STUDY ON THE EFFECTS OF DIFFERENT PLANTING DATES AND MECHANICAL SUPPORT FOR THE MANAGEMENT OF INSECT PESTS IN TOMATO

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CERTIFICATE

This is to certify that thesis entitled, **'Study on the Effects of Different Planting Dates and Mechanical Support for the Management of Insect Pests in Tomato'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of bona fide research work carried out by **Sultana Afreen**, **Registration No. 13-05747** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2014

Place: Dhaka, Bangladesh

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The Author

STUDY ON THE EFFECTS OF DIFFERENT PLANTING DATES AND MECHANICAL SUPPORT FOR THE MANAGEMENT OF INSECT PESTS IN TOMATO

ABSTRACT

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka during the period from November 2013 to April 2014 to study the effects of different planting dates and mechanical support for the management of insect pests in tomato. BARI Tomato 5 was used as planting material. The experiment was consisted of nine treatments. These were as follows- T_1: Planting at 25 November + No support; T_2: Planting at 25 November + Horizontal mechanical support; T_3: Planting at 25 November + Vertical mechanical support; T_4: Planting at 10 December + No support; T_5: Planting at 10 December + Horizontal mechanical support; T_6: Planting at 10 December + Vertical mechanical support; T_7: Planting at 25 December + No support; T_8: Planting at 25 December + Horizontal mechanical support and T_9: Planting at 25 December + Vertical mechanical support. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of white fly, at the entire growing season, minimum number of white fly plot^{-1} (16.67) was recorded from the treatment T_5, whereas the maximum (33.73) from the treatment T_7. For tomato fruit borer, at entire growing season, minimum number of fruit borer plot^{-1} (8.40) was recorded from the treatment T_5, whereas the maximum (20.93) from the treatment T_7. At early fruiting stage of tomato in number and weight basis, the highest percentage of infested fruit (10.65% and 10.99%) was recorded in T_7 treatment, while the lowest (2.67% and 4.35%) in T_5 treatment. At mid fruiting stage of tomato in number and weight basis, the highest percentage of infested fruit (11.92% and 12.62%) was recorded in T_7 treatment, while the lowest (3.13% and 4.50%) in T_5 treatment. At late fruiting stage of tomato in number and weight basis, the highest percentage of infested fruit (10.15% and 10.66%) was recorded in T_7 treatment, whereas the lowest (2.22% and 4.21%) in T_5 treatment. At total fruiting stage of tomato in number and weight basis, the highest percentage of infested fruit (10.93% and 11.43%) was recorded in T_7 treatment, whereas the lowest (2.66% and 4.35%) in T_5 treatment. The highest fruit yield (55.91 t ha^{-1}) was recorded in T_5, whereas the lowest yield (45.39 t ha^{-1}) in T_7 treatment. Planting at 10 December + Horizontal mechanical support was more effective for reduction of insect pest of tomato and also for highest yield.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) botanically referred to the family Solanaceae is one of the most important and popular vegetable crop. The centre of origin of the genus *Solanum* is the Andean zone particularly Peru-Ecuador-Bolivian areas (Salunkhe *et al*., 1987), but cultivated tomato originated in Mexico. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato contains 94 g water, 0.5 g minerals, 0.8 g fibre, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate and other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B-1, 0.06 mg vitamin B-2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010). Tomato ranks top of the list of canned vegetables and next to potato and sweet potato in the world vegetable production (FAO, 2012).

Bangladesh is producing a good amount of tomatoes and it is cultivated in almost all home gardens and also in the field due to its adaptability to wide range of soil and climate (Bose and Som, 1990). In Bangladesh it is mainly cultivated as winter vegetable, which occupies an area of 58,854 acres in 2011-12 with the total production of tomato was 190 thousand metric tons (BBS, 2013). Due to increasing consumption of tomato products, the crop is becoming promising. In Bangladesh, the yield of tomato is not enough satisfactory in comparison with other tomato growing countries of the World (Aditya *et al*., 1997). 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, land for production based on fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions. The environmental stresses resulting from drought, temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in crop production (Hernandez *et al.*, 2001; Lawlor and Cornic 2002; Alqudah *et al*., 2011).

Tomato is susceptible to insect pests and all parts of the plant including leaves, stems, flowers and fruits are subjected to attack. This crop is mainly atacked by Tomato Fruit worm, Potato Aphid, Stink Bugs and Leaffooted Bugs, Hornworms, Silver leaf, Whitefly etc. Among them tomato fruit borer *Heliothis armigera* (Hub.) is one of the major pests of tomato and damage by this pest may be up to 85-93.7% (Haque, 1995). With the increasing threat of resistance in *H. armigera* towards a wide range of pesticides, the necessity to design future pest management strategies to control this pest becomes more apparent. In Bangladesh, very few research works have been done mainly on cultural, mechanical, biological control by parasitoid and pathogens, development of resistant varieties sex pheromone, and use of botanical insecticides etc. Chemical control is generally being practiced for the management of insect pests. It has many limitations and side effects; it is not only expensive but also exerts some hazards to environment and human health. The indiscriminate use of pesticides causes phytotoxicity and destruction of beneficial organisms such as predators, parasitoids, microorganisms and pollinators (Berlinger *et al.*, 1988). Over the years, the entomologists are working to find ecologically sound and environmentally safe method for pest control (Bari and Sardar, 1998).

Management of tomato pests by adopting chemical, biological and mechanical is difficult, uneconomic and hazardous to environment (Berlinger *et al*., 1988). Breeding plants, which are resistant to the insect vector, although they may be susceptible to the virus can restrict virus damage (Berlinger and Dahan, 1988). Economically viable management has not been achieved regularly in most areas where geminiviruses infect tomato. Many workers explored the prospect of minimizing viral diseases by manipulating planting dates (Shaheen, 1983; Ioannou and Iordanou, 1995). The tomato fruit borer is difficult to control as it is a borer pest and has developed resistance to insecticides in many different countries. With the increasing threat of resistance in *H. armigera* towards a wide range of pesticides, the necessity to design future pest management strategies to control this pest becomes more apparent.

So far, very little efforts have been made to develop alternate approaches for the management of insect pests of tomato. Among available control methods, cultural method is considered to be the safest and environment friendly. Cultural control is the deliberate manipulation of the environment to make it less favorable for the pests by disrupting the reproductive cycle, eliminating their food or by making it more favorable for their natural enemies. This is a prophylactic measure of pest control. Many cultural practices can be usually employed in an IPM scheme such as sanitation or destruction of debris, destruction of alternate hosts and volunteer plants, changing dates of planting and harvesting to avoid pest attack, crop rotation to avoid building up of pests, tillage practices, habitat diversification, cropping system or intercropping, plant density, trap crops or trap logs, water management, etc. (Luckmann and Metcalf, 1975). Variation in sowing or planting date has been found to influence the incidence of many crop pests in the field (Husain and Begum, 1994). So, time of planting is a very important factor for tomato production (Haque *et al*., 2001) and it ensures to get optimum yield (Islam *et al*., 1991). Late planting reduces the number of mature fruits and reduces yield. Early harvest ensures higher income, as the market price of early crops is generally higher (Anon.1989).

Under the above perspective, the combination of planting dates and mechanical support has been thought to be environment friendly option for the management of insect pests of tomato. In above light of the back ground, the present piece of research work has been undertaken with the following objectives-

i. To find out the most suitable planting date and mechanical support for avoiding insect pest of tomato;

ii. To determine the most suitable planting date and mechanical support on the growth and yield of tomato.

CHAPTER II

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, minerals and also other nutrients. The crop has conventional less concentration by the researchers on various aspects because normally grown with minimum management practices. For that a very few studies on the related to major insect pest of tomato and their life cycle, seasonal abundance and also control measures through mechanical control with view to growth and development as well as yield of tomato have been carried out in our country as well as many other countries of the world. So the research work so far done on the mentioned issues in Bangladesh and is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the major insect pest of tomato and their life cycle, seasonal abundance and also control measures through mechanical control so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Major insect pests of tomato

Among the several constraints for growing tomato attack of insect pests are considered important. 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. 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).

2.1.1 Whitefly

The whiteflies cause damage to plant by three means, (i) large population of nymphs and adults suck sap directly from plant 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 from crop to crop (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, *B. tabaci* is an important pest worldwide for many vegetable crops as well as tomato. 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 and as well as also management (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 on crop growth and yield. Yield loss range from 20-100 per cent, depending on the crop, season, vector prevalence and other factors during the growing season.

The whitefly acts as a mechanical vector of many viral diseases for different vegetable crops (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, variety.

2.1.2 Leaf miner

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. 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 decreases yield by 0.26% and 0.87%, respectively.

2.1.3 Fruit borer

The tomato fruit borer, *H. armigera* 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), blackgram (as gram caterpillar), various leguminous crops (as pod borer), 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, *H. armigera* (Hub.) is one of the serious pests attacking tomato. 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, 1984). 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 pedicle is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually consumable 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, *H. 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.

Pinto *et al*. (1997) reported high infestations of the noctuidae *H. 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 *H. 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. This was related to low trichome 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 then 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. 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 *H. 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 *H. 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 by, 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 ripening fruit (Sutton, 1991).

2.2 Description of tomato fruit borer, *Helicoverpa armigera*, (Hub.)

2.2.1 Nomenclature

Tomato fruit borer, *H. armigera* 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 several numbers of species, including *H. armigera* and it is the serious pest of tomato (Mishra and Mishra, 1996),

2.2.2 Origin and distribution

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).

2.2.3 Life history of tomato fruit borer

Egg: Eggs are 0.4-0.5 mm in diameter, nearly spherical with flattened base, glistering yellowish-white in colour, changing to dark brown prior to hatching.

Larva: The fully grown larva (Plate 1) is about 40 mm in length general colour varies from almost black, brown or green to pale yellow or pink and is characterized by having a dark band along the back to each side of which there is a pale band. The larval period varies from 15-35 days.

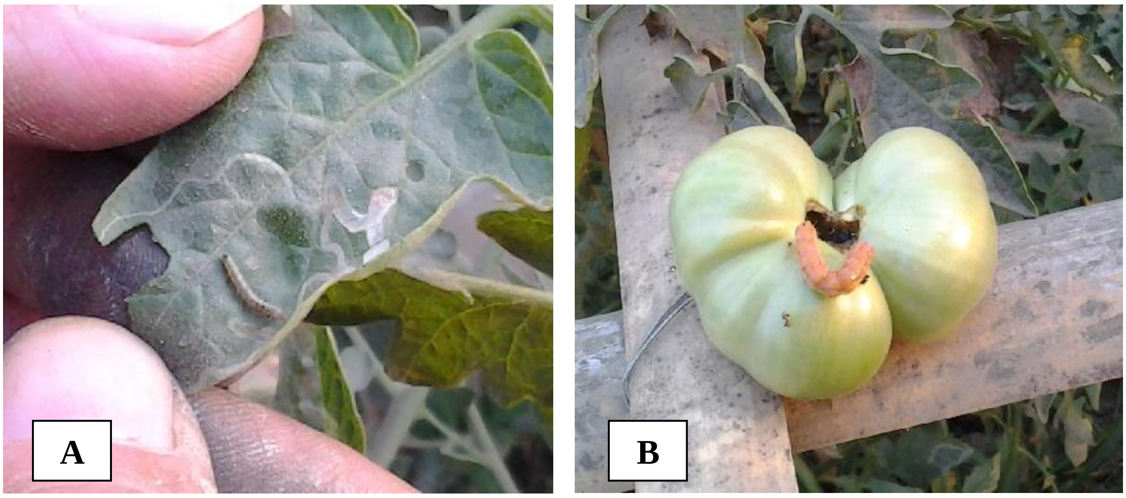


Plate 1. Tomato fruit borer larva on leaf (A) and larva feeds on tomato (B)

Pupa: The light brown pupa is about 22 mm in length, living in the soil (Plate 2).

Adult: Stout bodied moth has a wing span of 40 mm. general color varies from dull yellow or olive grey to brown with little distinctive marking (Plate 3). The moths become sexually mature mate about four days after emergence from the pupae having fed from the nectars of plants. The moth is only active at night and lays eggs singly on the plant. On hatching, the larva normally eats some or all eggs shell before feeding on the plant.

Plate 2. Pupa of tomato fruit borer in pupal chamber

Plate 3. Adult tomato fruit borer, *H. armigera*

2.2.4 Host range of tomato fruit borer

A wide range of host crop plants occurs including cotton, tobacco, maize, sorghum, pennisetum, sunflower, various legumes, citrus, okra and other horticultural crops. Wild plants considered important include species of Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portutacaceae, Convolvulaceae but many other plant families are reported to be the host (Jiirgen *et al*., 1977).

2.2.5 Status and nature of damage of tomato fruit borer

Tomato fruit borer, *H. armigera* is one of the serious pests of tomato. The pest causes damage to the extent of about 50-60% fruit (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93% (Tewari, 1985). Due to severe infestation, fruit as well as seed maturation hampered greatly and reduced the viability of seeds and seed quality also degraded (Dhamo *et al*., 1984). Pinto *et al*. (1997) observed high infestations of the noctuidae, *H. armigera* on field-cultivated tomatoes in the hilly area of Madonie, Palermo province, Sicily, in the summer. The infestations caused serious damage, resulting in a reduced, and at times, inadequate commercial return.

The larvae of this pest 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 pedicle is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually consumable and marketable (Husain *et al*., 1988).

2.2.6 Seasonal abundance

Gupta *et al.* (1998) studied on the effect of infestations with larvae of *H. armigera* on tomato yields. Infestations were heaviest (17.88%) in March- April and lightest in January- February. The avoidable yield loss was highest in March-April (37.79%) followed by January-February (36.36%) and October-November (22.39%). In crops harvested in October-November, January-February and March-April, 18.90, 18.00 and 21.64% of the total number of fruits, respectively, were infested. The average weight of infested fruit was 39.56- 40.32g and that of healthy fruit 50.18-61.43g. Infestations were heavier in the first 4 pickings. In fruit harvested in March-April, infestation was 49.70% at the first picking and 4.25% at the 7th. The data indicated that control measure should be taken at the flowering stage.

The seasonal history of tomato fruit borer, *H. armigera* varies considerably due to 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 second week of April, 50.08% and 33.04% of fruits 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.

Pandey *et al.* (1997) conducted a series of experiments in the Western Hills, Nepal, to understand the pest dynamics and to develop integrated pest management (IPM) technologies against tomato fruit borer *H. armigera.* Monitoring of *H. armigera* for several seasons across the agro-ecological zones indicated that March-April is the peak activity period of the moth. The period coincides with the flowering/fruiting season of tomato and the pest causes severe yield losses. Tomato cv. Roma and local landraces collected from Kholakhet, Parbat, were found to be less preferred for egg laying by this pest.

2.3 Management of insect pests of tomato

2.3.1 Mechanical control

Insect can be controlled mechanically. Mechanical control involves the operation of machinery or manual operation of hopper dozers, hopper catchers, aphidozers, fly traps, moth traps, maggot traps, light traps, electric traps and others for catching and killing a variety of insects. To obtain effective results these control measures must be initiated promptly and the results therefore be immediate (Basher, 2002). Planting under screen cover is the best mechanical method, as long as climatic conditions allow its use (Berlinger and Dahan, 1988).

Trapping system has been effectively employed in controlling a number of insect pest species. Light traps are effective against different kinds of rice borers. Collecting egg cluster by hand or collecting insect by using sweep net and then destroyed mechanically (Ahmed and Jalil, 1993).

Synthetic sex pheromone traps were used to catch and identify cutworm species, including turnip moth (*Agrotis segetum*), tomato fruit worm (*H. armigera*) and exclamotor (*Agrotis exclamationis*) (Rashidov and Khodzhaev, 2000).

Yellow sticky traps may become a major tool in monitoring the adult population of *B. tabaci* due to their attraction to yellow surfaces (Haider *et al.*, 2001). In a field experiment in 1995 and 1996 in Egypt with tomato, the use of yellow sticky traps decreased the egg density of *B. tabaci* by 14.0-29.6 % and 9.90-22.50 % and the nymphal population was decreased by 14.1-30.0 % and 14.0-30.7 %, respectively (Abdel-Megeed *et al.*, 1998).

2.3.2 Planting or sowing dates

Time of planting or sowing influences the yield of the crop and even with good seeds and good plants satisfactory and profitable crops can not be expected unless the planting is done at the right time. Changing planting dates or sowing dates constitute useful and economical method to manage insect pests of several crops. The conventional method of insect control may be too costly to justify year after year and for this reason many countries are trying to develop alternative methods of pest control. The control of pod borer, *Euchrysops cnejus* on mungbean can be achieved by carefully selection of a suitable sowing time of mungbean in the field to minimize the incidence of. *E. cnejus* (Husain and Begum, 1988).

Agronomic practices like intercropping and deviating the dates of sowing have been found very useful in controlling pests of many crops (Begum *et al*., 1992). If maize is sown after 15th of August, it escapes from the heavy attack of maize borer while early sowing of rice i.e. between 3rd week of May and mid of June is helpful in protecting it from the attack of rice borer in Punjab (Atwal, 1976).
Hossain *et al*. (1986) reported that early November is the best time for planting tomato than those of September and October, while other reported high incidence of diseases and low yield of tomato by late planting due to reduce number of vector (Anon.,1983).

The effect of planting date of tomato on population of *B. tabaci* and *H. armigera* and viral infection by *Tomato yellow leaf curl geminivirus* was determined by EI-Gendi *et al*. (1997). The highest population of *B. tabaci* (79 and 1326 nymphs/100 leaflets in 1993 and 1994, respectively) occurred on crops planted in late August. The level of viral infection in this crop reached 83 %. The highest tomato yield was recorded in crops planted in June. Attack of *H. armigera* was low in all the crops regardless of planting date.

During 1993-95, field experiments were carried out on the incidence of whitefly, *B. tabaci* and *Tomato leaf curl virus* (*Tomato yellow leaf curl geminivirus*) disease of tomato in Assam, India. The lowest disease incidence and whitefly population was recorded in the crop planted from October 10 to November 25. As the planting date advances the disease incidence and whitefly population increased while the fruit yield decreased (Borah and Bordoloi, 1998).

Sharma *et al*. (1997) reported that seedlings planted on 27 April gave highest marketable fruit yield per plant (1.205 kg) and per hectare (435.5 kg). Yield and yield components were found lowest when seedlings transplanted on 28 March or 12 April, which was primarily due to high infestation of fruit borer, *H. armigera*. Conversely, yield loss due to plant diseases was higher in crops transplanted later.

The study was conducted by Ahsan *et al*. (2008) at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) farm to find out the effect of varieties and planting dates on the incidence of aphid and white fly. Four varieties (i.e., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4 and BARI Tomato-6) were planted on November 20, November 30 and December 10. Results indicated that the incidence of insect pests was less in early planting crop, while the pest significantly increased in the late planting. In most of the cases, the intensity of insect pests attack and yield varied significantly among varieties and planting dates. The planting dates had much more influence than varieties on the abundance of insect pests and diseases of tomato. The variety BARI tomato-3 planted on November 30 had less infestation of insect pests, suffered less from TYLCV and TPVV and gave higher yield.

Waluniba and Alemla (2014) carried out an experiment at School of Agriculture Sciences and Rural Development, Nagaland University, showed that the incidence of aphids, whitefly, Serpentine leaf and fruit borer (*Helicoverpa armigera*) and reported that the incidence of aphid correlating with abiotic factors showed negative significant influence by maximum temperature at 4th December planting date, whitefly showed negative significant influence on 4th December planting date, leaf miner showed positive significant effect with maximum and minimum temperature in all the planting dates and also minimum relative humidity on 19th December planting showed positive significant effect and in case of tomato fruit borer it showed a positive significant effect with maximum temperature and minimum relative humidity at 19th November and 19th December planting respectively.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2013 to April 2014 to study the effects of different planting dates and mechanical support for the management of insect pests in tomato. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Location of the experimental site

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka. It is located in 24.09^{0}N latitude and 90.26^{0}E longitudes. The altitude of the location is 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207 (Anon., 1989).

3.2 Characteristics of soil

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

3.3 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of

April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

BARI Tomato 5 was used as planting material. The seeds of tomato were collected from Bangladesh Agricultural Research Institute (BARI) and grown at the nursery of Sher-e-Bangla Agricultural University Horticultural Farm.

3.5 Treatment of the experiment

The experiment was consisted of nine treatments. These were as follows-

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

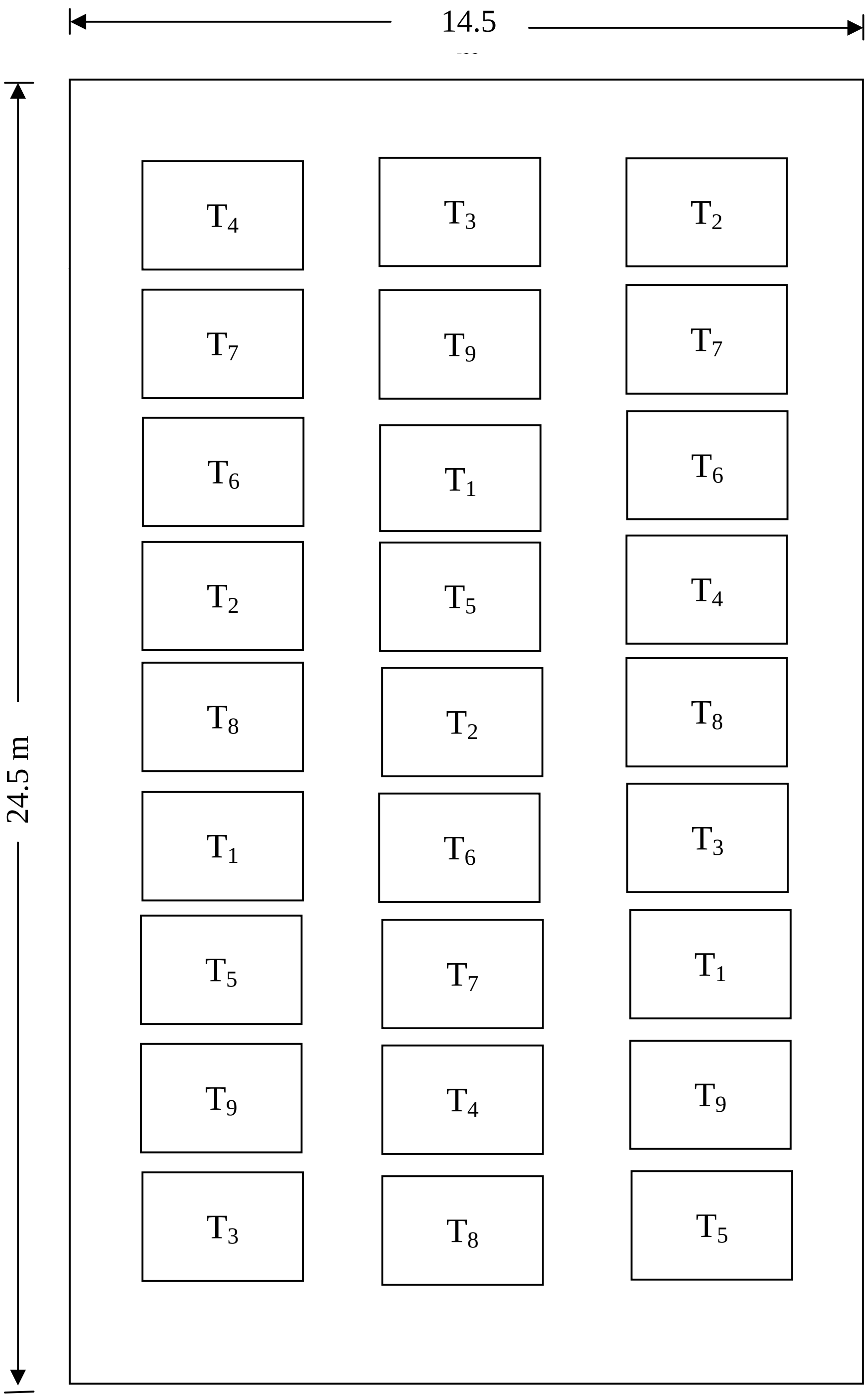
T_9: Planting at 25 December + Vertical mechanical support

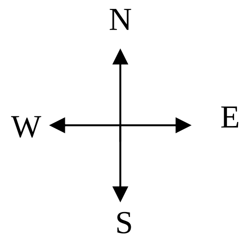
3.6 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing all of the treatments. Each experiment consists of total 27 plots of size 3.5 m × 2.0 m. The layout of the experiment is shown in Figure 1.

3.7 Raising of seedlings

The seedlings were raised in 3 m × 1 m size seed bed under special care at SAU Horticultural Farm Dhaka. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide





Plot size: 3.5 m × 2.0 m

Plot spacing: 50 cm

Between replication: 1.0 m

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

Figure 1. Layout of the experimental plot

was applied. Ten (10) grams of seeds were sown in seedbed on October 25, 2013, November 10, 2013 and November 25, 2103 for producing 30 days old seedlings as per treatment. After sowing, the seeds were covered with finished light soil. At the end of germination shading was done by bamboo mat over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering and weeding were done as when necessary to provide seedlings with ideal condition for growth.

3.8 Preparation of the main field

The selected experimental field was opened in the second week of November 2013 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 condition 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 the unit plots in accordance with the experimental design.

3.9 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O and H_3BO_3 as urea, TSP, MoP and borax were applied, respectively. The entire amounts of TSP, MoP and borax were applied during the final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after seedling transplanting. Well-rotten cowdung 20 t/ha also applied during final land preparation. The amount of manures and fertilizers were used which shown as recommended by BARI (2011).

Table 1. Fertilizer and manure applied for the experimental field

Manures and Fertilizers	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	20 tons	100	--	--	--
Nitrogen	300 kg	--	33.33	33.33	33.33
P_2O_5 (as TSP)	200 kg	100	--	--	--
K_2O (as MoP)	120 kg	100	--	--	--
H_3BO_3 (as Borax)	15 kg	100	--	--	--

3.10 Transplanting of seedlings

Healthy and uniform tomato seedlings of 30 days old were transplanted in the experimental plots on 25 November, 10 December and 25 December, 2013 as per treatment. The seedlings were transferred carefully from the seed bed to experimental plots to avoid damage of the root system. To minimize the damage of the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were transplanted in the plot with maintaining distance between row to row 60 cm and plant to plant 40 cm. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. The transplanted seedlings were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border if the experimental plots require any gap filling.

3.11 Intercultural operation

After transplanting of seedlings, various intercultural operations such as irrigation, weeding and top dressing etc. were accomplished for better growth and development of the tomato seedlings.

3.11.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after transplanting seedlings in every alternate day in the evening upto seedling establishment. Further irrigation was provided when needed. Excess water was effectively drained out at the time of heavy rain.

3.11.2 Weeding

Weeding was done to keep the plots clean and easy aeration of soil which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully. Mulching for breaking the crust of the soil was done when needed.

3.11.3 Top dressing

After basal dose, the remaining doses of urea were used as top-dressed in 3 equal installments at 15, 30 and 45 DAT. The fertilizers were applied on both sides of plant rows and mixed well with the soil. Eathing up operation was done immediately after top-dressing with nitrogen fertilizer.

3.12 Horizontal and vertical mechanical support

When the plants were well established, staking was given as per treatment of horizontal and vertical support (Plate 4) by bamboo sticks.

Plate 4. Horizontal support (A) and Vertical support (B)

3.13 Data collection

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

3.13.1 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.

3.13.2 Incidence of fruit borer

For recording data on fruit borer, 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 fruit borer up to the last harvesting of the fruit.

3.13.3 Fruit borer infestation

Total number of fruits and infested fruits 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 fruit borer infested fruits was calculated using the following formula:

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

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

3.14 Yield contributing characters and yield

3.14.1 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.

3.14.2 Number of leaves per plant

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

3.14.3 Number of branches per plant

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

3.14.4 Number of flower bunches per plant

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

3.14.5 Number of flowers per bunch

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

3.14.6 Single fruit weight

Single fruit weight was estimated by weighing 10 randomly selected fruits in every harvest and mean value was recorded.

3.14.7 Yield per hectare

The data on 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 hectare. Sum of the marketable yield, infested and deformed fruit yield finally expressed as the total yield in ton per hectare.

3.15 Statistically analysis

The data obtained from insect incidence and different growth and yield 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 combinations means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effects of different planting dates and mechanical support for the management of insect pests in tomato. The results have been presented by using different Table & Graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Number of white fly

At vegetative, flowering, fruiting, ripening stage and subsequently the entire growing period statistically significant variation was recorded in terms of number of whitefly plot^{-1} in tomato due to different planting dates and mechanical support under the present trial (Appendix III).

At vegetative stage, minimum number of white fly plot^{-1} (2.27) was recorded from the treatment T_5 (Planting at 10 December + Horizontal mechanical support) which was statistically similar (2.47) with T_6 (Planting at 10 December + Vertical mechanical support) and closely followed (2.80 and 3.00, respectively) by T_2 (Planting at 25 November + Horizontal mechanical support), T_3 (Planting at 25 November + Vertical mechanical support), T_1 (Planting at 25 November + No support) and T_4 (Planting at 10 December + No support), respectively (Table 2). On the other hand, the maximum (5.67) number of white fly plot^{-1} was found from T_7 (Planting at 25 December + No support) which was followed (4.40 and 3.80, respectively) by T_9 (Planting at 25 December + Vertical mechanical support) and T_8 (Planting at 25 December + Horizontal mechanical support), respectively.

At flowering stage, minimum number of white fly plot^{-1} (8.53) was recorded from the treatment T_5 which was statistically similar (8.73, 9.27 and 9.73, respectively) with the treatment T_6, T_2 and T_3 and closely followed (10.40 and 10.53, respectively) by T_1 and T_4, while the maximum (16.53) was recorded from the treatment T_7 which was closely followed (12.60) by T_9 treatment.

Table 2. Effect of planting dates and mechanical supports on number of white fly plot^{-1} in tomato at different stages of plant growth

Treatments	Number of white fly plot^{-1} at			
	Vegetative stage	Flowering stage	Fruiting stage	Total
T_1	3.00 d	10.53 cd	7.87 bc	21.40 d
T_2	2.80 de	9.27 de	6.40 d	18.47 ef
T_3	2.80 de	9.73 de	6.60 cd	19.13 e
T_4	3.00 d	10.40 cd	7.20 cd	20.60 d
T_5	2.27 f	8.53 e	5.87 d	16.67 g
T_6	2.47 ef	8.73 e	6.00 d	17.20 fg
T_7	5.67 a	16.53 a	11.53 a	33.73 a
T_8	3.80 c	11.07 c	8.67 b	23.53 c
T_9	4.40 b	12.60 b	8.67 b	25.67 b
$LSD_{(0.05)}$	0.468	1.183	1.273	1.595
CV(%)	8.07	6.31	9.62	3.40

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

At fruiting stage, minimum number of white fly plot^{-1} (5.87) was recorded from the treatment T_5 which was statistically similar (6.00, 6.40, 6.60 and 7.20, respectively) with the treatment T_6, T_2 and T_3 and T_4 and closely followed (7.87) by T_1, whereas the maximum (11.53) number of white fly plot^{-1} was recorded from the treatment T_7 which was closely followed (8.67) by T_8 and T_9 treatment.

At entire growing season, minimum number of white fly plot^{-1} (16.67) was recorded from the treatment T_5 which was statistically similar (217.20) with the treatment T_6 and closely followed (18.47) by T_2, whereas the maximum (33.73) number of white fly plot^{-1} was recorded from the treatment T_7 which was closely followed (25.67) by T_9 treatment.

From the above findings, it is revealed that planting at 10 December + Horizontal mechanical support was more effective against the white fly of tomato which was followed by planting at 10 December + vertical mechanical support. Probably planting of tomato at 10 December is the optimum time and the environmental condition also not favorable during this period and that is why the lowest number of white fly for 10 December planting. On the other hand, horizontal mechanical support reduced the number of white fly through create an unfavorable environmental condition for white fly. Planting on 25 December + no support was favorable for the growth and development of white fly that is why the highest number of white fly was recorded for this treatment. The literature available on the similar issues also supports our present study. 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 on crop growth and yield. The white flies are very small, fragile and active insects and this pest showed their existence in the tomato field from vegetative to ripening stage (Parihar *et al*., 1994).

4.2 Number of fruit borer

Statistically significant variation was recorded for number of bruit borer plot^{-1} in tomato due to different planting dates and mechanical support at fruiting and ripening stage and also subsequently the entire growing period (Appendix IV).

At fruiting stage, minimum number of fruit borer plot^{-1} (6.40) was recorded from the treatment T_5 which was statistically similar (6.87 and 7.00, respectively) with the treatment T_6 and T_2 and closely followed (7.40 and 7.53, respectively) by T_3 and T_4, respectively, whereas the maximum (13.13) number was recorded from T_7 which was closely followed (9.20 and 8.80) by T_9 and T_8 treatment, respectively.

At ripening stage, minimum number of fruit borer plot^{-1} (2.00) was recorded from the treatment T_5 which was statistically similar (2.67) with the treatment T_6 and closely followed (2.80 and 3.07, respectively) by T_2 and T_3, while the maximum (7.80) number of fruit borer plot^{-1} was recorded from the treatment T_7 which was closely followed (4.80 and 4.47) by T_9 and T_8 treatment, respectively.

At entire growing season, minimum number of fruit borer plot^{-1} (8.40) was recorded from the treatment T_5 which was statistically similar (9.54) with the treatment T_6 and closely followed (9.80 and 10.47, respectively) by T_2 and T_3, respectively, whereas the maximum (20.93) number of fruit borer plot^{-1} was recorded from the treatment T_7 which was closely followed (14.00 and 13.27) by T_9 and T_8 treatment, respectively.

From the above findings, it is revealed that planting at 10 December + Horizontal mechanical support was more effective against the fruit borer of tomato which was followed by planting at 10 December + vertical mechanical support and that may be happened due to the unfavorable environmental condition for fruit borer. The literature available on the similar issues also supports our present study. Tomato fruit borer, *H. armigera* (Hub.) is one of the serious pests attacking tomato (Singh and Singh, 1977). 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.

Table 3. Effect of planting dates and mechanical supports on number of fruit borer plot^{-1} in tomato at different stages

Treatments	Number of fruit borer plot^{-1} at		
	Fruiting stage	Ripening stage	Total
T_1	8.00 cd	4.13 bc	12.13 c
T_2	7.00 ef	2.80 e	9.80 ef
T_3	7.40 de	3.07 de	10.47 de
T_4	7.53 de	3.60 cd	11.13 cd
T_5	6.40 f	2.00 f	8.40 g
T_6	6.87 ef	2.67 ef	9.54 fg
T_7	13.13 a	7.80 a	20.93 a
T_8	8.80 bc	4.47 b	13.27 b
T_9	9.20 b	4.80 b	14.00 b
$LSD_{(0.05)}$	0.922	0.732	2.399
CV(%)	6.46	10.78	4.81

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

4.3 Effect of different treatments on fruit infestation of tomato

Healthy, infested fruits and infestation percentage of tomato were recorded at early, mid, late harvesting periods and subsequently for total harvesting period and significant variation was found for different treatment (Appendix V to XII).

4.3.1 At early fruiting stage

At early fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (9.73) in T_5 treatment which was statistically similar (9.53) with T_6 and closely followed (9.20) by T_2, while the lowest (6.67) number in T_7 which was closely followed (7.47) by T_9 treatment. The highest number of infested fruit plant^{-1} (0.80) was recorded in T_7 treatment which was statistically similar (0.60) with T_9 and closely followed (0.53 and 0.40, respectively) by T_8 and T_4, respectively, whereas the lowest number of infested fruit (0.27) in T_5 treatment which was statistically identical (0.33) with T_2, T_3 and T_6, respectively (Table 4). The highest percentage of infested fruit in number (10.65%) was recorded in T_7 treatment which was followed (7.45%, 6.14% and 5.94%, respectively) by T_9, T_8 and T_1, respectively, while the lowest percentage of infested fruit in number (2.67%) was recorded in T_5 treatment which was statistically similar (3.39%, 3.50%, 3.61% and 4.42%, respectively) with T_6, T_2, T_3 and T_4, respectively.

At early fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (915.70 g) in T_5 treatment which was statistically similar (913.79 g, 910.64 g, 898.02 g and 883.82 g, respectively) with T_6, T_2, T_3 and T_4, respectively and closely followed (863.14 g) by T_1, whereas the lowest (794.17 g) weight was recorded in T_7 which was closely followed (842.66 g and 850.55 g, respectively) by T_9 and T_8 treatment, respectively. The highest weight of infested fruit plant^{-1} (97.89 g) was recorded in T_7 treatment which was closely followed (75.96 g and 72.33 g, respectively) by T_9 and T_8, respectively, while the lowest weight of infested fruit (41.63 g) in T_5 treatment which was statistically identical (44.44 g and 45.68 g, respectively) with T_6 and T_2, respectively (Table 5). The highest percentage of infested fruit in weight (10.99%) was recorded in T_7 treatment which was followed (8.29% and 7.84%, respectively) by T_9 and T_8, respectively, while the lowest percentage of infested fruit in weight (4.35%) in T_5 which was statistically similar (4.64% and 4.77%, respectively) with T_6 and T_2, respectively.

Table 4. Effect of planting dates and mechanical supports in controlling tomato fruit borer at early fruiting stage by number

Treatments	Tomato fruit in number/plant		
	Healthy	Infested	Infestation (%)
T_1	8.47 de	0.53 bc	5.94 bc
T_2	9.20 bc	0.33 cd	3.50 d
T_3	8.87 cd	0.33 cd	3.61 d
T_4	8.67 d	0.40 bcd	4.42 cd
T_5	9.73 a	0.27 d	2.67 d
T_6	9.53 ab	0.33 cd	3.39 d
T_7	6.67 g	0.80 a	10.65 a
T_8	8.13 e	0.53 bc	6.14 bc
T_9	7.47 f	0.60 ab	7.45 b
$LSD_{(0.05)}$	0.468	0.205	2.209
CV(%)	3.17	15.49	14.04

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

Table 5. Effect of planting dates and mechanical supports in controlling tomato fruit borer at early fruiting stage by weight

Treatments	Tomato fruit in weight/plant (g)		
	Healthy	Infested	Infestation (%)
T_1	863.14 bc	61.85 c	6.69 c
T_2	910.64 a	45.68 ef	4.77 ef
T_3	898.02 ab	48.75 de	5.15 de
T_4	883.82 abc	51.85 d	5.55 d
T_5	915.70 a	41.63 f	4.35 f
T_6	913.79 a	44.44 ef	4.64 ef
T_7	794.17 d	97.89 a	10.99 a
T_8	850.55 c	72.33 b	7.84 b
T_9	842.66 c	75.96 b	8.29 b
$LSD_{(0.05)}$	42.61	4.548	0.655
CV(%)	5.81	4.38	5.85

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

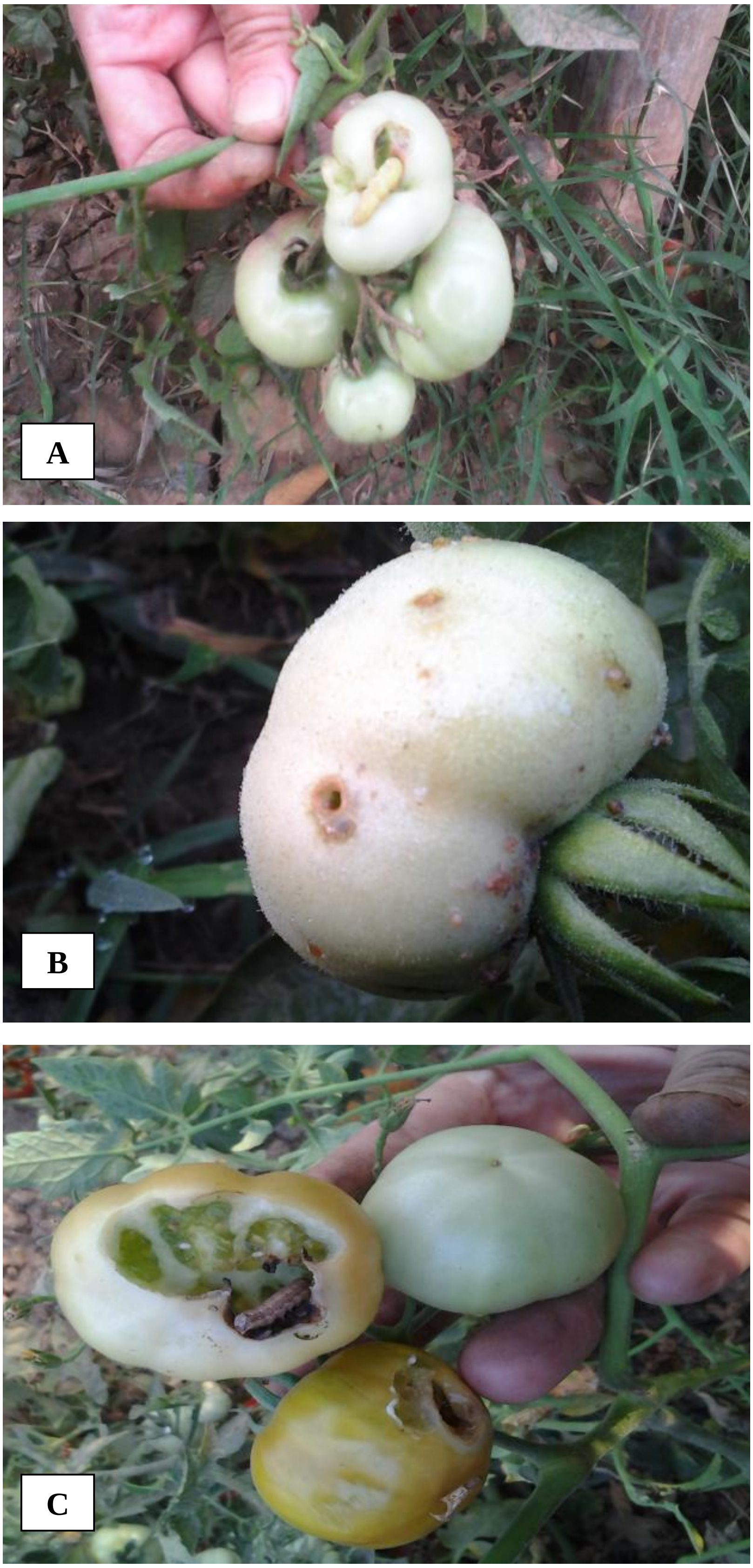


Plate 5. Infested fruits at early (A), mid (B) and late (C) fruiting stage of tomato

4.3.2 At mid fruiting stage

At mid fruiting stage of tomato in number basis, the healthy fruit $plant^{-1}$ was highest (10.27) in T_5 treatment which was statistically similar (10.07) with T_6 and closely followed (9.87) by T_2, while the lowest (7.40) number was recorded in T_7 treatment which was closely followed (8.20) by T_9 treatment. The highest number of infested fruit $plant^{-1}$ (1.00) was recorded in T_7 treatment which was statistically similar (0.87) with T_9 and closely followed (0.80 and 0.73, respectively) by T_8 and T_1, respectively, whereas the lowest number of infested fruit (0.33) was recorded in T_5 treatment which was statistically identical (0.40) with T_2 and T_6, respectively (Table 6). The highest percentage of infested fruit in number (11.92%) was recorded in T_7 treatment which was followed (9.57%, 8.51% and 7.67%, respectively) by T_9, T_8 and T_1, respectively, while the lowest percentage of infested fruit in number (3.13%) was recorded in T_5 treatment which was statistically similar (3.82% and 3.90%, respectively) with T_6 and T_2, respectively.

At mid fruiting stage of tomato in weight basis, the healthy fruit $plant^{-1}$ was highest (985.19 g) in T_5 treatment which was statistically similar (982.22 g, 975.30 g, 971.15 g and 947.89 g, respectively) with T_6, T_2, T_3 and T_4, respectively and closely followed (926.00 g) by T_1, while the lowest (826.40 g) weight was recorded in T_7 treatment which was followed (903.19 g and 913.29 g, respectively) by T_9 and T_8 treatment, respectively and they were statistically similar. The highest weight of infested fruit $plant^{-1}$ (119.13 g) was recorded in T_7 treatment which was closely followed (96.47 g) by T_9, whereas the lowest weight of infested fruit (46.48 g) was recorded in T_5 treatment which was statistically identical (48.19 g and 49.40 g, respectively) with T_6 and T_2, respectively (Table 7). The highest percentage of infested fruit in weight (12.62%) was recorded in T_7 treatment which was followed (9.65%) by T_9, whereas the lowest percentage of infested fruit in weight (4.50%) was recorded in T_5 treatment which was statistically similar (4.68% and 4.82%, respectively) with T_6 and T_2, respectively.

Table 6. Effect of planting dates and mechanical supports in controlling tomato fruit bore at mid fruiting stage by number basis

Treatments	Tomato fruit in number/plant		
	Healthy	Infested	Infestation (%)
T_1	8.80 e	0.73 bc	7.67 c
T_2	9.87 bc	0.40 ef	3.90 e
T_3	9.67 c	0.53 de	5.23 d
T_4	9.20 d	0.60 cd	6.12 d
T_5	10.27 a	0.33 f	3.13 e
T_6	10.07 ab	0.40 ef	3.82 e
T_7	7.40 g	1.00 a	11.92 a
T_8	8.60 e	0.80 b	8.51 bc
T_9	8.20 f	0.87 ab	9.57 b
$LSD_{(0.05)}$	0.367	0.134	1.326
CV(%)	5.34	12.23	11.51

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

Table 7. Effect of planting dates and mechanical supports in controlling tomato fruit borer at mid fruiting stage by weight basis

Treatments	Tomato fruit in weight/plant (g)		
	Healthy	Infested	Infestation (%)
T_1	926.00 bc	85.42 c	8.45 c
T_2	975.30 a	49.40 f	4.82 f
T_3	971.15 ab	62.52 e	6.05 e
T_4	947.89 abc	69.49 d	6.85 d
T_5	985.19 a	46.48 f	4.50 f
T_6	982.22 a	48.19 f	4.68 f
T_7	826.40 d	119.13 a	12.62 a
T_8	913.29 c	89.33 c	8.91 c
T_9	903.19 c	96.47 b	9.65 b
$LSD_{(0.05)}$	43.96	4.687	0.684
CV(%)	4.71	3.66	5.34

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

4.3.3 At late fruiting stage

At late fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (11.67) in T_5 treatment which was statistically similar (11.47) with T_6 and closely followed (11.07) by T_2, while the lowest (7.67) number was recorded in T_7 treatment which was closely followed (8.33) by T_9 treatment. The highest number of infested fruit plant^{-1} (0.87) was recorded in T_7 treatment which was statistically similar (0.80 and 0.73, respectively) with T_9 and T_8, respectively and closely followed (0.60) by T_1, whereas the lowest number of infested fruit (0.27) was recorded in T_5 treatment which was statistically identical (0.33 and 0.40, respectively) with T_6 and T_2, respectively (Table 8). The highest percentage of infested fruit in number (10.15%) was recorded in T_7 treatment which was statistically similar (8.77%) with T_9 and followed (7.31%) by T_8, whereas the lowest percentage of infested fruit in number (2.22%) was recorded in T_5 treatment which was statistically similar (2.82% and 3.49%, respectively) with T_6 and T_2, respectively.

At late fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (951.25 g) in T_5 treatment which was statistically similar (947.91 g, 940.15 g, 924.37 g, 914.85 g and 902.83 g, respectively) with T_6, T_2, T_3, T_4 and T_1, respectively and closely followed (895.22 g) by T_8, while the lowest (823.53 g) weight was recorded in T_7 treatment which was followed (885.35 g) by T_9. The highest weight of infested fruit plant^{-1} (98.27 g) was recorded in T_7 treatment which was closely followed (88.57 g) by T_9, whereas the lowest weight of infested fruit (41.67 g) was recorded in T_5 treatment which was statistically identical (43.43 g and 45.77 g, respectively) with T_6 and T_2, respectively (Table 9). The highest percentage of infested fruit in weight (10.66%) was recorded in T_7 treatment which was followed (9.08%) by T_9, whereas the lowest percentage of infested fruit in weight (4.21%) was recorded in T_5 treatment which was statistically similar (4.39% and 4.65%, respectively) with T_6 and T_2, respectively.

Table 8. Effect of planting dates and mechanical supports in controlling tomato fruit borer at late fruiting stage by number basis

Treatments	Tomato fruit in number/plant		
	Healthy	Infested	Infestation (%)
T_1	9.73 e	0.60 bc	5.81 cd
T_2	11.07 b	0.40 def	3.49 efg
T_3	10.73 c	0.47 cde	4.16 ef
T_4	10.27 d	0.53 cd	4.93 de
T_5	11.67 a	0.27 f	2.22 g
T_6	11.47 a	0.33 ef	2.82 fg
T_7	7.67 h	0.87 a	10.15 a
T_8	9.27 f	0.73 ab	7.31 bc
T_9	8.33 g	0.80 a	8.77 ab
$LSD_{(0.05)}$	0.319	0.164	1.516
CV(%)	4.85	17.49	15.87

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

Table 9. Effect of planting dates and mechanical supports in controlling tomato fruit borer at late fruiting stage by weight basis

Treatments	Tomato fruit in weight/plant (g)		
	Healthy	Infested	Infestation (%)
T_1	902.83 abc	68.53 d	7.05 d
T_2	940.15 ab	45.77 fg	4.65 fg
T_3	924.37 abc	51.62 f	5.29 f
T_4	914.85 abc	60.00 e	6.15 e
T_5	951.25 a	41.67 g	4.21 g
T_6	947.91 a	43.43 g	4.39 g
T_7	823.53 d	98.27 a	10.66 a
T_8	895.22 bc	81.75 c	8.37 c
T_9	885.35 c	88.57 b	9.08 b
$LSD_{(0.05)}$	45.51	6.764	0.664
CV(%)	5.89	6.07	5.77

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

4.3.4 At total fruiting stage

At total fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (31.67) in T_5 treatment which was statistically similar (31.07) with T_6 and closely followed (30.13 and 29.27, respectively) by T_2 and T_3, respectively, whereas the lowest (21.73) number was recorded in T_7 treatment which was closely followed (24.00) by T_9 treatment. The highest number of infested fruit plant^{-1} (2.67) was recorded in T_7 treatment which was followed (2.27 and 2.07, respectively) by T_9 and T_8, respectively, while the lowest number of infested fruit (0.87) was recorded in T_5 treatment which was statistically identical (1.07 and 1.13, respectively) with T_6 and T_2, respectively (Figure 2). The highest percentage of infested fruit in number (10.93%) was recorded in T_7 treatment which was followed (8.64%) by T_9, whereas the lowest percentage of infested fruit in number (2.66%) was recorded in T_5 treatment which was statistically similar (3.32% and 3.62%, respectively) with T_6 and T_2, respectively.

At total fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (2852.14 g) in T_5 treatment which was statistically similar (2843.92 g, 2826.09 g and 2793.54 g, respectively) with T_6, T_2 and T_3, respectively and closely followed (2746.56 g) by T_4, while the lowest (2444.09 g) weight was recorded in T_7 treatment which was statistically similar (2631.19 g and 2659.05 g, respectively) by T_9 and T_8, respectively. The highest weight of infested fruit plant^{-1} (315.29 g) was recorded in T_7 treatment which was closely followed (261.01 g) by T_9, whereas the lowest weight of infested fruit (129.78 g) was recorded in T_5 treatment which was statistically identical (136.06 g) with T_6 (Figure 3). The highest percentage of infested fruit in weight (11.43%) was recorded in T_7 treatment which was followed (9.03%) by T_9, whereas the lowest percentage of infested fruit in weight (4.35%) was recorded in T_5 treatment which was statistically similar (4.57%) with T_6.

From the above findings, it is revealed that planting at 10 December + Horizontal mechanical support was more effective against the fruit borer of tomato as well as reduction of infestation which was followed by planting at 10 December + vertical mechanical support. The tomato fruit borer, *H. armigera* 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). Gupta *et al.* (1998) found that infestations were heaviest (17.88%) in March- April and lightest in January- February. The fruits harvested in October-November, January-February and March-April showed 18.90, 18.00 and 21.64% infestation of the total number of fruits, respectively. Infestations were heavier in the first 4 pickings. The fruits harvested in March-April resulted infestation 49.70% at the first picking and 4.25% at the 7^{th}.

4.4 Yield contributing character and yield of tomato

Yield contributing characters and yield of tomato were recorded and statistically significant variation was recorded for different treatment under the present trial (Appendix XIII).

4.4.1 Plant height

Plant height of tomato showed significant differences for different planting dates and mechanical support under the present trial (Figure 4). The longest plant (96.33 cm) was recorded in T_5 which was statistically similar (94.44 cm, 93.82 cm, 93.22 cm, 91.70 cm and 91.47 cm, respectively) with T_6, T_2, T_3, T_4 and T_1 treatment, respectively and followed (86.60 cm) by T_8 treatment, while the shortest plant (77.71 cm) was found in T_7 treatment which was statistically similar (82.29 cm) with T_9.

4.4.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} of tomato showed significant differences for different planting dates and mechanical support (Table 10). The maximum number of leaves plant^{-1} (125.27) was recorded in T_5 treatment which was statistically similar (124.20, 122.87, 121.40, 119.27 and 118.27 and 111.47, respectively) with T_6, T_2, T_3, T_4, T_1 and T_8 treatment, respectively, whereas the minimum number (102.93) was found in T_7 treatment which was statistically similar (109.13) with T_9 treatment.

4.4.3 Number of branches plant^{-1}

Number of branches plant^{-1} of tomato showed significant differences for different planting dates and mechanical support under the present trial (Table 10). The highest number of branches plant^{-1} (17.27) was recorded in T_5 which was statistically similar (16.67 and 16.60, respectively) with T_6 and T_2 treatment, respectively and closely followed (15.20, 15.13 and 14.60) by T_3, T_4 and T_1 treatment, respectively, whereas the lowest number (12.33) was found in T_7 treatment which was statistically similar (13.40 and 14.13, respectively) with T_9 and T_8, respectively.

4.4.4 Number of flower bunch plant^{-1}

Number of flower bunch plant^{-1} of tomato showed significant differences for different planting dates and mechanical support under the present trial (Table 10). The maximum number of flower bunch plant^{-1} (17.27) was recorded in T_5 which was statistically similar (16.67 and 16.60, respectively) with T_6 and T_2 treatment, respectively, whereas the minimum number (12.33) in T_7 which was statistically similar (13.40 and 14.13, respectively) with T_9 and T_8 treatment, respectively.

Table 10. Effect of planting dates and mechanical supports on yield contributing characters and yield of tomato

Treatments	Number of leaf plant^{-1}	Number of branch plant^{-1}	Number of flower bunch plant^{-1}	Number of flower bunch^{-1}	Single fruit weight (g)	Fruit yield (t ha^{-1})
T_1	118.27 ab	14.60 bc	14.60 bc	6.00 cd	92.57 a	54.94 ab
T_2	122.87 ab	16.60 ab	16.60 ab	6.60 b	94.49 a	54.77 ab
T_3	121.40 ab	15.20 bc	15.20 bc	6.33 bc	93.67 a	54.21 ab
T_4	119.27 ab	15.13 bc	15.13 bc	6.20 cd	93.52 a	53.52 ab
T_5	125.27 a	17.27 a	17.27 a	7.27 a	95.15 a	55.91a
T_6	124.20 ab	16.67 ab	16.67 ab	7.00 a	94.89 a	55.27 ab
T_7	102.93 c	12.33 d	12.33 d	5.07 f	82.68 b	45.39 c
T_8	111.47 abc	14.13 cd	14.13 cd	5.87 de	91.02 a	51.08 abc
T_9	109.13 bc	13.40 cd	13.40 cd	5.60 e	88.56 ab	48.68 bc
$LSD_{(0.05)}$	13.69	1.905	1.905	0.371	6.744	6.134
CV(%)	6.75	7.32	5.22	3.47	4.24	6.73

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

T_1: Planting at 25 November + No support

T_2: Planting at 25 November + Horizontal mechanical support

T_3: Planting at 25 November + Vertical mechanical support

T_4: Planting at 10 December + No support

T_5: Planting at 10 December + Horizontal mechanical support

T_6: Planting at 10 December + Vertical mechanical support

T_7: Planting at 25 December + No support

T_8: Planting at 25 December + Horizontal mechanical support

T_9: Planting at 25 December + Vertical mechanical support

4.4.5 Number of flower bunch $^{-1}$

Number of flower bunch $^{-1}$ of tomato varied significantly for different planting dates and mechanical support under the present trial (Table 10). The maximum number of flower bunch^{-1} (7.27) was recorded in T_5 which was statistically similar (7.00) with T_6 treatment and closely followed (6.60 and 6.33, respectively) by T_2 and T_3 treatment, respectively, whereas the minimum number (5.07) in T_7 which was closely followed (5.60 and 5.87, respectively) with T_9 and T_8, respectively.

4.4.6 Single fruit weight

Single fruit weight of tomato showed significant differences for different planting dates and mechanical support under the present trial (Table 10). The highest single fruit weight (95.15 g) was recorded in T_5 which was statistically similar (94.89 g, 94.49 g, 93.67 g, 93.52 g, 92.57 g and 91.02 g, respectively) with $T_{6,}$ T_2, T_3, T_4, T_1 and T_8 treatment, respectively, whereas the lowest weight (82.68 g) was found in T_7 treatment which was statistically similar (88.56 g) with T_9.

4.4.7 Fruit yield heactare^{-1}

Fruit yield hectare^{-1} of tomato showed significant differences for different planting dates and mechanical support under the present trial (Table 10). The highest fruit yield (55.91 t ha^{-1}) was recorded in T_5 which was statistically similar (55.27 t ha^{-1}, 54.94 t ha^{-1}, 54.77 t ha^{-1}, 54.21 t ha^{-1}, 53.52 t ha^{-1} and 51.08 t ha^{-1}, respectively) with $T_{6,}$ T_1, T_2, T_3, T_4 and T_8 treatment, respectively, whereas the lowest yield (45.39 t ha^{-1}) was found in T_7 treatment which was statistically similar (48.68 t ha^{-1}) with T_9.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka during the period from November 2013 to April 2014 to study the effects of different planting dates and mechanical support for the management of insect pests in tomato. BARI Tomato 5 was used as planting material. The experiment was consisted of nine treatments. These were as follows- T_1: Planting at 25 November + No support; T_2: Planting at 25 November + Horizontal mechanical support; T_3: Planting at 25 November + Vertical mechanical support; T_4: Planting at 10 December + No support; T_5: Planting at 10 December + Horizontal mechanical support; T_6: Planting at 10 December + Vertical mechanical support; T_7: Planting at 25 December + No support; T_8: Planting at 25 December + Horizontal mechanical support and T_9: Planting at 25 December + Vertical mechanical support. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

In case of white fly, at the entire growing season, minimum number of white fly plot^{-1} (16.67) was recorded from the treatment T_5, whereas the maximum (33.73) from the treatment T_7. For tomato fruit borer, **a**t entire growing season, minimum number of fruit borer plot^{-1} (8.40) was recorded from the treatment T_5, whereas the maximum (20.93) from the treatment T_7.

At early fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (9.73) in T_5 treatment, while the lowest (6.67) in T_7 treatment. The highest number of infested fruit plant^{-1} (0.80) was recorded in T_7 treatment, whereas the lowest (0.27) in T_5 treatment. The highest percentage of infested fruit in number (10.65%) was recorded in T_7 treatment, while the lowest (2.67%) in T_5 treatment. At early fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (915.70 g) in T_5 treatment, whereas the lowest (794.17 g) in T_7 treatment. The highest weight of infested fruit plant^{-1} (97.89 g) was recorded in T_7 treatment, while the lowest (41.63 g) in T_5 treatment. The highest percentage of infested fruit in weight (10.99%) was recorded in T_7 treatment, while the lowest (4.35%) in T_5 treatment.

At mid fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (10.27) in T_5 treatment, while the lowest (7.40) in T_7 treatment. The highest number of infested fruit plant^{-1} (1.00) was recorded in T_7 treatment, whereas the lowest (0.33) in T_5 treatment. The highest percentage of infested fruit in number (11.92%) was recorded in T_7 treatment, while the lowest (3.13%) in T_5 treatment. At mid fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (985.19 g) in T_5 treatment, while the lowest (826.40 g) in T_7 treatment. The highest weight of infested fruit plant^{-1} (119.13 g) was recorded in T_7 treatment, whereas the lowest (46.48 g) in T_5 treatment. The highest percentage of infested fruit in weight (12.62%) was recorded in T_7 treatment, whereas the lowest (4.50%) in T_5 treatment.

At late fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (11.67) in T_5 treatment, while the lowest (7.67) in T_7 treatment. The highest number of infested fruit plant^{-1} (0.87) was recorded in T_7 treatment, whereas the lowest (0.27) in T_5 treatment. The highest percentage of infested fruit in number (10.15%) was recorded in T_7 treatment, whereas the lowest (2.22%) in T_5 treatment. At late fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (951.25 g) in T_5 treatment, while the lowest (823.53 g) in T_7 treatment. The highest weight of infested fruit plant^{-1} (98.27 g) was recorded in T_7 treatment, whereas the lowest (41.67 g) in T_5 treatment. The highest percentage of infested fruit in weight (10.66%) was recorded in T_7 treatment, whereas the lowest (4.21%) in T_5 treatment.

At total fruiting stage of tomato in number basis, the healthy fruit plant^{-1} was highest (31.67) in T_5 treatment, whereas the lowest (21.73) in T_7 treatment. The highest number of infested fruit plant^{-1} (2.67) was recorded in T_7 treatment, while the lowest (0.87) in T_5 treatment. The highest percentage of infested fruit in number (10.93%) was recorded in T_7 treatment, whereas the lowest (2.66%) in T_5 treatment. At total fruiting stage of tomato in weight basis, the healthy fruit plant^{-1} was highest (2852.14 g) in T_5 treatment, while the lowest (2444.09 g) in T_7 treatment.

The highest weight of infested fruit plant^{-1} (315.29 g) was recorded in T_7 treatment, whereas the lowest (129.78 g) in T_5 treatment. The highest percentage of infested fruit in weight (11.43%) was recorded in T_7 treatment, whereas the lowest (4.35%) in T_5 treatment.

The longest plant (96.33 cm) was recorded in T_5, while the shortest plant (77.71 cm) in T_7 treatment. The maximum number of leaves plant^{-1} (125.27) was recorded in T_5, whereas the minimum number (102.93) in T_7 treatment. The maximum number of branches plant^{-1} (17.27) was recorded in T_5, whereas the minimum number (12.33) in T_7 treatment. The maximum number of flower bunch plant^{-1} (13.00) was recorded in T_5, whereas the minimum number (10.33) in T_7 treatment. The maximum number of flower bunch^{-1} (7.27) was recorded in T_5, whereas the minimum number (5.07) in T_7 treatment. The highest single fruit weight (95.15 g) was recorded in T_5, whereas the lowest weight (82.68 g) in T_7 treatment. The highest fruit yield (55.91 t ha^{-1}) was recorded in T_5, whereas the lowest yield (45.39 t ha^{-1}) in T_7 treatment.

Conclusion

From the findings of the study, it is revealed that Planting at 10 December + Horizontal mechanical support was more effective for reduction of insect pest of tomato and also for highest yield which was followed by planting at 10 December + vertical mechanical support.

Recommendations

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

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;

2. Another component of integrated pest management practices may be included in further study.

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