties against *Henosepilachna vigintioctopunctata* (*Epilachna vigintioctopunctata*) at concn of 0.2 and 0.5% applied to brinjal leaves. Mortality after 24 h at both concn of *Bougainvillea spectabilis* and *Parthenium hysterophorus*, and 0.5% concn of *Azadirachta indica* was 100% (Rao *et al*. 1992).

4.4.2. Effect of treatments on the number of Epilachna beetle during fruiting stage

Table 12. Effect of treatments on the number of Epilachna beetle during fruiting stage

Treatment No.	Treatment name	Number of EB per plant	Decrease over control (%)
T_1	Neem oil	0.29 e	91.44
T_2	Neem seed kernel	0.40 de	88.20
T_3	Datura seed extract	1.02 c	69.91
T_4	Garlic bulb extract	0.69 d	79.64
T_5	Mehagany seed extract	0.47 de	86.13
T_6	Black pepper seed extract	1.73 b	48.96
T_7	Control	3.39 a	-
	$LSD_{0.05}$	**0.31**	-
	CV (%)	**9.70**	-

It is evident (Table 12) that there was varying degree of epilachna beetle (EB) infestation in terms of number of adult EB in the experimental field during the fruiting stage of grown crop in the rabi season of 2019-20. Number of EB amid the treatment regime ranged from 0.29 per leaf to 3.39 per plant. Treatments showed 48.96% to 91.44% decrease over control. The lowest EB infestation (0.29 EB per plant) obtained from T_1 (Neem oil). This treatment showed no statistical similarity i.e., significant variation with any other treatments used in the experiment except T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) and exhibited a 91.44% decrease (the highest control) of EB infestation over the control treatment. Later on, the EB infestation (0.40 EB per plant) was obtained from T_2 (Neem seed kernel) which was statistically different from other treatments of the experiment.

T_1 (Neem oil), T_4 (Garlic bulb extract) and T_5 (Mehagany seed extract). It showed a 88.20% decrease of EB infestation over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 0.47 EB per plant which showed statistical dissimilarity with other treatments of the experiment except T_1 (Neem oil), T_2 (Neem seed kernel) and T_4 (Garlic bulb extract). It showed a 86.13% decrease over the untreated plot. After that the EB infestation was followed by T_4 (garlic bulb extract) and obtained number of EB was 0.69 per plant. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_2 (Neem seed kernel) and T_5 (Mehagany seed extract) which showed a 79.64% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the EB infestation was observed 1.02 per plant. This treatment also showed statistical variation with other treatments of the experiment and showed a 69.91% decrease over control treatment of the current study. Later on, the infestation induced by EB (1.73 RPB per plant) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment and showed 48.96% (the lowest control) decrease of EB infestation over the control treatment. However, the highest EB infestation (3.39 EB per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

A field experiment was conducted during kharif 1988 to evaluate the efficacy of 1.0 per cent petroleum ether extracts of *Eucalyptus globulus*, *Calotropis gigantia*, *Pongamia glabra*, *Annona squamosa*, *Azadirachta indica* and *Lantana camara* in controlling the brinjal spotted leaf beetle, *Henosepilachna viginioctopunctata* Fab. Both at 24 h and 3 days after spraying, the extracts of *A. indica* and *A. squamosa* were effective in reducing the grub population. The order of efficacy of the remaining products was *L. camara* > *P. glabra* > *C. gigantia* > *E. globulus* (Reddy *et al*. 1990).

Petroleum ether and methanol solvent extracts of ata (*Annona squamosa*), neem (*Azadirachta indica*), dhutura (*Datura metel*) and castor (*Ricinus communis*) seeds were evaluated for their larvicidal properties against the larval stage of *E. vigintioctopunctata*. The result revealed that all the tested plant extracts had more or less insecticidal effect against the larvae and their progeny.

4.5. Effect of treatments on the percent of leaf damaged caused by defoliators

Table 13. Effect of treatments on the percent of leaf damaged caused by defoliators (red pumpkin beetle and epilachna beetle)

Treatment No.	Treatment name	Leaf damaged (%)	Decrease over control (%)
T_1	Neem oil	5.66 f	91.06
T_2	Neem seed kernel	10.33 ef	83.69
T_3	Datura seed extract	23.65 c	62.66
T_4	Garlic bulb extract	19.56 cd	69.11
T_5	Mehagany seed extract	14.39 de	77.28
T_6	Black pepper seed extract	31.76 b	49.85
T_7	Control	63.34 a	-
	$LSD_{0.05}$	**7.02**	-
	CV (%)	**10.32**	-

It is evident (Table 13) that there was varying degree of leaf damage in terms of percentage by numbers in the experimental field throughout the growing period of the rabi season of 2019-20. Percentage of damaged leaf by numbers caused by defoliators amid the treatment regime ranged from 5.66 percent damaged leaves per plant to 63.34 percent damaged leaves per plant. Treatments showed 49.85% to 91.06% decrease over control. The lowest leaf damage (5.66% damaged leaves per plant) was obtained from T_1 (Neem oil) treatment.

Statistically similarity i.e., no significant difference with T_2 (Neem seed kernel) used in the experiment and also exhibited a 91.06% decrease (the highest control) of leaf damage over the control treatment. Later on, the leaf damage percentage (10.33% damaged leaves per plant) was obtained from T_2 (Neem seed kernel) which was statistically similar with treatments T_1 (Neem oil) and T_5 (Mehagany seed extract) of the experiment. It showed an 83.69% decrease of leaf damage over control treatment. Subsequently, T_5 (Mehagany seed extract) showed 14.39% damaged leaves per plant which showed statistical dissimilarity with other treatments of the experiment except T_4 (garlic bulb extract) and T_2 (Neem seed kernel). It showed a 77.28% decrease over the untreated plot.

After that the damaged leaf percentage was followed by T_4 (garlic bulb extract) and observed leaf damaged was 19.56 percent per plant. This treatment also showed statistical dissimilarity with other treatments of the experiment except T_5 (Mehagany seed extract) and T_3 (Datura seed extract). It showed a 69.11% decrease over control treatment of the current study. This was followed by T_3 (Datura seed extract) where the percentage of damaged leaf was observed 23.65% per plant. This treatment also showed statistical variation with other treatments of the experiment except T_4 (garlic bulb extract) and showed a 62.66% decrease over control treatment of the current study.

Later on, the percent leaf damaged induced by defoliators (31.76% per plant) was observed from T_6 (black pepper seed extract) which was also statistically dissimilar from any other treatments of the experiment. It showed 49.85% (the lowest control) decrease of damage over the control treatment. However, the highest damaged leaf percentage (63.34% per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

4.6. Effect of treatments on the length of squash fruit

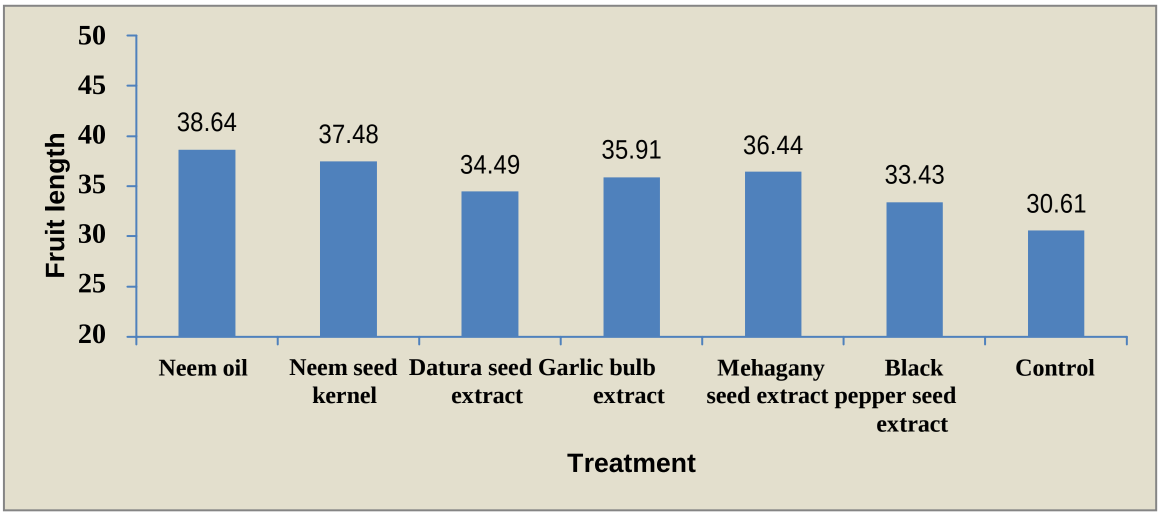


Figure 7: Effect of treatments on the length of squash fruit

It is evident (Fig. 7) that there was varying degree of fruit length in the experimental field. Fruit length obtained amid the treatment regime ranged from 30.61 cm to 38.64 cm individually. The highest fruit length (38.64 cm) obtained from T_1 (Neem oil) which was followed by T_2 (Neem seed kernel extract) and the fruit length observed was 37.48 cm. After that the length of fruit obtained from T_5 (Mehagany seed extract) was 36.44 cm.

These treatments showed significant variation with other treatments of the experiment. The length of individual fruit was then followed by T_4 (Garlic bulb extract) which was 35.91 cm. Fruit length obtained from T_3 (Datura seed extract) was 34.39 cm; furthermore, T_6 (Black pepper seed extract) showed 33.43cm fruit length. However, the lowest fruit length obtained from T_7 (Control treatment).

4.7. Effect of treatments on the yield of squash

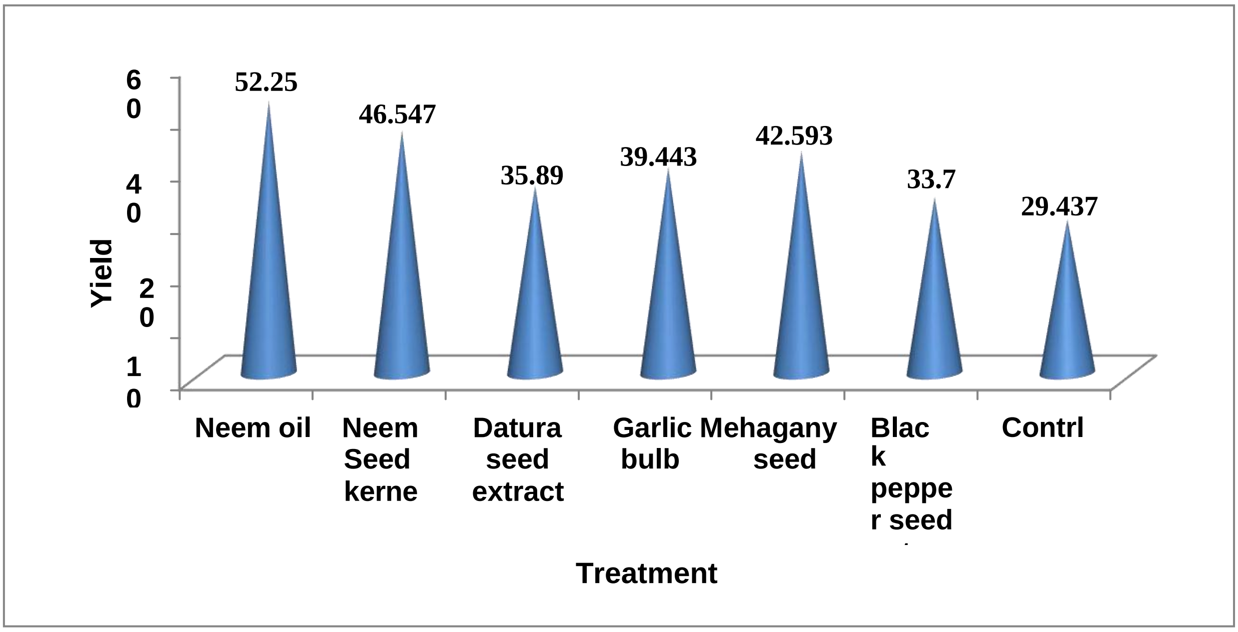


Figure 8: Effect of treatments on the yield of squash

It is evident (Fig. 8) that there was varying degree of yield in the experimental field. Yield obtained amid the treatment regime ranged from 52.25 ton/ha to 29.437 ton/ha. The highest yield (38.64 ton/ha) obtained from T_1 (Neem oil) which was followed by T_2 (Neem seed kernel extract) and the yield observed was 37.48 ton/ha.

After that the yield obtained from T_5 (Mehagany seed extract) was 36.44 ton/ha. These treatments showed significant variation with other treatments of the experiment. The yield was then followed by T_4 (Garlic bulb extract) which was 35.91 ton/ha. Yield obtained from T_3 (Datura seed extract) was 34.39 ton/ha; furthermore, T_6 (Black pepper seed extract) showed 33.43 ton/ha yield. However, the lowest yield obtained from T_7 (Control treatment).

CHAPTER V

SUMMARY AND CONCLUSION

The present study was undertaken in order to study the efficacy of some promising pesticides to control the major insect pests of summer squash in Bangladesh. The study was done in the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during rabi season of 2019-20. The treatments are Neem oil, Neem seed kernel extract, Datura seed extract, Garlic bulb extract, Mehagany seed extract, Black pepper seed extract and Absolute (control).

There was varying degree of fruit fly infestation in terms of fruit infestation percentage in the experimental field during first day after first spray of the rabi season of 2019-20. Percentage of fruit infestation amid the treatment regime ranged from 6.17 percent infested fruits per plot to 10.86 percent infested fruits per plot. Treatments showed 11.41% to 43.18% decrease over control. The lowest fruit infestation (6.17% infested fruits per plot) obtained from T_1 (Neem oil) and the highest fruit infestation (10.86% infested fruits per plot) from T_7 which was statistically different from any other treatments used in the current experiment.

In case of seventh days after first spray, percentage of fruit infestation amid the treatment regime ranged from 9.09 percent infested fruits per plot to 15.68 percent infested fruits per plot. Treatments showed 13.71% to 42.02% decrease over control. The lowest fruit infestation (9.09% infested fruits per plot) obtained from T_1 (Neem oil). The highest fruit infestation (15.68% infested fruits per plot) obtained from T_7 (control).

In terms of control during first day after second spray percentage in the experimental field. Percentage of fruit infestation amid the treatment regime ranged from 14.90 percent infested fruits per plot to 30.79 percent infested fruits per plot. Treatments showed 33.91% to 51.61% decrease over control.

The lowest fruit infestation (14.90% infested fruits per plot) obtained from (T_1 neem oil) and the highest fruit infestation (30.79% infested fruits per plot) obtained from T_7 (control). At seventh day after second spray percentage of fruit infestation amid the treatment regime ranged from 21.33 percent infested fruits per plot to 58.55 percent infested fruits per plot. Treatments showed 36.19% to 63.56% decrease over control. The lowest fruit infestation (21.33% infested fruits per plot) obtained from T_1 (Neem oil) and the highest fruit infestation (58.55% infested fruits per plot) obtained from T_7 (control).

Varying degree of aphid infestation in terms of number of nymphs and adult aphids obtained in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of aphids amid the treatment regime ranged from 6.54 per leaf to 38.56 per leaf. Treatments showed 46.93% to 83.03% decrease over control. The lowest aphid infestation (6.54 aphids per leaf) obtained from T_1 (Neem oil) and the highest aphid infestation (38.56 aphids per leaf) obtained from T_7 (control).

At fruiting stage number of aphids amid the treatment regime ranged from 4.23 per leaf to 25.57 per leaf. Treatments showed 25.02% to 83.45% decrease over control. The lowest aphid infestation (4.23 aphids per leaf) obtained from T_1 (Neem oil) and the highest aphid infestation in fruiting stage of crop (25.57 aphids per leaf) obtained from T_7 (control).

There was varying degree of red pumpkin beetle (RPB) infestation in terms of number of adult RPB in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of RPB amid the treatment regime ranged from 0.18 per leaf to 3.52 per plant. Treatments showed 28.24% to 94.88% decrease over control. The lowest RPB infestation (0.18 RPB per plant) obtained from T_1 (Neem oil) and the highest RPB infestation (3.52 RPB per plant) obtained from T_7 (control). At fruiting stage number of RPB amid the treatment regime ranged from 0.69 per leaf to 3.94 per plant. Treatments showed 24.87% to 82.48% decrease over control. The lowest RPB infestation (0.69 RPB per plant) obtained from T_1 (Neem oil).

At fruiting stage number of RPB amid the treatment regime ranged from 0.69 per leaf to 3.94 per plant. Treatments showed 24.87% to 82.48% decrease over control. The lowest RPB infestation (0.69 RPB per plant) obtained from T_1 (Neem oil) and the highest RPB infestation (3.94 RPB per plant) obtained from T_7 (control).

In case of Epilachna beetle, there was varying degree of infestation in terms of number of adult EB in the experimental field during the vegetative stage of grown crop in the rabi season of 2019-20. Number of EB amid the treatment regime ranged from 0.02 per leaf to 3.12 per plant. Treatments showed 53.20% to 99.35% decrease over control. The lowest EB infestation (0.02 EB per plant) obtained from T_1 (Neem oil). As expected, the highest EB infestation (3.12 EB per plant) obtained from T_7 (control). Similarly in fruiting stage, there was varying degree of epilachna beetle (EB) infestation in terms of number of adult EB in the experimental field during the rabi season of 2019-20. Number of EB amid the treatment regime ranged from 0.29 per leaf to 3.39 per plant. Treatments showed 48.96% to 91.44% decrease over control. The lowest EB infestation (0.29 EB per plant) obtained from T_1 (Neem oil). However, the highest EB infestation (3.39 EB per plant) obtained from T_7 (control) which was statistically different from any other treatments used in the current experiment.

Percentage of damaged leaf by number caused by defoliators amid the treatment regime ranged from 5.66 percent damaged leaves per plant to 63.34 percent damaged leaves per plant. Treatments showed 49.85% to 91.06% decrease over control. The lowest percent leaf damage (5.66% per plant) obtained from T_1 (Neem oil); whereas, the highest damaged leaf percentage (63.34% per plant) obtained from T_7 (control). In terms of yield attribute, the highest fruit length (38.64 cm) obtained from T_1 (Neem oil) which was followed by T_2 (Neem seed kernel extract) where the fruit length observed was 37.48 cm. However, the lowest fruit length obtained from T_7 (Control treatment). In terms of yield, the highest yield (38.64 ton/ha) obtained from T_1 (Neem oil) whereas, the lowest yield obtained from T_7 (Control treatment).

RECOMMENDATIONS

Followings are the major findings of the experiment; besides, several concluding remarks and recommendations are given-

- Summer squash plants are mostly affected by fruit fly, aphid, epilachna beetle, red pumpkin beetle. The degree of infestation varied throughout the growing period.
- Highest yield obtained from the plot where lowest number of insects was observed.
- Neem oil is the most effective insecticide against pest complex of squash.

However, more research and multilocation trial should be conducted to find out the best doses and time to apply Neem oil for the best control of squash insect pests.

CHAPTER VI

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