EFFECTIVENESS OF SOME INSECTICIDES FOR MANAGEMENT OF POTATO INSECT PESTS

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BY

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CERTIFICATE

This is to certify that the thesis entitled **"Effectiveness of some insecticides for management of potato insect pests"** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY**, embodies the results of a piece of bonafide research work carried out by **Mst. Mahfuzara Sultana**, Registration No. **12-05061** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2018
Dhaka, Bangladesh

Professor Dr. Mohammed Ali
Department of Entomology
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The present study was carried out on the effectiveness of some insecticides for management of potato insect pests. There were seven treatments such as T_1 (Pheromone Trap +Neem seed kernel extract), T_2 (Diazinon), T_3 (Carbofuran), T_4 (Fipronil), T_5(Pymetrozine + Nyten pyram), T_6(Cartap + Acetamiprid) and a check T_7 were evaluated on potato crop at the Sher-e-Bangla Agricultural University in Dhaka city during Rabi season from October 2017 to March 2018. The insecticides were applied at initial stage of crop growth and early mid stage of potato plants. The data were collected by counting cut plant by cutworm, by counting number of infested leaves by aphids by counting number infested tuber and weighing of infested tuber by cutworm, by counting the number of virus infected plants showing leaf roll and mosaic symptoms plant transmitted by aphids in each plot. The lowest number of cut plants was recorded in T_3 and T_6 (1) treatment and lowest in T_7 (6). The lowest number of infested leaves was counted in T_1 (1.67%) and the highest number of infested leaves was recorded in T_7(17.95%). At 15, 40, 60 days after emergence of seedling, the lowest number of virus infected plants was 1.33, 1.67 and 2.33 counted in T_1 and the highest number of virus infected plants was 4.33, 12.00 and 20.67 recorded in T_7 respectively. The lowest number of infested tuber was counted in T_1(1.33) and the highest number of infested tuber was counted in T_7(4.00). Average seasonal infestation was the lowest in T_1(Pheromone trap + neem seed kernel extract) followed by T_6(Cartap + Acetamiprid) and T_5(Pymetrozine + Nyten pyram) the highest in check plot.

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CHAPTER I

INTRODUCTION

Potato, *Solanum tuberosum* L. the king of vegetables is a native of South America; in Indian sub-continent people called it alu though also known as white or Irish potato and no doubt it is an indispensable part of Bangladesh cuisine. As per literature it is the most important vegetable crop ranking third after rice and wheat being a major staple food crop. As for as production is concerned, it is the fifth largest agricultural produced crop as well the largest tuber crop of the entire world (Anonymous, 2011a). Screening of literature revealed that different varieties of potatoes are grown in more than 150 countries of the world and more than a billion people eat it worldwide. The top ten producers in the world are China, Russia, India, USA, Ukraine, Germany, Poland, Belgium, Netherlands and France which together contribute about 70 per cent of the total production (Anonymous, 2011a). The total world potato production is estimated at 364.8 mollion tonnes in 2012 (FAO STAT, 2012). It is cultivated in large tracts and in home gardens as well.

The potato tubers are highly nutritive, rich in carbohydrates, proteins, phosphorus and minerals such as calcium, potassium and also vitamin A and C. It also contains significant levels of phenolic compounds and vitamin C as potent antioxidants (Brown, 2005) which inactivate reactive oxygen, reducing oxidative damage, lead to improved immune functions and reduce risk of cardiovascular disease, cancer, cataract, diabetes and aging (Kaur et al., 2004). Being a short duration crop, it produces more quantity of dry matter, gives energy and edible protein in short duration of time compared to cereals like rice and wheat. Hence, potato may prove to be a useful tool to achieve the nutritional security of the nation. Around 80 per cent of potato production is achieved as a Rabi crop. The Rabi crop is sown in October and harvested in March. Although potato is a seasonal crop it is grown around the country based on climatic conditions and harvested at different times, thus making it available throughout the year.

Potato is a temperate or cool season crop which needs a low temperature, low humidity, less windy and bright sunny days. It does perform well under well distributed rains or moist weather situations to high temperatures. Moreover, humidity and rains are not conducive to potato crop as often suffered with insects, nematodes and disease attacks. In fact, insects, nematodes, rats and other pests are detrimental in reducing the agricultural production of

potato in tropical countries (Waliullah, 2007; Ghosh and Khan, 2010). Apart from the direct attack on plant some of the insects and nematodes are the vectors of virus particularly those of sap feeders. They suck sap of leaves, shoots, stem and roots and causing diseases to plants and indirectly affect photosynthesis also. But nevertheless inspite of all efforts the control of insects and nematodes is challenging since vectors are usually mobile and small in size and more so it is very difficult to prevent colonization of some pests in fields (Chenulu, 1984; Banjo, 2010). It is well documented that this important vegetable crop in fields is always subjected to qualitative and quantitative losses due to biotic and abiotic stresses. Literature revealed that potato crop is attacked by more than 100 arthropods and 156 species of plant-parasitic nematodes that belonged to 52 genera all over the world. Out of these, 80 arthropods and 93 species of nematodes fall under 40 genera have been reported from India alone (Pandey, 2007). Cutworms and Potato – peach aphid are the two devastating insect pest in the spring crop (Sing 2002).

The economically important cutworms are lepidopterans belonging to genera *Agrotis, Euxoa, Discestra* and *Peridroma* of family Noctuidae. The genus *Agrotis* includes number of species of cutworms which cause extensive damage to vegetable and cereal crops in Bangladesh and most of these species look very similar especially as larvae. In India, five species of Agrotis, namely, *A. flammatra* Schiff., *A. Interacta* Walk., *A. ipsilon* (Hufn.), *A. segetum* and *A. spinifera* Hb. have been reported to damage potato crop (Chandel and Chandia, 2003). Cutworms are highly polyphagous and attack a large number of crops worldwide including India (Ram et al., 2001; Mrowczynski et al., 2003 and Napiorkowska and Gawowska 2004). The common cutworm, *Agrotis segetum* (Denis & Schiffermuller), is distributed throughout the temperate regions of Europe, Africa and Asia whereas, greasy or black cutworm, *Agrotis ipsilon* (Hufnagel) is commonly found in Asia and North America. Cutworms are notorious agricultural and garden pests. They get their name from the habit of "cutting" off a seedling at ground level by chewing through the stem. The cutworms typically coil up tightly into 'C' shape when disturbed. The cutworms usually remain hidden during the day and feed mostly at night. However, some feeding may occur during the day, but the cutworms generally remain concealed below the ground at that time. Cutworms are a large, diverse group of nocturnal moths. They cause considerable damage to a number of crops, often cutting the stem of seedling plants either below or just above the ground level and producing more damage than

actual feeding. The full grown larvae of the cutworm are dark or dark brown in colour with greasy body. The adult female cutworm lays their eggs on the grasses or on the weeds. The larva on emergence feeds on the epidermis of the leaves, biting the stems of seedling, eating the leaves and sometime the entire seedling and their habit changes according to their growth. The period of full bloom is the most sensitive plant growth stage, but even then defoliation on the order of 10% appears to cause little if any yield loss. Applications should be targeted to control small larvae (1st and 2nd instars), rather than larger larvae (Schreiber et al., 2010, Jensen et al., 2011).

Aphids cause serious losses in potato plants and tubers, mostly because they vector viruses. Due to their remarkable adaptations and colonization of several ecological systems, including crops, aphids are interesting models of study at different levels. Their biology (viviparity, oviparity, and parthenogenesis), physiology (osmoregulation, regulation of the water balance), and behavior (feeding, virus transmission, and plant manipulation) reveal unique adaptations and fascinating relationships with their host plants. The main aphid species associated with potatoes worldwide are non-specific to this crop. Most of them are cosmopolitan and polyphagous. The color of the aphids can also be highly variable within a given population and can be influenced by the symbiotic bacteria they host (Tsuchida et al. 2010). Morphology is influenced by several factors, such as environmental, climatic, and seasonal conditions; quality of the host plants and population densities. Research on potatoes often involves studying viruses because of their considerable impact on crop quality and yields. No antiviral treatment is available to control virus spread among cultivated plants. A very low tolerance for virus infection is allowed for potato seed certification.

Keeping in view the importance of above mentioned pests, attention has been paid to manage that cause heavy loss to the potato crop. Since, it is necessary for a researcher to have basic data on the pest complex along with their incidence, extent of damage and to develop an eco-friendly management strategies against the cutworm and other insect pest of potato crop.

The present research work, therefore, was planned with a view to find out the best management strategies for insect pest of the potato crop. The current study was carried out to find the effectiveness of some insecticides for management of potato insect pests.

Objectives of this experiment

1. To identify different methods of pest management, their benefits and limitations
2. To examine the practices, determine best management and recommendations for appropriate IPM technique

CHAPTER II

REVIEW OF LITERATURE

The available literature in relation to the present investigations is reviewed under the following heads.

1. Pest complex of potato (*Solanum tuberosum* L.)
2. Management practices against insect pests of potato

1. Pest complex of potato

Britton (1918) while working on insects attacking potato crop in Connecticut (USA) reported an number of chewing insects where the most important were Colorado potato beetle and potato flea beetle. He reported that three lined potato beetle, tortoise beetle, blister beetle, stalk borer, cutworm, wireworm, white grub and European corn borer caused occasional damage and according to him the principal sucking insect damaging potato were potato aphid species. Eden and Garrett (1955) reported that wireworms, primarily the Gulf wireworm and the imported fire ant were serious pests of the Irish potato crop in the Gulf Coast Area of Alabama. Sharma and Bhalla (1964) conducted a survey on insect pests of economic importance in Himachal Pradesh and reported 13 insect pests belonging to different orders from potato crop grown fields in hills.

Getzendaner (1966) reported that European earwig feeds on other insects, plants, ripe fruit, and garbage. Plants that it feeds on include clover, dahlias, zinnias, butterfly bush, hollyhock, lettuce, strawberry, celery, potatoes, roses, seedling beans, beets, tender grass shoots and roots. It also damages sweet corn by feeding on the silks.

Squire (1972) reported that the most important insect pests in root crop potato in Bolivia were Liriomyza spp., as the larvae of which feed in the stems. The material collected by him included L. quadrata (Mall.), L. brasiliensis (Frost) and several undescribed species. The leaves were attacked by Acordulecera sp. (a Tenthredinid that feeds on the parenchyma),

Empoasca fabialis DeLong, E. fabae (Harris) and Macrosiphum euphorbiae (Solanifolii (Ashm.)); this last transmits
the viruses causing potato mosaic and leaf-curl. Several species of Epicauta were noticed to feed on the leaves, and E. adspersa (Klug) and E. vittata (F.) occasionally destroy both leaves and young shoots. The major species attacking the tubers were Premnotrypes latithorax (Pierce) Phthorimaea (Gnorimoschema) operculella (Zell.). The tubers, particularly those growing in humus or peaty soil were also attacked by larvae of Cyclocephala melanocephala (F.), Bothynus (Ligyrus) burmeisteri (Steinheil) and Ontherus sulcator (F.). However, Leptinotarsa decemlineata (Say) was not recorded from Bolivia.

Sexana (1974) described some soil insect pests, defoliators, sap feeders and storage pests of potato in India and gave informations on their control. Adashkevich (1975) pointed out in a review paper that there were more than 600 species of insect, mite and other invertebrate pests of vegetable crops in the Soviet Union and in the European part alone more than 500 species of insect enemies of such pests. The crops most studied include, among field crops, cabbage, tomato, potato and cucurbits; 75 per cent of the enemies observed were polyphagous and less than 5 per cent monophagous. It was reckoned that they destroyed about half the pest population in general. The situation was less favourable in the case of L. decemlineata (Say), because the effect of its 50 species of enemies was small.

Dorozhkin et al. (1975) while working on combined protection of potatoes in Byelorussia, reported that potato were attacked by numerous diseases and insect pests where the most important being L. decemlineata (Say) and wireworms. In an another study at least 38 species of insect pests were reported to attack potato at Cusco (Peru) which was partly based on literature and partly on surveys carried out during 1972-73. These pests were placed in 7 orders and 18 families including 12 new species that were recorded for the first time from potato fields in Cusco (Escalante, 1975).

Menschoy (1975) made detailed studies on the insect pests of potato and their control. He found that the major pests attacking the young plants were noctuid larvae. The larvae of Phthorimaea operculella feed on the young shoots and other foliage parts of crop and those of the last generation make tunnels in the tubers. The larvae of Manduca (Phlegethontius) sexta

subsp. paphus feed extensively on the foliage and Epicauta spp., Diabrotica speciosa (Germ.) and Epitrix parvula (F.) also damage the foliage. He also reported that the important aphids like Myzus persicae (Sulz.), M.euphorbia (Thos.), Solanifolii (Ashm), Aulacorthum solani (Kalt) and Aphis euonymi F. which infested the potato crop at Brazil.

Butani and Verma (1976) studied on pests of vegetables and their control in India. They reported that Phthorimaea operculella, Agrotis ipsilon and other Agrotis species were attacking both above and underground parts of potato. M. persicae and 12 other species of aphids were associated with leaves whereas, Gryllotalpa africana and Eremotermes sp., Microtermes obesi and Odontotermes
obesus were the major insect pests which infested the other parts of potato crop.

Koppen et al. (1976) conducted an experiment for monitoring insect pests of potato in East Germany especially L. decemlineata; A. segetum and suggested that sampling with the aid of a check plot method should be based on certain characters and independent of pest distribution. Monitoring of L. decemlineata should also be done regularly that covers the stages which are important for short term prognosis and that cause active damage during growing season. The supervision of A. segetum covers young larvae and should be carried out 30 days after adult flight where the period could be detected with the aid of light traps.

Bacon et al. (1978) reviewed the damage caused by the most important pests of potato Phthorimaea operculella (Zell.) and M. persicae (Sulz.) in California by monitoring the populations of P. operculella in 1976 by means of water-pan traps baited with synthetic sex pheromone and found that in fields imperfectly irrigated, where the soil was cracked potato damage was heavier because adults and larvae were able to gain access to the tubers through the soil cracks. However, more damage was caused by M. persicae to potato through the transmission of leaf-roll virus. The population monitoring by means of water-pan traps during 1970-1972 showed an annual decline in numbers probably owing to insecticide applications and improved weed control; however, even short-lived aphids feeding briefly on infected plants, if present, were able to transmit the virus before being killed by the sprays.

Jensen et al. (1979) listed 67 species belonging from 24 genera to nematodes associated with potatoes. Among them the most damaging were the potato cyst nematode, Globodera rostochiensis and G. pallida causing tremendous losses in several countries. The other nematode species distributed worldwide causing significant losses including stubby root (Trichodorus and Paratrichodorus spp.), root lesion (Pratylenchus spp.), potato rot (Ditylenchus spp.) and Basirolaminus indicus (Waliullah, 1992).

Nagaich et al. (1979) made a collection of leaf hopper fauna from potato and other adjoining crops from different agroclimatic regions of India and collected 74 leaf hopper species.

Tsendsuren (1979) listed soil-inhabiting pests in Mongolia particularly those which were much damaging to crops, pastureland and soil-consolidating plants by wireworms, tenebrionids, cockchafers, lepidopterous larvae and other soil-inhabiting insects. Among 80 known species of wireworms, the most injurious to field crops were Selatosomus latus (F.), S. spretus (Mannh.), S. aeneus (L.), Agriotes obscures (L.), A. sputator (L.), A. lineatus (L.), A. meticulosus Cand. and A. dahuricus Cand. The larvae of those species damage cereal crops especially maize in May-June and also damage potatoes, cabbage, beet and onion. Further, over 100 species of scarabaeids were recorded and the most injurious include Amphimallon solstitiale (L.), which damages maize in irrigated soil in the south of the Mongol Altai region and likewise potatoes, sugarbeet and cereals, Other injurious beetles include species of Eodorcadion. Leaf feeding Lepidoptera in river valleys and other suitable sites include Euxoa islandica Stgr., E. tritici (L.) and A. exclamationis (L.), which damage especially vegetables, potato and other crops.

Kashyap and Verma (1982) conducted a survey on aphids infesting seed crop of potato in Haryana (India) and reported on a total of seven aphid species infesting potato crop namely A. craccivora Koch, A. gossypii, A. fabae, M. persicae Sulz., Rhopalosiphum nymphaeae Linn., R. rufiabdominalis and Tetraneura nigriabdominalis Sasaki.

Radcliffe et al. (1982) have reviewed the insect pests of potato that were belonged to 5 main headings: aphids (including aphid-transmitted potato viruses; aphid life-cycles and biology; aphids and virus transmission; population monitoring and modelling; insecticide resistance

and biological control), leafhoppers, Leptinotarsa decemlineata (Say), Phthorimaea operculella (Zell)., and pests of tubers and roots. A short section on varietal resistance to insect pests is also included.

Hooker et al. (1983) while studying the potato insect pests in Brazil, their status and future trends. They reported that the main pests of potato were M. persicae (Sulz.), as the main species limiting to seed production (on account of the viruses it transmits); Diabrotica speciosa (Germ.) and Epitrix spp., the larvae of which feed on the tubers of both seed and table crops and the adults of which feed on the foliage and Liriomyza huidobrensis (Blanch.) which is highly important as in some areas reduced yields by 30 per cent in 1981, while as P. operculella (Zell.), elaterids, A. ipsilon (Hufnagel.), M. euphorbiae (Thos.), Nezara viridula (L.) and Epicauta spp. recorded as minor pests.

Velupillai and French (1986) conducted a survey on previously reported diseases and pests of potato on the main Island of Sri Lanka. They confirmed that most pathogens and pests recorded had been reported previously except some fungi viz., Choanephora cucrditarum, Fusarium oxysporum, the aphid, Rhopalosiphoninus latysiphon Davidson and the mite Polyphagotarsenemus latus Banks.

Anwar et al. (1987) while recording the insect pests associated with potato cultivar Multan in Pakistan that included Gryllus bimaculatus and Acrotylus humbertianus. They further recorded peak population of aleyrodid Bemisia tabaci (2.25 individual plant-1) in the first week of February and the cicadellid Amrasca devastans (1.22 plant-1) in second week of January, while M. persicae (1.68 aphid plant-1) in the first week of December to (9.01 plant-1) in the fourth week of January and maximum attack of larvae of Phthorimaea operculella was also noted in February with 13.5 per cent of tuber infestation.

Hill et al. (1987) studied biology of Thysanoplusia orichalcea (Lepidoptera: Noctuidae) in New Zealand and reported that plusiine noctuid moth, T. orichalcea was a polyphagous pest with a host plant range differing from Chrysodeixzs eriosorna and more abundant than C. eriosoma on 7 species of plant could become a significant defoliating pest in legumes and brassicas.

Raodeo and Deshpande (1987) reported that white grubs (Scarabaeidae) in Marathwada region of Maharashtra (India) were attacking the roots of various crops including wheat, ground nut, potato, tomato and sugarcane.

Sharma et al. (1987) while investigating the occurrence of insect pests on stored potato tubers in an ordinary room temperature 20-25 oC and in cold storage at 2-3 oC, reported that potatoes in cold storage were not infested, while the tenebrionids Alphitobius laevigatus, Tribolium castaneum, the trogossitid Tenebroides mauritanicus and the dermestid Trogoderma granarium were found with greatest infestation on tubers stored in ordinary room.

Tyagi and Misra (1987) while surveying for the extent of damage done by white grub species (Lachnosterna coriacea and L. longipennis) in and around Shimla during 1984 and 1985 on potato crop reported that both attained the status of key pests of potato crop in certain pockets of Himachal Pradesh particularly at Shilaroo and its adjacent areas.

Das (1988) conducted trial on insect pests of potato crop and their control in Tripura (India) which revealed that 23 species of insect pests were infesting potato of which only Odontotermes obesus, Agrotis segetum, A. ipsilon, Aphis gossypii, A. fabae and M. persicae were of economic importance.

Das and Ram (1988) conducted a field study in Bihar (India) during 198384 and 1984-8 to determine the damage, incidence and carry-over of the noctuid A. ipsilon on potato revealed that during 1983-84, damage to tubers averaged 12.76 and 4.26 per cent during 1984-85. Further the plant damage was first observed during the 3rd week of December and increased thereafter until the 2nd week of January and the tuber damaged was first observed during late December that increased thereafter till harvest. No larvae were observed in 1st week after harvest and from the 4th week of February until April. However, larvae and pupae were found only on the following alternative host plants: Chenopodium album, Solanum nigrum, Portulaca oleracea, Amaranthus viridis, Evolvulus alsinoides and 2 unidentified weed species.

Misra and Agrawal (1988) while investigating on the potato pests in India and their control, reported that potatoes were attacked by more than 80 insects and several nematode pests in the fields. The pests were classified into soil pests, sucking sap feeders, defoliators and storage pests. They further reported two major nematode pests viz., root-knot and cyst forming ones infesting the crop. Rai et al. (1988) conducted a survey to record the insect pests of potato atthe experimental fields of R.A.R. Station Chhindwara, Madhya Pradesh and reported three new insect pest species for the first time on potato which were niger capsule fly, Dioxyna sororcula Wiedmann (Diptera: Tephritidae), niger green bug, Creontiades sp. (Hemiptera: Miridae) and mirid bug Taylorilygus pallidulus Walk (Hemiptera: Miridae).

Rajagopal and Trivedi (1989) reported that among the major insect pests that attack potato, the coccinellid Epilachna vigintioctopunctata is very important in Asia which is widely distributed in South and East Asia, Australia, America and the East Indies where some of the species are E. dodecastigma and E. vigintioctopunctata, E. ocellata and Henosepilachna sparsa [E. sparsa] commonly attack Solanaceous plants. They further reported that the peak period of infestation varied with region, but the peak was generally in July-August. The pest also feeds on aubergine, tomato, tobacco, pumpkin and bitter gourd Momordica charantia].

Sontakke et al. (1989) while studying the effect of climatic factors on the phenology of foliage pests of potato in Orissa (India) during the kharif and rabi seasons of 1983-84 and 1984-85, reported that potato crop was attacked by the aphids A. gossypii and M. persicae, the chrysomelid Chalaenosoma metallicum, the cicadellid Amrasca biguttula, the coccinellid Henosepilachna viginctioctopunctata [Epilachna vigintioctopunctata], the thrips Thrips flavus, the tarsonemid Polyphagotarsonemus latus and the noctuid A. ipsilon in both seasons. However, the phenology of the pests and the intensity of their attack varied considerably in the different seasons and regions. The correlation analysis between various meteorological variables and the incidence of the different pest species during the kharif season revealed that temperature was having positive significant correlation with the incidence of most of the insect pests, except A. ipsilon. The population development of A. ipsilon has shown significant influence by day temperature during the rabi season. An interdisciplinary research project on the management of potato pests in the highlands and coastal regions conducted at Peru contains chapters on the intensification of potato production and pesticide use there, pest

management practices in the highlands, the endemic potato pest Premnotrypes spp., the storage pests Phthorimaea operculella and Symmetrischema plaesiosema and a case study of Liriomyza huidobrensis in the Canete valley (Ewell et al., 1990).

Lal (1990) reported that many insect pests causing severe damage to the potato crop and the tubers in north-eastern India which were recorded for the first time and were different in different crop stages of the region. However, cutworms (Agrotis ipsilon Ratt), white grubs (Lachnosterna coriacea Hope), leaf-eating caterpillars (Prodenia litura Fab.), (Heliothis armigera Hubn.) and Plusia sp. and aphids (Myzus persicae Sulzer) were some amongst the common pests observed throughout that region. The potato tuber moth (Phthorimaea opercullela Zeller) caused severe damage only in Meghalaya, where it showed more than 50 per cent plant infestations and 70 per cent tuber damage under indigenous storage conditions. An Epilachna beetle (Henosepilachna vigintioctopunctata Fab.) caused severe damage to potato foliage in Assam (10-55%) and in Arunachal Pradesh (30-70%). Red ants (Dorylus orientalis Westwood) was prevalent in Meghalaya and Arunachal Pradesh causing about 37 and 20 per cent tuber infestation, respectively.Mole cricket (Gryllotalpa africana Palisot de Beauvois) was found damaging young plants only in Tripura (10-30%).

2. Management practices against insect pests of potato

Learmonth and Matthiessen (1990) studied the damage, biology and potential for the integrated control of the main soil insect pests of potato in Western Australia, Graphognathus leucoloma and Heteronychus arator. The other pests causing damage to smaller areas include Atrichonotus taeniatulus, Phlyctinus callosus, Otiorhynchus cribricollis and Asynonychus cervinus [Pantomorus cervinus]. Infact potatoes were attacked by several insects in fields as well as in storage withsevere damage caused by aphids, jassids, cutworms, termites, white grubs, leaf eating caterpillars, epilachna and other beetles whereas, tuber moth larvae damage the crop mainly in stores inflicting sometimes considerable losses in hills of Uttar Pradesh (Singh, 1990).

Trivedi and Verma (1990) while studying the population trend of M. persicae Sulzer on different stages of potato crop in Karnataka (India) reported that the aphid population was significantly different on 27, 38, 50 and 63 days crop and there was no significant differences

in 63 and 69 day old crop which indicate that stage of crop and its new emerging leaves have definite role on landing, settling and population build-up of aphids on potato in that region of the country.

Zaki and Masoodi (1990) listed some15 insect pests associated with the potato crop affecting both above and below ground parts of the plant. They also considered soil inhabiting insects as a major source of damage to potato crop in the Kashmir valley.

Tiwari et al. (1991) studied thepecies composition of white grubs (Scarabaeidae) in Himachal Pradesh (India) and reported total of 47 species of white grub among them 19 species including Popillia cyanea, Xylotropes gideon and Brahmina coracea which were collected for the first time. There are reports that several constraints being involved which are biotic, abiotic and agronomical that leads to both hectarage and yield of the crop very low. Insect pests are one of the biotic factors. A monitoring study of potato tuber moth (PTM) and aphids was conducted at Holetta for four years and the peak months with high PTM or aphid population were identified and an attempt was made to correlate aphid population fluctuation with some abiotic factors where temperature and moisture found to affect aphid population significantly. Besides, work on aphid virus transmission was also conducted where only M. persicae (green peach aphid) and Macrosiphum euphorbiae (potato aphid) gave positive results (Anonymous, 1992).

Misra et al. (1992) studied the impact/effect of different population levels of cutworm, A. segetum (Schiffer) larvae on tuber damage and determined the economic threshold level (ETL) for two years during summer crop season (March to September) on both the table and seed crops of potatoes at Shimla. They reported that a positive correlation was observed between the number of cutworm larvae released and damage caused by them to potatoes (tubers) on all the recorded parameters, viz., plant showing tuber damage (%), tubers damaged on number basis (%), damaged yield (%), and damaged yield (q/ha). Besides, the population level of 40 larvae/plot containing 16 plants (2.5 larvae/plant) was responsible for highest damage and yield losses. The economic threshold levels (ETLs) on table and seed crops were worked out, respectively to be 2.88 and 1.20 larvae of A. segetum per 10 m2 crop area.

Hence, they suggested that judicious and need-based control programmes could be decided accordingly.

Waliullah (1992) collected a total of 267 soil and root samples from 14 vegetable crops in the Kashmir valley. He observed that potato crops (S. tuberosum L.) were infested by several ecto and endoparasitic nematodes viz., Tylenchorhynchus spp., Basirolaimus indicus, Helicotylenchus spp. Pratylenchus spp., Tylenchorhynchus mashhoodi and Trichodorus spp. though their number and occurrence varied with localities.

Mishra and Singh (1993) studied on the biology of H. longipennis infesting potato in Uttar Pradesh and found that adult emergence began at the end of May and noted its peak in 2nd week of June. Eggs and 1st instar larvae were found during June- July with 2nd and 3rd instar larvae damaging tubers by the end
of July and during mid-August, respectively.

Rodri et al. (1993) conducted a survey to determine insect pests associated with potato and the extent of their damage in Costa Rica and reported that a total of 50 insect species were associated with potato crops where Phthorimaea operculella and Scrobipalposis solanivora were noted to cause high percentage of damage. They further reported that greatest damage of tubers was done by Phthorimaea spp., followed by Phyllophaga spp. and Epicaerus species.

Zaki et al. (1993) conducted two experiments to assess the extent or retrievable losses caused by plant parasitic nematodes in tomato and potato in Kashmir. The results indicated that 9.34 and 11.0 per cent retrievable losses in tomato and potato, respectively were recorded at pre-plant population of 170, 123, 48.5 and 81 per ml soil in tomato and 45, 20, 1510 and 21 per ml soil in potato of lesion, spiral and stunt nematodes and Tylenchus spp., respectively.

Parihar et al. (1994) studied the distribution and extent of damage topotato by Agriotes and Lygus species in the Lahaul and Spiti, a dry temperate region in the north-east of Himachal Pradesh (India) in July-September 1987. They have provided details of the tuber damage by Agriotes spp., Agrotis ipsilon and the number of Lygus spp. per 5 plants in 41 villages of Himachal Pradesh.

Mishra (1995) reported several species of insect pests that damage potatoes and found Holotrichia coriacea as the predominant species in north western hills of Himachal Pradesh. He further reported that the damage to potato tubers ranged from 15.5 to 80.0 per cent on the weight basis. Parihar et al. (1995) while conducting a survey on insect pests damaging potato in Himachal Pradesh reported 31 species of insect pests amongist them 9 species were found for the first time in this area.

Seyedoleslami and Naderi (1995) studied the populations of Thrips tabaci, Empoasca decipiens and Trioza sp. and a common arthropod predators during 1985 and 1988 in Iran. Cicadellids and psyllids had two distinct activity peak periods, the 1st being from early June to late July and the 2nd from late July to late September. The relative density of thrips was high from early June to late July and parasitism of adult cicadellids was synchronised with a peak in their activity.
It was noted that predators were most abundant in June and July where Trioza sp. was more common on a few new potato varieties.

Chandel et al. (1996) conducting a survey on white grub infesting potato in Lahaul valley of Himachal Pradesh (India) reported H. longipennis as a major specie of insects infesting potato.

Fauziah and Siti (1996) carried out a field experiment to monitor and identify major insect pests of potato in the lowlands from mid-1993 to 1994 at Selangor (Malaysia). Visual sampling on plants (3x) in Sungai Baging showed that the population of mites was high (greater than 43,000/100 shoots per plot) followed by whitefly, aphids, and thrips. As per their findings on yellow-sticky trap, whitefly was found dominant (greater than 10,000) followed by leaf miner, leaf hopper, aphids and potato flea beetle.

Nandhihalli et al. (1996) conducted a survey on insect pests associated to potatoes in Hassan area of Karnataka which revealed the occurrence of 33 species of insects belonging to 8 orders and 23 families and also a species of mite.

Pernal et al. (1996) investigated the patterns of feeding injury to potato by potato flea beetle (Coleoptera: Chrysomelidae) in Manitoba and noted that flea beetles exhibit preferences for feeding in specific portions of potato plants. These preferences change in response to previous defoliation which were influenced by meteorological conditions and according to these researchers counting, feeding and punctures would not be a reliable method of assessing whether control measures for potato flea beetles are justified.

Peter (1996) reported about 18 insect and non insect pests including nematodes that damage both above and below ground parts of the potato crop. The insect pests include aphids, thrips, leafhoppers, potato tuberworm, cutworm, flea beetle, Andean potato weevil, white grub, wireworm, leafminer flies, whiteflies, blister beetle and leaf beetles, whereas non insect pests include Globodera pallida, G. rostochiensis Meloidogyne spp., Pratylenchus spp. and Nacobbus aberrans.

Resnais (1996) published the article summarizing the main potato diseases and pests (potato top rot, the invasion of aphids-vehicles of viruses, colorado beetle, potato leaf dry spot disease, black scab, common scab, dry rot, wet rot, cockchafers, caterpillars and crackles caterpillars) in different regions of Latvia in 1995 and forecasts were given for 1996. He emphasized that in spring before the choice of potato fields one must examine the number of pests hibernating in the soil in order not to exceed the critical number.

Min et al. (1997) observed the occurrence pattern of major insect pests on 7 recommended cultivars of potato during growing season in Korea and reported that Myzus persicae Macrosiphum euphorbiae and Spodoptera exigua were the major insect pests damaging leaves while as, Selatosomus puncticollis destructive to tubers.

Maredia et al. (1998) presented the available data on the first occurrence and the damage severity of the potato leafhopper in the north central and northeastern United States collected during the 47 years (1951-1997) which were collected from a variety of sources including: potato leafhopper literature review; published reports; pest alerts; pest surveys; and delphi surveys. It was noted that first occurrence, severity data, arrival time of potato leafhopper and subsequent damage severity varied substantially from year to year. However, the correlation

analysis between date of first occurrence and severity of damage for Michigan, Minnesota, Wisconsin, the north central region and the north-eastern region indicated no significant relationship between first arrival dates and damage severity. The lack of a relationship between the time of arrival of the migrant leafhopper and severity indicated that other factors, including frequency and magnitude of arrivals, weather conditions during the growing season and crop management contribute to the eventual severity of damage caused to crops by this migratory pest. The analysis of potato leafhopper severity data showed significant differences between years. There were no significant differences in severity among states within the north central region, indicating that potato leafhopper

Verma et al. (1998) conducted field experiment during the main crop seasons from 1984-91 and 1995-97 at/around C.P.R.S. Modipuram Meerut (India) and reported that aphid M. persicae appeared on the unprotected potato crop from 15th November onwards every year i.e. approximately 35 days after planting the crop. They further mentioned that either M. persicae was not serving as an efficient vector or there was lack of the virus source for Potato Virus-Y and potato leafroll virus in and around the seed crop under the prevailing conditions.

Chandla et al. (2001) observed serious attack of white grub, Lachnosterna coriacea in and around Fagu village fields of potato in Shimla during 1997. They further recorded that soil type (sandy loam with loose texture), lower elevation and weather factors (rains) favoured pest actively with higher tuber damage.

Dharpure (2002a) conducted a survey in Madhya Pradesh (India) during 1995-98 to determine the insect pests attacking the crop and recorded a total of 28 pest species infesting potatoes from which Thrips palmi, Scirtothrips dorsalis and Haplothrips spp. were recorded for the first time as new pests on potato.

Dharpure (2002b) reported painted bug (Bagrada cruciferarum Kirkaldy) as a serious pest for the first time on potato in Madhya Pradesh India which otherwise was considered as the pest of cruciferous crops.

Konar and Mohasin (2002) while recording the incidence of Epilachna beetle at different locations of West Bengal (India) reported that maximum incidence of grub and adults was at Memari whereas, it was minimum at Boinchee of Hooghly district. They further noted that variations in incidence and damage of pest from place to place and year to year were due to the variation in the
prevailing environment factors.

Sing (2002) reported that potato crop is attacked and damaged by a number of insect pests including wireworms, white grub, aphids, cutworm and others as a result, the yield of the crop is adversely affected. Cutworms and Potato peach aphid were the two devastating insect pests in the spring crop.
Chandel and Chandla (2003) while working on the management of the tuber damaging pests of potato, reported that more than 100 insects attack potato that caused most variable and complex problems to potato farmers. These pests can damage potato plants by feeding on leaves, reducing photosynthetic area and efficiency by attacking stems, weakening plants and inhibiting nutrient transport and also by attacking potato tubers destined for consumption or use as seed. Among non-insect pests, snails, slugs and nematodes cause economic losses, the nematodes being more harmful than molluscs.

Chandel et al. (2003) studied the population dynamics of potato white grub by soil sampling in Shimla hills revealed high population of Brahmina coriaceae Hope representing all stages. Pupae were found in the soil during April followed by the adults in May and eggs in June-July. Larvae were present in the soil from July to April while as, 3rd instar grubs cause damage in SeptemberOctober and overwinter in earthen cells up to April and adult emergence begins in May, maximum being in mid-June.

Chib and Malik (2003) studied the population fluctuation of leaf hopper under different treatments reported that leaf hopper was a serious pest of potato and even relatively low numbers could cause significant yield reduction.

Garg et al. (2003) while studying the health status of potato crop in Leh and Ladakh (J&K) reported that crop showed heavy degeneration as was apparent from sickly appearance

marked with foliar symptoms of mosaics, wavy leaf margins and leafroll at majority of locations which was due to varied level (low to fairly high) of aphid population.

Mogahed (2003) conducted a field experiment during the winter season (from December to April) of 1999-2000 and 2000-01 at north Sinai Governorate (Egypt) and reported that potato cultivars had lesser infestation of cotton whitefly, cotton thrips, potato leaf aphids and potato leaf hoppers when intercropped with garlic and onion compared to the same cultivars of potato grown as monocrop and the average yield of potato tubers in plots of potato grown alone was lower compared as to those of intercropped potatoes.

Singh et al. (2003) conducted a survey to record the faunal composition of white grub in four hill districts of Garhwal (Uttaranchal) India during 1996 and1997 and recorded 33 species of white grub belonging to eight sub-families on 51 host plants including potato crop.

Prasad (2003) while studying the intensity and build-up of cyst nematodes in varying ecological situations at Nilgiri (India) found that nematodes were encountered at varying levels from all potato growing localities of Nilgiri situated at 920 to 2470 meters above sea level with the intensity low below 1550 and high to very high at altitudes above 2000 meters.

Kumar (2004) surveyed the insect pests of agricultural crops in high altitude arid temperate regions of north western Himalayas and noted several species of insect pests on almost all the crops and most of these species commonly occurred in plains and low hilly areas as well. However, he found that potato crops were mainly infested by cutworms (Agrotis spp.) and different species of
white grubs.

Singh et al. (2004) while studying the nature and extent of damage on 15 rainy season crops at 16 locations in Uttaranchal (India) reported that larvae of H. longipennis feed on live roots, thereby plants show stunted growth, yellowing, wilting and drying up. They further observed significant symptoms of damage that were not observed on the apical parts of potato, although the tubers were severally damaged. The extent of damage reported to be 5.67-65.16 and 4.96-

62.92 per cent in high and mid hills, respectively but very high hills showed lower mean damage (2.28-12.62%).

Lakra (2005) while monitoring the disease and insect pests of potato crop during 2001 to 2005 in Haryana, reported high incidence of apical leaf curl, whiteflies (Bemisia tabaci) and Jassids (Amrasca biguttula) on October sown crops while as, crops exhibited moderated incidence in November sown crop. He further noted that December planted crops were seriously attacked by an aphid (M. persicae), early blight, leaf roll and severe mosacic causing higher yield loss which was recorded upto 30 per cent.

Pandey (2007) reported that among pests, aphids and leaf hoppers were the most important vectors responsible for transmitting and spreading of a number of viral and mycoplasmal diseases. The other important pests were to be cutworms, white grubs, potato tuber moth and cyst nematodes. He further reported that cyst nematodes were confined to the southern hills of Shimla (H.P.) only. Among vertebrates, rats were often noticed in the potato fields in localities where potato is grown. A few rat species have also been reported to attack plants like floriculture crops including bulbs and corns in the field (Waliullah, 2007).

Kamano and Mbata (2008) while studying the incidence and abundance of insect pests of potatoes in the Fouta Djallon region of Guinea reported that insect pests such as tuber moth, Phythorimmaea opercullele (22.7%), the variegated grasshopper, Zonocerus variegatus (14.8%), the noctuid moths, Agrotis ipsilon (13.2%) and Helicoverpa spp (9.2%), and the whitefly, Bemisia tabaci (12.0%) were infesting the potato crop. Insect infestation was based on a method of diagonal 20-point observation in each plot. They further observed that some plants exhibited symptoms of viral attack and the proportion of sampled plants suffered with viral attack upto 7.5 per cent.

Omar et al. (2008) surveyed the occurrence of aphids and viral diseases on potatoes in Syria. Aphids were trapped in a yellow pan with water in a Tissue Culture Laboratory of the General Organization for Seed Multiplication (GOSM) at Al Eeramoun from June, 2006 to June, 2007. The number of winged aphids trapped increased slightly in Autumn and attained peak in Spring. On Autumn cultivated potato plants in the Aleppo and Hama areas, aphid densities

increased from mid-October to early November just before the harvest in 2006. On Spring cultivated potatoes aphid densities decreased from late May, although the densities were higher in Mid-April, just after sprouting, in 2007. Virus-infected plants were common in both Autumn- and Spring-cultivated potatoes in fields not contracted to GOSM, but there were a few in contracted fields in which virus-free plants grew. Aphid species belonging to 13 genera, including M. persicae, A. gossypii, A. fabae, A. craccivora, Schzaphis borealis and Lipaphis erysimi were identified among aphid samples collected from potato plants. In addition, Rhopalosiphum rufiabdominalis was found on rhizomes and roots of potato plants in GOSM greenhouses in 2007. The major aphids as potato pests were considered to be M. persicae, A. gossypii and A. fabae to a lesser extent.

Vallejo and Moron (2008) while studying on the description of immature stages and redescription of adults of Ancognatha scarabaeoides Erichson (Coleopthera: Scarabaeidae: Dynastinae) a member of soil white grub, described for the first time. A 3rd instar larva and a pupa of Ancognatha scarabaeoides Erichson and adults of both sexes were also redescribed in order to support the study of the soil white grub species, assemblage in Colombia, where it was found to be associated with potato crop.

Waliullah et al. (2008) while studying the diversity of nematodes on brinjal (S. melongena L.) in Jammu district of J&K state noted that frequency of both endo and ecto-parasitic nematodes varied with the age of crop and location.

Basavaraju et al. (2009) studied the yield loss estimation due to major insect and mite pests on potato in Madenur, Hassan, Beekanahalli and Chikmagalur (Karnataka) during 2004 and 2005 reported that aphids, M. persicae caused on an average 6 per cent loss in yield at Madenur and 3 per cent loss in Beekanahalli. The yield loss due to Spodoptera litura was 8 per cent at Madenur and 4 per cent at Beekanahalli. The yield loss due to potato tuber moth, Phthoremaea operculella was 9 per cent at Madenur while it was 6 per cent at Beekanahalli. The yield loss due to mite, Polyphagotarsonemus latus was 26.80 percent at Madenur and it was 4 per cent at Beekanahalli.

Khan et al. (2009) mentioned some major pests of potato in Kashmir Valley including spring tails (Sinella curvista), cutworm (A. ipsilon), white grub (Brahmina coriacea and H. longipennis), green peach aphid (M. persicae), root knot (M. hapla) and root lesion nematode (Pratylenchus spp.) causing heavy yield losses in potato.

Khanal et al. (2012) conducted a survey to study the abundance and distribution of white grubs in three districts Makawanpur, Tanahu and Chitwan representing different ecological domains of Nepal during June-July 2010 by installing two light traps for two nights in two locations each of districts and a season long light trap at Mangalpur of Chitwan district from April to September 2010 for assessing scarab beetles flight activity, revealed that the dominant species in Chitwan were Anomala dimidiata Hope (24%) followed by Maladera affinis Blanchard (23.75%), A. varicolor (Gyllenhal) (23%), Heteronychuslioderus Redtenbacher (14%) and Holotrichia spp. with a flight activity and species composition of scarab beetles in the three districts noted to be different.

Prasannakumar et al. (2012) while investigating the influence of weather parameters on pheromone trap catches of potato cutworm, S. litura (Fabricius) (Lepidoptera: Noctuidae) during 2007-08 (kharif and rabi) in and around 6 villages of Bengaluru rural district, Karnataka (India) to assess the percent potato cutworm damage. The trap catches (21.30±15.28 moths/trap/week) of potato cut worm were maximum (47.21 moths/trap) during 37th standard week. There was no significant difference in trap catches, but highly significant difference in moth catches during weeks and their interaction. They further revealed that there was a significant difference in moth catches across weeks and the trap catches lowered the damage caused by the insect. However, the performance of the pheromone traps, lures and the activity of the pest were influenced by several weather factors especially maximum and minimum temperatures, evaporation as well as wind speed which exhibited positive effects on the trap catches and per cent defoliation caused by the pest.

In a recent study Chandel et al. (2013) reported that more than 100 species of insect pests attack that damage tubers include white grubs, cutworms, potato tuber moth, termites, red ants and mole crickets. Sap-feeding insects such as aphids, leafhoppers, thrips and white files inflict damage by directly feeding on different parts of a plant and acting as vectors of plant

viruses. Aphids and whiteflies constitute a major threat to the cultivation of seed potato because they transmit viruses such as PLRV, PVY and Gemini viruses from one plant to another in an efficient manner. Leaf-feeding insects include several species belonging to the orders Lepidoptera and Coleoptera. The important leaf-feeding caterpillars are Spodoptera spp. H. armigera, Plusia orichalcea and Spilosoma obliqua. No doubt among coleopterans, the most destructive pests are hadda beetle, flea beetle, blister beetle and chaffer beetles.

Iqbal and Saljoki, Talpur et al. and Shah and Hussain , who reported significant control of cutworm with the application of endosulfan insecticides in tobacco crop.

Malik (1978) tested seven insecticides for the control of Agrotis ipsilon and achieved significant control of the pests in all the treated plots as compared to untreated plots. Relatively better results were obtained with Dipterex 80SP, Agrotix and Hostathion.

Rimpy and KS Verma (2018) tested seven insecticides for the control of Agrotis ipsilon and achieved significant control of the pests in all the treated plots as compared to untreated plots. . On the basis of average PT values of both the species, the descending order of toxicity of insecticides against third instar larvae of A. ipsilon and A. segetum was flubendiamide > chlorantraniliprole > novaluron > bifenthrin > spinosad > emamectin benzoate > cypermethrin at recommended concentrations.

Similarly, Shahid and Naeem investigated that Hostathion and of Kanga et al. and Greenstone who found considerable decrease in cutworm attack by using various acephate showed effectiveness in reducing cut worm attack as compared with untreated plots. .

The results were in agreement to Suss (1978) and Chang (1984), who reported effectiveness of various insecticides against Agrotis ipsilon. The pest is destructive at early stage so one time spray application was good enough to control Agrotis ipsilon. Effectiveness of a single application was also supported by Harris and Suss (1973), Khan et al. (1974) and Aslam et al. (1980) who used different insecticides in their studies for the Agrotis ipsilon control with single application of insecticides.

Munib (2011, 2012) stated that pests like white grub and cutworm are seemingly two major constraints in the successful cultivation of potato crop as were found to infest the crop.

Silvia (2014) said that potato is one of the most important food crops widely grown over many latitudes and elevations over the world. Increasing potato production in a sustainable manner requires an integrated approach covering a range of strategies. Combating pests is a continuous challenge that producers have to face as they intensify their production techniques to satisfy the increasing demands of the global market.

CHAPTER III
MATERIALS AND METHODS

3.1 Location

A field experiment on effectiveness of some insecticides for management of potato insect pests was conducted at the Sher-e-Bangla Agricultural University in Dhaka city during Rabi season from October 2017 to March 2018. The experimental site was medium high land in Agro-Ecological Zone of Madhupur Tract (AEZ no. 28).

Seven treatments i.e., T_1 (Pheromone Trap +Neem seed kernel extract), T_2 (Diazinon), T_3 (Carbofuran), T_4 (Fipronil), T_5(Pymetrozine + Nyten pyram), T_6(Cartap + Acetamiprid) and a check T_7 were evaluated.

3.2 Climate

The climate of the study site was under the subtropical climate, characterized by three distinct seasons, the Rabi from November to February and the Kharif- I, pre-monsoon period or hot season from March to April and the Kharif- II monsoon period from May to October (Edris *et al*., 1979). The monthly average temperature, relative humidity and rainfall during the crop growing period were collected from weather yard, Bangladesh Meteorological Department and presented in Appendix I. During the experimental period the maximum temperature (27.1^0C) and highest rainfall (30 mm) was recorded in the month of February 2018, whereas the minimum temperature (12.4^0C) and no rainfall was recorded in the month of January 2018. Average relative humidity over the season was 75%.

3.3 Soil

Soil of the study site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8- 6.5, CEC-25. The selected plot was medium high land.

3.4 Land preparation

The land was ploughed or dug to a depth of about 20 cm and harrowed to pulverize the soil. Bed method was practiced for potato cultivation in these experiment. The experimental plot was opened in the first week of November 2017 with a power tiller, and was exposed to the sun for a week, after which the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and later clods were broken into smaller pieces. After ploughing and laddering, all the stabbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiments were followed immediately after land preparation.

Plate 1. Cleaning the field

Plate 2. Preparation of land

Plate 3. Bed preparation

3.5. Manure and Fertilizer

The fertilizers N, P, K in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP) respectively. The entire amount of organic manure, TSP, MP and half amount of Urea were applied as basal dose during the final land preparation. Rest amount of Urea was applied 40 days after planting of tuber in the side of row. The dose and method of application of fertilizers are shown in Table (BARI).

Name of fertilizer	Amount (kg/ha)
Urea	235
TSP	150
MP	100

Plate 4. Applying manure and fertilizer

3.6 Planting material

Planting material was Tuber of BARI potato 7 (Diamond). It was collected from BADC (Bangladesh Agriculture Development Corporation) of Dhaka.

3.7 Application of insecticides

Insecticides were applied after emergence of the seedling and upon the appearance of symptoms of attacking insect pests in the field, at their recommended doses. Insecticides i.e. Dianol, Furadan, Asend were applied in natural field conditions in soil. Asiprid and Pyrazin were sprayed leaves and drenched the lower portion of plants. The insecticides were sprayed, for determining their relative effectiveness for potato insect pests control.

3.8 Sex pheromone trap for cutworm

Pheromone trap was putting near the stem of seedling above the surface of soil.

3.9 Neem seed kernel extract

Neem seed kernel extract was sprayed on base of potato plants.

3.10 Intercultural operation

3.10.1 Irrigation

Three times irrigation was done. At first 10 days of planting, secondly 15 and 40 days after emergence of seedling.

3.10.2 Weeding

At 15 and 40 days after emergence of seedling, weeding was done before irrigation.

3.10.3 Earthing up

After insecticides application in soil, earthing up was done. Here mentioned that insecticides were applied at 10 and 40 days after emergence of seedling.

3.11 Design of Experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into three blocks maintaining 1m block to block distance and each block was subdivided into 7 plots for 7 treatments maintaining 3 m x 2 m plot size. Thus the total number of plots was 21. The plot to plot distance was 0.5 m was kept to facilitate different intercultural operations. All the treatments were replicated three times. Experimental unite was having 35 plants per plot grown in the rows (ridges) made in each plot. There was 5 rows per plot and 7 plants in each rows. The distance between the tubers and rows was same and it was 50 cm.

3.12 Planting

The potato tubers were planted in the experimental field on 21st November, 2017.

3.13 Harvesting

Harvesting of potato was done on 12th March, 2018. Finally per hectare yield was calculated by converting yield of harvested potato /per plant.

3.14 Yield

Firstly, the healthy and infested tubers were sort out. Then weighing of both type was done separately. Finally, added both weight and recorded total yield of tuber. Total yield of tuber was 210 kg from 170m^2 land that was 12.25 ton/ha.

3.15 Data collection

Data was collected on the basis of following parameter

1. Number of cut plants per plot
2. Infestation of leaves by aphids
3. Yield per plot
4. Weight of Tuber per plot
5. Weight of healthy tuber
6. Number of infested Tuber by cutworm
7. Weight of infested Tuber by cutworm
8. Number of Adult cutworm per plot caught by pheromone trap

3.16 Aphids infestation

In case of aphids infestation during spring migration, winged adult travel many miles to many hosts depositing nymphs in colonies up to 20 on the lower third of plants. Later these nymphs colonies will produce more winged adults that travel further summer migration. During these migration cycle is when viral transmission occurs as the nymphs pick up virus from the colonized plant and the winged adults transmit them to other plants. So, leaves should be chosen from this area of the plant. Many species of aphids cause the greatest damage in late spring when the temperatures are warm but not hot.

3.17 Assessment of infested leaves

Ten potato plants were randomly selected from each plot and three leaves were picked from top, middle and bottom of each plant. Then number of infested leaves by aphids were counted.

3.18 Assessment of virus infection

For assessment of virus infection, count the infected plant number. Incidence of virus infection was determined as the proportion of plants showing leaf roll and mosaic symptoms. Virus incidence was determined from second week after emergence to crop maturity.

3.19 Treatment

Treatments	Treatment descriptions
T_1	Cutworm sex pheromone mass trapping was started at15 DAE and remain til to harvest + Neem seed kernel extract sprayed at 10 and 40 DAE potato plants
T_2	Dianol (Diazinon) 10 G @ 15kg/ha at 10 and 35 DAE of seedling applied in soil
T_3	Furadan 5G (Curbofuran) @ 20kg/ha during land preparation and 35 DAE of seedling applied in soil
T_4	Ascend (Fipronil) 50 SC @ 0.5gm/L water at 10 and 35 DAE of seedling Applied in soil
T_5	Pyrajin 70 WDG (Pymetrozine50% + Nyten pyram 20%) @ 0.5gm/L water at 10 and 35 DAE of seedling was sprayed on leaves and base portion of potato plants
T_6	Asiprid 95 SP (Cartap 92% + Acetamiprid 3%) @ 0.5gm/L water at 10 and 35 DAE of seedling was sprayed on leaves and base portion of potato plants
T_7	Untreated control

Plate 5. Cut potato plant infested with cutwor

Plate 6. Cutworm larvae in potato tuber

Plate 7. Ring shaped larvae of potato cutworm

Plate 8. Pupa of black cutworm

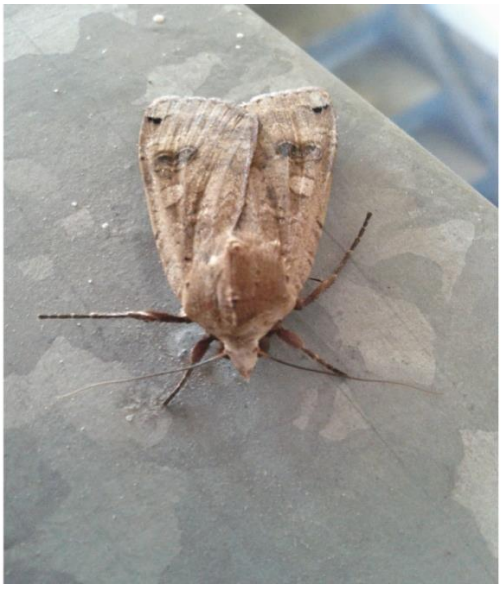

Plate 10. Adult moth of potato cutworm

Plate 11. Showing aphids species

Plate 12. Showing healthy and infected potato plant with virus

CHAPTER IV

RESULTS AND DISCUSSION

Statistical analysis of the data showed that application of insecticides significantly reduced the infestation of insect pests as compared with untreated plots (Control). However, the Pheromone trap for cutworm with neem seed kernel extract proved to be the best with minimum infestation.

Caught adult cutworm

In this experiment pheromone trap is used for catching adult moth of cutworm. Pheromone trap used only in the three replication of treatment 1. There are 35 plants in each replication. 12 adult cutworm were caught in 105 plants which exceed economic threshold level for cutworm.

Percent of wilted plant

Several experimental report revealed that the economic threshold level of cutworm is 2-3% wilted plants. The highest number of cut plants for the whole season was observed T_7 (5.71%) as compared to other insecticidal treatment (Fig 1). It showed that in the untreated control percentage of cut plant exceed economic threshold level. Number of wilted plants were reduced due to insecticides application.

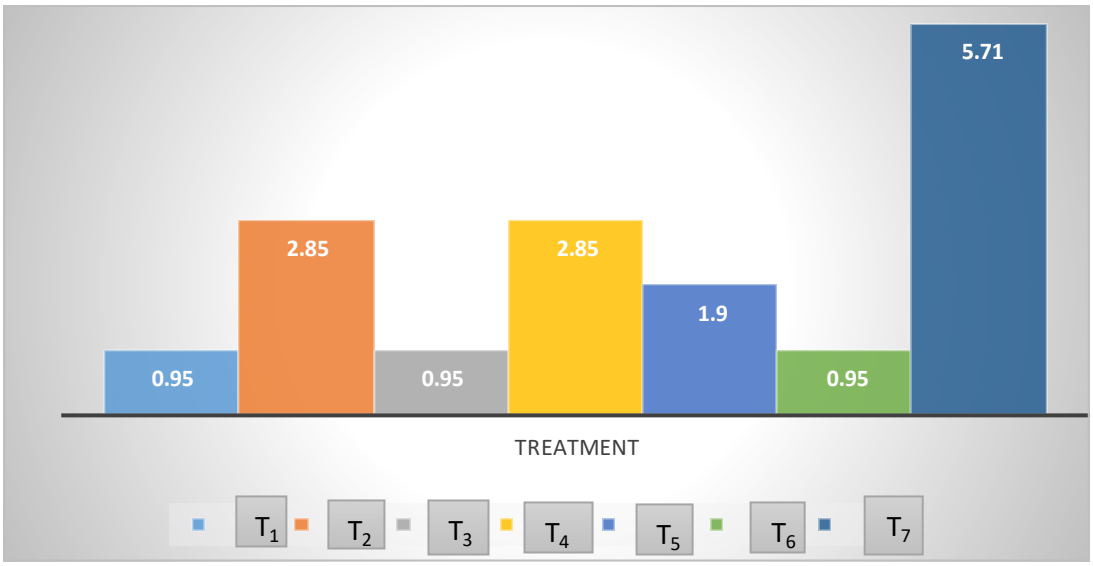

Figure 1. Percent of wilted plant at different management practices

Number of wilted plants

Number of wilted plants was the highest in T_7 (6.00) treatment and the lowest 1.00 in T_1, T_3 and T_6 treatments (Fig 2).

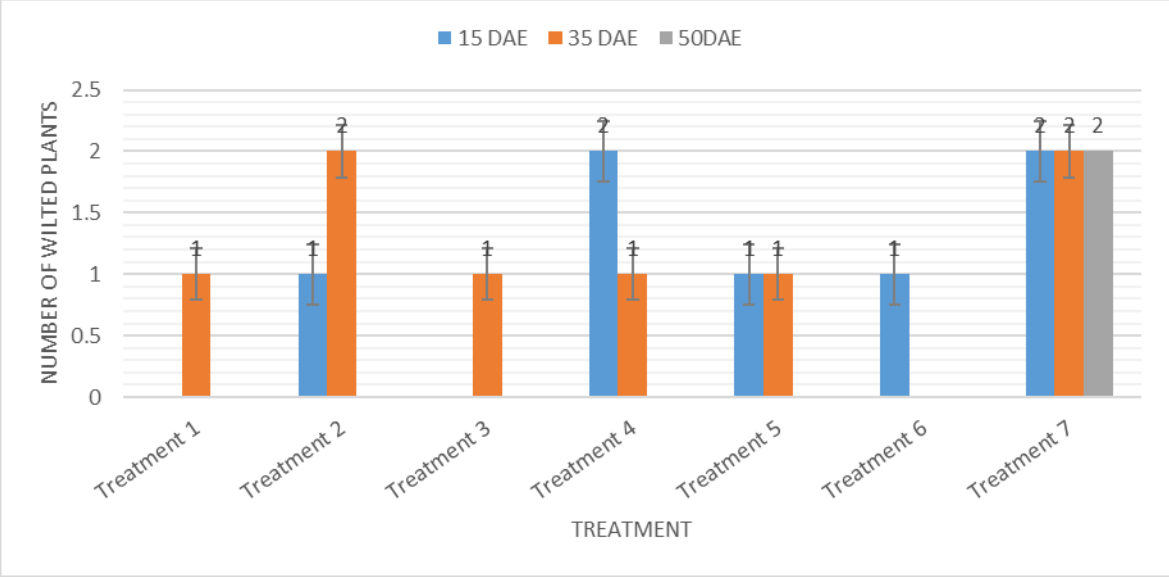

Figure 2. Number of cut plants at different management practices

Infestation of leaves by aphids at 15 days after emergence of seedling

Top leaves

In case of top leaves of potato at 15 days after emergence of seedling, it was observed that the highest number of infested leaves were recorded from T_7 (4.33) treatment which has significant difference with other treatment, while the lowest number of infested leaves were observed from T_1 (1.00) treatment which was statistically similar with T_6 (1.33) treatment (Table 1).

Middle leaves

In case of middle leaves of potato at 15 days after emergence of seedling, it was seen that the highest number of infested was counted from T_7 (7.33) treatment which has significant difference with other treatment, while the lowest number of infested leaves were observed from T_1 (1.33) treatment followed by T_6 (1.67) treatment (Table 1).

Bottom leaves

In case of bottom leaves of potato at 15 days after emergence of seedling, it was noticed that the highest number of infested leaves were recorded from T_7 (10.33) treatment which has significant difference with other treatment, while the lowest number of infested leaves were counted from T_1 (1.67) treatment followed by T_6 (2.00) treatment (Table 1).

Table 1. Number of infested potato leaves of at 15 days after emergence of seedling

Treatment	Infested number of top leaves	Infested number of middle leaves	Infested number of bottom leaves
T_1	1.00 a	1.33 a	1.67 a
T_2	2.33 c	2.67 c	3.33 cd
T_3	1.67 b	2.00 b	2.33 b
T_4	2.00 bc	2.67 c	3.00 c
T_5	1.67 b	2.00 b	3.67 d
T_6	1.33 a	1.67 ab	2.00 ab
T_7	4.33 d	7.33 d	10.33 e
LSD (0.05)	0.642	0.592	0.488
CV (%)	24.4	16.69	10.72

Means followed by same letters are not significantly different at 5% level of significance

Infestation of leaves by aphids at 40 days after emergence of seedling

Top leaves

In case of top leaves of potato at 40 days after emergence of seedling, it was recorded that the highest number of infested leaves were counted from T_7 (6.33) treatment which has significant difference with other treatment, while the lowest number of infested leaves were observed from T_1 (1.33) treatment which was statistically similar with T_6 (1.67) treatment (Table 2).

Middle leaves

In case of middle leaves of potato at 40 days after emergence of seedling, it was watched that the highest number of infested leaves were recorded from T_7(11.00) treatment which has significant difference with other treatment, while the lowest number of infested leaves were counted from T_1 (1.67) treatment which was statistically similar with T_6 (2.00) treatment (Table 2).

Bottom leaves

In case of bottom leaves of potato at 40 days after emergence of seedling, it was observed that the highest number of infested leaves were recorded from T_7 (15.67) treatment which has significant difference with other treatment, while the lowest number of infested leaves were counted from T_1 (2.00) treatment which was statistically similar with T_6 (2.33) treatment (Table 2).

Table 2. Number of infested potato leaves at 40 days after emergence of seedling

Treatment	Infested number of top leaves	Infested number of middle leaves	Infested number of bottom leaves
T_1	1.33 a	1.67 a	2.00 a
T_2	4.33 d	7.00 e	7.33 d
T_3	3.00 bc	5.33 c	6.00 c
T_4	3.67 c	6.67 d	7.00 d
T_5	2.67 b	3.00 b	3.33 b
T_6	1.67 a	2.00 a	2.33 a
T_7	6.33 e	11.00 f	15.67 e
LSD $_{(0.05)}$	0.69	0.501	0.434

CV (%)	16.67	7.6	4.33

Means followed by same letters are not significantly different at 5% level of significance

Infestation of leaves by aphids at 60 days after emergence of seedling

Top leaves

In case of top leaves of potato at 60 days after emergence of seedling, it was seen that the highest number of infested leaves were recorded from T_7 (10.33) treatment which has significant difference with other treatment, while the lowest number of infested leaves were counted from T_1 (1.67) treatment which was statistically similar with T_6 (3.00) treatment (Table 3).

Middle leaves

In case of middle leaves of potato at 60 days after emergence of seedling, it was noticed that the highest number of infested leaves were counted from T_7 (15.00) treatment which has significant difference with other treatment, while the lowest number of infested leaves were observed from T_1 (2.00) treatment followed by T_6 (3.67) treatment (Table 3).

Bottom leaves

In case of bottom leaves of potato at 60 days after emergence of seedling, it was watched that the highest number of infested leaves were recorded from T_7 (20.67) treatment which has significant difference with other treatment, while the lowest number of infested leaves were counted from T_1 (2.33) treatment followed by T_6 (4.33) treatment (Table 3).

Table 3. Number of infested potato leaves at 60 days after emergence of seedling

Treatment	Infested number of top leaves	Infested number of middle leaves	Infested number of bottom leaves
T_1	1.67 a	2.00 a	2.33 a
T_2	7.33 e	8.00 f	8.67 f
T_3	5.00 c	5.67 d	6.33 d
T_4	6.33 d	7.00 e	7.67 e
T_5	4.00 c	4.33 c	5.33 c
T_6	3.00 b	3.67 b	4.33 b
T_7	10.33 f	15.00 g	20.67 g

LSD (0.05)	0.5934	0.418	0.70
CV (%)	8.54	5.1	7.04

Means followed by same letters are not significantly different at 5% level of significance

From the above table 1, 2 and 3 it observed that the infestation by aphid were increased with increase of days after emergence of potato seedling in each treatment and the highest infestation was recorded in 60 days after emergence of seedling. It also observed that infestation was higher in lower portion of plant than upper portion of respective treatment.

Average infestation percentage of leaves

In case of average infestation percentage of leaves, it was observed that the highest infestation observed in 60 DAE and lowest infestation observed in 15 DAE of the respected treatment (Fig 3).

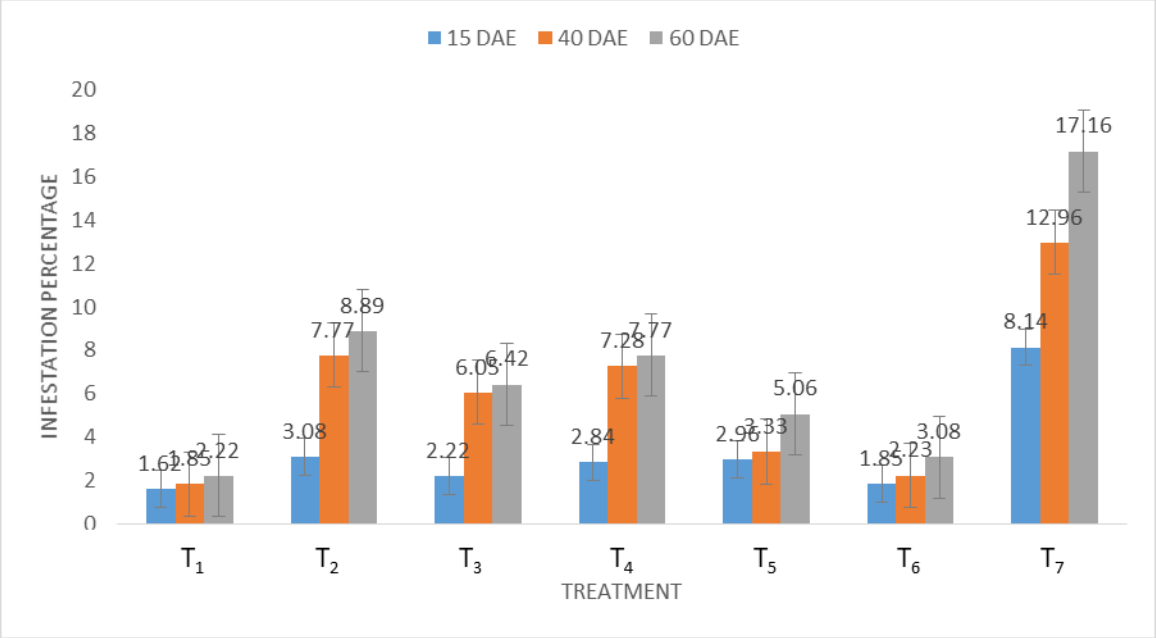

Figure 3. Infestation of leaves at different days after emergence of seedling

Incidence of virus infection on plants showing leaf roll and mosaic symptoms plant transmitted by aphids at several days after emergence of seedling

At 15 DAE

In case of potato plants at 15 days after emergence of seedling, it was noticed that the highest number of infected plants were recorded from T_7 (7.67) treatment which has significant difference with other treatment, while the lowest number of infected plants were counted from T_1 (1.33) treatment followed by T_6(1.67) treatment (Table 4).

At 40 DAE

In case of potato plants at 40 days after emergence of seedling, it was recorded that the highest number of infected plants were recorded from T_7 (12.00) treatment which has significant difference with other treatment, while the lowest number of infected plants were counted from T_1 (1.67) treatment followed by T_6(2.00) treatment (Table 4).

At 60 DAE

In case of potato plants at 60 days after emergence of seedling, it was seen that the highest number of infected plants were counted from T_7 (20.67) treatment which has significant difference with other treatment, while the lowest number of infected plants were observed from T_1 (2.33) treatment followed by T_6(4.33) treatment (Table 4).

Table 4. Incidence of virus infection on plants showing leaf roll and mosaic symptoms plant transmitted by aphids at several days after emergence of seedling

Treatment	15 DAE	40 DAE	60 DAE
T_1	1.33 a	1.67 a	2.33 a
T_2	2.67 c	7.00 e	8.67 f
T_3	2.00 b	5.67 c	6.33 d
T_4	2.33 bc	6.33 d	7.67 e
T_5	2.67 c	3.00 b	5.33 c
T_6	1.67 a	2.00 a	4.33 b
T_7	7.67 d	12.00 f	20.67 g
LSD $_{(0.05)}$	0.42	0.537	0.70
CV (%)	11.39	7.94	7.04

Means followed by same letters are not significantly different at 5% level of significance

Effect of insect pests in tuber observed after harvest

Total yield

In case of harvested tuber of potato, it was recorded that the highest total yield of tuber was recorded from T_1(12.20 kg/plot) treatment which has significant difference with other treatment, while the lowest total yield of tuber was observed from T_7 (6.5 kg/plot) treatment which has statistically significant difference with other treatment. In case of yield increased over control, the highest yield value was 5.70 kg/plot recorded from T_1 treatment.

Marketable yield

In case of harvested tuber of potato, it was noticed that the highest marketable yield tuber was recorded from T_1(11.0 kg/plot) treatment which has significant difference with other treatment, while the lowest marketable yield of tuber was observed from T_7 (3.5 kg/plot) treatment which has statistically significant difference with other treatment. In case of yield increased over control highest yield value was 7.50 kg/plot recorded from T_1 treatment.

Table 5. Total and marketable yield of tuber at different management practices

Treatment	Total yield (kg/plot)	Total yield (ton/ha)	Yield increased over control (kg/plot)	Marketable yield (kg/plot)	Marketable yield (ton/ha)	Marketable yield increased over control (kg/plot)
T_1	12.20 a	20.33 a	5.70	11.0 a	18.33 a	7.50
T_2	9.45 d	15.75 d	2.95	7.55 cd	12.58 cd	4.05
T_3	10.45 c	17.42 c	6.95	8.85 b	14.75 b	5.35
T_4	9.70 cd	16.17 cd	2.20	7.9 bc	13.17 bc	4.40
T_5	10.30 c	17.17 c	3.80	8.6 bc	14.33 bc	5.10
T_6	11.40 b	19.00 b	4.90	10.0 a	16.67 a	6.50
T_7	6.5 e	10.83 e	_	3.50	5.83 e	_
LSD $_{(0.05)}$	0.642	1.287		1.08	1.79	

CV (%)	5.10	4.50		10.5	9.45	

Means followed by same letters are not significantly different at 5% level of significance

Determination tuber infestation as weight basis

The healthy and damaged tubers was weighing and the percent infestation was calculated using the following formula:

$$\%\ \text{tuber infestation} = \frac{\text{weight of infested storage tubers}}{\textit{Total weight of tubers}} \times 100$$

Percent infestation of infested tuber was worked out at final Harvesting. In case of marketable yield percentage, highest value was recorded in T_1(90.16%) treatment, while lowest value was recorded in T_7 (53.85%). In case of infestation percentage, highest value was recorded in T_7(46.15%) treatment, while lowest value was recorded in T_1 (9.84%) treatment.

Determination tuber infestation as number basis

All the harvested tubers were counted from 10 randomly selected tuber from each plot and examined. The healthy and damaged storage tubers were counted and the percent storage root infestation was calculated using the following formula:

$$\%\ \text{tuber infestation} = \frac{\text{Number of infested storage tubers}}{\textit{Total number of tubers examined}} \times 100$$

Percent infestation of infested tuber was worked out at final Harvesting.

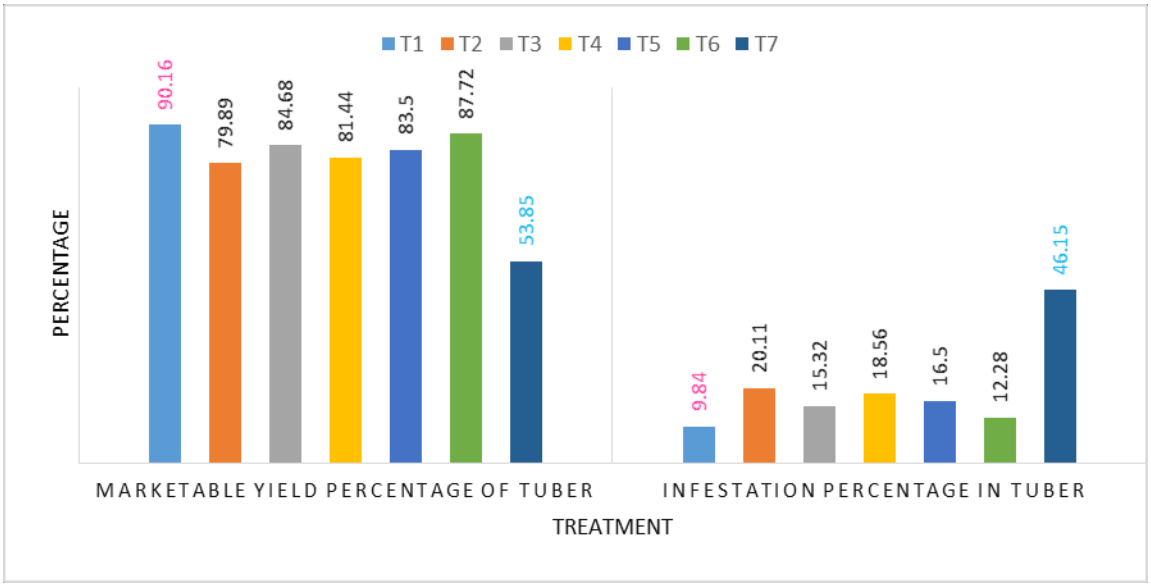

Figure 4. The marketable yield percentage and infestation percentage of tuber at different management practice

Infestation as weight basis

In case of harvested tuber of potato as weight basis, it was watched that the highest infested value of tuber was recorded from T_7 (3.00 kg/plot) treatment which has significant difference with other treatment, while the lowest weight of total tuber was observed from T_1 (1.2 kg/plot) treatment which has statistically significant difference with other treatment. The highest value of infestation reduction over control was 1.80 kg/plot recorded from T_1 treatment.

Infestation as number basis

In case of harvested tuber of potato as number basis, it was observed that the highest infested value of tuber was recorded from T_7(3.67) treatment which has significant difference with other treatment, while the lowest weight of total tuber was observed from T_1 (1.67) treatment which has statistically significant difference with other treatment. The highest value of infestation reduction over control was 2.67 recorded from T_1 treatment.

Table 7 . Incidence of infestation in tuber of potato after harvesting as number and weight basis

Treatment	Infested no. Number basis	Infestation reduction over control	Infested no. Weight basis (kg/plot)	Infested no. Weight basis (ton/ha)	Infestation reduction over control (kg/plot)
T_1	1.33 a	2.67	1.2 a	2.00 a	1.80
T_2	2.67 c	1.33	1.9 c	3.17 c	1.10
T_3	2.00 b	2.00	1.6 b	2.67 b	1.60
T_4	2.33 bc	1.67	1.8 c	3.00 c	1.20
T_5	2.00 b	2.00	1.7 bc	2.83 bc	1.30
T_6	1.67 ab	2.33	1.4 ab	2.33 ab	1.60
T_7	4.00 d	_	3.0 d	5.00 d	_
$LSD_{(0.05)}$	0.56		0.228	0.297	
CV(%)	18.8		10.0	8.90	

Means followed by same letters are not significantly different at 5% level of significance

Marketable yield increased over control

In case of marketable yield increased over control in percent, the highest value was recorded from T_1(68.18%) treatment

Infestation reduction over control

In case of infestation reduction over control in percent, the highest value was seen from T_1(60.00%) treatment.

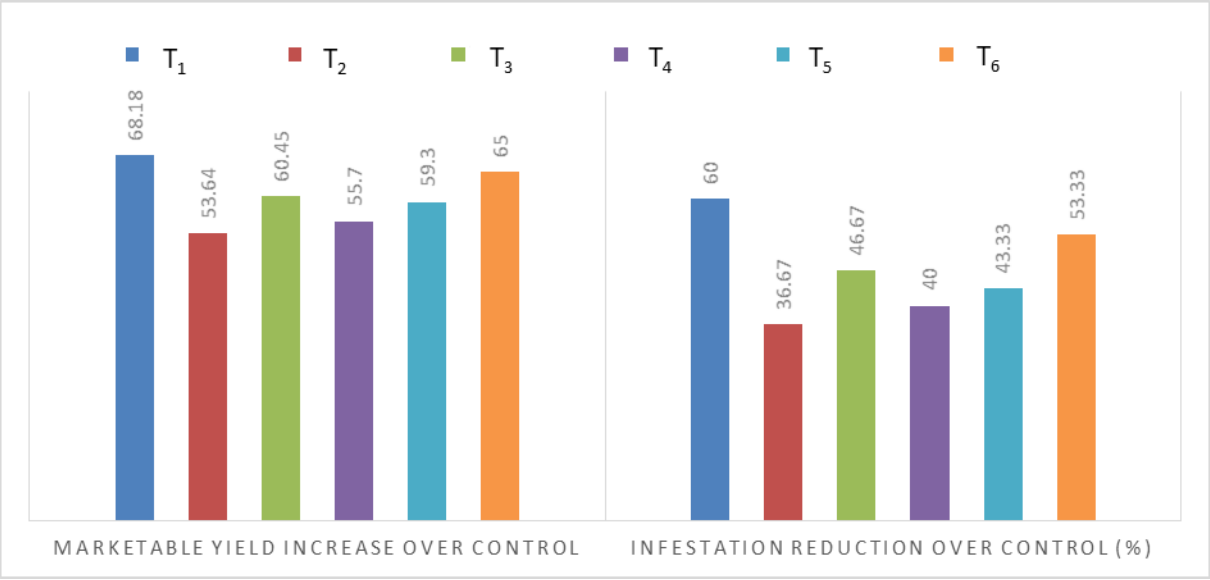

Figure 5. Increase marketable yield percentage and infestation reduction percentage over control

CHAPTER V

SUMMARY

A field experiment on effectiveness of some insecticides for management of potato insect pests was conducted at the Sher-e-Bangla Agricultural University in Dhaka city during Rabi season from October 2017 to March 2018.

Seven treatments i.e.,T_1 (Pheromone Trap +Neem seed kernel extract), T_2 (Diazinon), T_3 (Carbofuran), T_4 (Fipronil), T_5(Pymetrozine + Nyten pyram), T_6(Cartap + Acetamiprid) and a check T_7 were evaluated.

The highest percent of wilted plants for the whole season was observed T_7 (5.71%) as compared to other insecticidal treatment. Number of wilted plants were redued due to insecticides application. Number of wilted plants was lowest in T_1 followed by T_3 and T_6 treatments and highest in T_7 (6) treatment. At 15 DAE of seedling, the lowest number of infested top leaves was observed from T_1 (1.00) treatment which was statistically similar with T_6 (1.33) while the highest number of infested top leaves was recorded from T_7 (4.33) treatment. The lowest number of infested middle leaves was counted from T_1 (1.33) treatment followed by T_6 (1.67) while the highest number of infested middle leaves was recorded from T_7 (7.33) treatment. The lowest number of infested bottom leaves was observed from T_1 (1.67) treatment followed by T_6 (2.00) while the highest number of infested bottom was recorded from T_7 (10.33). At 40 DAE of seedling, the lowest number of infested top leaves was observed from T_1 (1.33) treatment which was statistically similar with T_6 (1.67), the highest number of infested top leaves was recorded from T_7 (6.33) treatment. The lowest number of infested middle leaves was recorded from T_1 (1.67) treatment which was statistically similar with T_6 (2.00) while the highest number of infested moddle leaves was counted from T_7 (11.00) treatment. The lowest number of infested bottom leaves was seen from T_1 (2.00) treatment which was statistically similar with T_6 (2.33) while the highest number of infested bottom leaves was counted from T_7 (15.67) treatment. At 60 DAE of seedling, the lowest number of infested top leaves was noticed from T_1 (1.67) treatment which was statistically similar with T_6 (3.00) while the highest number of infested top leaves was recorded from T_7 (10.33) treatment. The lowest number of infested middle leaves was seen from T_1 (2.00) treatment followed by T_6 (3.67) while the highest number of infested middle leaves was counted from T_7 (15.00) treatment. The lowest number of infested bottom leaves

was observed from T_1 (2.33) treatment followed by T_6(4.33) while the highest number of infested bottom leaves was recorded from T_7 (20.67) treatment. The lowest percent of infested leaves was observed from top leaves of T_1 (1.11%) treatment, while the highest percent of infested leaves was recorded from bottom leaves of T_7 (22.97%) treatment. At 15 DAE of seedling, the lowest number of infected plants was counted from T_1 (1.33) treatment followed by T_6(1.67) while the highest number of infected plants was recorded from T_7(7.67) treatment. At 40 DAE of seedling, the lowest number of infested leaves was seen from T_1 (1.67) treatment followed by T_6(2.00) while the highest number of infected plants was counted from T_7(12.00) treatment while. At 60 DAE of seedling, the lowest number of infected plants was observed from T_1 (2.33) treatment followed by T_6(4.33) while the highest number of infected plants was recorded from T_7 (20.67) treatment which has significant difference with other treatment. The highest total yield of tuber was recorded from T_1 (12.2 kg/plot) treatment, while the lowest total yield of tuber was observed from T_7 (6.5kg/plot) treatment. In case of yield increased over control the highest yield value was 7.50 kg/plot recorded from T_1 treatment**.** The highest marketable yield of tuber was recorded from T_1 (11.0 kg/plot) treatment while the lowest marketable yield of tuber was observed from T_7 (3.5kg/plot) treatment. In case of yield increased over control the highest yield value was 5.70 kg/plot recorded from T_1 treatment. The highest marketable yield was recorded in T_1 (90.16%) treatment, while lowest value was recorded in T_7 (53.85%). The highest infestation percent was recorded in T_7 (46.15%) treatment, while the lowest value was recorded in T_1 (9.84%) treatment. The lowest weight of infested tuber was observed from T_1 (1.2kg/plot) treatment while the highest infested value of tuber was recorded from T_7 (3.00kg/plot) treatment. The highest value of infestation reduction over control was 1.80 kg/plot recorded from T_1 treatment. In case of marketable yield increased over control in percent, the highest value was seen from T_1(68.18%) treatment. In case of infestation reduction over control in percent, the highest value was recorded from T_1(60.00%) treatment.

CONCLUSION

In this experiment neem seed kernel extract with pheromone trap showed the best result. Neem seed kernel extract was found to be most potent insect repellent, antifeedant and an insect growth regulator and it affects more than 600 species of insects. The insecticide Asiprid (Cartap + Acetamiprid) also shows better result to control insect pests of potato It can be concluded that Neem seed kernel extract and Asiprid (Cartap + Acetamiprid) may be used for the management of potato insect pests.

RECOMMENDATIONS

It is suggested that the timing of the application of the insecticides is important and the most appropriate time for the cut worm is immediately after the first evidence of the cut worm damage and for aphid peek infestation occurred in seventh and eighth weeks in the potato field. So, insecticides should be applied fourth/fifth week after seedling emergence. However, further study of this experiment is also needed in different agro-ecological zones of Bangladesh for accuracy of the results obtained from the present experiment.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from October, 2017 to January 2018

Month	Air temperature		Relative humidity	Rainfall (mm)
	Maximum	Minimum		
October, 2018	26.7	16.7	80	10
November, 2018	25.8	16.0	78	00
December, 2019	22.4	13.5	74	00
January, 2019	24.5	12.4	68	00

Appendix II. Analysis of variance on number of insect pests on leaves of potato at 15 days after emergence of seedling

Source of Variance	Degree of Freedom	Mean square		
		Top leaves	Middle leaves	Bottom leaves
Treatment	6	3.6037**	12.65**	27.27**
Replication	2	0.0514	6.335**	11.762**
Error	12	0.2689	0.2217	0.15075

**: Significant at 0.01 level of significance *: Significant at 0.05 level of significance

Appendix III. Analysis of variance on number of insect pests on leaves of potato at 40 days after emergence of seedling

Source of variance	Degree of Freedom	Mean square		
		Top leaves	Middle leaves	Bottom leaves
Treatment	6	8.72**	33.30**	66.19**
Replication	2	9.14**	8.05**	11.62**
Error	12	0.3095	0.1586	0.11916

**: Significant at 0.01 level of significance *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance on number of insect pests on leaves of potato at 60 days after emergence of seedling

Source of Variance	Degree of Freedom	Mean square		
		Top leaves	Middle leaves	Bottom leaves
Treatment	6	26.31**	54.2**	108.19**
Replication	2	10.335**	10.34**	18.47**
Error	12	0.2225	0.1108	0.31

**: Significant at 0.01 level of significance *: Significant at 0.05 level of significance

Appendix V. Analysis of variance on incidence of virus infection on plants showing leaf roll and mosaic symptoms plant transmitted by aphids at several days after emergence of seedling

Source of variance	Degree of Freedom	Mean square		
		15 DAE	40 DAE	60 DAE
Treatment	6	25.08**	63.09**	108.19**
Replication	2	0.57*	5.34**	18.47**
Error	12	0.127	0.1666	0.31

**: Significant at 0.01 level of significance *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance on incidence of insect pests in tuber of potato after harvesting as number and weight basis

Source of	Degree	Mean square

Variance	of Freedom	Total weight	Marketable weight	Infested number Basis	Infested weight Basis
Treatment	6	9.87**	102.79**	2.27**	1.01**
Replication	2	0.14	1.68	0.143	0.02
Error	12	0.2603	0.739	0.1984	0.0328

**: Significant at 0.01 level of significance *: Significant at 0.05 level of significance

Appendix VII. Infestation of leaves increased over time

Treatment	15 DAE	40 DAE	60 DAE
T_1	1.62	1.85	2.22
T_2	3.08	7.77	8.89
T_3	2.22	6.05	6.42
T_4	2.84	7.28	7.77
T_5	2.96	3.33	5.06
T_6	1.85	2.23	3.08
T_7	8.14	12.96	17.16

Appendix VIII. Marketable yield and infestation percentage of tuber at different management practice

Treatment	Marketable yield percentage of tuber	Infestation percentage in tuber
T_1	90.16	9.84
T_2	79.89	20.11
T_3	84.68	15.32
T_4	81.44	18.56
T_5	83.50	16.50
T_6	87.72	12.28
T_7	53.85	46.15

Appendix IX. Increased marketable yield over control and infestation reduction percentage over control

Treatment	Marketable yield increased over control (%)	Infestation reduction over control (%)
T_1	68.18	60.00
T_2	53.64	36.67
T_3	60.45	46.67
T_4	55.70	40.00
T_5	59.30	43.33
T_6	65.00	53.33