EVALUATION OF SOME BOTANICALS AS PEST MANAGEMENT PRACTICES AGAINST PEST COMPLEX IN TOMATO

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Dedicated To

My Beloved Parents

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By

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ABSTRACT

The present experiment was conducted to evaluate some botanicals as pest management practices against pest complex in tomato in the farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2006 to April 2007. The experiment consisted of 8 treatments such as T_1: Neem leaf extract @ 0.5kg/L of water at 3 days interval; T_2: Neem leaf extract @ 0.5kg/L of water at 7 days interval; T_3: Neem oil @ 3.0ml/L of water at 3 days interval; T_4: Neem oil @ 3.0ml/L of water at 7 days interval; T_5: Garlic extract @ 0.5kg/L of water at 3 days interval; T_6: Marsh Pepper extract @ 0.5kg/L of water at 3 days interval; T_7: Marsh Pepper extract @ 0.5kg/L of water at 7 days interval and T_8: Untreated control. The lowest number (22.40) of white fly per plot was recorded from T_3 treatment, while the highest number (145.00) of white fly per plot was recorded from untreated control. The lower average leaf infestation (3.19%) was recorded from the treatment T_3 plots and the highest (15.77) leaf infestation was recorded from untreated control. The lowest % of infested fruit by weight (3.47%) was recorded from the treatment T_3 plots and the highest % of infested fruit by weight (14.45%) was recorded from untreated control plots. The highest weight of fruit per hectare (66.80 t) was recorded from the treatment T_3 plots and the lowest (56.86 t) weight of fruit per hectare was recorded from untreated control plots. The highest weight of healthy fruit per hectare (64.48 t) was recorded from the treatment T_3 treated plots and the lowest (48.65 t) weight of healthy fruit per hectare was recorded from untreated control plots. Considering the controlling of tomato fruit borer highest benefit cost ratio (2.82) was recorded in the T_3 treated plots (application of Neem oil at 3 days interval) on the other hand the lowest cost benefit ratio (0.06) was recorded in T_2 treated plots. Among the different treatments Neem oil application at 3 days interval was most effective than other treatment. The botanicals which applied at 3 days interval were effective than those applied at 7 days interval in controlling insect pests of tomato

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Chapter 1

Introduction

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) belongs to the family Solanaceae is one of the most popular and important vegetable crop. The crop ranks next to potato and sweet potato in the world vegetable production (FAO, 1997) and top the list of canned vegetables (Chowdhury, 1979). Its food value is very rich because of higher contents of vitamins A, B and C and also minerals like calcium (Bose and Som, 1990).

In Bangladesh the yield of tomato is not satisfactory in comparison with other tomato growing countries of the World (Aditya *et al*., 1997). Bangladesh grew tomato in around 15.4 thousand hectares of land in the year 2005-2006 with a total production of 131 thousands tonnes approximately with an average yield of 8.51 t per ha (BBS, 2007). In the United States, the average yield for a mechanically harvested crop is 56 t/ha while in India yield varies between 16-24 t/ha (Sutton, 1991). The low yield of tomato in Bangladesh however is not an indication of low yielding potentially of this crop, but of the fact that the low yield may be attributed to a number of reasons viz., unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper irrigation facilities. Tomato is susceptible to insect attack from seedling to fruiting stage. All parts of the plant including leaves, stems, flowers and fruits are subjected to attack. This crop is attacked by different species of insect pests in Bangladesh. These are Tomato Fruit worm, Potato Aphid, Stink Bugs and Leaffooted Bugs, Hornworms, Silver leaf, Whitefly etc. Among them tomato fruit borer *Helicoverpa armigera (*Hub.*)* is one of the major pests of tomato (Haque, 1995). Damage by this pest may be up to 85-93.7% (Tewaei, 1984). With the increasing threat of resistance in *Helicoverpa armigera* towards a wide range of pesticides, the necessity to design future pest management strategies to control this pest becomes more apparent.

The tobacco whitefly, *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) has been reported to be the most serious pest of tomato all over the world. *B. tabaci* is highly polyphagous and has been recorded on 540 plants species belonging to 77 families including numerous field crops, ornamentals and weeds (Basu, 1995). The whitefly causes damage to the plant by direct feeding and transmission of virus. Leaf miner populations were significantly correlated with leaf injury, whereby an increase of one leaf miner adult corresponds to 1.76% leaf injury, and an increase of one leaf miner larva corresponds to a 3.06% leaf injury. An increase in leaf injury by leafminer adult and larva decreases yield by 0.26% and 0.87%, respectively (Oloan *et al.* 2003).

In Bangladesh, very few research works have been done only on pesticide approaches for the management of tomato insect pests. The research work, cultural control, mechanical control, biological control by utilizing parasitoid and pathogens, development of resistant varieties, sex pheromone, and use of botanical insecticides etc are scantly. Use of chemical to control a disease is the most popular means to farmers till now. However, application of precise dose of the chemical to the field is a difficult job for them. Indiscriminate and long time use of chemical affect the soil health. Harmful chemical substances enter into the food chain that ultimately causes serious health hazards. Eco-friendly management of plant diseases such as use of botanical extracts has a great chance to save the beneficial soil microorganisms. Most of the botanical extracts also cost effective and readily available near to the farmers in timely. As a result botanical pesticides are becoming popular day by day. Now a days, these are using against many insects.

Use of botanical extract against pest control is however is a recent approach to insect pest management and it has drawn a special attention of the Entomologist all over the world. In Bangladesh, only a few attempts have been made to evaluate botanical extracts against insect pests (Karim, 1994). Many researchers reported botanical extracts having pesticide properties and thus having potential to be used against many insect pests. It would help to avoid environmental pollution caused by chemicals and thus become most rewarding one in our existing socio-economic conditions and environmental threat.

In light of the above back ground, the present piece of research work has been undertaken with the following objectives-

i. To know the effectiveness of different botanical pesticides utilized against different insect pest of tomato;

ii. To know the effect of different botanical pesticides on yield and yield contributing characters of tomato;

iii. To estimate the economics of tomato cultivation with different botanicals.

Chapter 2
Review of Literature

REVIEW OF LITERATURE

Tomato is one of the important vegetable in Bangladesh and as well as many countries of the world and a major source of vitamins and minerals. The crop has been given less attention by the researchers because of its use as process food and grown with lowest management practices. Among the several constraints for growing tomato, attack of insect pests are considered important. It has been postulated that without insect pests world food production would increase by about one-third (Van Emden, 1974). Insects cause damage directly by eating, grasping or sucking or indirectly by transmitting viral diseases (Berlinger and Dahan, 1988).

Sutton (1991) reported aphids, whitefly, cutworm, leaf miner, red spider, mite, thrips, and tomato hornworm as the pest of vegetative stages of tomato. Fruit borer, fruit worm, budworm are the pest of flower, fruits and leaves. Tomato hornworm and tobacco hornworn caterpillars are voracious leaf feeders, consuming entire leaves and small stems and may even chew large pieces from green fruit. Large number can defoliate tomato plant. Of these insect pests aphids, whitefly, cutworm, leaf miner and red spider mite are most damaging and could cause 25-60 per cent yield loss (Khan and Griffin, 1999).

Very few studies related to growth, yield and development of tomato and pests management through botanicals have been carried out in our country as well as many other developing countries of the world. So the research works so far done in Bangladesh are not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the botanical control of different insect pests of tomato so far been done at home and abroad on vegetable crop production have been reviewed in this chapter under the following heading :

2.1 Whitefly

The whiteflies cause damage to plant by three means, (i) large population of nymphs and adults suck sap directly from plant and greatly reduce yield, (ii) heavy colonization of *B. tabaci* can cause serious damage to some crops due to honeydew excreted by all stages, particularly the late nymphal instars which encourages growth of "sooty mould" that affect yield both in quantity and quality and (iii) they reduce crop yield through transmission of viral diseases (Kajita and Alam, 1996).

The adult of whitefly is soft and pale yellow, change to white within few hours due to deposition of wax on the body and wings (Haider, 1996). Eggs are laid indiscriminately almost always on the under surface of the young leaves. The whitefly, *Bemisia tabaci* is an important pest worldwide. The whiteflies are very small, fragile and active insects, jump from plant to plant with very slight disturbance and because of this there is great difficulty in handling them during experimental work (Parihar *et al.*, 1994).

Brown and Bird (1992) have pointed out the increased prevalence as well as expanded distribution of whitefly borne viruses during the last decade and resulting devastating impact. Yield loss range from 20-100 per cent, depending on the crop, season, vector prevalence and other factors.

The whitefly acts as a mechanical vector of many viral diseases (Butani and Jotwani, 1984). Young plant may even die in case of severe infestation. The pest is active during the dry season and its activity decreases with the on set of rains. As a result of their feeding the affected parts become yellowish, the leaves become wrinkle, and curl downwards and eventually fallen off. This happens mainly due to viral infection. Bock (1982) reported yield loss due to *Bean golden mosaic virus* (BGMV) varied from 40-100 %, depending on age and variety.

2.2 Leaf minor

Leafminers *(Phyllocmistis citrella)* a serious pest of tomato it belongs to the order Lepidoptera and Family Gracillariidae. Leafminers attack many row crops but are particularly damaging on celery, crucifers, cucurbits, okra, potato and tomato. Florida growers report that leafminers are the second most important tomato insect pest especially in south and central production areas. Leaf miners population peak between October and March. The two major species of leafminer that cause problems in vegetables are leafminer (*L. sativae*) and most commonly (*Liriomyza trifolii)* - sometimes referred to as the celery leafminer but which has no approved common name. The adults are small yellow and black flies about the size of a gnat. The female punctures or "stipples" the leaves with her ovipositor to lay eggs in the leaf tissue or to feed on sap.

Leafminer damage is easily recognized by the irregular serpentine mines in leaves, which are caused by feeding larvae. Heavy leaf mining damage can reduce photosynthesis and cause leaf desiccation and abscission. The yellow maggots with black, sickle-shaped mouthparts feed on the mesophyll or chlorophyll tissue between upper and lower leaf surface leaving a winding trail or pattern through the leaf. The tunnel is clear with the exception of a trail of black fecal material left behind as the maggot feeds.

There are three larval stages. Each larval instar is completed in 2 - 3 days. The larvae feed approximately 7 days growing to about 1/10 to inch in length prior to exiting the leaf to pupate on the ground or mulch under infested plants. Leafminer injury is readily visible to the grower but healthy plants can tolerate considerable damage without excessive loss of vigor and yield. Heavily damaged leaves will often drop, due in part to entry of pathogenic organisms into old mines.

Due to its feeding habit, this pest is resistant to many insecticides. Cyromazine (Trigard) alternated with abamectin (Agrimek) are effective against leafminer in tomato. Both of these products have limited crop registrations and must not be used on unregistered crops. Some other materials that may be used to conserve beneficials include azadirachtin (Neem ix) and Neem seed oil. Both products are approved for use by organic growers.

Field sanitation is an important control tactic that is overlooked. When crops are not present in the fields, leafminers can survive on a variety of broad-leaf weeds. These plants serve as reservoirs for pest.

Oloan *et al.* (2003) reported that the population of leaf miner on selected highland crops was assessed and the percent leaf injury caused by adult and larval leaf miner and effect of leaf miner population and leaf injury on the yield of garden pea, potato, onion, and tomato were determined. Population of leaf miner adult ($8.15/in^2$) and leaf injury (47.5%) were highest in potato. Larval count was highest in onion (3.03/leaf) and leaf injury by leaf miner larva was highest in garden pea (31.25%). Tomato had the lowest count of adult and larval leaf miner and the lowest leaf injury of all the crops tested. Correlation analysis showed that adult and larval populations were significantly correlated with leaf injury, whereby an increase of one leaf miner adult corresponds to 1.76% leaf injury, and an increase of one leaf miner larva corresponds to a 3.06% leaf injury. An increase in leaf injury by leaf miner adult and larva decreased yield by 0.26% and 0.87%, respectively.

2.3 Fruit borer

The tomato fruit borer, *Helicoverpa armigera* Hubner has been identified as a major pest of tomato in many countries of the world and cause damage to the extent of about 50-60 per cent fruits (Singh and Singh, 1977). It has a wide range of hosts including chickpea, pigeon pea (Arhar), cowpea (as the pod borer), blackram (as gram caterpillar), various leguminous crops (as pod borer), cotton (as american ball worm), maize (as cobworm), millets, sorghum and oil seed crops such as sunflower, soybean, groundnut etc. (Haque, 1995). It has been reported to infest 181 cultivated and uncultivated plant species in India, distributed in 45 families (Manjunath *et al*., 1985).

Tomato fruit borer, *Helicoverpa armigera* (Hub.) is one of the serious pests attacking tomoto. The pest causes damage to the extent of about 50-60 percent fruit (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93% (Tewari, 1985). Due to severe infestation fruits as well as seeds maturation hampered greatly (Dhamo *et al*., 1984). The viability of the seeds is reduced and quality seed is degraded. They bore circular holes and thrust only a part of their body inside the fruit and eat the contents. If the fruit is bigger in size, it is only partly damaged by the caterpillar but later it is invariably invaded by fungi bacteria and spoiled completely. A small-darkened partially healed hole at the base of the fruit pedicel is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually marketable. Sometimes the damage by this pest is followed by fungal infection which causes rotting of the fruits (Husain *et al*., 1988).

Jitender, *et al*. (1999) conducted the estimation of avoidable yield loss due to fruit borer, *Helicoverpa armigera*, in tomato (cv. Roma) planted at three dates (first week each of April, May and June), during 1993 and 1994, in Kullu valley, Himachal Pradesh, India, showed that in crop transplanted in the first week of April yield loss to the extent of 105.29, 76.02 and 57.02% could be avoided by giving three sprays of acephate (0.05%), fenvalerate (0.01%) and endosulfan (0.05%), respectively. In crop transplanted in the first week of May yield loss of 32.64, 28.04 and 18.50% could be avoided as a result of sprays of respective insecticides. Whereas in June-transplanted crop, 2 sprays each of acephate, fenvalerate and endosulfan helped in avoiding 25.03, 13.91 and 11.76% yield loss, respectively. Irrespective of dates of transplanting, the average yield loss to the extent of 49.27, 36.54 and 26.59% could be avoided by sprays of acephate, fenvalerate and endosulfan. The average net return per rupee invested worked out to be Rs 14 for acephate, Rs 13.18 for fenvalerate and Rs 7.80 for endosulfan sprays.

Pinto *et al.* (1997) high infestations of the noctuid *Helicoverpa armigera* on field-cultivated tomatoes (cultivars Interpel and Universal Mec) in the hilly area of Madonie, Palermo province, Sicily, in the summer of 1996. The infestations caused serious damage, resulting in a reduced, and at times, inadequate commercial return. Notes are given on the geographic distribution, host plants, morphology, biology, ecology, injuriousness, natural enemies and control of the pest. When the population exceeds the economic threshold, control can be effected using systemic products such as phosphoric esters (acephate, methomyl, dimethoate) or synthetic pyrethroids (alphamethrin [alpha-cypermethrin], deltamethrin); the latter must be used once only so as not to favour the build-up of mites. Agronomic methods of defence may also be used, such as weeding to kill the pupae, deep ploughing of adjacent uncultivated areas during the period of oviposition, and elimination of weeds on which the females oviposit.

Sivaprakasam (1996) carried out laboratory and field experiments on the ovipositional preference of *Helicoverpa armigera* on 9 tomato cultivars revealed that more laid on the under surface of leaves than on the petiole, inter nodal stem and calyx. More eggs were deposited on hairy than glabrous cultivars. Least number of eggs were deposited on cv. Paiyur-1. This was related to low trachoma density and long calyx.

The seasonal history of tomato fruit borer, *H. armigera* varies considerably due different climatic conditions throughout the year. A study revealed that the population of *H. armigera* began to increase from the mid January and peaked during the last week of February. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall. Parihar and Singh (1986) in India showed that, the larval population of *H. armigera* on tomato was low until the first week of February and increased rapidly there after, reaching a peak in the last week of March. In the last week of April, population declined to 4 larvae /10 plants, percentage fruit infestation was low up to the end of February, while in the season week of April 50.08% and 33.04% of fruit were infested in 1984 and 1985, respectively.

Patel and Keshiya (1997) worked on seasonal abundance of *H. armigera* during kharif season, the pest started its activity in groundnut from first week of July. There after, the pest moves to cotton crop from last week of July and started to build up its population during the month of August to mid September. Simultaneously the pest infestation was also noticed in Sunflower and pearl millet during this period but the population was very low in sunflower. However, in pearl millet, it was at peak during September. In Rabi season, pest activity was observed in chickpea during November to February. However, its population was at peak during December. In summer season, the pest started its activity on groundnut in February and was active up to June.

Tomato fruit borer is a versatile and widely distributed polyphagous insect. Beside Bangladesh, this pest occurs in Southern Europe, probably the whole of Africa, the Middle East, India, Central and South East Asia to Japan, the Philippines, Indonesia, New Guinea, the eastern part of Australia, New Zealand and a number of pacific islands except for desert and very humid region (Singh, 1972).

Tomato fruit borer *Helicoverpa armigera (*Hub.) is a polyphagous insect, belonging to the family Noctuidae of the order Lepidoptera. There are several genera under this family and the genus *Heliothis* contains more number of species, including *Heliothis armigera*, which is the serious pest of tomato (Mishra *et al*., 1996).

Reedy *et al*. (1996) reported that among the insect pests attacking chickpea, the pod borer, *H. armigera* Hub. is the most common and serious one causing up to 80 per cent yield loss. The loss in yield due to attack of *H. armigera* in India, as estimated on two pulse crops, chickpea and pigeon pea, may exceed $ 300 million annually. Adult females lay eggs on the flowering and fruiting structures of these crops, where voracious larval feeding leads to substantial economic loss (Reed and Pawar, 1982). The adult insect is a pale-brown or reddish-brown moth with a black dot on each of the forewings. Full-grown caterpillars are 44-48 mm long, apple green in color with whitish and dark-grey broken longitudinal stripes. Full-grown caterpillars drop down to ground and pupate in the soil (Butani and Jotwani, 1984). Incubation, larval and pupal periods is 2-4, 15-24 and 10-14 days, respectively. Eggs are generally laid singly on the leaves at the top of the plant or on the flowers or on the fruits. After 1-3 days of hatching the larvae begin feeding. They feed inside the fruit when only the posterior of the larval body is visible from outside. When first instar larvae emerged from eggs and fed on leaves, occasionally on inflorescence, and some burrowed into fruit when they reached the 3rd instar. During the 4th and 5th instars, they fed alternately on leaves and fruit, and occasionally on stems. Towards the end of their development, the larvae went through a searching phase to look for a shelter for metamorphosis. This typical sequence could be altered and become more complex in relation to the emerging site of the larvae. Green fruits of tomato are usually damaged by larvae of at least 7-8 days old which made several entry holes. Normally there is only one larva per green fruit, in which they complete their life cycle. More commonly green fruits are attacked at the calyx end and they appear to dislike ripen fruit. Usually ripening fruit is not attacked by fruit borer (Sutton, 1991).

2.4 Botanical pest management against pest

Sundarajan (2002) conducted methanol extracts of selected plants namely *Anisomeles malabarica, Ocimum canum [O. americana], O. basilicum, Euphorbia hirta, E. heterophylla, Vitex negundo, Tagetes indica and Parthenium hysterophorus* have been screened for their insecticidal activity against the fourth instar larvae of *H. armigera* by applying dipping method of the leaf extracts at various concentrations (0.25, 0.5, 1.0, 1.5 and 20) on young tomato leaves. The larval mortality of more than 50% has been recorded for all the plant extracts in 2 per cent test concentration (48 h) except *E. heterophylla* which recorded 47.3 per cent mortality in 2 per cent concentration. Among the plant extracts tested *V. negundo* is found to show higher rate of mortality (82.5%) at 2 per cent concentration.

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important for pest control like seed kernels of neem, *Azadiracta indica*, *Pongamia glabra* [*P. pinnata*], leaves of tobacco, *Nicotiana tabacum* and indiara, a neem based herbal product, against *H. armigera* on chickpea cv. I.C.C.V.5 for its management in Rabi seasons of 1993-96 at College of Agriculture, Nagpur, Maharashtra, India. The results revealed that the crop treated with the leaf extract of *N. tabacum* and seed extract of *P. glabra* (5%) and indiara (1%) and neem seed kernel extract (5%) exhibited low level of population built up compared to control.

Sundararajan (2001) carried out toxicological studies to evalute the effect of leaf methanolic extracts of 5 indigenous plant materials namely, *Abutilon indicum*, *Achyranthes aspera, Ailanthus excelsa, Alstonia venenata and Azima tetracantha* against *Helicoverpa armigera*. Twenty healthy larvae collected from a tomato field were released into plastic containers containing tomato leaves treated with each of the plant extracts. The larval mortality was recorded 48 h after the release. Larval mortality on tomato leaves treated with *Azima tetracantha, Achyranthes aspera, Abutilon indicm, Ailanthus excelsa and Alstonia venenata* averaged 51, 58, 62, 67 and 73%, respectively.

Ju *et al.* (2000) conducted six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest *Heliothis armigera* [*Helicoverpa armigera*]. An artificial diet containing 5% aqueous extracts of *Cynanchum auriculatum* or *Peganum harmala* var. multisecta showed strong toxicity to the larvae and caused mortality of 100% and 55%, respectively. These two extracts at the same dosage also significantly affected metamorphosis of the insect. An artificial diet containing 1% aqueous extracts of *C. auriculatum* or 5% aqueous extracts of *P. harmala* resulted in mortality of 85% and 55%, respectively, and a zero emergence rate. Tests of extracts of *C. auriculatum* made at different pH showed that the pH 3 and pH 10 portions of the extracts affected the larvae growth significantly. The other plant species tested were *Euphorbia helioscopia, Sophora alopecuroides, Peganum nigellastrum and Thermopsis lanceolata*; extracts of these species caused either much lower mortality of *H. armigera* or zero mortality (*E. helioscopia*).

Sundarajan and Kumuthakalavalli (2000) conducted Petroleum ether extracts of the leaves of *Gnidia glauca* Gilg., *Leucas aspera* Link., and *Toddalia asiatica* Lam. tested against sixth instar larvae of *Helicoverpa armigera* (Hubner.) at 0.2, 0.4, 0.6, 0.8 and 1.0% by applying to okra slices. After 24 h, percentage mortality, EC50 and EC90 were calculated. Total mortality was recorded in the treatment with 0.8% of the extract of *G. glauca.* Of the three leaf extracts used, *G. glauca* showed an EC_{50} of 0.31%.

Lopez *et al.* (1999) assayed short-term choice and no-choice feeding used to assess the antifeedant activity of *T. havanensis* fruit extracts (at 5000 ppm) against 5th-instar *H. armigera* larvae. The acetonic extract gave the highest activity and was further fractionated by silica gel column chromatography. Of the 7 fractions isolated, 5 were identified as the limonoids azadirone, trichilinone acetate, 14,15-deoxyhavanensin-1,7-diacetate, 14,15-deoxyhavanensine-3,7-diacetate and a mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate. Choice and no-choice feeding assays of each fraction at 1000 ppm, showed that the mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate had the highest antifeedant activity against *H. armigera* larvae. Azadirone and trichilinone acetate were also antifeedants. No antifeedant activity was found in the remaining fractions. It is suggested that all of the limonoids with antifeedant activity have a similar mode of action, which is probably toxic.

Khorsheduzzaman *et al.* (1998) reported that neem oil @ 30 ml/l of water can provide 41.11% infestation over control by the brinjal shoot and fruit borer. The neem oil provided 49.1% brinjal shoot and fruit borer infestation reduction over control.

Gopal, *et al.* (1997) conducted field trials in India during 1989-92 to determine the efficacy of insecticides (endosulfan and diflubenzurun), neem products and nuclear polyhedrosis virus (NPV) alone or in combination for the control of fruit borer, *Helicoverpa armigera*, on tomatoes. Neem seed kernel extract (NSKE) 3% + endosulfan 0.035% + NPV at 250 larval equivalents (LE) ha^{-1} applied 3 times at 45,55 and 65 days after planting gave the highest larval mortality, reduced fruit damage, and the highest fruit yield, followed by neem oil 3% + endosulfan 0.035% + NPV at 250LEha^{-1}, and endosulfan 0.07% gave the highest cost:benefit ratio, followed by NSKE 3% + NPV at 250LE ha^{-1}, AND NSKE 3% + endosulfan 0.035% +NPV at 250 LE ha^{-1}.

Tomato plants (variety UC-97) were cultivated in pots and left to become naturally infested with *Bemisia tabaci* in an open field and were sprayed with various concentrations of extract. The high concentration of all the tested extracts exhibited positive response (Diemetry, *et al.*, 1996). Saibllon *et al.* (1995) studied the effects of extracts from *Ricinus communis*, *Melia azadarach*, *Azadiracta indica*, and a tobacco derived commercial product against *Bemisia tabaci*. None of the treatments controlled *Bemisia tabaci*, but numbers were reduced on neem treated plants and these plots gave higher yield than others.

Botanical pesticides are becoming popular day by day. It was found that Lepidopteran insect is possible to control by botanical substances. Weekly spray application of the extract of neem seed kernel has been found to be effective against *Helicoverpa armigera* (Karim, 1994). The leaf extract of neem tested against the leaf caterpillar of brinjal, *Selepa docilis* Bult. at 5% concentration had a high antifeedent activity (Jacob and Sheila, 1994).

Chitra *et al.* (1993) reported that extract of leaves of *Argemone mexicana* (0.1%), leaves of *Azadirachta indica* (0.1%) and neemguard (0.5%) gave 76.18%, 69.55% and 55.92% control over untreated control, respectively. Butler and Henneberry (1991) reported that commercially available plant cooking oils (soybean, sunflower, corn and peanut) reduced adult and immature populations of *Bemisia tabaci* in tomato for 5 days following application.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2006 to April 2007 to evaluate some botanicals as pest management practices against pest complex in tomato. The materials and methods used for conducting the experiment were presented in this chapter under the following headings:

3.1 Experimental site

The present experiment was carried out in the field of Central Farm and in the laboratory of Entomology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^{0}74^{\prime}$N latitude and $90^{0}35^{\prime}$E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Characteristics of soil

The soil of the research area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil testing Laboratory, SRDI Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix I.

3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon or the rainy season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the metrological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting materials

In this research work, the seeds of tomato of the variety BR-2 (Ratan) were sown in seed bed. The seedlings were the farm product of Sher-e-Bangla Agricultural Farm. The age of the seedling was 30 days during transplanting.

3.5 Treatments of the experiment

The experiment considered eight treatments. The details of the experiments were presented below:

T_1: Neem leaf extract @ 0.5 kg/L of water at3 days interval)

T_2: Neem leaf extract @ 0.5 kg/L of water at 7 days interval)

T_3: Neem oil @ 3.0 ml/L of water +trix at 3 days interval)

T_4: Neem oil @ 3.0 ml/L of water +trix at 7 days interval)

T_5: Garlic extract @ 0.5 kg/L of water at 3 days interval)

T_6: Marsh Pepper extract @ 0.5 kg/L of water at 3 days interval)

T_7: Marsh Pepper extract @ 0.5 kg/L of water at 7 days interval)

T_8: Untreated control

3.6 Design and layout of the Experiment

The experiment was laid out at Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatment combinations in each plot of each block. There were 24 unit plots altogether in the experiment. The size of the plot was 2.0 m × 1.5 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.7 Preparation of the main field

The selected experimental field was opened in the First week of November 2006 with a power tiller and was exposed to the sun for a week for sun drying. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth for the growth of tomato seedlings. Weeds and stubbles were removed and finally obtained a desirable tilth of soil. The experimental field was partitioned into unit plots in accordance with the experimental design.

3.8 Application of manure and fertilizers

Well decomposed cowdung as per recommendation was applied at the time of final land preparation (Rashid, 1993) The sources of fertilizers used for N, P and K were urea (500 kg/ha), TSP (400 kg/ha), MP (200 kg/ha), respectively (Rashid, 1993). The entire amounts of TSP, MP were applied during final land preparation. Only urea was applied in three equal installments at 30 and 45 and 60 Days after planting (DAT).

3.9 Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development. After 15 days of transplanting a single healthy seedling and luxuriant growth per pit was allowed to grow discarding the others, propping of each plant by bamboo stick was provided on about 1.0 m height from ground level for additional support and to allow normal creeping. Weeding and mulching in the plot were done, whenever necessary.

3.10 Irrigation

Light over-head irrigation was applied with a watering can in the plots immediately after germination of seed. Irrigation was also applied two times considering the moisture status of field.

3.11 Weeding

Weeds were found in the plots and weeding was done three times in the plots considering the optimum time for removal.

3.12 Data collection

The data were recorded on the incidence of white fly, leaf miner infested leaves and fruit borer infested shoots, infested and healthy fruit and yield contributing characters and yield of tomato.

3.12.1 Incidence of whitefly

For recording data on whitefly, five (5) plants from each plot were randomly selected and tagged. Five fully expanded compound leaves from top, middle and bottom of each plant were checked silently without jerking the plant in situ at an interval of 10 days commencing from vegetative to ripening stage and counted the number of whitefly up to the last harvesting of the fruit.

3.12.2 Leaf minor infested leaves

For recording the data on leaf miner infested leaves five (3) plants from each plot were randomly selected. Five fully expanded compound leaves from top, middle and bottom of each plant were checked visually and the infestation was identified. Percent infestation of leaf was estimated by measuring length and breadth of total and infested leaf.

3.12.3 Fruit borer infestation

Total number of fruits and infested fruits (bored) 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 made by the larvae.

The percentage of borer infested fruits was calculated using the following formula:

$$\text{\% Borer infested fruit (by number)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\text{\% Borer infested fruit (by weight)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

3.12.4 Yield contributing characters and yield

3.12.4.1 Plant height

The height of plant was recorded in centimeter (cm) during harvest by using a meter scale. The height was measured from the ground level to the tip of the growing point of an individual plant. Mean value of the 5 selected plants was calculated for each unit plot.

3.12.4.2 Number of leaves per plant

Number of leaves per plant was counted at harvest from 5 plants and mean value was recorded.

3.12.4.3 Number of branch per plant

Number of branch per plant was counted at harvest from 5 plants and mean value was calculated.

3.12.4.4 Number of flower bunch per plant

Number of flower bunch per plant was counted at harvest from 5 plants and mean value was calculated.

3.12.4.5 Number of flower per bunch

Number of flower per bunch was counted at harvest from 5 plants and mean value was calculated.

3.12.4.6 Single fruit weight (g)

Single fruit weight was measured by weighing 10 randomly selected fruits in every harvest and mean value were computed.

3.12.4.7 Healthy and infested fruit

The number of the healthy and infested fruit was counted at each harvest and continued up to the last harvest from the plants. Healthy fruits recorded at each observation were pooled and finally expressed in percentage.

3.12.4.8 Yield per hectare

The data on the number of healthy, infested and deformed fruits for each treatment from whole plot along with their number and weight were recorded at each harvest. The plot yield of healthy, infested and deformed fruits was transformed into healthy, infested and deformed fruit yields in ton per ha. Sum of the marketable yield, infested and deformed fruit yield finally expressed as the total yield in ton per ha.

3.12.4.9 Benefit Cost Ratio (BCR):

Economic analysis of different botanicals as pest management practices was calculated. In this study, the untreated control did not require any pest management cost. The cost for the treatment of neem oil was incurred for Neem oil, trix liquid detergent, its preparation and its application. For leaf extract labor cost also involved.

3.13 Statistically 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 MSTAT Program. The significance of the difference among the treatment means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of probability (GomezandGomez, 1984).

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

The present experiment was conducted to evaluate some botanicals as pest management practices against pest complex in tomato. Data on whitefly abundance, leaf miner infestation on leaf and fruit borer infestation and their effect on yield and yield contributing characters were recorded. The results of different parameter under the experiment have been presented, discussed, and possible interpretations also given under the following headings:

4.1 Number of white fly

At vegetative, early and late flowering, fruiting and ripening stages,statistically significant variation was recorded in number of whitefly per plot in tomato (Appendix III).

At vegetative stage the lowest number of whitefly per plot (2.20) was recorded from the treatment T_3 plots having application of neem oil (@ 3.0ml/L of water) at 3 days interval which was statistically similar (2.80) to that of T_6 treated plots using marsh pepper (@0.5 kg/L of water) applied at 3 days interval (Table-1). No significant difference was found among the effects of Neem leaf extract (@0.5 kg/L of water) (3.40) and garlic extract (@0.5 kg/L of water) (3.60) applied at 3 days interval in controlling whitefly. On the other hand the highest (21.20) number of whitefly per plot was recorded from T_8 untreated plots which was closely followed (5.80) by T_2 and T_7 (5.00) treated plots using neem leaf extract (@0.5 kg/L of water) and marsh pepper extract (@0.5 kg/L of water) applied at 7 days interval, respectively (Table-1).

At early flowering stage the lowest number of whitefly per plot (4.80) was recorded from T_3 treated plots which was statistically similar (5.00) with that of treatment T_6, while the highest (25.80) number of white fly per plot was recorded from untreated control plot which was followed (7.80) by T_2 treatment (Table-1). Statistically significant and similar results was found in T_1 (5.60) and T_5 (6.20) treated plots utilizing as application of Neem leaf extract

(@0.5 kg/L of water) and Garlic extract (@0.5 kg/L of water) at 3 days interval, respectively. At late flowering stage lowest number of white fly per plot (5.60) was recorded from T_3 and T_6 treated plots, while the highest (29.20) number of white fly per plot was recorded from untreated control which was closely followed (9.20) by T_2 and T_7 (8.80) treated plots (Table-1).

At early fruiting stage the lowest number of whitefly per plot (3.80) was recorded from the treatment T_3 which was statistically similar (4.00) with that of treatment T_6, while the highest (26.60) number of white fly per plot was recorded from untreated control plots which was followed (7.40) by the T_2 treated plots. At late fruiting stage the lowest number of whitefly per plot (3.20) was recorded from the treatment T_3 which was statistically similar (3.60) with that of treatment T_6, while the highest (21.80) number of whitefly per plot was recorded from untreated control which was followed (7.20) by the treatment T_2. At ripening stage the lowest number of whitefly per plot (2.80) was recorded from T_3 treated plots which was statistically identical (3.20) that of the treatment T_6. On the other hand the highest (20.40) number of whitefly per plot was recorded from untreated control plots which followed (5.80) by the T_2 treated plots. Total number of white fly per plot in tomato for different treatment showed statistically significant differences (Appendix III). The lowest number of whitefly per plot (22.40) was recorded from T_3 treated ones which was followed (24.20) by the T_6 treated plots. On the other hand the highest (145.00) number of whitefly per plot was recorded from untreated control plots (T_8) which was followed (43.20) by the treatment T_2 treated plots Among rest of the treatments number of whitefly was the lowest in treatment T_1 (26.80) & T_5 (29.80) and highest number of whitefly per plot was recorded from T_4 (35.20) & T_7 (40.00) treated plots. The highest (84.55%) reduction of whitefly incidence over control was recorded from the T_3 treated plots.

Table 1. Effect of some botanicals as the management approaches against white fly in the tomato field per plot during the cultivation period of 2006-2007

Treatment	Number of white fly per plot							
	Vegetative stage	Flowering stage		Fruiting stage		Ripening stage	Total	Reduction over control (%)
		Early	Late	Early	Late			
T_1	3.40 cde	5.60 de	6.00 de	4.80 c	3.60 ef	3.40 de	26.80f	81.52
T_2	5.80 b	7.80 b	9.20 b	7.40 b	7.20 b	5.80 b	43.20b	70.21
T_3	2.20 e	4.80 e	5.60 e	3.80 c	3.20 f	2.80 e	22.40h	84.55
T_4	4.80 bcd	6.80 bcd	8.20 c	5.60 bc	5.20 d	4.60 bcd	35.20d	75.72
T_5	3.60 cde	6.20 cde	6.80 d	5.20 c	4.00 e	4.00 cde	29.80e	79.45
T_6	2.80 de	5.00 e	5.60 e	4.00 c	3.60 ef	3.20 de	24.20g	83.31
T_7	5.00 bc	7.40 bc	8.80 bc	7.20 b	6.40 c	5.20 bc	40.00c	72.41
T_8	21.20 a	25.80 a	29.20 a	26.60 a	21.80 a	20.40 a	145.00a	--
$LSD_{(0.05)}$	1.931	1.411	0.853	1.895	0.724	1.309	1.276	--
CV(%)	18.08	9.28	4.91	13.40	6.02	12.11	7.59	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)
T_2: Neem leaf extract (@ 0.5 kg/L of water at 7 days interval)
T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)
T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)
T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)
T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)
T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)
T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Reduction of whitefly incidence was recorded from (83.31%)T_6 treatment which was followed (81.52%) by the treatment T_1 While the lowest (70.21%) reduction over control was recorded from T_2 treated plots. Here reduction over control of whitefly incidence were (75.72%), (79.45%) & (72.41%) obtained from T_4, T_5 & T_7 treated plots (Table 1).

From the above results it was found that Neem oil (@3.0 ml/L of water) and marsh pepper (@0.5 kg/L of water) extract at 3 days interval was most effective in reduction whitefly incidence. The results of Neem leaf extract (@0.5 kg/L of water) and garlic (@0.5 kg/L of water) extract had significant effect on whitefly controlling. But the performance of Neem oil (@3.0 ml/L of water) and marsh pepper (@0.5 kg/L of water) extract at 7 days interval was poor as compared to that of untreated control. Similar results have been reported by Maleque *et al.* (2002).

4.2 Leaf infestation for leaf miner attack (%)

At early, mid and late fruiting and ripening stage statistically significant variation was recorded for leaf infestation due to the attack of leaf miner (Appendix IV).

As shown in Table 2, at early fruiting stage the lowest leaf infestation (1.05%) due to leaf miner attack was recorded from T_3 treated plot which was statistically identical (1.42%) to that of the treatment T_6. At early fruiting stage the lowest leaf infestation also found (1.88%) in treatment T_1 and was followed (2.56%) by the treatment T_5. On the other hand the highest leaf infestation (7.22%) was recorded from untreated control which was followed (3.95%) by the treatment T_2. The intermediate level leaf infestation was recorded 3.00% & 3.61%from the treatment T_4 & T_7 treated plots (Plate 1A and 1B).

At mid fruiting stage the lowest leaf infestation (1.22%) due to leafminer attack was recorded from the treatment T_3 which was followed (1.95%) by the treatment T_6. At mid fruiting stage the lowest leaf infestation also found (2.33%) in treatment T_1 was followed (2.82%) by the treatment T_5. On the other hand the highest leaf infestation (9.39%) was recorded from untreated control which was followed (4.02%) by the treatment T_2. No significant difference was observed in leaf infestation (3.16%) from the treatment T_4 and treatment T_7 (3.52%) (table-2) .

At late fruiting stage the lowest leaf infestation (2.66%) due to leaf miner attack was recorded from the treatment T_3 which was statistically identical (3.285%)to that of the treatment T_6(table-2). At late fruiting stage the lowest leaf infestation also found (2.44%) in treatment T_1 which was followed (3.66%) by the treatment T_5. On the other hand the highest leaf infestation (12.25%) was recorded from untreated control which was closely followed (4.34%) by T_2 treated plot. The leaf infestation was moderate (3.85%) in the treatment T_4 which was closely followed (4.08%) by the treatment T_7 (table-2).

At early ripening stage the lowest leaf infestation (3.84%) due to leaf miner attack was recorded from T_3 treated plot which was closely followed (3.92% and 4.12%) by the treatment T_6 and T_1, respectively. At early ripening stage the lowest leaf infestation also found (4.68%) in treatment $T_{5.}$ On the other hand the highest leaf infestation (17.81%) was recorded from untreated control which was followed (6.03%) by the treatment T_2. At early ripening stage intermediate level of leaf infestation was found (5.00%) in treatment $T_{4,}$ which was followed (5.86%) by the treatment T_7.

At mid ripening stage the lowest leaf infestation (4.62%) due to leaf miner attack was recorded from the treatment T_3 which was statistically similar (4.95% and 5.02%) with the treatments T_6 and T_1, respectively. On the other hand the highest leaf infestation (21.08%) was recorded from untreated control which was followed (6.46%) by the treatment T_2.

At mid ripening stage medium level of leaf infestation (5.29%), (5.81%) and (6.08%) was also recorded from the $T_{5,}$ T_4 and T_7 treated plot, respectively (table-2). At late ripening stage the lowest leaf infestation (5.75%) for leaf miner attack was recorded from the T_3 treated plot which was statistically identical (6.38%) with the T_6 treated once. On the other hand the highest leaf infestation (26.86%) was recorded from untreated control which was followed (8.35%) by the treatment T_2 (Plate 1C). At late ripening stage leaf infestation ranged from 6.92 % - 8.12% in T_2, T_5 T_4 and T_7 treated plot, respectively (table-2).

Average leaf miner infested leaf (%) for various treatment showed statistically significant differences among than (Appendix IV). The lowest average leaf infestation (3.19%) was recorded from T_3 treated plot which was followed (3.65%) by T_6. treated plot .On the other hand the highest (15.77) leaf infestation was recorded from untreated control plots which was followed (5.52) by the T_2 treated plots.

Average leaf miner infested leaf (%) from various treatments T_2, T_5, T_4 and T_7 ranged from 3.95%-5.21% which showed statistically significant difference among the treatment. Reduction of leaf infestation for different treatment was calculated over control. The highest (79.77%) reduction of leaf infestation over control was recorded from the T_3 treated plot while the lowest (65.00%) was recorded from T_2 treated plot (Table 2)

From the above information on whitefly incidence and abundance of leaf miner infestation on tomato, it may concluded that in controlling these pests the neem oil (@ 3.0ml/L of water) and marsh pepper (@0.5 kg/L of water)extract applied at 3 days interval was most effective while the performance of Neem leaf extract (@0.5 kg/L of water) and garlic extract (@0.5 kg/L of water) at 3 days interval was effective but the effectiveness of Neem oil and marsh pepper applied at 7 days interval was poor.

Table 2. Effect of some botanicals as pests management practices on percent leaf infestation due to the attack of leaf miner in tomato field during 2006-07.

Treatment	% leaf infestation at							
	Fruiting stage			Ripening stage			Average	Reduction over control (%)
	Early	Mid	Late	Early	Mid	Late		
T_1	1.88 e	2.33 e	3.44 bcd	4.12 d	5.02 d	6.92 de	3.95 ef	74.95
T_2	3.95 b	4.02 b	4.34 b	6.03 b	6.46 b	8.35 b	5.52 b	65.00
T_3	1.05 f	1.22 f	2.66 d	3.84 d	4.62 d	5.75 f	3.19 g	79.77
T_4	3.00 c	3.16 cd	3.85 bc	5.00 bcd	5.81 bc	7.81 bc	4.77 cd	69.75
T_5	2.56 d	2.82 d	3.66 bc	4.68 cd	5.29 cd	7.44 cd	4.41 de	72.04
T_6	1.42 f	1.95 e	3.28 cd	3.92 d	4.95 d	6.38 ef	3.65 fg	76.85
T_7	3.61 b	3.52 c	4.08 bc	5.86 bc	6.08 bc	8.12 bc	5.21 bc	66.96
T_8	7.22 a	9.39 a	12.25 a	17.81 a	21.08 a	26.86 a	15.77 a	--
$LSD_{(0.05)}$	0.376	0.384	0.877	1.164	1.164	0.726	0.576	--
CV(%)	6.93	6.18	10.68	10.38	5.18	4.27	5.67	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)
T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)
T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)
T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)
T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)
T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)
T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)
T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Plate 1A

Plate 1B

Plate 1C

Plate 1. A. Healthy plant of tomato
B. Leaf miner infested leaf
C. Leaf miner infested tomato plant

4.3 Fruit borer infestation

4.3.1 Fruiting status of tomato at early stage

4.3.1.1 Healthy fruit by number

Statistically significant variation was recorded in number of healthy and infested fruit, % infestation at early fruiting stage against tomato fruit borer using different botanicals as pest management practices under the present trial (Appendix V). The highest number of healthy fruit per plant (9.58) was recorded from the treatment T_3 which was statistically identical (9.07 and 9.02) to that of the treatment T_1 and T_6, respectively (Table 3) (Plate 3). On the other hand the lowest (6.70) number of healthy fruit was recorded from untreated control which was followed (7.48) by the treatment T_2. From T_4, T_7 & T_5 treated plots healthy fruits were harvested and they were ranged from (7.71%-8.24%). The lowest % of infested fruit in number (1.77%) was recorded from the treatment T_3 which was statistically similar (2.40% and 2.55%) to that of the treatment T_6 and T_1. On the other hand the highest % of infested fruit in number (11.71%) was recorded from untreated control which was followed (7.76% and 6.81%) by the treatment T_2 and T_7. Moderate results were found (5.95%), (6.61) from treatment T_4, and T_5 respectively (Plate 2). Divakar *et al.* (1987) reported almost the similar results from their experiment. These findings are in agreement with the findings of Divokar and Pawar (1987). Fruit infestation reduction over control in number was estimated and the highest (84.88%) infestation reduction over control was recorded from the treatment T_3 which was followed by neem leaf extract treated plots (78.22) and the lowest was (33.73%) recorded from the T_2 treated plots (Table 3). From the findings it is revealed that treatment T_3 produced the highest number of healthy fruit and the lowest number of infested fruit as well as the lowest % of fruit infestation in number whereas in control treatment the situation is reverse.

Table 3.Effect of some botanicals as pests management practices in controlling tomato fruit borer at early harvesting stage in terms of fruits per plant by number and weight

Treatment	Tomato fruit by number				Tomato fruit by weight (g)			
	Healthy	Infested	% infestation	Increase over control (%)	Healthy	Infested	% infestation	Increase over control (%)
T_1	9.07 ab	0.24 c	2.55 c	78.22	824.50 b	50.21 e	5.74 bc	50.60
T_2	7.48 cd	0.63 b	7.76 b	33.73	772.38 bc	80.53 b	9.46 ab	18.59
T_3	9.58 a	0.17 c	1.77 c	84.88	901.07 a	32.81 f	3.52 c	69.71
T_4	7.71 c	0.55 b	6.61 b	43.55	805.48 bc	74.65 c	8.53 abc	26.59
T_5	8.24 bc	0.50 b	5.95 b	49.19	798.89 bc	52.23 e	6.12 abc	47.33
T_6	9.02 ab	0.22 c	2.40 c	79.50	880.36 a	51.93 e	5.57 bc	52.07
T_7	7.82 c	0.57 b	6.81 b	41.84	754.97 c	66.30 d	8.06 abc	30.64
T_8	6.70 d	0.89 a	11.71 a	--	693.55 d	90.96 a	11.62 a	--
$LSD_{(0.05)}$	0.884	0.124	1.995	--	54.78	5.193	5.193	--
CV(%)	7.84	15.24	16.38	--	4.69	8.56	10.23	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)
T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)
T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)
T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)
T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)
T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)
T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)
T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Plate 2A

Plate 2B

Plate 2. A. Borer infested Tomato B. Borer infested fruit with larva

4.3.1.2 Tomato fruit by weight

Statistically significant variation was recorded in weight of healthy and infested fruit, % infestation at early fruiting stage against tomato fruit borer using different botanicals as pest management practices under the present trial (Appendix V). Highest weight of healthy fruit per plant (901.07 g) was recorded from the T_3 treated plots which was statistically identical (880.6 g) to that of the treatment T_6 (Table 3). The second highest healthy fruit weight was recorded from T_1 (824.50g) treated plots which was followed by T_4 (805.48g) and T_5 (798.89g) treated ones. On the other hand the lowest (693.55 g) weight of healthy fruit was recorded from untreated control which was followed (772.38 g) by the treatment T_2. Thakur *et al.* (1998), Divokar and Pawar (1987), Gopal and Senquttuvan (1997) reported the similar results. This finding was supported by the findings of Divakar *et al.* (1987). Fruit infestation reduction over control in weight was estimated the highest (69.71%) infestation reduction over control was recorded from the treatment T_3 and the lowest was (18.59%) recorded from the treatment T_2. From the findings it is revealed that treatment T_3 produced the highest number of healthy fruit and the lowest % of fruit infestation in weight Whereas in control treatment the situation is reverse under the present condition. The treatment of T_1 and T_5 was successful against tomato fruit borer next to T_3 and T_6 applied at 3 days interval. But when interval increased to 7 days for application with the same spray material their performance was poor.

4.3.2 Fruiting status of tomato at mid stage

4.3.2.1 Tomato fruit by number

Statistically significant variation was recorded by number of healthy and infested fruit, % infestation at mid fruiting stage against tomato fruit borer using for different botanicals as pest management practices (Appendix VI). The highest number of healthy fruit per plant (10.33) was recorded from the treatment T_3 which was statistically identical with 10.01 and 9.42 using the treatment T_6 and T_1, respectively (Table 4). The second highest number of healthy fruits was found in T_5 (8.99) treatment which was followed by T_7 (8.26) and T_4 (7.92) treated plots. On the other hand the lowest (7.68) number of healthy fruit was obtained from untreated control plots which were followed (7.82) by the T_2 treated plots. The lowest % of infestation in number (2.55%) was recorded from the treatment T_3 which was statistically similar (3.70%) with the treatment T_6 and T_1 (4.57%). On the other hand the highest % of infested fruit in number (13.65%) was recorded from untreated control (T_8) which was closely followed (11.09%) by the treatment T_2 and T_4 (10.70%). Percent infestation was lower in treatment T_5 (7.54%) and T_7 (8.57%) treated plots. Fruit infestation reduction over control in number was calculated with highest value (81.32%) infestation reduction over control was recorded from T3 treated plots and the lowest (18.75%) recorded from the T_2 (Table 4) treated plots. Fruit infestation reduction over control ranged from (37.22-66.52) in T_7, T_5 and T_1 treated plots. From the findings it is revealed that at mid fruiting stage T_3 treatment produced the highest healthy fruit and the lowest infested fruit in number as well as the lowest % of fruit infestation in number whereas in control treatment the situation is reverse under the present condition. At mid stage infestation level was higher than the early stage. Divakar *et al.* (1987) had similar results reported earlier from their study. Divokar and Pawar (1987), Gopal and Senquttuvan (1997) also reported the similar results.

4.3.2.2 Tomato fruit by weight

Statistically significant variation was recorded by weight of healthy and infested fruit, % infestation at mid fruiting stage using different botanicals as pest management practices for controlling tomato fruit borer. (Appendix VI). Highest Weight of healthy fruit per plant (927.11 g) was recorded from the treatment T_3 which was statistically identical (900.98 g) with the T_6 treated plots(Table 4). The second highest weight of healthy fruit was found in T_1 (878.27g) which was followed by T_4 (788.89g) and T_7 (747.45g) treated plots.

Table 4.Effect of some botanicals as pests management practices in controlling tomato fruit borer at mid harvesting stage in terms of fruits per plant by number and weight

Treatment	Tomato fruit by number			Tomato fruit b weight (g)		
	Healthy	% infestation	Increase over control (%)	Healthy	% infestation	Increase over control (%)
T_1	9.42 abc	4.57 d	66.52	878.27 a	6.65 c	47.56
T_2	7.82 de	11.09 b	18.75	651.34 d	12.65 a	0.24
T_3	10.33 a	2.55 e	81.32	927.11 a	3.66 d	71.14
T_4	7.92 de	10.70 b	21.61	788.89 b	10.23 b	19.32
T_5	8.99 bcd	7.54 c	44.76	694.21 cd	7.14 c	43.69
T_6	10.01 ab	3.70 de	72.89	900.98 a	6.26 c	50.63
T_7	8.26 cde	8.57 c	37.22	747.15 bc	9.69 b	23.58
T_8	7.68 e	13.65 a		643.14 d	12.68 a	--
$LSD_{(0.05)}$	1.125	1.634	--	66.00	1.313	--
CV(%)	5.74	14.61	--	4.02	6.60	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)
T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)
T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)
T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)
T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)
T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)
T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)
T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

On the other hand the lowest (643.14 g) weight of healthy fruit was recorded from untreated control which was followed (651.34 g) by the T_2 treated plots. The lowest % of infested fruit by weight (3.66%) was recorded from the treatment T_3 which was followed (6.26% and 7.14%) with the treatment T_6 and T_5, respectively. On the other hand the highest % of infested fruit in weight (12.68%) was recorded from untreated control which was statistically similar (12.65%) to treatment T_2. Divakar *et al.* (1987), Gopal and Senqputtuvan (1997), Kulat *et al.* (2001), Sundarajan (2001 & 2002) also reported similar results in their studies. Fruit infestation reduction over control by weight was estimated the highest (71.14%) from the T_3 treated plots and the lowest (0.24%) was recorded from T_2 treatment (Table 4). From the findings it is revealed that treatment T_3 produced higher healthy fruits and the lower infested fruit as well as the lowest % of fruit infestation by weight whereas in control treatment the result is reverse

4.3.3 Fruiting status of tomato at late stage

4.3.3.1 Tomato fruit by number

Statistically significant variation was recorded in number of healthy and infested fruit, % infestation at late fruiting stage utilizing different botanicals as pest management practices for controlling tomato fruit borer (Appendix VII). The highest number of healthy fruit per plant (12.53) was recorded from the treatment T_3 which was statistically identical to (11.98, 11.42 and 10.35 obtained from the treatment T_6 and T_1 and T_4, respectively (Table 5). On the other hand the lowest (8.93) number of healthy fruit was recorded from untreated control plots which was statistically similar (9.43) to that of the treatment T_2. The lowest % of infested fruit in number (3.04%) was recorded from the treatment T_3 which was statistically similar (3.73%) to that of the treatment T_6. On the other hand the highest % of infested fruit in number (14.43%) was recorded from untreated control which was followed (11.41%) by the treatment T_2. Divakar *et al.* (1987) reported the similar results from their study. Fruit infestation reduction over control by number was calculated the highest (78.93%) from the treatment T_3 and the lowest (20.93) obtained from T_2 treatment (Table 5). From the findings it is revealed that treatment T_3 produced the highest number of healthy fruit and the lowest % of fruit infestation by number whereas in control treatment the situation was reverse. At late stage, the infestation level was higher than the early stage.

4.3.3.2 Tomato fruit by weight

Statistically significant variation was recorded by weight of healthy and infested fruit, % infestation at late fruiting stage using different botanicals as pest management practices for controlling tomato fruit borer (Appendix VII).The highest weight of healthy fruit per plant (1073.43 g) was recorded from the treatment T_3 which was statistically identical (980.82 g) to those of the treatment T_6 (Table 5). On the other hand the lowest (829.89 g) weight of healthy fruit was recorded from the treatment T_2 which was followed (852.52 g) by untreated control. The lowest weight of infested fruit (36.32 g) was recorded from the treatment T_3 which was followed (75.71 g) by the treatment T_6, while the highest weight of infested fruit (185.32 g) was recorded from untreated control and this was followed

Table 5.Effect of some botanicals as pests management practices in controlling tomato fruit borer at late harvesting stage in terms of fruits per plant in number and weight

Treatment	Tomato fruit in number			Tomato fruit in weight (g)		
	Healthy	% infestation	Increase over control (%)	Healthy	% infestation	Reduction over control (%)
T_1	11.42 ab	5.00 d	65.35	910.50 bc	7.60 d	57.52
T_2	9.43 c	11.41 b	20.93	829.89 c	16.11 ab	9.95
T_3	12.53 a	3.04 d	78.93	1073.43 a	3.26 e	81.78
T_4	10.35 bc	10.50 bc	27.23	931.53 bc	14.66 bc	18.05
T_5	9.51 c	7.86 c	45.53	942.34 bc	9.08 d	49.25
T_6	11.98 a	3.73 d	74.15	980.82 ab	7.20 d	59.75
T_7	9.75 c	10.35 bc	28.27	893.33 bc	13.61 c	23.92
T_8	8.93 c	14.43 a	--	852.52 bc	17.89 a	--
$LSD_{(0.05)}$	1.360	2.645	--	121.8	1.956	--
CV(%)	7.40	18.22	--	7.50	9.99	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)
T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)
T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)
T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)
T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)
T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)
T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)
T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(158.95 g) by the treatment T_2. The lowest % of infested fruit by weight (3.26%) was recorded from the treatment T_3 which was followed by (7.20% and 7.60%) obtained from the treatment T_6 and T_1, respectively. On the other hand the highest % of infested fruit by weight (17.89%) was recorded from untreated control which was statistically similar (16.11%) to that of the treatment T_2. Divakar *et al.* (1987), Alam *et al.* (1996), Azam *et al.* (1997) reported the similar results. This finding agreed with those of Brown and Bird (1992) and Channarayappa *et al.* (1982).

Fruit infestation reduction over control by weight was calculated as the highest (81.78%) from the treatment T_3 and the lowest (9.95%) was obtained from the treatment T_2 (Table 5). From the findings it is revealed that T_3 had to potential to produce the highest number of healthy fruit and the lowest number of infested fruit the lowest % of fruit infestation by weight was also evident. But in control treatment the result was reverse. At late stage the infestation level was higher than those of early and mid stage.

4.3.4 Fruit bearing status of tomato

4.3.4.1 Tomato fruit by number

Statistically significant variation was recorded in number of healthy and infested fruit, % infestation utilizing different botanicals as pest management practices for controlling tomato fruit borer (Appendix VIII).

As shown in Table 6 the highest number of fruit per plant (33.20) was recorded from the treatment T_3 which was followed (32.08) by the treatment T_6. The next highest fruit per plant was recorded fromT_1 (31.20) treated plots which was followed by T_5 (28.79) and T_4 (28.68) treated ones. The lowest (26.92) number of total fruit was recorded from untreated control which was followed (27.55) by T_2.treated plots. Highest number of healthy fruit per plant (32.44) was recorded from the treatment T_3 which was statistically identical (31.01) to those of T_6 treated plots. Among the treatment T_1, T_4 and T_5 the healthy fruit by number per plant was highest in T_1 (29.91) and this was followed by T_5 (2674)

and T_4 (25.97) treated plots. On the other hand the lowest (23.31) number of healthy fruit was recorded from untreated control which was statistically similar (24.73) to those T_2 treated plots. The lowest % of infestation in fruit by number (2.50%) was recorded from the treatment T_3 and this was statistically similar (3.31%) to those of the treatment T_6. In T_1 (4.13) treatment the percent infestation was also lower which was followed by T_5 (7.13). On the other hand the highest % of infested fruit by number (13.373%) was recorded from untreated control which was followed (10.22%) by the treatment T_2 and T_4 (9.44). Divakar *et al.* (1987) reported the similar in their present study. Fruit infestation reduction over control in number was calculated to be the highest (81.30%) in the treatment T_3 and the second highest was (75.24%) obtained T_6 which was followed by T_1 (69.11%). The lowest (23.56%) was recorded from the treatment T_2.

From the findings it is revealed that treatment the treatment T_3 produced the highest number of healthy fruits and the lowest number of infested fruit, as well as the lowest % of fruit infestation by number, whereas in control treatment the situation was reverse.It was evident that the performance of neem leaf extract and garlic extract was better compare to that of neem oil applied with frequent intervals. At late stage, the infestation level was higher than the early stage.

Table 6. Effect of some botanicals as pests management practices in controlling tomato fruit borer in terms of fruits per plant in number during total cropping season

Treatment	Tomato fruit/plant in number			
	Total	Healthy	% infestation	Increase over control (%)
T_1	31.20 c	29.91 b	4.13 e	69.11
T_2	27.55 f	24.73 cd	10.22 b	23.56
T_3	33.27 a	32.44 a	2.50 f	81.30
T_4	28.68 d	25.97 c	9.44 bc	29.39
T_5	28.79 d	26.74 c	7.13 d	46.67
T_6	32.08 b	31.01 ab	3.31 ef	75.24
T_7	28.30 e	25.83 c	8.73 c	34.70
T_8	26.92 g	23.31 d	13.37 a	--
$LSD_{(0.05)}$	0.341	2.048	0.928	
CV(%)	3.95	4.02	7.21	

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)

T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)

T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)

T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)

T_5: Garlic extract ((@ 0.5 kg/L of water at 3 days interval)

T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)

T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)

T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.3.4.2 Tomato fruit by weight

Statistically significant variation was recorded by weight of healthy and infested fruit, % infestation controlling using different botanicals as pest management practices against tomato fruit borer (Appendix VIII).The highest weight of total fruit per plant (3006.01 g) was recorded from the treatment T_3 which was followed (2949.94) with the treatment T_6 and T_4 (2849.78). Total fruit weight was higher in treatment T_1 (2801.77g) (Table 7). On the other hand, the lowest (2558.85 g) weight of fruit per plant was recorded from untreated control which was followed (2587.40 g) by the treatment T_2 and T_5 (2635.19g). The highest weight of healthy fruit per plant (2901.61 g) was calculated from the treatment T_3 and these was followed (2762.16 g) to that of the treatment T_6 and T_1 (2613.27g) (Table 7). On the other hand, the lowest (2189.21 g) weight of healthy fruit was recorded from untreated control which was followed (2253.62 g) by the treatment T_2 (2253.62g). The lowest % of infested fruit by weight (3.47%) was calculated from the treatment T_3 which was followed (6.37% and 6.72%) by the T_6 and T_1 treated plots.

On the other hand the highest % of infested fruit by weight (14.45%) was recorded from untreated control which was followed (12.90%) by the T_2 treated plots. Percent infestation was also higher in T_4 (11.36) and T_7 (10.70) treatments. Dilbagh *et al.* (1990), El-Defrawi *et al.* (2000) reported the similar results in their present study. Fruit infestation reduction over control by weight was calculated the highest (75.99%) infestation reduction over control was calculated from the treatment T_3 and the lowest (10.73%) was recorded from T_2 treated plots. From the findings it is revealed that the treatment T_3 produced the highest number of healthy fruit and the lowest infested fruit as well as the lowest % of fruit infestation by weight whereas in control treatment the results is reverse.

Table 7. Effect of some botanicals as pests management practices in controlling tomato fruit borer in terms of fruits per plant in weight during total cropping season

Treatment	Tomato fruit per plant in weight (g)			
	Total	Healthy	% infestation	Increase over control (%)
T_1	2801.77 c	2613.27 cd	6.72 e	53.49
T_2	2587.40 e	2253.62 a	12.90 b	10.73
T_3	3006.01 a	2901.61 d	3.47 f	75.99
T_4	2849.78 cd	2525.90 ab	11.36 c	21.38
T_5	2635.19 d	2435.44 bcd	7.58 d	47.54
T_6	2949.94 b	2762.16 cd	6.37 e	55.92
T_7	2682.29 d	2395.45 abc	10.70 c	25.95
T_8	2558.85 e	2189.21 a	14.45 a	--
$LSD_{(0.05)}$	137.0	123.8	0.771	--
CV(%)	2.84	2.82	4.79	--

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)

T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)

T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)

T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)

T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)

T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)

T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)

T_8:Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Effect of temperature, rainfall and humidity on fruit infestation of tomato at different harvesting time

With increased temperature at different harvesting time, the percent fruit infestation by fruit borer increased, while with decreased the temperature fruit infestation rate also showed decreased trend (Figure 1). And it was clearly seen at 6^{th} harvesting time, (16.03.07) when the highest mean temperature was raised at 28.81^0C. Similar result was found Dhillon *et al.*, (2005), they expressed that the extent of losses vary 30 to 100% depending on the species and season and the abundance of white fly increased when the temperature fall bellow 32^0C. Brevault *et al.*, (2000) also reported that the developmental rate of the different life stages increased linearly with increasing temperature up to 30^0 C. Percent fruit infestation trend was found more or less similar when the mean rainfall was bellow 40 mm and the trend was increasing when the mean rainfall was more than 150 mm (Figure 1).

Result also supported by the report of Hui *et al.*, (2007) They concluded that the population was depressed when the monthly mean rainfall was lower than 50 mm but increased when rainfall ranged from 100 to 200 mm and when the monthly rainfall amount was higher than 250 mm, the white fly population was reduced remarkably. Like temperature positive effect was also found in case of relative humidity.

With increasing relative humidity, percent fruit infestation by fruit borer increased and with the decreasing relative humidity, percent fruit infestation decreased. It was clear at 6^{th} harvesting time when the highest relative humidity was 70.61% (Figure 1). Dhillon *et al.*, (2005) also stated that the abundance of white fly increased when the relative humidity ranges between 60 to 70%.

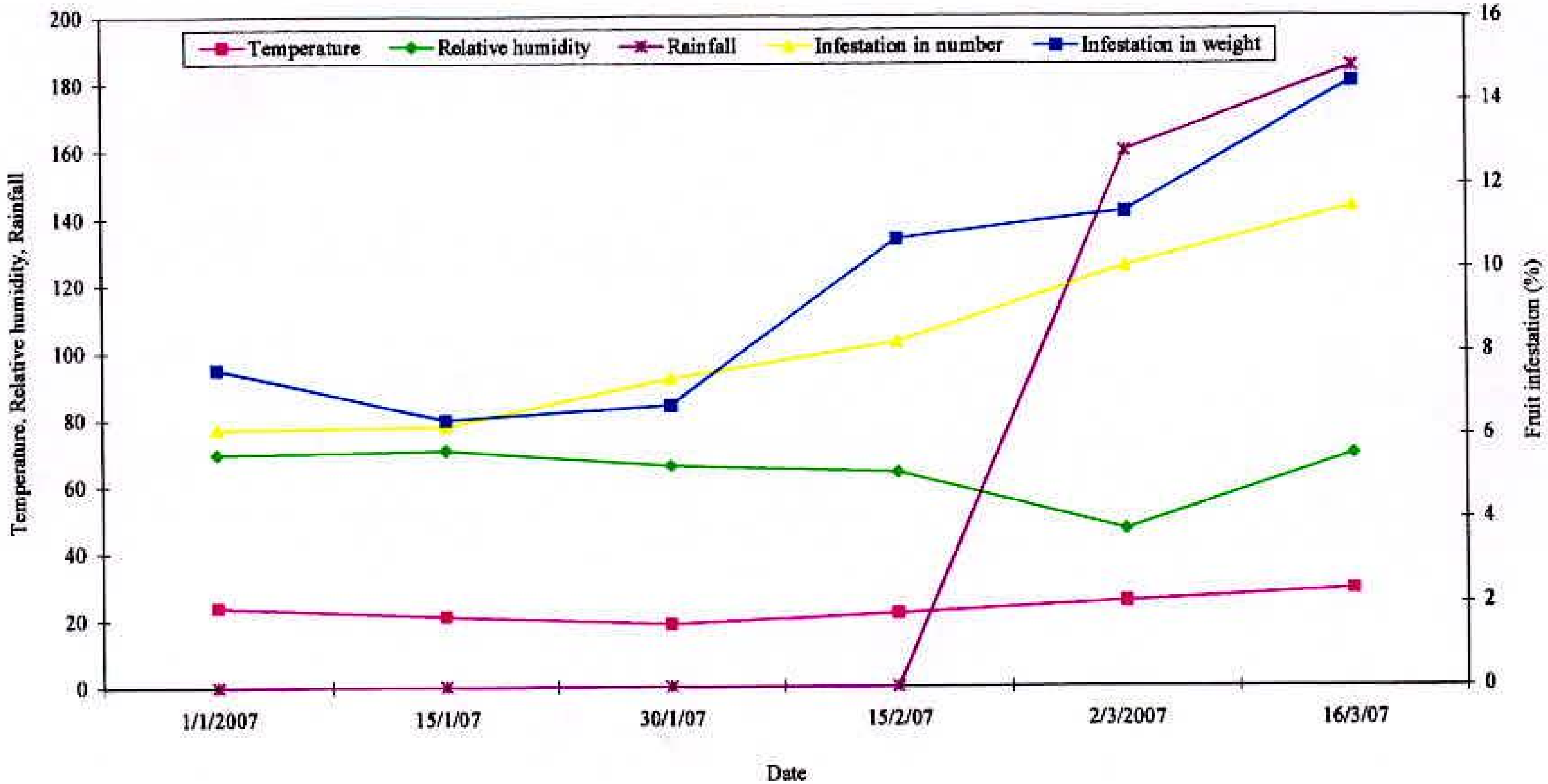

Figure 1. Figure showing relationship between temperature, relative humidity, rainfall with fruit infestation

4.3.5 Tomato fruit per hectare

Statistically significant variation was recorded in weight of healthy and infested fruit, % infestation per ha for using different botanicals as pest management practices against tomato fruit borer (Appendix IX).

The highest weight of fruit per ha (66.80t) was recorded from the treatment T_3 which was followed (65.55 t) with the treatment T_6. The second highest fruit per ha was recorded from T_1 (62.26 ton.) treated plots. On the other hand the lowest (56.86 t) weight of total fruit per ha was recorded from untreated control which was closely followed (57.50 t) by T_2 Treated plot Highest weight of healthy fruit per ha (64.48 t) was recorded from the treatment T_3 which was followed (61.38 t) by T_6 (Table 8) Treated plot. The next highest weight of healthy fruit per ha was recorded from T_1 (58.07 t) Treated plots which was followed by T_5 (54.12 t) Treated plot On the other hand the lowest (48.65 t) weight of healthy fruit per ha was recorded from untreated control which was statistically similar (50.08 t) by the treatment T_2. Healthy fruit increase over control was calculated as the highest (17.48%) in T_3 treated plots and the lowest (1.13%) recorded from T_2 treatment (Table 8). The lowest weight of infested fruit (2.32 t) was recorded from the treatment T_3 which was closely followed (4.17 t) by the treatment T_6. While the highest weight of infested fruit (8.21 t) was recorded from untreated control plots which was statistically similar (7.42 t) to that of T_2 treatment. From the findings it is revealed that treatment T_3 produced the highest number of healthy fruit and the lowest number of infested fruit among with the lowest % of fruit infestation by weight. Whereas in control treatment had than reversed condition.

Table 8. Effect of some botanicals as pests management practices on healthy and infested and total fruit in ha of tomato

Treatment	Tomato fruit yield /ha (t) of tomato			
	Total	Healthy	Increase over control (%)	Infested
T_1	62.26 d	58.07 c	9.50	4.19 cd
T_2	57.50 g	50.08 e	1.13	7.42 a
T_3	66.80 a	64.48 a	17.48	2.32 d
T_4	63.33 c	56.13 cd	11.38	7.20 ab
T_5	58.56 f	54.12 d	2.99	4.44 bcd
T_6	65.55 b	61.38 b	15.28	4.17 cd
T_7	59.61 e	53.23 d	4.84	6.37 abc
T_8	56.86 h	48.65 e	--	8.21 a
$LSD_{(0.05)}$	0.594	3.045	--	2.751
CV(%)	2.84	2.82	--	6.12

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)

T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)

T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)

T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)

T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)

T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)

T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)

T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.4 Yield contributing characters

4.4.1 Plant height

Plant height varied significantly for different treatments (Appendix IX). The highest plant height (88.51 cm) was recorded from the treatment T_3 which was closely followed (85.79 cm) by the treatment T_6, while the lowest plant height (67.62 cm) was recorded from untreated control plots which was followed (75.33 cm) by the treatment T_2 (Figure 2).

4.4.2 Number of leaves per plant

Different botanicals as pest management practices showed significant differences for number of leaves per plant (Appendix IX).

Highest number of leaves (425.33) was recorded from T_3 treatment which was closely followed (421.67) by the treatment T_6. On the other hand the lowest number of leaves per plant (388.33) was recorded from untreated control plots which was closely followed (403.33) by the treatment T_2 plots (Figure 3).

4.4.3 Number of branches per plant

Different botanicals as pest management practices showed significant differences for number of branches per plant (Appendix IX).

The highest number of branches per plant (16.25) was recorded from the treatment T_3 which was followed (15.08) by the treatment T_6 (Plate 4). On the other hand the lowest number of branches per plant (12.85) was recorded from untreated control plots and was followed (13.12) by the treatment T_2 (Figure 4) (Plate 5).

Plate 3. Showing the highest flower per bunch in the healthy plant

Plate 4. Showing highest fruit per bunch in the healthy plant

Plate 5. Showing the lowest fruit per bunch in the plant

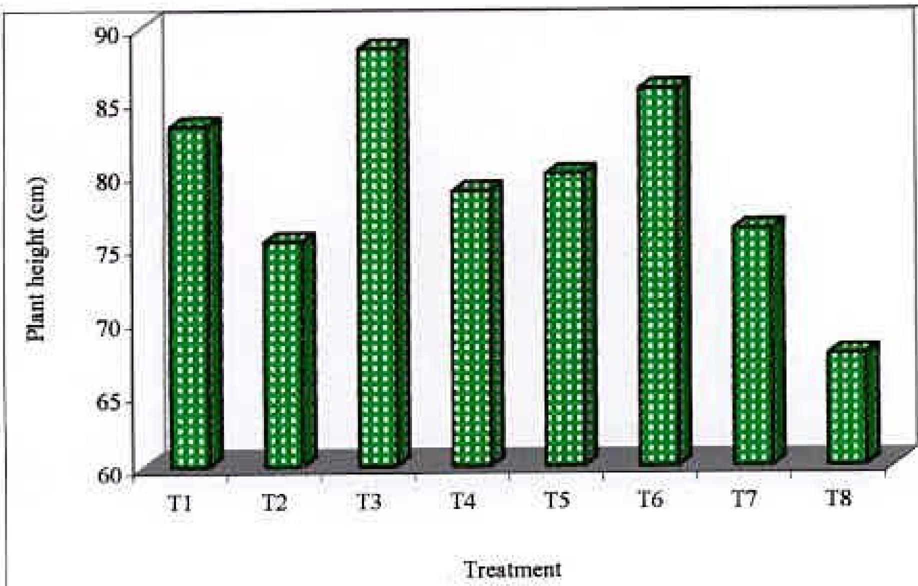

Figure 2. Effect of some pest management practices on plant height of tomato

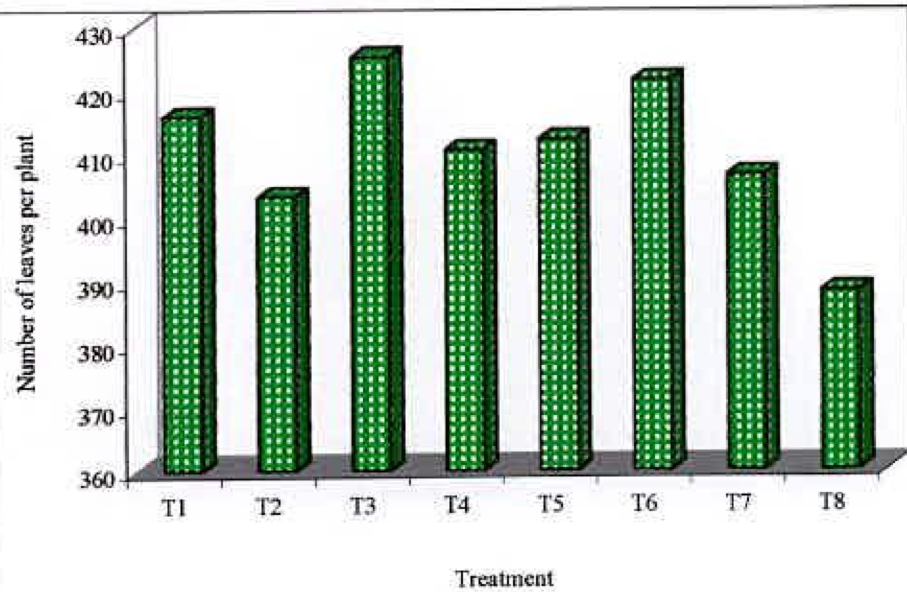

Figure 3. Effect of different botanical pest management on number of leaves per plant

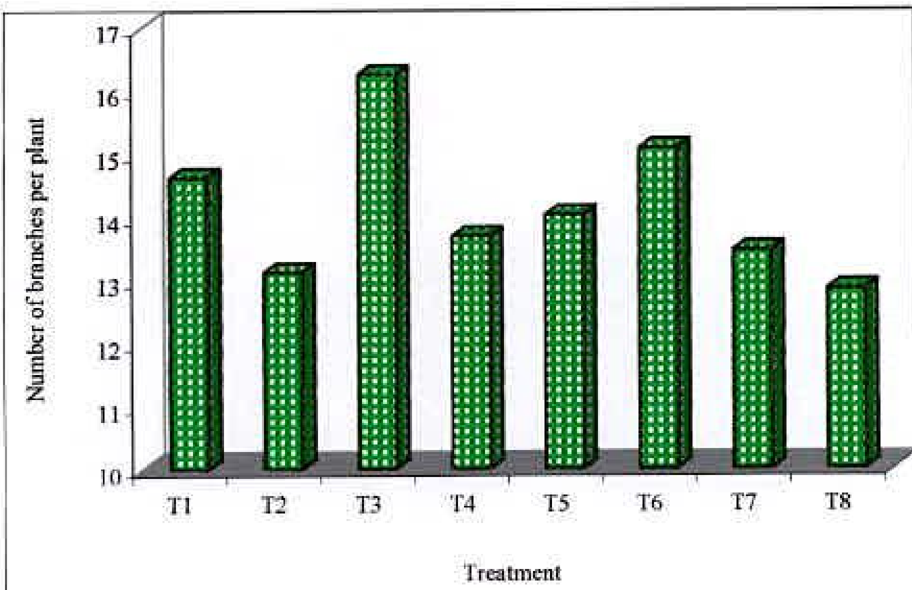

Figure 4. Effect of different botanical pest management practices on number of branches per plant of tomato

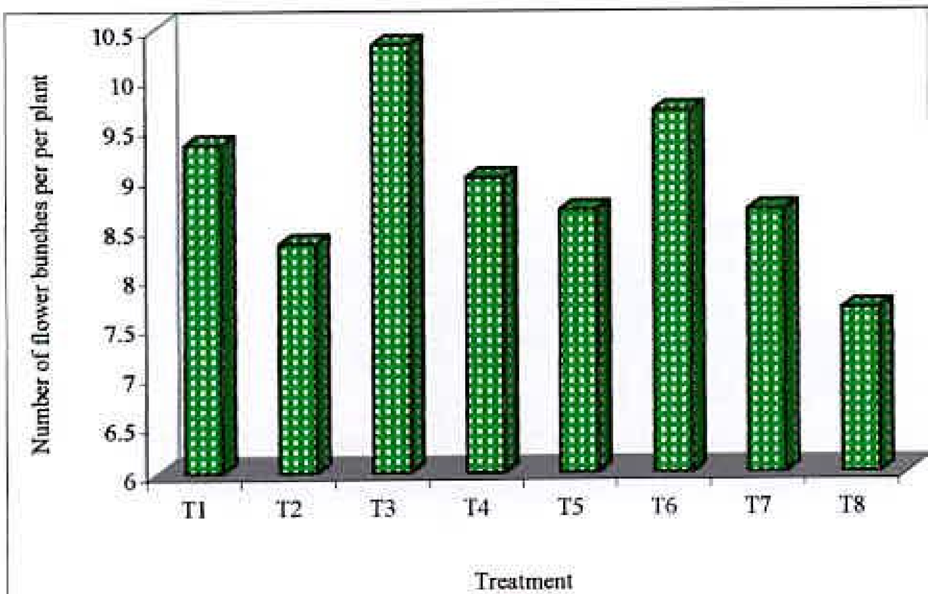

Figure 5. Effect of different botanical pest management on number of flower bunches per plant

4.4.4 Number of flower bunch per plant

Different botanicals as pest management practices showed significant variation for number of flower bunch per plant (Appendix IX).

The highest number of bunch per plant (10.33) was recorded from the treatment T_3 which was followed (9.67) by the treatment T_6. On the other hand the lowest number of bunch per plant (7.67) was recorded from untreated control (T_8) plots which was followed (8.33) by the treatment T_2 (Figure 5).

4.4.5 Number of flower per bunch

Different botanicals as pest management practices showed significant variation for number of flower per bunch (Appendix IX).

The highest number of flower per bunch (6.33) was recorded from T_3 treatment which was followed (6.00) by the treatment T_6 (Plate 3). On the other hand the lowest number of flower per bunch (4.67) was recorded from untreated control plots which was followed (5.67) by the treatment T_2 (Figure 6).

4.4.6 Single fruit weight (g)

Different botanicals as pest management practices showed significant variation for single fruit weight (Appendix IX).

The highest fruit weight (126.33 g) was recorded from the treatment T_3 which was closely followed (119.67 g) by the treatment T_6. On the other hand the lowest fruit weight (100.33 g) was recorded from untreated control plots which was followed (111.00 g) by the treatment T_2 (Figure 7).

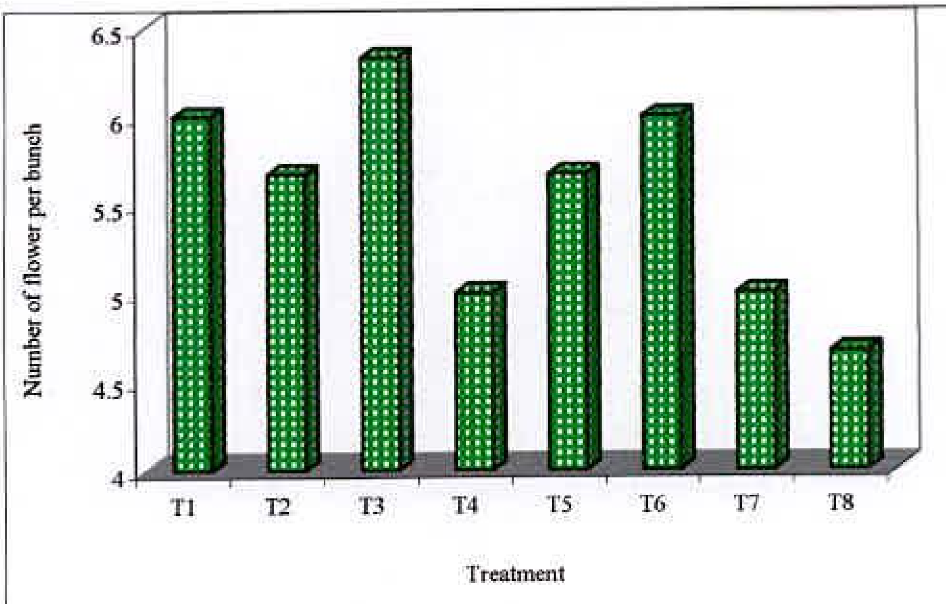

Figure 6. Effect of different pest management practices on number of flower per bunch of tomato

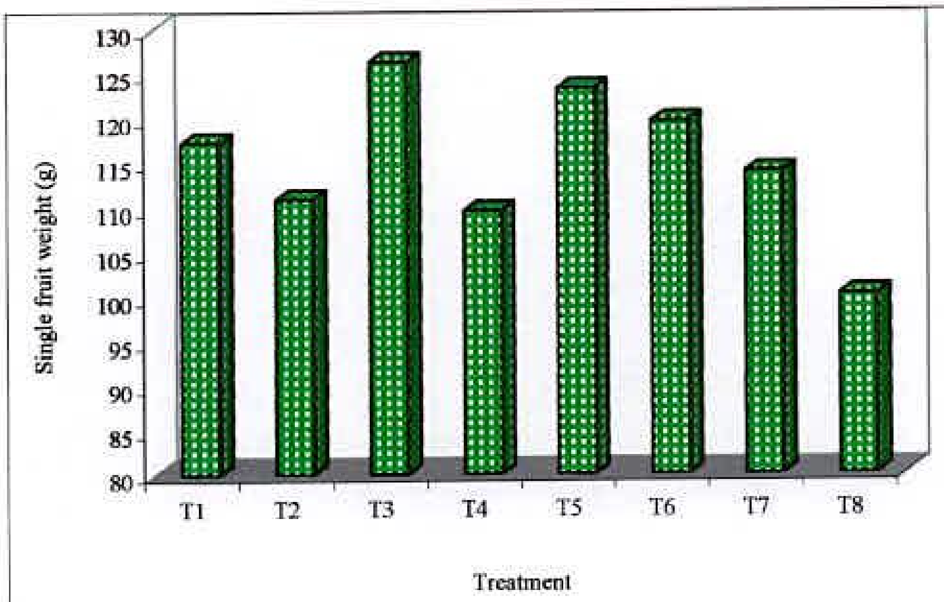

Figure 7. Effect of different botanical pest management on single fruit weight of tomato

From the above findings it was observed that the yield contributing characters using the botanicals as pest management practices had positive effect. Among the practices application of Neem oil at 3 days interval was superior if tomato yield contributing characters are considered. Neem leaf extract and garlic extract had also significant effect on the yield and yield contributing characters.

4.5 Economic analysis

Economic analysis of different botanicals as Tomato fruit borer management practices was calculated and presented in Table 9.

In this study, the untreated control did not require any pest management cost. The cost for the treatment of neem oil was incurred for Neem oil, trix liquid detergent, its preparation and its application. For leaf extract labor cost also involved.

Considering the controlling of tomato fruit borer the highest benefit cost ratio (2.82) was calculated in the treatment T_3 applying Neem oil (@ 3.0 ml/L of water at3 days)interval and next highest BCR was found in T_4 (2.75) which included application of neem oil (@ 3.0 ml/L of water)at 7 days interval. Another Neem product Neem leaf extract (@0.5 kg/L of water) T_1 gave the satisfactory benefit cost ratio (2.33) with higher net return. On the other hand the lowest cost benefit ratio (0.06) was calculated in treatment T_2 comprising application of neem leaf extract (@ 0.5 kg/L of water) and the application of garlic extract(@ 0.5 kg/L of water) also gave the lower benefit cost ratio (0.99)(Table 9).

From the above findings it was found that the commercially produced neem oil was best in controlling the insect pests of tomato giving the highest BCR. On the other hand, the botanicals which were used in this study having minimum application at 3 days interval were effective than the treatments with higher interval at 7 days. Thus the botanicals could be used depending on their availability and in ready forms. This might ensure safety of human health and wealth as well as pollution free environment.

Table 9. Cost benefit analysis for different botanicals as pest management

Treatments	Cost of pest Management (Tk.)	Yield		Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
		Healthy	Infested				
T_1	34000	58.07	4.19	900380	866380	79160	2.33
T_2	15000	50.08	7.42	803140	788140	920	0.06
T_3	51400	64.48	2.32	983440	932040	144820	2.82
T_4	28000	56.13	7.2	892350	864350	77130	2.75
T_5	28000	54.12	4.44	842880	814880	27660	0.99
T_6	48000	61.38	4.17	949890	901890	114670	2.39
T_7	20000	53.23	6.37	843040	823040	35820	1.79
T_8	0	48.65	8.21	787220	787220	--	--

Price of tomato: Tk. 15 for healthy and Tk. 7 for infested fruit

T_1: Neem leaf extract (@ 0.5 kg/L of water at3 days interval)

T_2: Neem leaf extract ((@ 0.5 kg/L of water at 7 days interval)

T_3: Neem oil (@ 3.0 ml/L of water +trix at 3 days interval)

T_4: Neem oil (@ 3.0 ml/L of water +trix at 7 days interval)

T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval)

T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval)

T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval)

T_8: Untreated control

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Chapter 5
Summary and Conclusion

SUMMARY AND CONCLUSION

The present experiment was conducted to evaluation of some botanicals as pest management practices against pest complex in tomato in the farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2006 to April 2007. The experiment consists of 8 treatments such as T_1: Neem leaf extract (@ 0.5 kg/L of water at 3 days interval); T_2: Neem leaf extract (@ 0.5 kg/L of water at 7 days interval); T_3: Neem oil (@ 3.0 ml/L of water at 3 days interval); T_4: Neem oil(@ 3.0ml/L of water at 7 days interval); T_5: Garlic extract (@ 0.5 kg/L of water at 3 days interval); T_6: Marsh Pepper extract (@ 0.5 kg/L of water at 3 days interval); T_7: Marsh Pepper extract (@ 0.5 kg/L of water at 7 days interval) and T_8: Untreated control. The experiment was laid out in Randomized Complete Block Design. Data on white fly abundant, leaf miner infestation on leaf and fruit borer infestation and their effect of yield contributing characters and yield were recorded.

At vegetative stage the lowest number of whitefly per plot (2.20) was recorded from the treatment T_3 as applying of neem oil @ 3.0ml/L of water at three days interval and the highest (21.20) number of whitefly per plot was recorded from untreated control (T_8) plots. At early flowering stage the lowest number of whitefly per plot (4.80) was recorded from the treatment T_3, while the highest (25.80) number of whitefly per plot was recorded from untreated control. At late flowering stage lowest number of whitefly per plot (5.60) was recorded from T_3 and T_6 treated plots, the highest (29.20) number of whitefly per plot was recorded from untreated control. At early fruiting stage lowest number of white fly per plot (3.80) was recorded from T_3 treated plot while the highest (26.60) number of whitefly per plot was recorded from untreated control. At late fruiting stage lowest number of whitefly per plot (3.20) was recorded from the treatment T_3 and the highest (21.80) number of whitefly per plot was recorded from untreated control. At ripening stage lowest number of whitefly per plot (2.80) was recorded from the treatment T_3 and the highest (20.40) number of whitefly per plot was recorded from untreated control.

At early fruiting stage the lowest leaf infestation (1.05%) due to leaf miner attack was recorded from T_3 treatment and the highest leaf infestation (7.22%) was recorded from untreated control. At mid fruiting stage lowest leaf infestation (1.22%) caused by leaf miner attack was recorded from the treatment T_3, while the highest leaf infestation (9.39%) was recorded from untreated control plot. At late fruiting stage lowest leaf infestation (2.66%) caused by leaf miner attack was recorded from the treatment T_3. On the other hand the highest leaf infestation (12.25%) was recorded from untreated control plots. At early ripening stage lowest leaf infestation (3.84%) caused by leaf miner attack was recorded from the treatment T_3, while the untreated control plots had the highest leaf infestation (17.81%). At mid ripening stage lowest leaf infestation (4.62%) for leaf miner attack was recorded from the treatment T_3 and the highest (21.08%) was recorded from untreated control. At late ripening stage lowest leaf infestation (5.75%) caused by leaf miner attack and this was recorded from the treatment T_3 the highest leaf infestation (26.86%) was recorded from untreated control.

The highest number of per plant (33.20) was recorded from the treatment T_3 and the lowest (26.92) number of fruit was recorded from untreated control. The highest number of healthy fruit per plant (32.44) was obtained from the treatment T_3 and the lowest (23.31) number of healthy fruit was harvested from untreated control plots. The lowest number of infested fruit (0.83) was obtained from the treatment T_3, while the highest number of infested fruit (3.61) was harvested from untreated control. The lowest % of infested fruit by number (2.50%) was recorded from the treatment T_3 and the highest % of infested fruit by number (13.373%) was recorded from untreated control.

The highest weight of fruit per plant (3006.01 g) was recorded from the treatment T_3 and the lowest (2558.85 g) weight of total fruit per plant was recorded from untreated control. Highest weight of healthy fruit per plant (2901.61 g) was recorded from the treatment T_3 and the lowest (2189.21 g) weight of healthy fruit was measured from untreated control. Lowest weight of infested fruit (104.40 g) was obtained from the treatment T_3, while the highest weight of infested fruit (369.63 g) was recorded from untreated control. The lowest % of infested fruit by weight (3.47%) was recorded from the treatment T_3 and the highest % of infested fruit by weight (14.45%) was recorded from untreated control.

The highest weight of fruit per hectare (66.80 t) was recorded from the treatment T_3 and the lowest (56.86 t) fruit per hectare was recorded from untreated control. The highest weight of healthy fruit per hectare (64.48 t) was harvested from the treatment T_3 and the lowest (48.65 t) weight of healthy fruit per hectare was measured from untreated control.

The lowest abundance of Whitefly and leaf miner in tomato was might be due to effectiveness of neem oil at different stage of plant growth on the other hand the treatments with neem leaf extract, garlic extract were less effective in controlling the pests.

In controlling tomato fruit borer the highest benefit cost ratio (2.82) was calculated from the T_3 treated plots having application of Neem oil @ 3.0ml/L of water at 3 days interval. On the other hand the lowest cost benefit ratio (0.06) was recorded from neem leaf extract used in treatment T_2. Among the different treatment neem oil application at 3 days interval was most effective than other treatments. The other treatments like neem leaf extract and garlic extract also showed better performance in relation to all concern parameters comparing to that of neem oil and marsh pepper. The poor performance of neem oil and marsh pepper might be due to its application intervals. It may be concluded from the study that depending on the availability the application of botanicals as pest management in at 3 days interval might safer to better results.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Similar study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other botanicals extraction may be used in the future study;
3. Different concentration and interval of application of botanicals may be introduced for further study.

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Appendices

APPENDICES

Appendix I. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	33.18
Silt	60.61
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.19
Organic carbon (%)	1.41
Total nitrogen (%)	0.08
Available P (ppm)	21.4
Exchangeable K (%)	0.2

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from May to January 2007

Month	Air temperature (^0C)			RH (%)	Total rainfall (mm)	Sunshine hour
	Maximum	Minimum	Mean			
November 2006	29.18	18.26	23.72	69.52	00	163.25
December 2006	25.82	16.04	20.93	70.61	00	158.68
January 2007	24.6	12.5	18.7	66	0	171.01
February 2007	27.1	16.8	21.95	64	0	158.68
March 2007	31.5	16.9	25.55	47	160	255.01
April 2007	33.74	23.87	28.81	69.41	185	234.6

Appendix III. Analysis of variance of the data on number of white fry per plot in tomato field as influenced by some botanical pests management practices

Source of variation	Degrees of freedom	Mean square						
		Number of white fly per plot stage at						
		Vegetative	Flowering		Fruiting		Ripening	Total
			Early	Late	Early	Late		
Replication	2	1.125	0.500	0.180	1.445	0.320	0.605	0.010
Treatment	7	115.989**	147.118**	188.089**	173.312**	115.335**	102.255**	4981.934**
Error	14	1.216	0.649	0.237	1.171	0.171	0.559	0.531

** : Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on percent leaf infestation due to the attack of leaf miner in tomato field as influenced by some botanical pests management practices

Source of variation	Degrees of freedom	Mean square						
		Leaf infestation stage at						
		Fruiting stage			Ripening stage			Average
		Early	Mid	Late	Early	Late		
Replication	2	0.001	0.021	0.245	0.891	0.541	0.254	0.222
Treatment	7	11.473**	19.064**	28.751**	65.759**	92.632**	146.497**	50.414**
Error	14	0.046	0.048	0.251	0.442	0.147	0.172	0.108

** : Significant at 0.01 level of probability

Appendix V. **Analysis of variance of the data on in controlling tomato fruit borer at early stage in terms of fruits per plant in number and weight as influenced by some botanical pests management practices**

Source of variation	Degrees of freedom	Mean square					
		Tomato fruit in number			Tomato fruit in weight (g)		
		Healthy	Infested	% infestation	Healthy	Infested	% infestation
Replication	2	0.195	0.004	0.759	205.957	13.468	0.068
Treatment	7	3.226**	0.316**	46.750**	38453.360**	1387.074**	31.116**
Error	14	0.255	0.005	1.298	978.396	8.793	0.323

** : Significant at 0.01 level of probability

Appendix VI. **Analysis of variance of the data on in controlling tomato fruit borer at mid stage in terms of fruits per plant in number and weight as influenced by some botanical pests management practices**

Source of variation	Degrees of freedom	Mean square					
		Tomato fruit in number			Tomato fruit in weight (g)		
		Healthy	Infested	% infestation	Healthy	Infested	% infestation
Replication	2	1.326	0.008	1.329	1558.346	13.961	0.108
Treatment	7	2.781*	0.182**	33.739**	13415.566**	1091.499**	19.916**
Error	14	0.413	0.005	0.871	1420.611	28.590	0.562

** : Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on in controlling tomato fruit borer at late stage in terms of fruits per plant in number and weight as influenced by some botanical pests management practices

Source of variation	Degrees of freedom	Mean square					
		Tomato fruit in number			Tomato fruit in weight (g)		
		Healthy	Infested	% infestation	Healthy	Infested	% infestation
Replication	2	0.096	0.022	1.313	1464.971	106.333	1.133
Treatment	7	5.280**	0.506**	49.675**	17561.838*	8247.379**	78.437**
Error	14	0.603	0.031	2.281	4836.143	174.400	1.247

** : Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on in controlling tomato fruit borer at total cropping season in terms of fruits per plant in number and weight as influenced by some botanical pests management practices

Source of variation	Degrees of freedom	Mean square							
		Tomato fruit in number				Tomato fruit in weight (g)			
		Total	Healthy	Infested	% infestation	Total	Healthy	Infested	% infestation
Replication	2	1.739	1.347	0.033	0.125	7837.482	5944.439	304.314	0.252
Treatment	7	15.757**	31.493**	2.848**	43.282**	84969.680**	177930.048**	25508.286**	41.895**
Error	14	1.368	1.224	0.038	0.281	6122.705	4997.919	233.140	0.194

** : Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on in controlling tomato fruit borer at total cropping season in terms of fruits per hectare and yield contributing characters as influenced by some botanical pests management practices

Source of variation	Degrees of freedom	Mean square								
		Yield per hectare			Yield contributing characters					
		Total	Healthy	Infested	Plant height (cm)	Number of leaf/plant	Number of branch/plant	Number of flower bunch per plant	Number of flower per bunch	Single fruit weight (g)
Replication	2	3.870	2.936	0.150	0.252	0.152	1.125	0.185	0.0125	1.258
Treatment	7	41.960**	87.867**	12.597**	41.895**	12.458**	12.451**	14.152**	7.158**	16.458**
Error	14	3.024	2.468	0.115	0.194	3.151**	1.254	0.258	0.122	2.158

** : Significant at 0.01 level of probability