MANAGEMENT OF MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.) USING BOTANICALS

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CERTIFICATE

This is to certify that thesis entitled, "Management of Mustard Aphid, *Lipaphis erysimi* (Kalt.) Using Botanicals" 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 Md. Rezaul Kabir, Registration No. 06-01879 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:
Place: Dhaka, Bangladesh

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MANAGEMENT OF MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.) USING BOTANICALS

ABSTRACT

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2012 to March 2013 to study the management of mustard aphid, *Lipaphis erysimi* (kalt.) using botanicals. Seeds of BARI Sarisa-15 were used as a test crop for this experiment. The experiment comprised of the treatments T_1: Neem seed karnel extract 5% at 7 days interval, T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval, T_3: Neem oil @ 0.3% at 7 days interval, T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval, T_5: (Neem seed karnel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval, T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval, T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval and T_8: untreated control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of aphid population, at the total flowering stage, the lowest number of aphid (2.19) was recorded from T_7 and the highest number (30.00) from T_8. At the total fruiting stage, the lowest number of aphid (4.64) was recorded from T_7, while the highest number (31.40) from T_8. At early flowering stage, the highest infested plant/m^2 (15.56%) was attained in T_8 treatment again, the lowest (1.11%) in T_7. At mid flowering stage, the highest infested plant/m^2 (17.78%) was observed in T_8 treatment and the lowest infested plant/m^2 (2.22%) in T_7. At late flowering stage, the highest infested plant/m^2 (21.11%) was recorded in T_8 treatment, whereas the lowest infested plant/m^2 (3.33%) was recorded in T_7.At early fruiting stage the highest infested plant/m^2 (18.89%) was recorded in T_8 treatment, while the lowest (4.44%) in T_7. At mid fruiting stage, the infested plant/m^2 (22.22%) was attained in T_8 treatment, whereas the lowest (5.56%) in T_7. At late fruiting stage, the highest infested plant/m^2 (24.44%) was found in T_8 treatment and the lowest (6.67%) in T_7.The highest seeds yield per hectare (2.45 ton) was recorded in T_7, whereas the lowest (2.02 ton) was found in T_8 treatment. Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for controlling mustard aphid.

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CHAPTER I

INTRODUCTION

Mustard (*Brassica campestris*) belongs to the genus *Brassica* of the family Cruciferae. It is one of the leading oilseed crops in Bangladesh as well as in the World. It is one of the important oleiferous crops and constitute major source of edible oil for the human consumption and it's cake for animals (Bakhetia, 1984). In Bangladesh more than 291.54 thousand metric tons of rape and mustard produced from total 245.815 thousand hectares of cultivable land in the year 2009-2010 (BBS, 2011). Mustard occupied the top of the list in respect of area and production compare to among the oilseed crops that are grown in Bangladesh. It is mainly a self-pollinating crop, although on an average 7.5 to 30% out-crossing does occur under natural field conditions (Abraham, 1994; Rakow and Woods, 1987). Oilseed crops play a vital role in human nutrition. It is used as a condiment, salad, green manure, fodder crop, and a leaf and stem as vegetable in the various mustard growing countries. In Bangladesh, sources of edible oils are rapeseed-mustard, sesame, groundnut, soybean, niger, linseed, sunflower and safflower. But rapeseed-mustard is one of the major oilseed crops of the world after soybean and palm (FAO, 2004).

The Oliferous oil contained not only rich source of energy (about 9 Kcal/g) but also rich in fat soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6 g of oil for a diet with 2700 Kcal. On RDA basis, the edible oil need for 150 millions people are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% area of total cropped area in Bangladesh. The annual oil seed production of 0.41 million tons of which the share of rapeseed-mustard was 0.21 million tons, which comes about 52% of the total edible oil seed production (BBS, 2011).

Bangladesh is running with acute shortage of edible oil and it is about 70% of the total demand of the country. Annually producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons and to meet up the demand, the country has to import oil and oilseeds to the tune of about 160 million US $ every year (Wahhab *et al*., 2002). Oil cake of mustard is used as fertilizer in the South Asian region for centuries. In combination with cowdung manure and ashes, the oil cakes sustained the fertility levels of marginal farms. Oil cakes render indirect help in promoting the microflora and microfauna of soils providing readily available amino acids and free sugars to the latter. It is clear that oil cakes are rich sources of nitrogen, phosphorus and potassium micronutrients nutrients and trace amounts of micro nutrients.

Every efforts is being made to raise the productivity of mustard crops by adopting modern agricultural practices such as use of high yielding varieties, suitable manuring and assured irrigation in order to meet the growing demand of oils although insect pests is a serious problems. More than three dozen of pests are known to be associated with various phonological stages of mustard crops (Singh and Singh, 1983). Among them mustard aphid, sawfly, mustard leaf eating caterpillar etc. are the very important insect pests. Mustard aphid is the most serious and destructive pest and limiting factors for successful cultivation of mustard in South Asia (Bakhetia, 1983 and Zaman, 1990). The rate of reproduction varies from 5-9 young in a single day by a single female and the total numbers of young produced by the female varies from 76-188 (Nair, 1986). Both the nymph and adult of the aphid suck sap from leaves, steams, inflorescences and pods, as a result the plant show stunted growth, flowers wither and pod formation is hindered (Atwal and Dhaliwal, 1997; Begum 1995 and Butane and Jotwanil, 1984). The loss in grain weight due to these pests varies greatly within Brassicae; being 35.0-73.3% under different agro climatic regions with a mean loss of 54.2% (Reddy *et al*., 1990).

Good control of mustard aphid can be obtained by spraying traditional organic insecticides (Bakhetia, 1984 and Khurana *et al*., 1989). However, some chemicals

have posed some serious problems to health and environmental safety, because of their high toxicity and prolonged persistence. Thus, newer approaches for pest control are continuously being sought. The naturally occurring, biologically active plants appear to have a prominent role for the development of future commercial pesticides not only for increased productivity but for the safety of the environment and public health. Botanicals are, in general, more compatible with the environmental components than the synthetic pesticides, owing primarily to their susceptibility to degradation by light, heat and microorganisms. Moreover, there is no report of pest resurgence due to the use of botanicals pesticides. The ecological approach to pest management suggests the use of botanical pesticide and some chemical pesticide only and where necessary. It may become therefore, absolutely impetration that a fresh approach to insect pest control be undertaken by studying its population fluctuation in relation to agro-cofactors. Such study will provide an opportunity to face the pest challenge with integrated management.

In view of these, sincere efforts were undertaken in this direction for assaying the insecticidal properties of different plant extracts, chemical and their combination against mustard aphid. With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

- To find out the incidence of aphid infestation on mustard in the field.
- To find out the most suitable management package among different promising botanicals and insecticides for the controlling of mustard aphid.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the important oil crop in Bangladesh and as well as many countries of the world. There are many insect pests of mustard among them aphids is the most important one. Farmers mainly control the insect pest through use of different chemicals. The concept of management of pest employing eco-friendly materials gained momentum as mankind became more safely about environment. But the research work in these aspects so far done in Bangladesh and else where is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the control of insects and pests through using botanicals, chemicals and also their integrated uses so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Performance of aphid on different Brassica species

Rana (2005) conducted a 2-year study on the preference and performance of *Lipaphis erysimi* on different Brassica species in the field and under greenhouse conditions revealed that rapeseed (*B. campestris* var. BSH-1, B. campestris var. YSPB-9) and mustard (*B. juncea* RH-30) were better hosts for this aphid than other Brassica species (*B. napus*, *B. nigra*, *Eruca sativa*, *B. carinata*). On the first group of plants, the rate of nymphal development, longevity and fecundity of this pest were significantly less than on the second group of plants. Development was significantly prolonged when the aphid was reared on second group of plants.

Experiment was conducted by Vekaria, and Patel (2005) during rabi 1993-94 and 1994-95 revealed that the incidence of aphid commenced 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AI) at 14 WAS coinciding with second week of February during 1993-94, however, during 1994-95 aphid incidence commenced late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AI) 13 WAS coinciding with first week of February.

The aphid population exceed fluctuated above (ETL) economic threshold level between 11 and 14 WAS coinciding with the third week of January to second week of February.

The incidence of mustard aphid (*Lipaphis erysimi*) in 8 *B. carinata* cultivars (C-3248-8, Peela Raya, Brown Raya, MMC-5, C-90-1063, UCD-593, C-90-1204 and C-90-1205) was studied by Rustamani *et al*. (2005) in Pakistan. The abundance of mustard aphid was evaluated when the plants were 2 weeks old; subsequent evaluation was conducted at weekly intervals. Aphid reproduction was also evaluated for 3 weeks. The aphid population, initially observed on the first week of December (1.45 per plant, on average), peaked on the first week of February (198.75 per plant, on average) in all cultivars, then declined until the maturity of the crop. UCD-593 (25.41 per plant) and Peela Raya (24.78 per plant) showed the lowest aphid densities, whereas MMC-5 recorded the highest aphid density (85.93 per plant). Peela Raya and UCD-593 were resistant to the aphid; the other cultivars were susceptible. The number of progenies remained below 10 per cage in Peela Raya, UCD-593 and C-90-1204.

A field experiment was conducted by Verma *et al*. (2005) during the rabi seasons of 2001/02 and 2002/03 at Kanpur, Uttar Pradesh, India to screen 16 mustard cultivars (15 *B. juncea* and one *B. nigra*) for their resistance to the mustard aphid, *Lipaphis erysimi*. Aphid infestation index (AII, 0-5 scale) was calculated at full flowering and full pod formation stages. Banarsi Rai and Rohini were considered highly resistant to aphid infestation, with AII of 0.56-0.67 and 0.79-069 in 2001/02 and 2002/03, respectively. RK-819, Krishna, RK-9304, RGN-19, RK-9801, RK-90, Basanti, SBG-51, Urvashi and MLN-157 were moderately resistant, with AII of 2.1-2.95 in both years. Varuna, Vaibhav, Vardan and UPN-9 were susceptible, with AII of 3.8-3.3, 3.8-3.0, 3.4-3.0 and 3.3-3.0 in both years.

Devi *et al*. (2004) reported that a mosaic disease of leaf mustard (*Brassica juncea* var. rugosa) was found widespread in different locations of Manipur (up to 90.50%) and prevalent in the market samples from different sources (up to

89.58%). Disease incidence was low during October-November and high during February-March months.

The causal virus was transmissible by sap (7.88%) and by three species of aphid (*Myzus persicae*, *Lipaphis erysimi* and *Brevicoryne brassicae*) but not through seeds.

Indian mustard seeds were sown on 8, 18 and 28 November, and 8 and 18 December in a field experiment conducted by Patel *et al*. (2004) in India during winter and reported that the critical period of mustard exposure to aphids was during the flowering stage of the crop. The aphid population increased in December.

Roy *et al*. (2004) conducted an experiment on aphid dynamics in mustard crop with reference to weather and phenological stages and reported that three Brassica cultivars, Agrani, Pusa Jaikisan and Varuna, were sown under 3 sowing dates, i.e. 1 October, 15 October and 1 November, in New Delhi, India, during the rabi seasons. The first crop season experienced relatively warmer temperature during seed filling and pod maturing stage compared to the second crop season. Early sowing resulted in early flowering, early pod development, longer seed filling period and maturity duration. Days taken to maturity were reduced with delayed sowing. Mustard aphid (*Lipaphis erysimi*) infestation started during either flowering or pod formation stage. Peak population of mustard aphid was mostly found during seed filling stage.

An experiment was conducted by Reza *et al*. (2004a) in Nadia, West Bengal, India, during the rabi season to investigate the effect of some abiotic factors on the population fluctuation of mustard aphid, *L. erysimi*. The population built up of mustard aphid was initiated in the 51st standard week during the end of December with initial intensity of 22.67/plant. The population increased up to 3rd standard week in January at the peak of 318.61. At the time of peak infestation, the maximum and minimum temperature was 27.37 and 14.62^0C, respectively.

The maximum and minimum relative humidity was 95.28 and 62.28%, respectively. In the 4th and 5th standard weeks, a rainfall of 7.40 and 13.10 mm, respectively, decreased down the aphid population from 274.33 to 186.33/plant. None of the ecological parameters alone was responsible for rapid multiplication of the aphid.

Thirteen new strains of *B. juncea*, developed through intraspecific hybridization, were grown during rabi, at Pura, Jammu, India, and evaluated by Gupta and Bijral (2004) for their resistance to mustard aphid (*Lipaphis erysimi*). RSPR-69 recorded the highest seed yield of 16.33 q/ha, followed by RSPRO-13 (13.133 q/ha). However, RSPRO-13 recorded the lowest plant infestation and aphid population both at the flower initiation and full bloom stages.

A laboratory study was conducted by Mishra and Kanwat (2003) with 5 promising Brassica genotypes, i.e. *B. juncea* cultivars Varuna and Kranti, *B. campestris* cv. BSH-1, B. napus cv. R-15 and B. carinata cv. HC-2, indicated that mustard aphid, *L. erysimi*, passed through 4 nymphal instars. The total nymphal period varied from 8.19 (Kranti) to 9.65 (BSH-1) days. The pre-reproductive, reproductive and post-reproductive periods ranged from 1.25 (HC-2) to 1.53 (Kranti), 14.33 (Varuna) to 17.20 (R-15) and 2.40 (Varuna) to 2.64 (BSH-1) days, respectively. The adult longevity varied from 13.53 (Varuna) to 16.77 (R-15) days. The daily fecundity varied from 4.93 (Varuna) to 6.02 (R-15) nymphs per female per day.

An investigation was carried out by Keot *et al.* (2002) in Assam, India, to know the insect pest associated with the brassica vegetables and their seasonal incidence. As many as ten insect pests under four orders and six families were recorded infesting the brassica vegetables right from the seedling stage to the harvest of the crop.

Four insects, cabbage butterfly (*Pieris canidia*), mustard aphid (*Lipaphis erysimi*), mustard sawfly (*Athalia lugens proxima*) and mustard flea beetle (*Phyllotreta cruciferae*) were found as major pests. Cutworm (*Agrotis ipsilon*), flea beetle (*Monolepta signata*), cabbage semilooper (*Plusia orichalcea* [*Thysanoplusia orichalcea*]), leaf eating caterpillar (*Spodoptera litura*) were found as minor pests.

2.2 Effect of botanical extract on aphid management

An experiment was conducted by Rahman and Saikia (2005) in laboratory and field (Jorhat, Assam, India) to evaluate efficacy of 5 plant products, i e neem (*Azadirachta indica* at 1, 2 and 3%), sweet flag (*Acorus calamus* at 2.5, 3 and 3.5%), tobacco (*Nicotiana tabacum* at 1, 2 and 3%), water pepper (*Polygonum hydropiper* at 2.5, 3 and 3.5%), and Econeem (0.02, 0.05 and 0.1%) against mustard aphid (*L. erysimi*), and their toxicity to honeybee (*Apis cerana*) on 'M 27' toria (*Brassica rapa* var. napus [*B. campestris* var. toria] cv. M 27). Among the plant products, the maximum reduction of *L. erysimi* population was obtained with the treatment of Econeem (0.1%) followed by *Acorus calamus* (3.5%), *N. tabacum* (3%), neem (3%) and *P. hydropiper* (3.5%). There was no significant effect of plant products on *L. erysimi* mortality except Econeem 0.1% which showed moderate toxicity to honeybee.

A trial was conducted by Gupta (2005) with mustard cv. Pusa Bold in Madhya Pradesh, India, during 1999-2000 and 2000-01 to investigate the efficacy of neem (*Azadirachta indica*) leaf extracts (NLE) and neem kernel extracts (NKE) in cow urine, neem oil, phosphamidon, dimethoate and their combinations were evaluated against the mustard aphid (*Lipaphis erysimi*) along with their impact on the activity of coccinellid beetles (biological control agents of mustard aphid). The treatments comprised NLE at 1% (5 l cow urine+1.250 kg neem leaves/ha), NLE at 2% (10 l cow urine+2.500 kg neem leaves/ha), NLE at 3% (15 l cow urine+3.750 kg neem leaves/ha), NKE at 1% (5 l cow urine+500 g neem kernels/ha), NKE at 2% (10 l cow urine+1 kg neem kernels/ha), NKE at 3% (15 l cow urine+1.500 kg neem kernels/ha), Neem oil at 1% (5 l neem oil/ha),

phosphamidon (Phosphamidon 85 EC) at 0.04% (240 ml/ha) and untreated control. These treatments were framed on the basis of preliminary studies conducted at this station during 1998-99. During 2000-01, dimethoate at 0.045% was taken in place of phosphamidon at 0.04%. Three combination treatments were added: NLE (in cow urine) at 3%+dimethoate at 0.03%, NKE (in cow urine) at 3%+dimethoate at 0.03% and neem oil at 1%+dimethoate at 0.03%.

The treatments significantly reduced the incidence of mustard aphid and increased the grain yield of mustard. Combination treatments of dimethoate at 0.03% either with NKE at 3% or NLE at 3% followed by dimethoate at 0.045% and phosphamidon at 0.04% were the most effective in reducing the aphid incidence. Mean grain yield was highest (1836 kg/ha) in phosphamidon at 0.04%, followed by neem oil at 1%+dimethoate at 0.03% (1541 kg/ha) and NKE at 3% (1508 kg/ha). Mean net profit was also highest in phosphamidon at 0.04% (Rs 9246/ha) and NKE at 3% (Rs 5938/ha). The incremental cost benefit ratio was highest in NKE at 2% (15.5%) and NKE at 3% (15.1). The results suggest that the incidence of mustard aphid can be safely and successfully managed by adopting 3 or 4 foliar sprays of NKE (in cow urine) at 3% either alone or in combination with reduced dose of dimethoate at 0.03%.

Indian mustard cv. Varuna was grown by Srivastava and Jyoti (2003) for 3 winter (rabi) seasons under 2 sowing dates (October 10-15 and October 25-30), 2 spacings, and treatment with 2 chemicals and one botanical pesticide. The highest grain yield (1929 kg/ha) was obtained with sowing on 10-15 October when no mustard aphid (*Lipaphis erysimi*), and minimum pressure of mustard saw fly (*Athalia proxima*) and white rust disease (*Albugo candida*) were recorded. Soil application of neem leaf powder at 75 kg/ha during sowing in furrows also reduced the population of mustard saw fly, mustard aphid.

The efficacy of leaf (5 or 10%) and seed kernel (5%) extracts of neem [*Azadirachta indica*] and leaf extract (5 or 10%) of *Ageratum* sp. and a formulated fish product (5%) was tested under laboratory condition against bean aphid, *Aphis craccivora* by Prabal *et al*. (2000). All the treatments showed significantly better nymphal mortality than the control. The maximum aphid mortality (97.50%) was observed at neem seed kernel extract, followed by neem leaf extract at 10% (61.88%).

2.3 Effect of chemicals on aphid management

Studies on the efficacy of nine insecticides (as foliar sprays) against mustard aphid, *Lipaphis erysimi* on mustard cv. Varuna were carried out by Kumar *et al*. (2007) in Meerut, Uttar Pradesh, India, during the rabi season. Studies revealed that after 1 and 3 days of spray, oxydemeton-methyl 25 EC at 0.025% (88.0% and 96.7%, respectively) proved to be the most effective against mustard aphid. However, on the seventh day, imidacloprid 17.8 SL at 0.0178% (99.6%) gave the most effective control. On the seventh day after spraying, the order of efficacy was imidacloprid at 0.0178% > oxydemeton-methyl at 10.025% > monocrotophos at 0.036% > dimethoate at 0.03% > chlorpyrifos at 0.05% > malathion at 0.05% > endosulfan at 0.07% > cypermethrin at 0.01% > neemarin.

Reza *et al*. (2004b) find out the efficacy of profenofos (0.02 and 0.05% a.i.), triazophos (0.02 and 0.05% a.i.), dimethoate (0.2 and 0.05% a.i.) oxydemeton-methyl (0.025 and 0.05% a.i.) and quinalphos + cypermethrin (0.023 and 0.046% a.i.) in controlling aphids (*L. erysimi*) infesting mustard cv. B-85 was determined in a field experiment conducted in West Bengal, India. Spraying with 0.05% a.i. oxydemeton-methyl resulted in the lowest mean aphid population and highest mean aphid mortality during the first spraying followed by spraying with 0.05% a.i. dimethoate. Second spraying with both treatments resulted in the total control of the aphid population. Spraying with 0.05% a.i. oxydemeton-methyl resulted in the highest crop yield (13.82 q/ha) and gain in yield over the control (87.26%), whereas spraying with 0.025% a.i. oxydemeton-methyl resulted in the highest cost:benefit ratio (1:13.64).

The efficacy of beta -cyfluthrin (0.00125%), cartap hydrochloride (0.05%), endosulfan (0.07%), imidacloprid (0.01%), ethofenprox [etofenprox] (0.01%) and lambda -cyhalothrin (0.01%) against L. erysimi on mustard was evaluated in New Delhi, India, by Meena and Lal (2004). At 7 days after the initial spraying, imidacloprid and endosulfan reduced the aphid population by 91.99 and 91.88% in 1998/99, and by 92.60 and 92.24% in 1999/2000, respectively.

Significant reductions in aphid population were also obtained with endosulfan and ethofenprox in 1998/99 (by 91.88 and 91.45%) and 1999/2000 (by 92.60 and 91.88%). Lambda -Cyhalothrin, cartap hydrochloride and beta -cyfluthrin were the least effective among the insecticides.

Mustard aphids (*L. erysimi*) were reared by Rajeev and Sachan (2004) on yellow sarson (*Brassica campestris* var. sarson), brown sarson (*B. campestris* var. sarson) and Indian mustard (cv. Varuna) in Pantnagar, Uttar Pradesh, India, and the effect of host on the susceptibility of the aphid to insecticides was estimated by comparing LC_{50} values. The susceptibility to endosulfan was governed largely by the host, as the aphids reared on yellow sarson were more susceptible by 9.93- and 4.76-fold to endosulfan than those reared on brown sarson during 2001 and 2002, respectively. Deltamethrin was the most toxic, with LC_{50} value 0.000052%, to aphids on Indian mustard among all the tested insecticides. The aphids from Indian mustard were the most susceptible to deltamethrin and methyl-O-demeton [demeton-O-methyl] and to monocrotophos. Differences in the toxicity of an insecticide to a particular insect species feeding on different host indicate that the host plant on which the insect feeds play an important role in governing the toxicity of the chemical.

The efficacy of contact (endosulfan and malathion) and systemic (dimethoate and oxydemeton-methyl) insecticides against *L. erysimi*, collected from various locations in Punjab (Siengo, Joga, Ludhiana, Khoonde, Sherpur and Saheri), India, was evaluated by Gaurav and Udeaan (2004) with leaf disc residue and leaf-petiole dip methods, respectively, using leaves of Indian mustard cv. GSL-1.

Mortality was recorded 5 h after treatment for malathion, and after 24 h for the other insecticides. The lowest LC_{50} value of endosulfan (0.001%) was recorded for the population from Saheri (Ropar), whereas the highest (1.866%) was recorded for the population from Siengo (Bathinda). For malathion, the lowest (0.003%) and highest (0.154%) LC_{50} values were against the population from Sherpur (Hoshiarpur) and Siengo, respectively. The results suggested that the susceptibility of *L. erysimi* to malathion did not vary over the 14 years.

A slight increase in tolerance of dimethoate and oxydemeton-methyl was observed in the population from Ludhiana. Endosulfan was much less effective than malathion, indicating the development of resistance to the former, whereas dimethoate and oxydemeton-methyl were more toxic than malathion.

Field studies were conducted by Ahuja and Kalyan (2003) in Jodhpur, Rajasthan, India, to evaluate the different spray schedules for the management of mustard aphid (*Lipaphis erysimi*) infesting Indian mustard cv. Varuna during the rabi season. Spraying with a knapsack sprayer was initiated at 45 days after sowing when the aphids started appearing on the crop. Monocrotophos at 1 ml/litre was sprayed at various intervals. Data were recorded for the mean number of aphids per 1 cm inflorescence, seed yield, percent avoidable loss, net economic returns and incremental cost-benefit ratio. Spraying at 45, 60, 75, 90 and 105 days after sowing gave the highest mean seed yield (2457 kg/ha) and net returns (Rs. 10,170/ha).

Indian mustard cv. Varuna was grown by Srivastava and Jyoti (2003) for 3 winter (rabi) seasons under 2 sowing dates (October 10-15 and October 25-30), 2 spacings, and treatment with 2 chemicals and one botanical pesticide. The highest grain yield (1929 kg/ha) was obtained with sowing on 10-15 October when no mustard aphid (*Lipaphis erysimi*), and minimum pressure of mustard saw fly (*Athalia proxima*) and white rust disease (*Albugo candida*) were recorded.

The yield obtained higher than that under wider spacing by 7.91%. Oxydemeton-methyl and Dithane M-45 [mancozeb] were the most effective for the control of aphids.

Singh and Hridayesh (2003) conducted an experiment with petroleum ether extract of mustard seed (*Brassica campestris* var. sarson) was found to be very effective against mustard aphid, *L. erysimi*. It caused 100% mortality (indicated by non-motility of the insects) at 2% conc. in 24 h. Fecundity was also reduced significantly. Lower concentrations (1.5 and 1%) were also effective but required a longer time to cause complete mortality.

Avoidable losses in grain yield due to mustard aphid (*L. erysimi*) were assessed by Gupta *et al*. (2003) in four Ethiopian mustard (*B. carinata*) cultivars (JTC-1, JTC-46, HC-1 and JTC-18) and were compared to Indian mustard (*Brassica juncea*) cv. Varuna in a field experiment conducted at Tikamgarh, Madhya Pradesh, India during the rabi seasons. The plants were treated with three rounds of foliar sprays of 0.04% phosphamidon (at 15 days interval) during the first two years and with 0.04% dimethoate during the third year. Aphid population, plant height, number of branches, number of silique, seed yield and percentage avoidable losses were recorded. The incidence of aphid was significantly reduced in the crops protected with three foliar sprays of insecticides. Mean plant height was marginally increased in treated crops compared to the control. The mean number of branches and silique per plant were significantly increased in treated plants. Plant height and number of branches and silique per plant were maximum in treated JTC-18. Grain yield was significantly increased in protected plots compared to the control. A net profit of Rs 2310, 3025, 3179, 4257 and 5478, and a cost-benefit ratio of 4, 4.93, 5.13, 6.53 and 8.11 was obtained for HC-1, JTC-46, JTC-21, JTC-18 and Varuna, respectively.

The results of 11 different insecticide treatments in a field experiment conducted by Gami *et al*. (2002) in Junagadh, Gujarat, India, during 1998-99 rabi season on Indian mustard cv. GM-2 showed that the treatment with methyl-o-demeton

[demeton-o-methyl] 0.025%, carbosulfan 0.04%, methyl parathion [parathion-methyl] 2% dust at 25 kg/ha and monocrotophos 0.04% were highly effective against mustard aphid, Lipaphis erysimi. Profenophos [profenofos] 0.05% and azadirachtin 0.00075% were less effective. Two sprays of methyl-o-demeton 0.025% gave maximum seed yield (1575 kg/ha). The treatment with phosphamidon 0.03% was more economical as it gave the highest cost benefit ratio (1:12.7) followed by methyl-o-demeton 0.025% (1:8.2), monocrotophos 0.04% (1:7.7) and methyl parathion 2% dust (1:6.6).

2.4 Integrated management of aphid

A field experiment was conducted by Yadav (2004) in Punjab, India to investigate the integrated control of mustard pests. Integrated pest management was possible using the tolerant genotype PBR 91, sowing on 20 October, seed treatment with Apron 35 SD [metalaxyl] at 6 g/kg, and need based spraying with Ridomil MZ 72 WP [mancozeb + metalaxyl] at 0.25% + Indofil M-45 [mancozeb + thiophanate-methyl] at 0.2% (2 sprays at 20-day intervals).

An experiment was conducted by Singh *et al*. (2003a) during 1995/96 and 1996/97 to develop and validate an integrated pest management (IPM) module for mustard under Haryana, India, agroclimatic conditions. The treatments comprised IPM module (T_1); chemical control (T_2); and control (T_3). Data were recorded for the incidence of pests, i.e. painted bug (*Bagrada hilaris*), saw fly (*Athalia lugens proxima* [*Athalia lugens*]), leaf miner (*Chromatomia horticola* [*Chromatomyia horticola*]), and aphid (*Lipaphis erysimi*). T_1 reduced pest incidence compared to T_2 and T_3. There was no observed incidence of painted bug and saw fly. Leaf miner incidence was low during both cropping seasons. Crop yield was highest with T_1 compared to T_2 and T_3. Tabulated data on the IPM module for mustard crop is also presented.

Singh *et al*. (2003b) reported an integrated pest management (IPM) module, involving the timely sowing of the crop, seed treatment with carbendazim at 2 g/kg seed, soil application of the fungal biological control agent *Trichoderma*

viride at 1 kg/acre, mechanical removal of aphid-infested twigs at the initial stage of attack and 3 inoculative releases of aphid predator (Chrysoperla carnea) larvae, was validated at farmers' fields in Bhora Khurd village, Guargon district, Haryana, India during 1997-98, for the management of pests and diseases of mustard. The IPM module reduced the pest attack on the crop and gave higher yield compared to untreated plots.

Four neem (*Azadirachta indica*) formulations, two synthetic insecticides (dimethoate and endosulfan) and *Bacillus thuringiensis* used alone and in combination with endosulfan were evaluated by Men *et al*. (2002) for safety to *Diaeretiella rapae*, a potential parasitoid of the mustard aphid, *Lipaphis erysimi*, on Indian mustard cv. Pusa Bold at Akola, Maharashtra, India, during 1999. It was found that *B. thuringiensis* (1 kg/ha) and Neemark (1%) were the safer treatments followed by neem leaf extract (5%), *B. thuringiensis* at 0.5 kg/ha + endosulfan (0.03%), endosulfan (0.05%), Achook (0.15%) and neem seed extract (5%). Dimethoate (0.03%) proved toxic to the hyperparasitoid.

The role of aphidophagous insects for field control of mustard aphid (*Lipaphis erysimi*), which infests Brassica juncea cv. M-27 is discussed by Devi *et al*. (2002) along with the efficacy of neem product and conventional chemical insecticides. The results of the field evaluation, Manipur, India indicated not only the reduction in aphid density but the population of the predatory insects were also not affected much by the insecticide treatment. This revealed that neem pesticide, endosulfan and phosalone could be used along with the biological control agents for the control of mustard aphid.

Singh and Singh (2002) presented a comprehensive review of the integrated management of insect pests of rapeseed-mustard in India. The pests belonging to the insect families Aphididae, Pentatomidae, Tenethridinidae, Agromyzidae, Pieridae, Pyralidae, Arctiidae and Noctuidae are controlled by cultural, biological and chemical methods.

The use of botanical insecticides in the control of some pest families, and the role of pest resistance in some cultivars in integrated pest management are also mentioned.

Field experiments were conducted by Kular *et al*. (2001) in Punjab, India, from 1995/96 to 1999/2000 to study the effect of aphid management practices, such as cultural methods, use of resistant/tolerant genotypes, biological control agents (*Chrysoperla carnea* and *Verticillium lecanii*), and need [*Azadirachta indica*]-based applications of insecticides, on the seed yield of rapeseed mustard. Early (18 October)-sown crops gave significantly higher yields (6.87 and 11.83 q/ha) than the late (17 November)-sown crops (4.48 and 4.91 q/ha) during 1995-96 and 1997-98, respectively; were on a par with normal (2 November)-sown crops during 1997-98; and superior to normal-sown crops (5.85 q/ha) during 1995-96. Significantly higher seed yield (7.75 q/ha) was obtained with *Brassica carinata* (cv. PC5), which showed tolerance to mustard aphid compared to *B. juncea* (cv. RL 1359) and *B. napus* (cv. GSL 2) during 1996-97. Significantly higher seed yields of 9.44, 8.44 and 6.89 q/ha were obtained when the aphid was controlled with insecticides at the economic threshold level (ETL) compared to untreated crops (2.49, 2.00 and 1.22 q/ha) under early, normal, and late sowing conditions, respectively, during 1995-96. However, the yield was on a par with fixed spray schedule (8.78 q/ha) under early sowing conditions but significantly higher than fixed spray schedule under normal sowing and late sowing conditions. Thus, insecticidal sprays given at ETL were more effective than fixed spray schedule of insecticides.

The above cited review represents that aphid pest management in mustard suggested that the use of botanical pesticide and chemical pesticide in integrated way was more effective.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to March 2013 to study the management of mustard aphid, *Lipaphis erysimi* (Kalt.) using botanicals. The details of the materials and methods that used to conduct the experiment are presented below:

3.1 Location

The experiment was carried out in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Climate

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter 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 meteorological 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 I.

3.3 Soil

The soil of the experimental 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 presented in Appendix II.

3.4 Test crop and its characteristics

BARI SARISA-15 were used as a test crop for this experiment. This variety was developed at the Bangladesh Agricultural Research Institute. The plant height of this variety is 95-110 cm and life cycle 90-95 days for robi season cultivation.

3.5 Treatments of the experiment

The experiment comprised of the following treatments-

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

3.6 Collection and preparation of treatment components

3.6.1 Preparation of neem seed kernel

Neem seeds were selected to use for this experiment.

Preparation of plant dust

Drying and grinding:

- After collection of neem seeds were washed with water and kept in the shade up to 15 days for air-drying.
- The dried materials (seed/fruit) were ground separately with electrical grinder and sieving through 0.66 mm diameter sieve to obtain fine dusts.
- The dust was being preserved into plastic pot at low temperature till their uses.

3.6.2 Preparation of neem leaf extract

The leaves of neem used for the experiments were collected from trees in and around the university campus. After bringing leaves to the laboratory, they were washed in running water. Firstly, the plant materials were kept in the shade for air-drying and then dried in the oven at 60^0C to gain constant weight. Dusts were prepared by pulverizing the dried leaves with the help of a grinder. Then dusts were passed through a 25-mesh diameter sieve to obtain fine and uniform materials. The dusts were preserved in airtight condition in polythene bags and were used mixed with trix detergent @ 10 ml/L of water.

3.6.3. Preparation of tobacco leaf dust

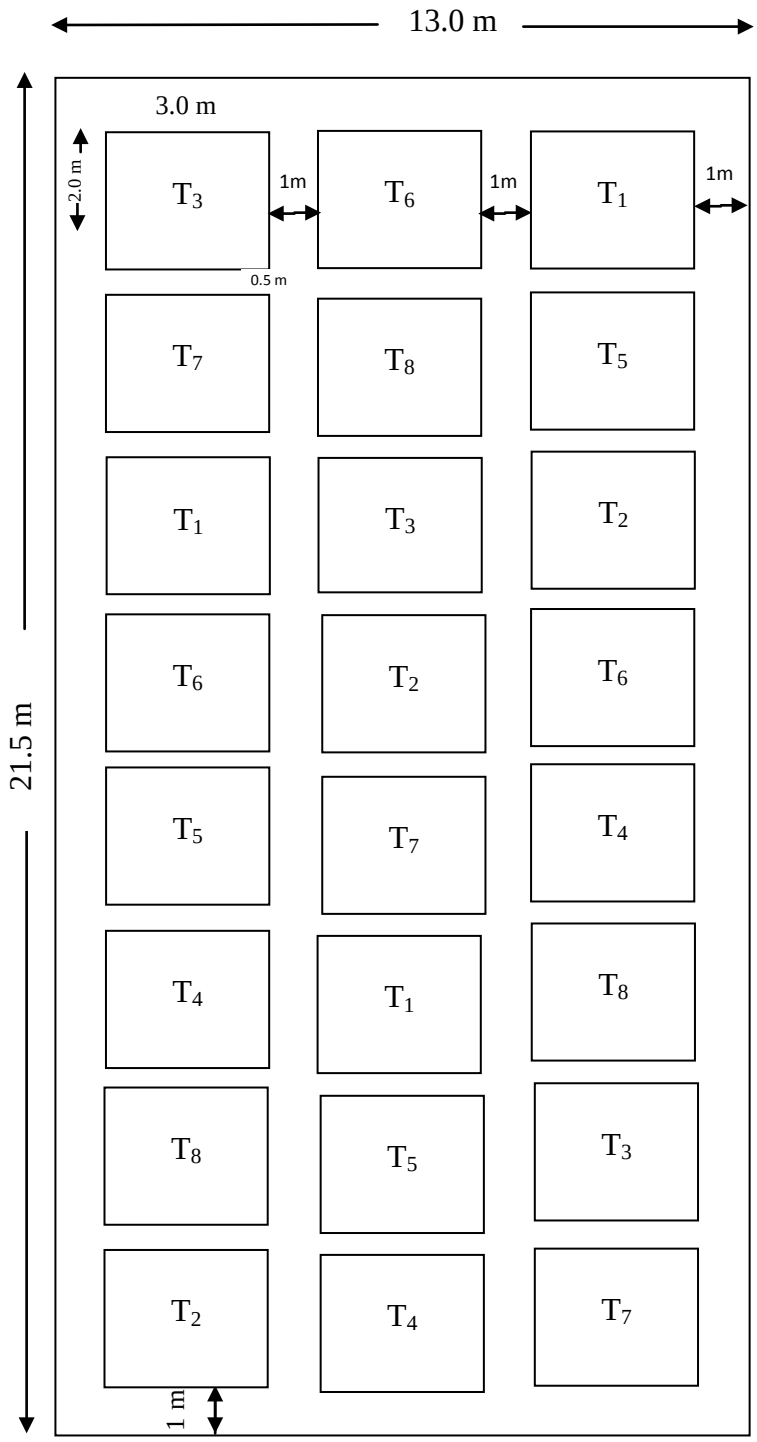
Tobacco leaf was selected to use in this experiment.

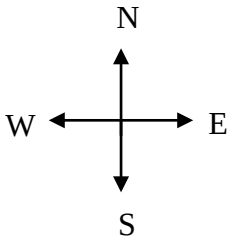
Drying and grinding

- After collection, fresh leaves of the tobacco plants were washed with water and kept in the shade up to 15 days for air-drying.
- The dried plant materials were then ground separately with electrical grinder and sieving through 0.66 mm diameter sieve to obtain fine powder.
- The powder was being preserved into plastic pot at low temperature till their uses.

3.7 Experimental design and layout

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 24 plots of size 3.0 m × 2.0 m. All the 8 treatments of the experiment was assigned at random into 8 plots of each block/replication. The layout of the experiment is shown in Figure 1.





Plot size: 3.0 m × 2.0 m

Plot spacing: 50 cm

Between replication: 1.0 m

Treatment

T_1: Neem seed kernel extract 5% at days interval

T_2: Tobacco leaf dusts @ 20 g/L water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interv

T_4: Sumi Alpha 5EC @ 1ml/L of wa at 7 days interval

T_5: (Neem seed kernel extract 5% Sumi Alpha 5EC @ 1ml/L water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L water + Sumi Alpha 5EC @ 1ml of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alp 5EC @ 1ml/L of water) at 7 da interval

T_8: Untreated control

Figure 1. Layout of the experimental plot

3.8 Growing of crops

The experiment plot was opened in the second week of November 2012 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for mustard seed sowing.

3.9 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of Urea, TSP, MP, Gypsum, Zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land. Urea was applied in two equal installments at final land preparation and before flowering after 45 days of seeds sowing. The dose and method of application of fertilizer are shown in Table 1 (Anon., 2005).

Table 1. Dose and method of application of fertilizers in mustard field

Fertilizers	Dose (kg/ha)	Application (%)	
		Basal	1st installment
Urea	300	50	50
TSP	180	100	--
MP	100	100	--
Gypsum	180	100	--
Znic sulphate	07	100	
Borax	15	100	--

3.10 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mustard plant.

3.10.1 Irrigation and drainage

Single irrigation was provided before flowering stage and it was arranged well drained facilities as prevention process of removing rain water if any.

3.10.2 Weeding

Weeding was done in the field to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at flowering stage by mechanical means.

3.11 Harvesting, threshing and cleaning

The mustard was harvested at the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mustard. The seeds were cleaned and finally the weight was calculated and converted into per hectare yield.

3.12 Monitoring of insect pest and data collection

The mustard plants were closely examined at regular intervals commencing from flowering to pod maturity. Aphids from one square meter area were recorded at weekly intervals in central rows and starting from early flowering to pod maturity and converted. The aphid population was collected by a needle brush in a petridish. The entire period was divided into early, mid and late flowering and fruiting stage and the incidence of aphid's was measured.

3.13 Determination of plant infestation

All the healthy and infested plant were counted from one square meter area in the middle of of each plot and examined. The collected data were divided into early, mid and late flowering and fruiting stage. The healthy and infested plants were counted and the per cent plant infestation was calculated using the following formula:

$$\% \text{ Plant infestation} = \frac{\text{Number of infested plant}}{\text{Total number of plant}} \times 100$$

$$\% \text{ Infestation reduction} = \frac{(\% \text{ Infestation in control} - \% \text{ Infestation in the concerned treatment})}{\% \text{ Infestation in control}} \times 100$$

3.14 Data recording on yield contributing characters and yield of mustard

Data were recorded on yield contributing characters and yield of mustard on the following parameters-

3.14.1 Plant height

The height of plant was recorded in centimeter (cm) at harvest in the experimental plots. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot after harvest. The height was measured from the ground level to the tip of the growing point of the main branch.

3.14.2 Number of branches per plant

The total number of branches arisen from the stem of a plant was counted as the number of branches per plant.

3.14.3 Number of siliquae per plant

The total numbers of siliquae of the randomly selected 10 plants of a plot were recorded and then average number of siliquae was estimated.

3.14.4 Length of siliqua

Distance between the ends of the peduncle to the starting point of the beak was recorded as siliqua length and was presented in centemeter (cm).

3.14.5 Number of seeds per siliqua

Ten siliquae from each plant were selected randomly and number of seeds was counted and the average number of seed per siliqua was determined.

3.14.6 Weight of 1000 seeds

One thousand seeds were counted randomly from the total seeds of cleaned harvested seeds and then weighted in grams.

3.14.7 Yield per hectare

Seed weight per plot was measured from the harvested seeds of mustard and then converted into hectare yield and expressed in ton.

3.15 Statistical Analysis

The data related to aphid incidence and different yield contributing characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the management of mustard aphid, *Lipaphis erysimi* (Kalt.) using botanicals. The analysis of variance (ANOVA) of the data on is given in Appendix III-XI. The results have been presented with the help of different Table and Graphs possible interpretations are given under the following headings:

4.1 Aphid population

4.1.1 At flowering stage

Number of aphid at early, mid and late flowering stage due to integrated management of aphid in mustard plant showed significant variations (Table 2). Data indicate that at early flowering stage, the lowest number of aphid (0.43) was recorded from T_7 (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) which was statistically similar (0.63) with T_6 (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval) and followed by T_5 (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval), T_4 (Sumi Alpha 5EC @ 1ml/L of water at 7 days interval) and T_3 (Neem oil @ 0.3% at 7 days interval). While the highest number of aphid (7.90) was observed from T_8 (untreated control) which was followed by 2.67 and 2.27 in T_1 (Neem seed kernel extract 5% at 7 days interval) and T_2 (Tobacco leaf dusts @ 20 g/L of water at 7 days interval), respectively. At mid flowering stage, the lowest number of aphid (0.83) was recorded from T_7 which was closely followed (1.33) by T_6 and then (1.93 and 2.30) by T_5 and T_4, again the highest number (9.70) was found from T_8 which was followed (3.90) by T_1. At late flowering stage, the lowest number of aphid (0.93) was found from T_7 which was followed (1.77 and 2.27) by T_6 and T_5 and they were statistically similar, while the highest number of aphid (12.40) was observed from T_8 which was followed (4.43 and 4.13) by T_1 and T_2.

Table 2. Aphid population at early, mid and late flowering stages due to effect of treatments

Treatments	Number of aphid at the flowering stages of		
	Early	Mid	Late
T_1	2.67 b	3.90 b	4.43 b
T_2	2.27 bc	3.30 c	4.13 bc
T_3	2.10 cd	3.00 c	3.67 cd
T_4	1.70 d	2.30 d	3.07 d
T_5	1.03 e	1.93 d	2.27 e
T_6	0.63 ef	1.33 e	1.77 e
T_7	0.43 f	0.83 f	0.93 f
T_8	7.90 a	9.70 a	12.40 a
$LSD_{(0.05)}$	0.429	0.467	0.678
Level of significance	0.01	0.01	0.01
CV(%)	10.44	8.10	9.49

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% mixed trix detergent @ 10 ml/L of water at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

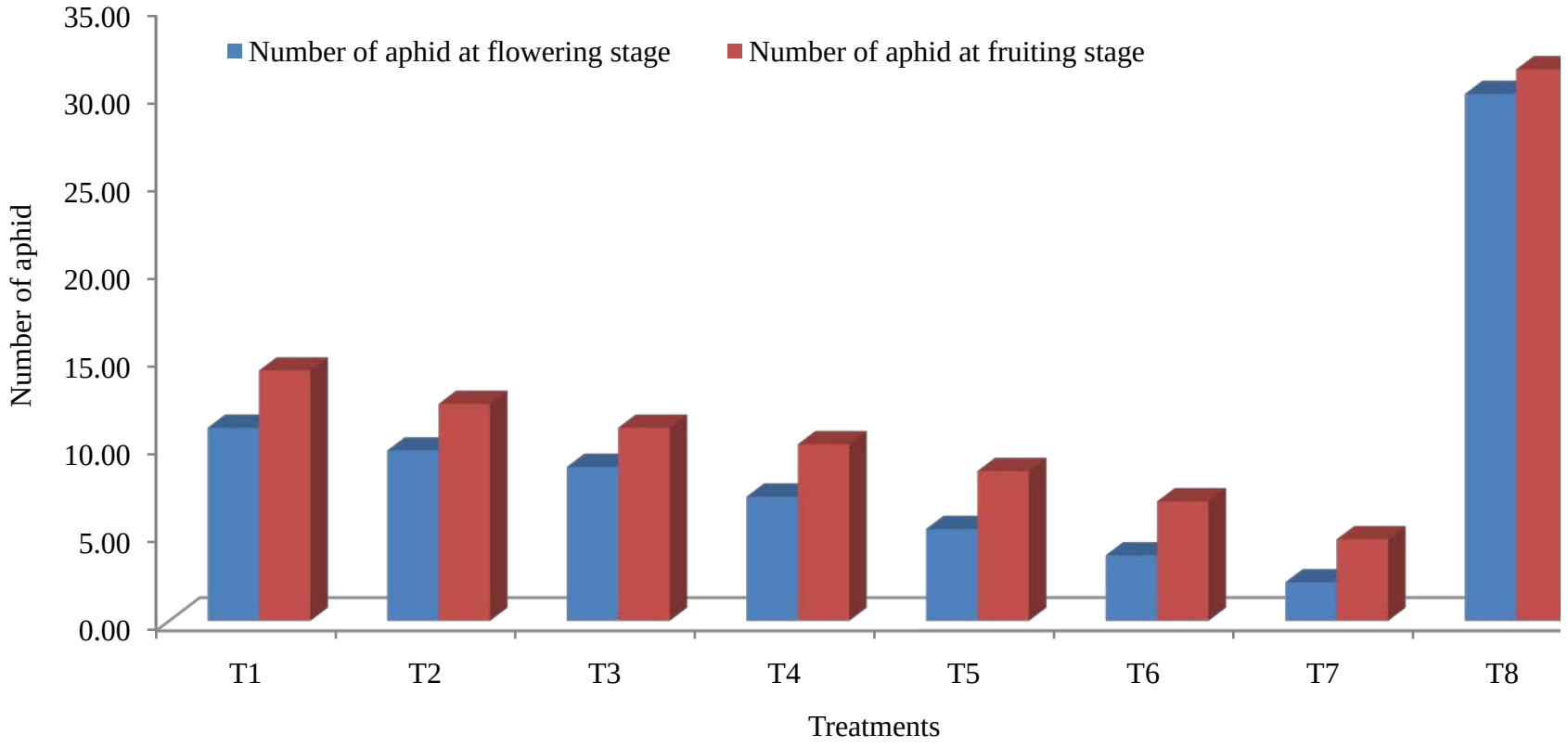
T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

At the total flowering stage, the lowest number of aphid (2.19) was recorded from T_7 which was closely followed (3.73) by T_6 and the highest number of aphid (30.00) from T_8 which was followed (11.00 and 9.70) by T_1 and T_2 and they were statistically similar (Figure 2). It is revealed Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval was more effective among the management practices for controlling aphid at flowering stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval.

4.1.2 At fruiting stage

Integrated management of aphid in mustard plant showed statistically significant variation in terms of number of aphid population at early, mid and late fruiting stage (Table 3). Data represent that at early fruiting stage, the lowest number of aphid (1.17) was observed from T_7 which followed (2.00 and 2.17) by T_6 and T_5 and they were statistically similar, while the highest number (8.27) was attained from T_8 which was followed (4.13) by T_1. At mid fruiting stage, the lowest number of aphid (1.60) was found from T_7 which was closely followed by T_6 (2.20) and T_5 (3.03). Again the highest number of aphid (10.63) was recorded from T_8 which was followed (4.90) by T_1. At late fruiting stage, the lowest number of aphid (1.87) was observed from T_7 which was statistically similar (2.60) with T_6 and closely followed (3.33) by T_5, whereas the highest number of aphid (12.50) was attained from T_8 which was followed (5.23 and 4.73) by T_1 and T_2. At the total fruiting stage, the lowest number of aphid (4.64) was recorded from T_7 which was closely followed by T_6 (6.80), while the highest number of aphid (31.40) was found from T_8 which was followed by 14.26 and 12.36 in T_1 and T_2, respectively. From the findings it is observed that Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for controlling aphid at the entire fruiting stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval.



T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/Lg at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20g/kL+ Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

Figure 2. Number of aphid per plant of mustard plant during flowering and fruitngn stage

Table 3. Aphid population at early, mid and late fruiting stages due to effect of treatments

Treatments	No. of aphid at		
	Early fruiting stages	Mid fruiting stages	Late fruiting stages
T_1	4.13 b	4.90 b	5.23 b
T_2	3.33 c	4.30 c	4.73 bc
T_3	3.10 c	3.87 cd	4.03 cd
T_4	2.60 d	3.63 d	3.83 d
T_5	2.17 e	3.03 e	3.33 de
T_6	2.00 e	2.20 f	2.60 ef
T_7	1.17 f	1.60 g	1.87 f
T_8	8.27 a	10.63 a	12.50 a
$LSD_{(0.05)}$	0.429	0.495	0.745
Level of significance	0.01	0.01	0.01
CV(%)	7.32	6.67	8.93

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

4.2 Aphid infested mustard plant at flowering stage

4.2.1 At early flowering stage

Number of healthy plant, infested plants and per cent infestation of mustard plant showed significant differences at early flowering stage for different integrated management practices of mustard aphid (Table 4). The highest number of healthy plants/m^2 (29.67) was recorded in T_7 (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) treatment which was statistically similar (29.33, 29.00 and 28.67) with T_6 (Tobacco leaf dusts @ 5.0 g/kg + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval), T_5 (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval), T_4 (Sumi Alpha 5EC @ 1ml/L of water at 7 days interval) and T_3 (Neem oil @ 0.3% at 7 days interval), respectively and closely followed (28.00 and 28.33) by T_1 (Tobacco leave dusts @ 5.0 g/kg at 7 days interval) and T_2 (Neem seed kernel extract 5% at 7 days interval). On the other hand, the lowest number of healthy plants/m^2 (25.33) was found in T_8 (untreated control) treatment. The highest number of infested plant/m^2 (4.67) was recorded in T_8 treatment, whereas the lowest number (0.33) was observed in T_7 treatment which was statistically similar (0.67, 1.00 and 1.33) with T_6, T_5, T_4 and T_3, respectively and closely followed (1.67 and 2.00) by T_2 and T_1. The highest infested plant/m^2 (15.56%) was attained in T_8 treatment which was followed (6.67%, 5.56%) by T_1, and T_2, respectively. Again, the lowest number of infested plant/m^2 (1.11%) was found in T_7 treatment which was statistically similar (2.22%, 3.33% and 4.44%) with T_6, T_5, T_4 and T_3. Mustard plant infestation percentage reduction over control at early flowering stage was estimated for different management practices and the highest value (92.87%) was found in T_7 and the lowest value (57.13%) from T_1 treatment. From the findings it is revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the early flowering stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval. Rahman and Saikia (2005) reported that there was no significant effect of plant products on *L. erysimi* mortality except Econeem 0.1%.

Table 4. Effect of treatments on plant infestation at early flowering stage

Treatments	Early flowering stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	28.00 c	2.00 b	6.67 b	57.13
T_2	28.33 bc	1.67 bc	5.56 bc	64.27
T_3	28.67 abc	1.33 bcd	4.44 bcd	71.47
T_4	29.00 abc	1.00 bcd	3.33 bcd	78.60
T_5	29.33 ab	0.67 cd	2.22 cd	85.73
T_6	29.33 ab	0.67 cd	2.22 cd	85.73
T_7	29.67 a	0.33 d	1.11 d	92.87
T_8	25.33 d	4.67 a	15.56 a	--
$LSD_{(0.05)}$	0.927	0.927	3.087	--
Level of significance	0.01	0.01	0.01	--
CV(%)	4.86	14.31	14.31	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

4.2.2 At mid flowering stage

Statistically significant differences was recorded in terms of number of healthy plant, infested plants and percent infestation of mustard plant at mid flowering stage for different integrated management practices of mustard aphid (Table 5). The highest number of healthy plants/m^2 (29.33) was recorded in T_7 treatment which was statistically similar (29.00 and 28.67) with T_6 and T_5 and closely followed (28.33) by T_4, whereas the lowest number of healthy plants/m^2 (24.67) was recorded in T_8 treatment which was closely followed (27.33 and 27.67) by T_1 and T_2. The highest number of infested plant/m^2 (5.33) was attained in T_8 treatment, while the lowest number (0.67) was recorded in T_7 treatment which was statistically similar (1.00 and 1.33) with T_6 and T_5, respectively and closely followed (1.67) by T_4. The highest infested plant/m^2 (17.78%) was observed in T_8 treatment which was followed (8.89%, 7.78%) by T_1, and T_2, respectively. On the other hand, the lowest infested plant/m^2 (2.22%) was found in T_7 which was statistically similar (3.33% and 4.44%) with T_6 and T_5. Mustard plant infestation percentage reduction over control at mid flowering stage was estimated for different management practices and the highest value (87.51%) was recorded for the treatment T_7 and the lowest value (50.00%) from T_1 treatment. It is revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the mid flowering stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval. Devi *et al.* (2002) revealed that neem pesticide, endosulfan and phosalone could be used along with the biological control agents for the control of mustard aphid. Singh and Singh (2002) reported that pests belonging to the insect families Aphididae, Pentatomidae, Tenethridinidae, Agromyzidae, Pieridae, Pyralidae, Arctiidae and Noctuidae are controlled by cultural, biological and chemical methods. The use of botanical insecticides in the control of some pest families, and the role of pest resistance in some cultivars in integrated pest management are also mentioned.

Table 5. Effect of treatments on plant infestation at mid flowering stage

Treatments	Mid flowering stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	27.33 e	2.67 b	8.89 b	50.00
T_2	27.67 de	2.33 bc	7.78 bc	56.24
T_3	28.00 cde	2.00 bcd	6.67 bcd	62.49
T_4	28.33 bcd	1.67 cde	5.56 cde	68.73
T_5	28.67 abc	1.33 def	4.44 def	75.03
T_6	29.00 ab	1.00 ef	3.33 ef	81.27
T_7	29.33 a	0.67 f	2.22 f	87.51
T_8	24.67 f	5.33 a	17.78 a	--
$LSD_{(0.05)}$	0.844	0.844	2.812	--
Level of significance	0.01	0.01	0.01	--
CV(%)	3.73	22.67	22.67	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

4.2.3 At late flowering stage

Number of healthy plant, infested plants and percent infestation of mustard plant showed statistically significant differences at late flowering stage for different integrated management practices of mustard aphid (Table 6). The highest number of healthy plants/m^2 (29.00) was attained in T_7 treatment which was statistically similar (28.67 and 28.33) with T_6 and T_5 and closely followed (28.00) by T_4, while the lowest number of healthy plants/m^2 (23.67) was found in T_8 treatment which was closely followed (27.00) by T_1 and T_2. The highest number of infested plant/m^2 (6.33) was observed in T_8 treatment, again the lowest number (1.00) was recorded in T_7 treatment which was statistically similar (1.33 and 1.67) with T_6 and T_5, respectively and closely followed (2.00) by T_4. The highest infested plant/m^2 (21.11%) was recorded in T_8 treatment which was followed (10.00% and 7.78%) by T_1, T_2 and T_3, respectively, whereas the lowest infested plant/m^2 (3.33%) was recorded in T_7 treatment which was statistically similar (4.44%) with T_6. Plant infestation percentage reduction over control at late flowering stage was estimated for different management practices and the highest value (84.23%) was recorded for the treatment T_7 and the lowest value (52.63%) from T_1 treatment. From the findings it is revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the late flowering stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval. Prabal *et al*. (2000) reported that maximum aphid mortality (97.50%) was observed at neem seed kernel extract, followed by neem leaf extract at 10% (61.88%). Kular *et al*. (2001) reported that the yield was on a par with fixed spray schedule under early sowing conditions but significantly higher than fixed spray schedule under normal sowing and late sowing conditions. Thus, insecticidal sprays given at ETL were more effective than fixed spray schedule of insecticides.

Average healthy and infested plant and percentage of infestation at flowering stage presented in Figure 3.

Table 6. Effect of treatments on plant infestation at late flowering stage

Treatments	Late flowering stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	27.00 d	3.00 b	10.00 b	52.63
T_2	27.00 d	3.00 b	10.00 b	52.63
T_3	27.67 cd	2.33 bc	7.78 bc	63.15
T_4	28.00 bc	2.00 cd	6.67 cd	68.40
T_5	28.33 abc	1.67 cde	5.56 cde	73.66
T_6	28.67 ab	1.33 de	4.44 de	78.97
T_7	29.00 a	1.00 e	3.33 e	84.23
T_8	23.67 e	6.33 a	21.11 a	
$LSD_{(0.05)}$	0.753	0.753	2.507	
Level of significance	0.01	0.01	0.01	
CV(%)	4.57	16.63	16.63	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

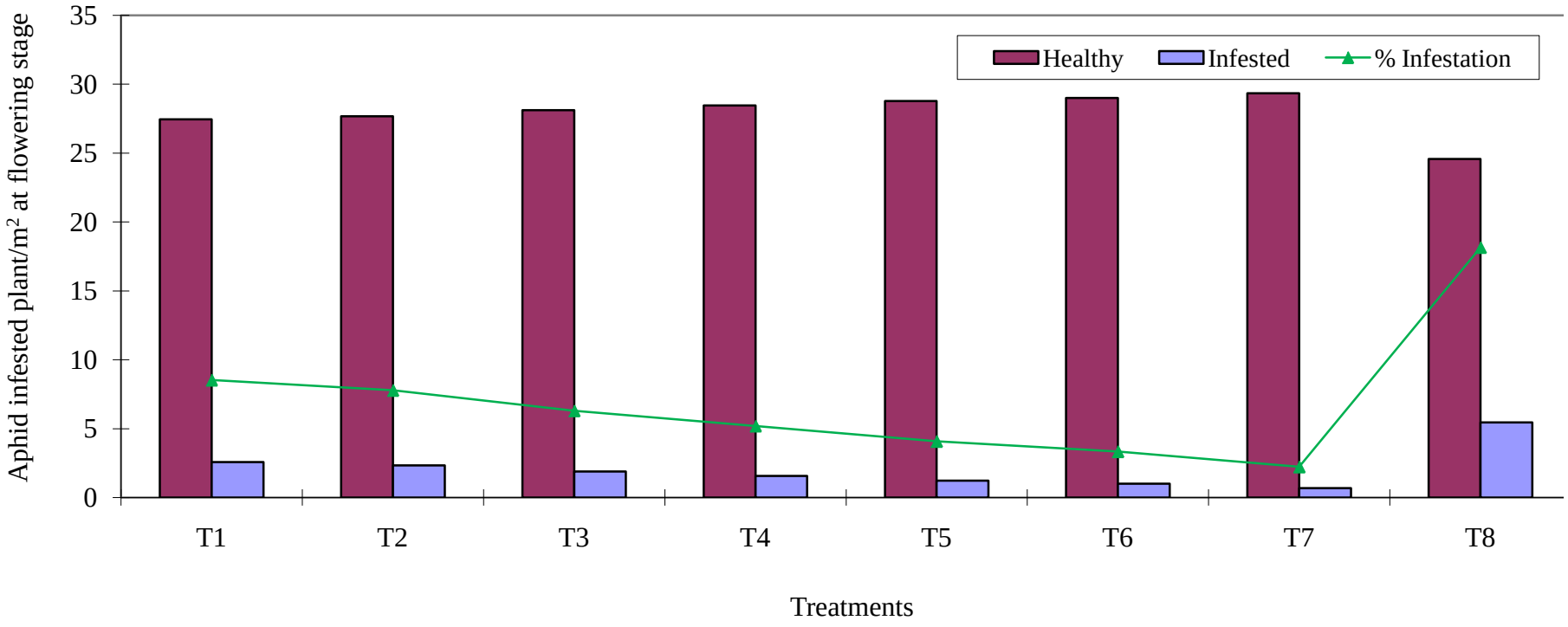
T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control



T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/Lg at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20g/kL+ Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

Figure 3. Aphid infestation per plant at flowering stage due to effect of treatments

4.3 Aphid infested mustard plant at fruiting stage

4.3.1 At early fruiting stage

Integrated management practices of mustard aphid showed statistically significant differences at early fruiting stage for number of healthy plant, infested plants and percent infestation (Table 7). The highest number of healthy plants/m^2 (28.67) was found in T_7 (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) treatment which was statistically similar (28.33 and 28.00) with T_6 (Tobacco leave dusts @ 5.0 g/kg + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) and T_5 (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) and by T_4 (Sumi Alpha 5EC @ 1ml/L of water at 7 days interval), respectively and closely followed (27.67) by and T_3 (Neem oil @ 0.3% at 7 days interval) and T_2 (Neem seed kernel extract 5% at 7 days interval). On the contrary, the lowest number of healthy plants/m^2 (24.33) was observed in T_8 (untreated control) treatment which was followed (27.00) by T_1 (Tobacco leave dusts @ 5.0 g/kg at 7 days interval). The highest number of infested plant/m^2 (5.67) was found in T_8 treatment, while the lowest number (1.33) was recorded in T_7 treatment which was statistically similar (1.67, 2.00 and 2.33) with T_6, T_5, T_4, T_3 and T_2, respectively and closely followed (3.00) by T_1. The highest infested plant/m^2 (18.89%) was recorded in T_8 treatment which was followed (10.00% and 7.78%) by T_1, T_2 and T_3, respectively, while the lowest infested plant/m^2 (4.44%) was recorded in T_7 treatment which was statistically similar (5.56%, 6.67% and 7.78%) with T_6, T_5, T_4, T_3 and T_1. At early fruiting stage plant infestation percentage reduction over control was estimated for different management practices and the highest value (76.50%) was recorded for the treatment T_7 and the lowest value (47.06%) from T_1 treatment. From the findings it is revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the early fruiting stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval.

Table 7. Effect of treatments on plant infestation at early fruiting stage

Treatments	Early fruiting stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	27.00 c	3.00 b	10.00 b	47.06
T_2	27.67 bc	2.33 bc	7.78 bc	58.81
T_3	27.67 bc	2.33 bc	7.78 bc	58.81
T_4	28.00 ab	2.00 c	6.67 c	64.69
T_5	28.33 ab	1.67 c	5.56 c	70.57
T_6	28.33 ab	1.67 c	5.56 c	70.57
T_7	28.67 a	1.33 c	4.44 c	76.50
T_8	24.33 d	5.67 a	18.89 a	--
$LSD_{(0.05)}$	0.907	0.907	3.021	--
Level of significance	0.01	0.01	0.01	--
CV(%)	4.88	20.70	20.70	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

4.3.2 At mid fruiting stage

Statistically significant variation was recorded in terms of number of healthy plant, infested plants and percent infestation of mustard plant at mid fruiting stage for different integrated management practices of mustard aphid (Table 8). The highest number of healthy plants/m^2 (28.33) was recorded in T_7 treatment which was statistically similar (28.00 and 27.67) with T_6 and T_5 and closely followed (27.33) by T_4. On the other hand, the lowest number of healthy plants/m^2 (23.33) was recorded in T_8 treatment which was closely followed (26.33 and 26.67) by T_1 and T_2. The highest number of infested plant/m^2 (6.67) was observed in T_8 treatment. Again, the lowest number (1.67) was recorded in T_7 treatment which was statistically similar (2.00 and 2.33) with T_6 and T_5, respectively. The highest infested plant/m^2 (22.22%) was attained in T_8 treatment which was followed (12.22% and 11.11% and 10.00%) by T_1, T_2 and T_3, respectively, whereas the lowest infested plant/m^2 (5.56%) was recorded in T_7 treatment which was statistically similar (6.67% and 7.78%) with T_6 and T_5. Plant infestation percentage reduction over control at mid fruiting stage was estimated for different management practices and the highest value (74.98%) was recorded for T_7 and the lowest value (45.00%) from T_1. From the findings it is revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the mid fruiting stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval. Roy *et al*. (2004) Mustard aphid (*Lipaphis erysimi*) infestation started during either flowering or pod formation stage and peak population of mustard aphid was mostly found during seed filling stage. Singh *et al*. (2003b) reported that the IPM module reduced the pest attack on the crop and gave higher yield compared to untreated plots. Men *et al*. (2002) found that *B. thuringiensis* (1 kg/ha) and Neemark (1%) were the safer treatments followed by neem leaf extract (5%), *B. thuringiensis* at 0.5 kg/ha + endosulfan (0.03%), endosulfan (0.05%), Achook (0.15%) and neem seed extract (5%).

Table 8. Effect of treatments on plant infestation at mid fruiting stage

Treatments	Mid fruiting stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	26.33 e	3.67 b	12.22 b	45.00
T_2	26.67 de	3.33 bc	11.11 bc	50.00
T_3	27.00 cde	3.00 bcd	10.00 bcd	55.00
T_4	27.33 bcd	2.67 cde	8.89 cde	59.99
T_5	27.67 abc	2.33 def	7.78 def	64.99
T_6	28.00 ab	2.00 ef	6.67 ef	69.98
T_7	28.33 a	1.67 f	5.56 f	74.98
T_8	23.33 f	6.67 a	22.22 a	--
$LSD_{(0.05)}$	0.763	0.763	2.547	
Level of significance	0.01	0.01	0.01	
CV(%)	4.63	13.78	13.78	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

4.3.3 At late fruiting stage

Number of healthy plant, infested plants and percent infestation of mustard plant showed statistically significant differences at late fruiting stage for different integrated management practices of mustard aphid (Table 9). The highest number of healthy plants/m^2 (28.00) was recorded in T_7 treatment which was statistically similar (27.67 and 27.33) with T_6, T_5 and T_4 and closely followed (27.00) by T_3, while the lowest number of healthy plants/m^2 (22.67) was recorded in T_8 treatment which was followed (26.33 and 26.67) by T_1 and T_2. The highest number of infested plant/m^2 (7.33) was attained in T_8 treatment, while the lowest number (2.00) was recorded in T_7 treatment which was statistically similar (2.33 and 2.67) with T_6, T_5 and T_4, respectively and closely followed (3.00) by T_3. The highest infested plant/m^2 (24.44%) was found in T_8 treatment which was followed (12.22%, 11.11 and 10.00%) by T_1, T_2 and T_3, respectively. On the contrary, the lowest infested plant plant/m^2 (6.67%) was observed in T_7 treatment which was statistically similar (7.78% and 8.89%) with T_6, T_5 and T_4. Mustard plant infestation percentage reduction over control at late fruiting stage was estimated for different management practices and the highest value (72.71%) was recorded for T_7 and the lowest value (50.00%) from T_1 treatment. Data revealed that spraying of Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for reduction of plant infestation by aphid at the late fruiting stage which was followed by tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water-at 7 days interval. Men *et al*. (2002) reported that found that *B. thuringiensis* (1 kg/ha) and Neemark (1%) were the safer treatments followed by neem leaf extract (5%), *B. thuringiensis* at 0.5 kg/ha + endosulfan (0.03%), endosulfan (0.05%), Achook (0.15%) and neem seed extract (5%). Dimethoate (0.03%) proved toxic to the hyperparasitoid.

Average healthy and infested plant and percentage of infestation at fruiting stage presented in Figure 4.

Table 9. Effect of treatments on plant infestation at late fruiting stage

Treatments	Late fruiting stage			
	Healthy plant (No.)	Infested plant (No.)	% infestation	Infestation reduction over control (%)
T_1	26.33 d	3.67 b	12.22 b	50.00
T_2	26.67 cd	3.33 bc	11.11 bc	54.54
T_3	27.00 bcd	3.00 bcd	10.00 bcd	59.08
T_4	27.33 abc	2.67 cde	8.89 cde	63.63
T_5	27.67 ab	2.33 de	7.78 de	68.17
T_6	27.67 ab	2.33 de	7.78 de	68.17
T_7	28.00 a	2.00 e	6.67 e	72.71
T_8	22.67 e	7.33 a	24.44 a	--
$LSD_{(0.05)}$	0.799	0.799	2.664	--
Level of significance	0.01	0.01	0.01	--
CV(%)	4.71	13.69	13.69	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 1.0 m^2 selected 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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

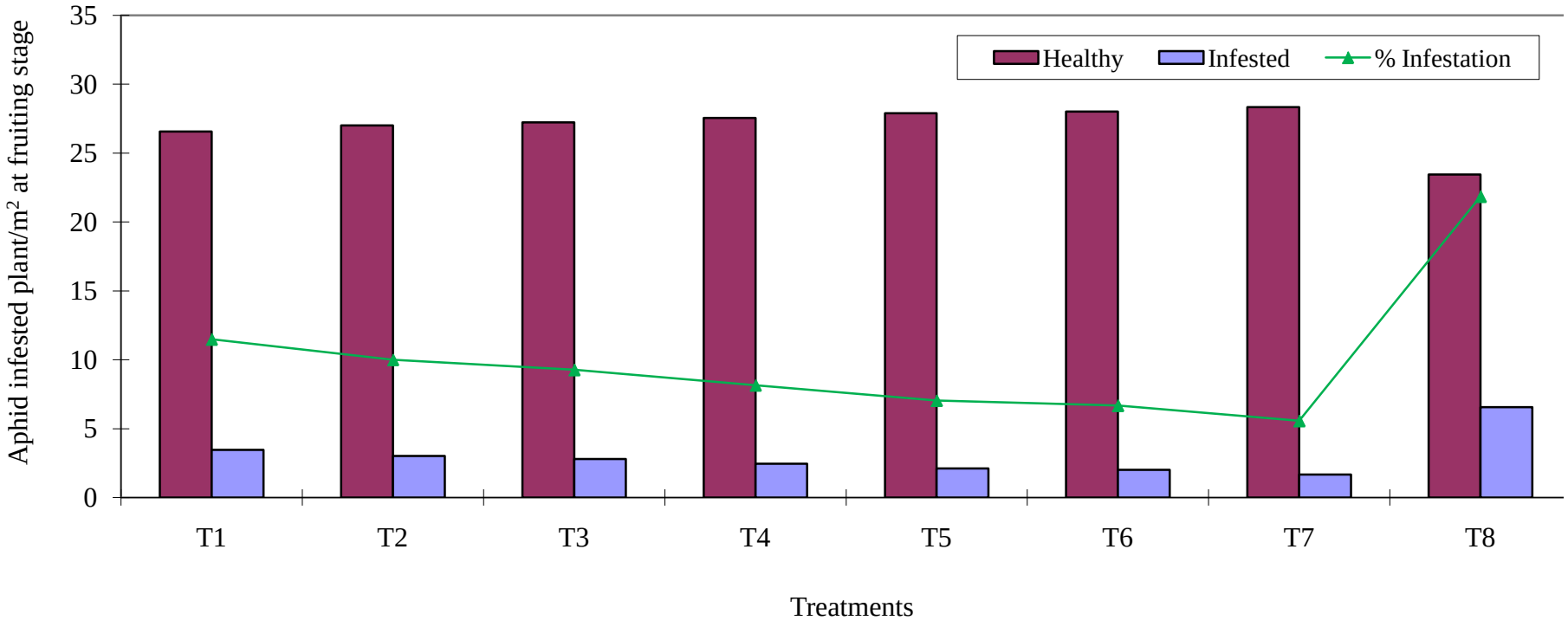
T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control



T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/Lg at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20g/kL+ Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

Figure 4. Aphid infestation per plant at fruiting stage due to effect of treatments

4.4 Effect of treatments on yield contributing characters and yield

4.4.1 Plant height at harvest

Plant height of mustard at harvest for controlling aphid through integrated management practices showed statistically significant differences (Table 10). The longest plant (118.56 cm) was recorded in T_7 (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval) treatment which was statistically identical (116.84 cm, 116.76 cm, 113.22 cm and 110.50 cm) with T_6 (Tobacco leaf dusts @ 20 g/L + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval), T_5 (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water- at 7 days interval), T_4 (Sumi Alpha 5EC @ 1ml/L of water at 7 days interval) and T_3 (Neem oil @ 0.3% at 7 days interval), respectively and closely followed (106.66 cm) by T_2 (Tobacco leaf dusts @ 20 g/L at 7 days interval), while the shortest plant (101.20 cm) was recorded in T_8 (untreated control) treatment which was statistically similar (104.67 cm) with T_1 (Neem seed kernel extract 5% at 7 days interval).

4.4.2 Number of branches per plant

Integrated management practices for controlling mustard aphid showed statistically significant differences in terms of number of branches per plant (Figure 5). Data revealed that the maximum number of branches per plant (13.20) was found in T_7 treatment which was statistically identical (12.80 and 12.70) with T_6 and T_5 which is closely followed (11.80) by T_4, while the minimum number of branches per plant (10.30) was observed in T_8 treatment which was statistically similar (10.90 11.10 and 11.50) with T_1, T_2 and T_3.

4.4.3 Number of siliqua per plant

Number of siliqua per plant of mustard for controlling aphid through integrated management practices showed statistically significant differences (Table 10). It was found that the maximum number of siliqua per plant (129.20) was observed in T_7 treatment which was statistically identical with other treatment except T_8 and T_1 and the minimum number of siliqua per plant (103.70) was attained in T_8 treatment which was statistically similar (106.50) with T_1.

Table 10. Yield and yield contributing characters due to integrated management of mustard aphid for controlling aphid infestation

Treatments	Plant height (cm)	Number of siliqua per plant	Length of siliqua (cm)	Weight of 1000 seeds (g)	Seed yield (t/ha)
T_1	104.67 cd	106.50 bc	3.48 bc	3.32 bc	2.18 bc
T_2	106.88 bcd	111.60 abc	3.55 b	3.38 abc	2.24 abc
T_3	110.50 abcd	114.70 abc	3.61 ab	3.42 abc	2.29 ab
T_4	113.22 abc	121.50 abc	3.65 ab	3.45 ab	2.32 ab
T_5	116.76 ab	124.80 ab	3.72 ab	3.51 ab	2.36 ab
T_6	116.84 ab	125.50 a	3.78 ab	3.54 ab	2.37 ab
T_7	118.56 a	129.20 a	3.88 a	3.70 a	2.45 a
T_8	101.20 d	103.70 c	3.22 c	3.09 c	2.02 c
$LSD_{(0.05)}$	10.17	16.78	0.282	0.313	0.228
Level of significance	0.05	0.05	0.01	0.05	0.05
CV(%)	5.23	8.18	4.43	5.25	5.66

In a column, numeric data represents the mean value of 3 replications;

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

Treatments:

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_8: Untreated control

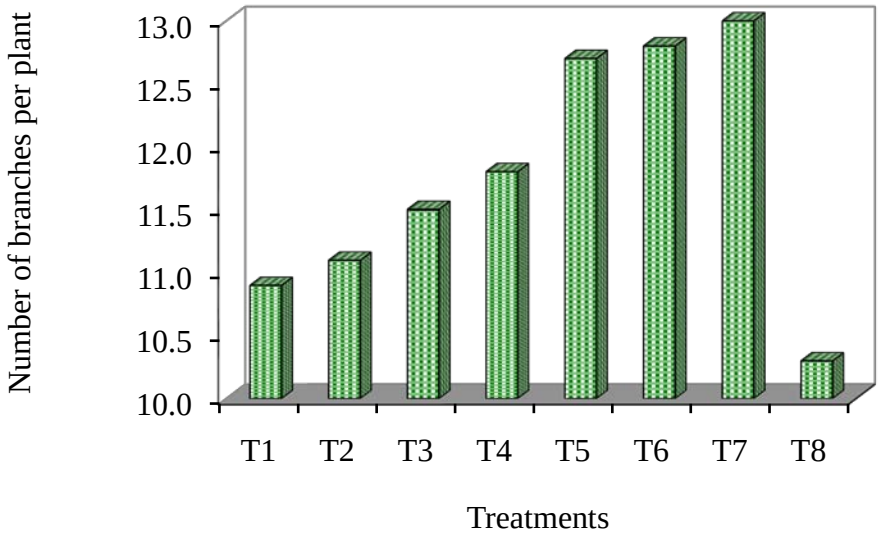


Figure 5. Effect of treatments in mustard on number of branches per plant

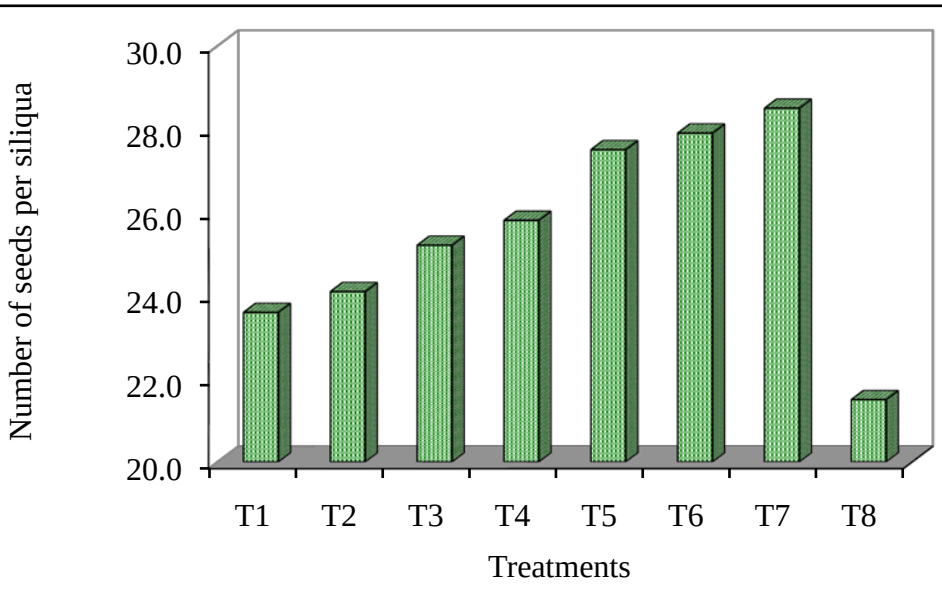


Figure 6. Effect of treatments in mustard on number of seeds per siliqua

T_1: Neem seed kernel extract 5% at 7 days interval

T_2: Tobacco leaf dusts @ 20 g/L at 7 days interval

T_3: Neem oil @ 0.3% at 7 days interval

T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval

T_5: (Neem seed kernel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

T_6: (Tobacco leaf dusts @ 20 g/L + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval

4.4.4 Length of siliqua

Statistically significant variation was recorded for length of siliqua of mustard for controlling aphid through integrated management practices (Table 10). The longest length of siliqua (3.88 cm) was found in T_7 treatment which was statistically identical with other treatment except T_8, T_1 and T_2, whereas the shortest length (3.22 cm) was recorded in T_8 treatment which was closely followed (3.48 cm and 3.55 cm) by T_1 and T_2 and they were statistically similar.

4.4.5 Number of seeds per siliqua

Number of seeds per siliqua of mustard for controlling aphid through integrated management practices showed statistically significant differences (Figure 6). It was found that the maximum number of seeds per siliqua (28.50) was recorded in T_7 treatment which was statistically identical with other treatment except T_8, T_1 and T_2, while the minimum number of seeds per siliqua (21.50) was observed in T_8 treatment which was statistically similar (23.60) with T_1.

4.4.6 Weight of 1000 seeds

Integrated management practices for controlling aphid showed significant differences in terms of weight of 1000 seeds of mustard (Figure 5). It was found that the highest weight of 1000 seeds (3.90 g) was attained in T_7 which was statistically identical with other treatment except T_8 and T_1, whereas the lowest weight (3.09 g) in T_8 treatment which was statistically similar (3.32 g) with T_1.

4.4.7 Seeds yield per hectare

Significant difference was recorded in terms of seeds yield per hectare of mustard for controlling aphid through integrated management practices (Table 10). Data revealed that the highest seeds yield per hectare (2.45 ton) was recorded in T_7 treatment which was statistically identical with other treatment except T_8 and T_1, whereas the lowest seed yield per hectare (2.02 ton) was found in T_8 treatment which was statistically similar (2.18 ton) with T_1. Ahuja and Kalyan (2003) reported that spraying at 45, 60, 75, 90 and 105 days after sowing gave the highest mean seed yield (2457 kg/ha).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2012 to March 2013 to study the management of mustard aphid, *Lipaphis erysimi* (Kalt.) using botanicals. Seeds of BARI Sarisa-15 were used as a test crop for this experiment. The experiment comprised of the treatments of T_1: Neem seed karnel extract 5% at 7 days interval, T_2: Tobacco leaf dusts @ 20 g/L of water at 7 days interval, T_3: Neem oil @ 0.3% at 7 days interval, T_4: Sumi Alpha 5EC @ 1ml/L of water at 7 days interval, T_5: (Neem seed karnel extract 5% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval, T_6: (Tobacco leaf dusts @ 20 g/L of water + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval, T_7: (Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water) at 7 days interval and T_8: Untreated control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on aphid population at early, mid and late flowering and fruiting stage, healthy and infested plant, % infestation and infestation reduction over control at early, mid and late flowering and fruiting stage, different yield parameters and yield were recorded and significant variation was observed among different treatment.

In case of aphid population, from the data it was found that at early flowering stage, the lowest number of aphid (0.43) was found from T_7, whereas the highest number (7.90) from T_8. At mid flowering stage, the lowest number of aphid (0.83) was found from T_7, while the highest number (9.70) from T_8. At late flowering stage, the lowest number of aphid (0.93) was attained from T_7, while the highest number (12.40) from T_8. At the total flowering stage, the lowest number of aphid (2.19) was recorded from T_7 and the highest number (30.00) from T_8. At early fruiting stage, the lowest number of aphid (1.17) was observed from T_7, while the highest number (8.27) from T_8. At mid fruiting stage, the lowest number of aphid (1.60) was found from T_7 again the highest number (10.63) from T_8.

At late fruiting stage, the lowest number of aphid (1.87) was observed from T_7, whereas the highest number (12.50) from T_8. At the total fruiting stage, the lowest number of aphid (4.64) was recorded from T_7, while the highest number (31.40) from T_8.

In case of number of healthy plant, infested plants and percent infestation of mustard plant at early flowering stage, the highest number of healthy plants/m^2 (29.67) was recorded in T_7 and the lowest number (25.33) in T_8. The highest number of infested plant/m^2 (4.67) was recorded in T_8 treatment, whereas the lowest number (0.33) in T_7. The highest infested plant/m^2 (15.56%) was attained in T_8 treatment again, the lowest (1.11%) in T_7. At mid flowering stage, the highest number of healthy plants/m^2 (29.33) was recorded in T_7 treatment, whereas the lowest number (24.67) in T_8. The highest number of infested plant/m^2 (5.33) was attained in T_8 treatment, while the lowest number (0.67) in T_7. The highest infested plant/m^2 (17.78%) was observed in T_8 treatment and the lowest infested plant/m^2 (2.22%) in T_7. At late flowering stage, the highest number of healthy plants/m^2 (29.00) was attained in T_7 treatment, while the lowest number of healthy plants/m^2 (23.67) in T_8 treatment. The highest number of infested plant/m^2 (6.33) was observed in T_8 treatment again the lowest number (1.00) in T_7. The highest infested plant/m^2 (21.11%) was recorded in T_8 treatment, whereas the lowest infested plant/m^2 (3.33%) was recorded in T_7.

For number of healthy plant, infested plants and percent infestation at early fruiting stage the highest number of healthy plants/m^2 (28.67) was found in T_7 and the lowest number (24.33) in T_8. The highest number of infested plant/m^2 (5.67) was found in T_8 treatment, while the lowest number (1.33) in T_7. The highest infested plant/m^2 (18.89%) was recorded in T_8 treatment, while the lowest (4.44%) in T_7. At mid fruiting stage, the highest number of healthy plants/m^2 (28.33) was recorded in T_7 treatment and the lowest number (23.33) in T_8. The highest number of infested plant/m^2 (6.67) was observed in T_8 treatment again, the lowest number (1.67) in T_7. The highest infested plant/m^2 (22.22%) was attained in T_8 treatment, whereas the lowest (5.56%) in T_7.

At late fruiting stage, the highest number of healthy plants/m^2 (28.00) was recorded in T_7, while the lowest number (22.67) was recorded in T_8. The highest number of infested plant/m^2 (7.33) was attained in T_8 treatment, while the lowest number (2.00) in T_7. The highest infested plant/m^2 (24.44%) was found in T_8 treatment and the lowest (6.67%) in T_7.

The longest plant (118.56 cm) was recorded in T_7, while the shortest plant (101.20 cm) was recorded in T_8. The maximum number of branches per plant (13.20) was found in T_7 treatment, while the minimum (10.30) was observed in T_8. The maximum number of siliqua per plant (129.20) was observed in T_7 treatment and the minimum number (103.70) was attained in T_8. The longest length of panicle (3.88 cm) was found in T_7 treatment, whereas the shortest length (3.22 cm) was recorded in T_8. The maximum number of seeds per siliqua (28.50) was recorded in T_7, while the minimum number (21.50) was observed in T_8. The highest weight of 1000 seeds (3.90 g) was attained in T_7 treatment, whereas the lowest weight (3.09 g) in T_8. The highest seeds yield per hectare (2.45 ton) was recorded in T_7, whereas the lowest (2.02 ton) was found in T_8 treatment.

Conclusion

From the above findings it may be concluded that Neem oil @ 0.3% + Sumi Alpha 5EC @ 1ml/L of water at 7 days interval was more effective among the management practices for controlling mustard aphid.

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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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2011 to March 2012

Month	*Air temperature (^{0}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2011	25.82	16.04	78	00
December, 2011	22.4	13.5	74	00
January, 2012	24.5	12.4	68	00
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	11

* Monthly average,

*** Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212**

Appendix II. Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix III. Analysis of variance of the data on the aphid population at early, mid and late flowering and fruiting stages due to effect of treatments

Source of variation	Degrees of freedom	Mean square							
		Number of aphid at flowering stage of				Number of aphid at fruiting stage of			
		Early	Mid	Late	Total	Early	Mid	Late	Total
Replication	2	0.008	0.054	0.083	0.124	0.027	0.015	0.152	0.132
Treatment	7	17.035***	23.241***	38.181***	71.243***	14.315***	23.315***	32.825**	69.352**
Error	14	0.060	0.071	0.150	0.319	0.060	0.081	0.181	0.281

** Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on the controlling aphid infestation at flowering stage due to effect of treatments

Source of variation	Degrees of freedom	Mean square								
		Early stage			Mid stage			Late stage		
		Healthy plant (No.)	Infested plant (No.)	% infestation	Healthy plant (No.)	Infested plant (No.)	% infestation	Healthy plant (No.)	Infested plant (No.)	% infestation
Replication	2	0.042	0.042	0.463	0.375	0.375	4.167	0.042	0.042	0.463
Treatment	7	5.708**	5.708**	63.426**	6.375**	6.375**	70.833**	8.452**	8.452**	93.915**
Error	14	0.280	0.280	3.108	0.232	0.232	2.579	0.185	0.185	2.050

** Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on the controlling aphid infestation at fruiting stage due to effect of treatments

Source of variation	Degrees of freedom	Mean square								
		Early stage			Mid stage			Late stage		
		Healthy plant (No.)	Infested plant (No.)	% infestation	Healthy plant (No.)	Infested plant (No.)	% infestation	Healthy plant (No.)	Infested plant (No.)	% infestation
Replication	2	0.125	0.125	1.389	0.667	0.667	7.407	0.542	0.542	6.019
Treatment	7	5.714**	5.714**	63.492**	7.333**	7.333**	81.481**	8.762**	8.762**	97.355**
Error	14	0.268	0.268	2.976	0.190	0.190	2.116	0.208	0.208	2.315

** Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on the controlling aphid infestation at fruiting stage due to effect of treatments

Source of variation	Degrees of freedom	Mean square						
		Plant height (cm)	Number of branches per plant	Number of siliqua per plant	Length of siliqua (cm)	Number of seeds per siliqua	Weight of 1000 seeds (g)	Seed yield (t/ha)
Replication	2	14.825	0.125	4.805	0.003	1.201	0.002	0.012
Treatment	7	121.135*	3.175**	267.209*	0.124**	17.361**	0.097*	0.055*
Error	14	33.745	0.448	91.831	0.026	4.647	0.032	0.017

**** Significant at 0.01 level of probability, * Significant at 0.05 level of probability**