EFFECTIVENESS OF SOME CONTROL OPTIONS AGAINST THE INSECT PESTS OF WHEAT AND THEIR NATURAL ENEMIES

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CERTIFICATE

This is to certify that thesis entitled, **'Effectiveness of Some Control Options Against the Insect Pests of Wheat and their Natural Enemies'** 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 bonafide research work carried out by **Md. Shahanur Parvez**, bearing the Registration No. **12-05251** 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.

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TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted to evaluate the effectiveness of some control options against the insect pests of wheat and their natural enemies during the period from November, 2012 to March, 2013 at the central farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment consists of six management practices such as; T_1: Cultural control (weeding) at 10 days interval; T_2: Mechanical control (handpicking of infested tiller) at 7 days interval; T_3: Cultural control + Mechanical control at 7 days interval; T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control; T_5: Spraying of Marshal @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval; T_6:Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval and T_7: Untreated control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Incidence of major insect pest of wheat was recorded as aphid, wireworm, stem fly and army worm. Incidence of natural enemies were also recorded as lady bird beetle, parasitic wasps (parasitoid), syrphid fly and spider. At tillering stage, the lowest infested plants were observed from T_5 (1.37%) treatment, on the other hand, the highest infested plant was recorded in T_7 (13.23%) untreated control treatment. At panicle initiation stage, the lowest infested plants were observed from T_5 (1.75%) treatment, but the highest infested plants were recorded in T_7 (15.60%) untreated control treatment. Finally, during grain filling stage, the lowest infested plants were observed from T_5 (2.49%) treatment, whereas the highest infested plants were recorded in T_7 (18.77%) untreated control treatment. The longest plant was measured from T_5 (92.80 cm) treatment, while the shortest plant was obtained from T_7 (77.56 cm) untreated control treatment. The highest yield was recorded from T_5 (3.43 t/ha) treatment, while the lowest yield was obtained from T_7 (2.14 t/ha) untreated control treatments. Spraying of Marshal @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval showed superior for controlling wheat insect pests.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important protein containing cereal with high amount of carbohydrate and is a staple food for two third of the total world's population (Majumder, 1991). It is cultivated throughout the world and is grown under different environmental conditions ranging from humid to arid, subtropical to temperate zone (Saari, 1998). The largest area of wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh (Dubin and Ginkel, 1991). In Bangladesh, wheat is the second most important cereal crop. It contributes to the national economy by reducing the volume of import of cereals for fulfilling the food requirements of the country (FAO, 2007). Wheat supplies mainly carbohydrate (69.60%) and reasonable amount of protein (12%), fat (1.72%), and also minerals (16.20%) elements (BARI, 1997).

In context of environmental condition of Bangladesh, wheat is a well adapted cereal crop for its vegetative growth and development. Wheat cultivation has been increased manifolds to meet up the food shortage in the country. Presently wheat is grown on 0.40 million hectares that occupies 2.94% of total cropped area (Anon., 2013). Currently, Bangladesh is producing 0.96 million tons of wheat against the national demand of 3.0 million tones FAO, 2009. The consumption rate of wheat is increasing at the rate of 3% per year (Anon., 2013). But, in spite of its importance, the yield of the crop in the context of our country is low (2.2 t ha^{-1}) in comparison to other countries of the world (FAO, 2007). The area, production and yield of wheat have been increasing dramatically based on the demand of over increasing population of Bangladesh during the last two decades. But its present yield is too low in comparison to that of some developed countries like Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 t ha^{-1}, respectively (FAO, 2009).

Yield and quality of seeds of wheat is very low in Bangladesh. The low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing, proper fertilizer management, improper or limited irrigation facilities, the infestation of insect pests and diseases. The major biotic factors influencing wheat loss are insects, moulds, birds and rats (Baloch *et al.*, 1994). Insects can be a major threats to wheat producers by direct feeding or as vectors or carriers of disease. In our country the major wheat insect pests are Aphids, Hessian fly, Cinch Bug, Cutworms, Grasshoppers, Cereal Leaf Beetle, Stink Bug, True Armyworm etc. Beneficial arthropods and some insects are work as natural enemies in wheat field. Some predators such as lady beetles, lacewings, syrphids, dance flies, parasitoids and spiders and are major natural enemies of insect pests of wheat. Parasitoid wasps and spider were more tolerant and active to prey (Anon., 2012).

The most commonly used insecticides against the infestation of wheat are Carbaryl (Sevin), Cobalt, Chlorpyrifos, Endosulfan, Malathion, Santap, Marsal, Gamma-cyhalothrin (Proaxis), Methyl Parathion (Cheminova Methyl 4 EC), Methomyl (Lannate), etc. (Anon., 2004). Pesticides are toxic chemicals designed to be deliberately released into the environment. Although, each pesticide is meant to kill a certain pest, but a very large percentage reach to a destination other than their target and they enter into air, water, sediments and even in our food (Anon., 2010). Non-judicious use of pesticides creates in a series of problems like loss of their effectiveness in the long run and certain externalities such as pollution and health hazards (FAO, 2003). Again, abuse of insecticides application has so many serious drawback, like excessive residue, resistance development, killing of non-target organism, pest resurgence etc. (Debach and Rosen, 1991).

However some insecticides are less toxic, more selective, and less harmful to arthropods biodiversity and the environment as well. Flubendiamide was highly toxic to Lepidopterous insects but was very safe for different natural enemies like lady bird beetles, spiders, parasitic wasps, lace wings, predatory bugs and predatory mites (Tohnishi *et al.*, 2005). Botanicals are in general more compatible with the environmental components than the synthetic pesticides, owing their susceptibility to degradation by light, heat and microorganisms. Plant products were found to be effective against various pests (Rajasekaran and Kumaraswami, 1985). Moreover, there is no investigation reported about pest resurgence due to the use of botanicals. The ecological approaches to pest management suggested that the use of botanicals and chemical pesticides 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. Neem products are less harmful to natural enemies (Schuster and Stansly, 2000). But very few works have been done on this aspect in Bangladesh.

Mechanical and cultural control in combination with insecticide reduced insect pest infestation and increased yield with the highest Benefit Cost Ratio-BCR (Alam *et al.*, 2003, Rahman *et al.*, 2002). Integrated Pest Management with insecticides is insect specific, nontoxic to environment, left no residues on the crops. Moreover, it is least expensive and long lasting which reduces production cost. The above discussions justify the efforts for better alternatives to sole reliance on insecticides for managing insect pest infestation in wheat. Under the above perspective the present study has been undertaken with fulfilling the following objectives-

- To know the infestation status of insect pest on wheat by different treatments
- To evaluate the efficacy of some control options against the insect pests of wheat
- To identify the safer eco-friendly control options for the natural enemies of insects pests of wheat.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Wheat is one of the important cereal crop in Bangladesh and as well as many countries of the world. There are many insect pests that attacks of wheat. 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 Insect pest incidence in wheat

Globally, all crop production practices are being highly challenged by biotic and a-biotic stresses. Biotic stresses especially insect pests and diseases causes devastating damage in terms of yield and quality. On average pests cause 20-37% yield losses worldwide that translates to approximately $70 billion annually (Pimentel *et al.*, 1997). In agro-ecosystems, herbivore insects are abundant and likely to colonies within same population and disperse from one crop field to another depending on the availability of plant tissues and feeding behavior of insects. Quantitative feeding style of the herbivore insect on specific crop resulting significant damage to the crop during the entire life cycle which believed specific insect as pest of that particular crop. Single pest may attack multiple crops within single growing season that make crop rotation and pest management more challenged. Wheat producing areas encounter with either sucking and piercing pests or plant tissue feeding pests. Regional pests also observed in wheat growing areas as major damaging pests worldwide. The breeding strategy against these insects/pests heavily relies on the inheritance of resistance mechanism in the crops under consideration. The insect resistance is mainly governed by three types of mechanisms/genes i.e., Oligogene's; where resistance is conferred by single gene as in case of hessian fly in wheat, polygene's; where several genes having small and additive effect bring about resistance against insects of cereal leaf beetle in wheat and sometime cytoplasmic genes resistance against insects/pests e.g., in maize and lettuce against European corn borer and root aphid, respectively.

Large numbers of chemical formulations have been developed as pesticides to control pest problems in different crops, however, control of stages of insect i.e. egg, larva, pupa and adult is almost impossible. It is therefore, important to understand biology of insect pest simultaneously with the crop biology that what chemical should be used to control specific insect/pest effectively. In addition, integrated pest management practices can also enhance control measures with minimum input and with no or less environmental hazards. Here, outlined major insects of wheat along with their biology and control strategies to minimize grain yield losses.

2.1.1 Wheat aphids

There are six species of aphids that damage cereals. These species include *Rhopalosiphum padi, Schizaphis graminurn, Sitobion avenae, Metopoliphiurn dirhodum, R. Maidis* and *Diuraphis noxia.* Two of those species commonly known as Russian Wheat Aphid (*Diuraphis noxia*) and Bird Cherry-Oat Aphid (*Rhopalosiphum padi*) are considered notorious for their direct and indirect losses.

Russian Wheat Aphid (RWA) is known to be a sporadic insect causing significant yield losses by spreading out from its origin. The centre of origin for RWA is considered to be the central Asian mountains of Caucasus and Tian Shan. The specie could now be found in South Africa, Western United States, Central and Southern Europe and Middle East (Berzonsky *et al.*, 2003). The RWA was first reported in South Africa in 1978 (Walters, 1984), in Mexico during 1980 (Gilchrist *et al.*, 1984), in United States in 1986 and Canadian Prairie Province during 1988 (Morrison *et al.*, 1988). RWA is present in almost all significant wheat producing areas of the world except Australia (Hughes and Maywald

1990). RWA attacks most of the cereals including wheat, barley, triticale, rye and oat. Alternate hosts of RWA are cool season (crested) and wheat grasses (*Agropyron spp.*). The economic impact of RWA include direct and indirect losses that have been estimated to be $893 million in Western United States during 1987 to 1993 (Morrison and Peairs, 1998) whereas 37% yield losses in winter have been reported in Canadian Prairies (Butts *et al*., 1997). Direct losses have also been assessed as an increased input cost due to insecticides and indirect losses include reduced yield due to RWA infestation.

Biology: Climatic conditions and temperature in particular, plays a significant role in population dynamics of the aphids. A warmer temperature can potentially accelerate the aphid's growth both in terms of number and size, yet, the extreme temperatures can possibly reduce the survival and spread. RWA is known to be present in its three different morphological types: immature wingless females, mature wingless females and mature winged females. Winged mature females or adults spread the population and infection to the surrounding host plants whereas the wingless types or apterous cause damage by curling and sucking the young leaves. Heavily infested plants may typically look prostrated and/or stunted with yellow or whitish streaks on leaves. These streaks, basically, are formed due to the saliva injected by the RWA (Kazemi *et al*., 2001). The most obvious symptoms due to heavy infestations can be reduced leaf area, loss in dry weight index, and poor cholorophyll concentration. Plant growth losses could be attributed mainly due to reduced photosynthetic activity to plants RWA infestation (Millar *et al*., 1994; Burd and Elliott, 1996). The photochemical activity of the plants reportedly inhibited by the RWA feeding from leaves and disruption in electron transport chain (Haile *et al*., 1999). Spikes can have bleached appearance with their awns tightly held in curled flag leaf. RWA can feed from main stem, flag leaf sheath and/or even developing kernels at flowering, resulting in shrivelled/empty grain or spike death (Peairs 1998). In the event of sever attack; the wheat tiller can have purplish streaks. Approximately 1% to 0.67% yield losses per percentage of the infested tillers are reported at two tiller stage in Montana and Washington, respectively (Archer *et al.*, 1998). Yield losses can greatly vary due to infestation at different growth stages, duration of infestation and climatic conditions (wind patterns and temperature). A number of biotypes for RWA have been reported to be present throughout the cereal production areas of the world. These biotypes are classified due to significant genetic differences among them (Weng *et al.*, 2007).

Strategies to mitigate of RWA: A number of strategies have been deployed to mitigate RWA. Among these strategies, the host plant resistance has been the most effective and economic method to induce antixenosis, antibiosis and/or tolerance against RWA. Its host plant resistance is well known to be qualitative in nature, and about nine resistance genes have been documented so far. A number of alternate methods to control this pest has been suggested and practiced that include cultural, biological and chemical control methods. Cultural control strategies involved eradication of volunteer and alternate host plants is generally recommended. Another strategy is grazing the volunteer plants which significantly reduce the RWA infestation (Walker and Peairs, 1998). Adjusting planting dates to de-synchronize the insect population dynamics and favourable environmental conditions of any particular area can also help to control RWA (Butts, 1992). The enhanced fertigation of infested field, and biological control of RWA is also possible with 29 different species of insects and 6 fungus species (For further detail the readers are encouraged to read Hopper *et al.* (1998). Of the predator insects, 4 different species of wasps have become adopted to United States. Besides these cultural practices, chemical control method is also widely practiced with equivocal cost efficiency.

2.1.2 Wireworm

Several species of wireworms, to all as quite similar appearance, attack the roots of many crops. When young they are cream colored, about 1/4 inch long, and less than 1/16 inch in diameter. But when mature they are 1/4 to 1/2 inches long and about 1/8 inch in diameter. The pupal stage is free, the entire structure of the adult's body being apparent. The adult is a click beetle. When placed on its back, it flips into the air with an audible snap and lands on its feet. The eggs are tiny, white globules found in the soil (Weng *et al.*, 2007).

Biology: The winter is spent as a larva or beetle in the soil. In the spring the adults become active, feed, and lay their eggs. Adults may live for as long as 12 months. The larva may live for two to six years in the soil, feeding on roots of weeds, grasses, and other crops. The pupal stage is short, perhaps two weeks, and is spent in a cell in the soil. With this long a life cycle, one generation may require six or seven years for completion (Weng *et al.*, 2007).

Strategies to mitigate: Fields with a history of high wireworm densities will tend to maintain those populations over many years. Since grasses are excellent hosts for wireworms, fields recently cleared, previously in sod or pasture, or planted with grass cover crops are more prone to high wireworm densities. Such fields should be avoided for wheat production if there is a low tolerance for wireworm injury. Wireworms are also typically more abundant in low-lying areas and in fields high in organic matter (Vikramsrf, 2012).

2.1.3 Dipteran stem maggot

The wheat stem maggot is found in wheat growing regions from Mexico to Canada. Damage is evident from May through June in the form of conspicuous white heads on stems where the flag leaf is still green. Although this insect is widespread and produces a very distinctive type of damage, it is usually considered to be a minor pest problem (Weng *et al.*, 2007).

Biology: The wheat stem maggot passes the winter in the larval stage, in the lower parts of the stems of wheat and other hosts. They pupate in the spring and the adults emerge in May. Eggs are laid singly on the leaves near the stem. These eggs hatch into green colored maggots which feed inside the stem of the upper most joint of the host plant. The first indication of the larvae is the dying out and whitening of the head and upper stem while the flag leaf is still green. These white heads can easily be pulled from the plant revealing an inch or two of browned and tunneled stem a few inches below where the leaf sheath of the flag leaf would have been attached. The damage is fairly distinctive because of the white heads without kernels on a still green plant. Another generation of flies emerges in midsummer to lay eggs on volunteer and other grasses. The fall generation emerges in late August to early September and lays eggs in the new winter wheat crop. The adults are yellowish-white flies about 1/5 inch long, with three conspicuous black stripes on the thorax and abdomen with bright-green eyes. The larvae are greenish and the maggot about 1/4 inch in length (Vikramsrf, 2012).

Strategies to mitigate: The use of delayed planting, following the dates recommended to escape Hessian fly infestations, is an effective management practice. Destruction of volunteer plants is also recommended. The effectiveness of chemical control is still unknown. Currently, we do not have the knowledge to time such applications properly. Fortunately, damage rarely exceeds 1 to 2 percent of the heads and is usually considered inconsequential.

2.1.4 Army Worm

Army Worm *(Mythimna separat)* mostly found in the warmer climates of central India and to some extent in northern plains.

Biology & Strategies to mitigate of army worm: The larvae are found in the cracks of soil and hide during the day but feed during night or early morning. In wet and humid weather, they may feed during day time also. They survive during summer on the subsequent crops like rice and also continue to exist in rice stubbles before wheat crop comes in the field. Recently, this pest is catching attention in the northern India under Rice-Wheat rotation and where rice stubbles / straw remain in the fields (Vikramsrf, 2012).

2.1.5 Natural enemies

Winter wheat and spring wheat fields in South Dakota are looking good with few insect issues. This could be attributed to low insect pressure in the first place and also to the abundant natural enemies active in wheat fields. Wheat fields are full of beneficial insects like ladybird beetles, lacewings, damsel bugs, and many different parasitoid wasps. The beneficial services provided by predators and parasitoids are not as obvious as the feeding damage caused by pest insects, but clean and healthy fields are of their effectiveness. The three common predatory insects that have been observed to be especially abundant this year are: ladybird beetles, lacewings, and damsel bugs (Vikramsrf, 2012).

2.2 Management of insect pests of wheat

The avail techniques for controlling insect pests are conveniently categorized in order of complexity as cultural, mechanical, physical, biological, chemical, genetic, regulatory and biotechnological methods. Among these, chemical method and botanicals were widely and frequently used. However, very limited research reports on the performance of cultural, mechanical, chemical and botanical as well as their combination on the controlling of major insect pests of wheat have been done in various part of the world. In Bangladesh work so far done is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect reviewed under the following headings:

2.2.1 Cultural Control

Cultural controls include all management activities that can contribute to better pest control. A key cultural control for cereal aphids is to avoid planting at high risk times by sowing later in the autumn (i.e. after May) to avoid aphid flights. This option is becoming less common due to concerns about yield loss with current cultivars. If the decision is made to sow later, monitoring is still essential until the crop is past GS31 as some winters are mild enough for secondary spread of BYDV and selective chemical applications may still be necessary. Soil preparation, good quality seed and weed management are also important cultural control. If the crop can be established quickly and the plants are growing well thus problems with pests will reduced (SFF, 2010).

2.2.2 Mechanical control

Yellow sticky traps can be used to monitor small flying insects such as aphids or brown lacewings. These traps can help to detect sudden increases in a particular type of insect, which can lead to more timely decision making. Pitfall traps (any container dug into the ground flush with the surface and half-filled with diluted antifreeze as a preservative) will collect insects and other invertebrates that are active on the soil surface. They are a good way to see if there are any carabid beetles in the paddock (aphids can also be found on the surface). Following establishment of the crop, direct searching for colonies of aphids or leaf damage is simple and quick. Slug activity can be monitored using anything that provides shelter, such as wooden tiles or sacks (SFF, 2010).

2.2.3 Chemical control

Imidacloprid (Confidor 200 SL) was evaluated by Joshi and Sharma (2009) either alone or with a fungicide (Tilt 0.01%) against wheat aphids. There were seven different treatments, including an untreated control. All the treatments were replicated three times in a similar field environment. Population of wheat aphids was recorded on randomly selected five plants in each plot at different intervals, both before and after spraying. Confidor 200 SL @ 400 ml/ha treatment was found most effective against wheat aphids. However, mixing of Confidor 200 SL @ 100 ml/ha with Tilt @ 0.01 %, was found significantly least effective against wheat aphid.

Carter (1987) reported that the effect on aphid population development of creating natural enemy refuges by spraying only alternate strips of winter wheat with the aphid-specific insecticide pirimicarb at 140 g a.i./ha. The numbers of *Sitobion avenae* (F.), *Metopolophium dirhodum* (Walker) and *Rhopalosiphum padi* (L.) increased rapidly in the unsprayed block and in the unsprayed strips to reach similar peak densities in early August. Instead, aphids re-colonized the sprayed strips more quickly than the sprayed block, and the peak density in the former was similar to those in the unsprayed areas.

El-Wakeil *et al.* (2014) evaluated the efficacy of range of compounds: one botanical insecticide (NeemAzal T/S) and two pyrethroid insecticides, lambda-cyhalothrin (Karate 9.4% S.C) and deltamethrin (Decis 2.8% EC) were evaluated to control *Rhopalosiphum padi* (L.) and *Metopolophium dirhodum* (Wlk.) in the laboratory; as well as to control fruit fly, *Oscinella frit* (L.). The later insect was also controlled companying with three species of entomopathogenic nematodes (EPNs) (*Steinernema carpocapsae*, *S. feltiae* and *Heterorhabditis bacteriophora*). Management of wheat midges with different botanicals was also studied; Karate (pyrethroid), Biscaya (neonicotinoid) and NeemAzal T/S were sprayed on wheat at heading stage (GS 55). While frit fly and wheat midges were managed in winter and spring wheat fields and evaluated at 3, 7 and 15 days after botanicals application. Surveying wheat insects and the associated natural enemies were inspected before and after treating of botanical insecticides. The mortality reached 100% after 24 h in *M. dirhodum* and after 48 h in *R. padi*. Most of the tested compounds caused acceptable levels of cereal aphid's control. All treatments induced reduction in frit fly infestation and increased larval mortality as well. Karate resulted in significantly lower population densities of frit fly. Insecticide applications to fields of midge-infested winter wheat significantly reduced the wheat midge damage. Compatibility between natural insecticides and natural enemies is highly required to keep the environment clean.

El-Wakeil and Volkmar (2013) reported that beneficial arthropods and wheat insects were monitored using sticky traps through large-scale field in Saxony, Germany before and after insecticide applications. The tested compounds (Karate, Biscaya and NeemAzal T/S) were sprayed twice at Elongation stage (GS 32) and at the heading stage (GS 55). The results proved that Karate caused the highest per cent mortality to wheat insect pests. Karate also reduced natural enemy diversities. Biscaya and Neemazal T/S is correlated with an equivalent mortality per cents to wheat insect pests and resulted in a smaller effects on natural enemies compared with Karate.

2.2.4 Control by using botanicals

The effect of six different botanical extracts-Orange peel (*Citrus sinensis*); Bitter gourd (*Momordica dioica*); Garlic (*Allium vineale*); Marigold; Hot pepper (*Capsicum frutescens*) and Tobacco (*Nicotiana tabacum*) extract on wheat aphid was assessed by Iqbal *et al.* (2011) in field of Adaptive Research Farm, Gujranwala. Wheat aphids were deliberately exposed to the above botanical extracts and then the number of live and dead aphids was counted in meter square ring on tagged spikelet's. The botanical extracts showed varying effect on aphid population. Application of Orange Peel extract inflicted consistently the maximum level of aphid mortality (65.69%) followed by Garlic (57.91%) and Tobacco (57.90%).

Field studies were conducted by Korat and Dabhi (2009) during three successive wet seasons in rice fields in Gujarat, India, to determine the efficacy of various concentrations of azadirachtin (Nimbicidine, Neemax, and Neem Gold (all 300 ppm), Econeem (3000 ppm), Neem Azal T/S (10,000 ppm) and Fortune Aza (1500 ppm)) compared to chlorpyrifos for the control of *Cnaphalocrocis medinalis*, *Sogatella furcifera* and *Scirpophaga incertulas*. Results showed that although all neem formulations were effective against pests and resulted in an increased yield none were superior in efficacy to chlorpyrifos.

El-Wakeil *et al.* (2006) reported that there was no serious side effect on parasitism and emergence rates of *T. pretiosum* (Riley) and *T. minutum* (Riley) when treated with neem products. Similarly, neem products achieved a good control of H. armigera in greenhouse. Therefore, neem products are recommended for controlling Helicoverpa and are compatible with mass release of Trichogramma.

Visalakshimi *et al.* (2005) reported that application of neem effectively reduced the oviposition of *H. armigera* through out the crop period. Among various IPM components (neem 0.06%, HaNPV 250 L/ha, bird perches one/plot, endosulfan 0.07%), neem and HaNPV found as effective as endosulfan in the terms of reduction larval population and pod damage, further, endosulfan comparatively found toxic to natural enemies present in chickpea eco-system.

Jeyakumar and Gupta (1999) reported neem seed kernel extract (NSKE) reduced the oviposition of *H. armigera* in a dose dependent manner during the exposure periods of 0-24 h and 24-48 h and showed oviposition detergency effect. Reduction of oviposition was highest (60.9%) with 10% NSKE. The hatchability of the laid eggs was also affected on NSKE treated surface.

Akhauri and Yadav (1999) observed that aqueous extracts of neem seed kernel and green castor leaves each at 5 and 10 per cent concentration, neem and mahua oils and mangraila (*Nigella sativa* L.) seed extract in water each at 2 per cent concentration, were effective in controlling *Melanagromyza obtusa, Apion clavipes Gerist* and *H. armigera.*

Butani and Mittal (1993) studied the efficacy of neem seed kernel suspension and several conventional insecticides against *H. armigera* and reported that all the tested insecticides significantly reduced the pest population and neem seed kernel suspension being equally effective.

Sarode *et al.* (1994) studied the efficacy of different doses of neem seed kernel extract (NSKE) for the management of pod borer. It was found two sprays of NSKE 6% at 7 days interval provided significantly high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%) and suggested that it may be used in managing *H. armigera.*

Oils of plant origin such as neem seed oil, soybean oil, cotton seed oil have been tested against whitefly and the results were encouraging (Butler *et al.*, 1991). In a laboratory study, Butler and Rao (1990) reported that 0.5% sprays of 3 commersial neem oil formulation namely Neemguard, Newark, Neempon to single eggplant leaves against whitefly resulted 97% fewer eggs and 87% fewer immature compared to those on untreated leaves. The crude extracts and active principles isolated from number of other plants have anti feedant, insecticidal, hormonal and repellants properties (Jayaraj, 1988).

Plant products play an important role in evolving an ecologically sound and environmentally acceptable pest management system. Grainage *et al.* (1985) reported that neem is the major source of anti feedant principles and the seed contain a number of toxic terpenoids. The ether extract of *Tribulus terrestris* L. had juvenilising effects on cutworm *(Spodoptera litura)* and pod borer (*Heliothis armigera*), respectively (Gunasekaran and Chelliah, 1985).

2.2.5 Integrated management

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.* (2003) to develop and validate an integrated pest management (IPM) module for mustard under Haryana, India, agro-climatic conditions. The treatments comprised IPM module (T_1); chemical control (T_2); and control (T_3). 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.

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, 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. 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.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study on the effectiveness of some control options against the infestation of insect pests of wheat and their natural enemies during the period from November, 2012 to March, 2013. A brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters under the following headings are presented below:

3.1 Experimental site

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$ N latitude and $90^{0}35^{/}$ E longitude (Anon., 1989).

3.2 Soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soil. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of sandy loam with pH and Cataion Exchange Capacity 5.6 and 2.64 meq 100 g $soil^{-1}$, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I and II (Khatun, 2014).

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, relative humidity and rainfall during experimental period were collected from Weather Yard, Bangladesh Meteorological Department and presented in Appendix III.

3.4 Planting material

Wheat variety 'Shatabdi' was used as a test crop to conduct the study. The seeds were collected from the Department of Agronomy under Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

3.5 Land preparation

The selected land was opened for the experiment in the 1st week of November 2012 with a power tiller. The land was exposed to the sun for a week which was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed to obtain a desirable tilth of soil for sowing of seeds.

3.6 Manures and fertilizers application

The nutrient components N, P, K and S as fertilizers in the form of Urea, TSP, MP and Gypsum, respectively were applied to the field. The entire amount of TSP, MP and Gypsum, 2/3rd of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation. The dose and method of application of fertilizer are presented below-

Table 1. Doses and method of application of fertilizers in wheat field according to the recommendation of WRC, BARI, 2006

Fertilizers	Dose (per ha)	Application (%)	
		Basal	1st installment
Urea	220 kg	66.66	33.33
TSP	180 kg	100	--
MP	50 kg	100	--
Gypsum	120 kg	100	--
Cowdung	10 ton	100	--

3.7 Sowing of seeds in the field

Furrows were made properly for sowing the wheat seeds and seeds were sown at 28 November, 2012. Seeds were sown continuously maintained distance 20 cm line to line and 5 cm plant to plant. After sowing, seeds were covered with soil and slightly pressed by hand.

3.8 Treatments of the experiment

The experiment consists of the following management practices. There were seven treatments which are as follows:

T_1: Cultural control (removal of weeds at 10 days interval).

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval.

T_3: Cultural control + Mechanical control at 7 days interval.

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control.

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval.

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval.

T_7: Untreated control.

3.9 Experimental layout and design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 19.50 m × 13.00 m was divided into three equal blocks. Each block was divided into 7 plots, where 7 treatment combinations were allocated at randomly. There were 21 unit plots altogether in the experiment. The size of the each unit plot was 3.00 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.10 Application of different treatments

The experimental plot was cleaned by removing all stubbles and weeds and sun dried for 10 days as cultural control. Infested tillers were removed by hand picking as mechanical from the field with a keen observation of the experimental plot. Suntap, Marshal and Neem oil were sprayed in assigned plots and dosages by using knapsack sprayer. The spraying was done in the afternoon. The spray materials were applied uniformly to obtain complete coverage of whole plants of the assigned plots at 07 days interval starting from 45 days after seed germination and continued upto grain filling stage. Caution was taken to avoid any drift of the spray mixture to the adjacent plots at the time of the spraying. The spray mixture was freshly prepared at each application of each treatment.

3.11 Intercultural operations

Heavy irrigation was done at tillering, panicle initiation and grain filling stage 30, 45 and 60 days after sowing (DAS), respectively followed by weeding.

3.12 Crop sampling and data collection

Plants for from each treatment were randomly marked inside the four central row of each plot with the help of sample wooden frame. The selected wheat plants of different treatments were closely examined at regular intervals commencing from germination to harvesting. The following parameters were considered during data collection -

- Number of insect pests / plot^{-1}
- Number of natural enemies / two sweeps in each treatment
- Number of healthy tiller plot^{-1}
- Number of infested tiller plot^{-1}
- Plant height after harvest plot^{-1}
- Number of spike hill^{-1}
- Number of filled grains spike^{-1}
- Number of unfilled grains spike^{-1}
- Weight of 1000-grain (g)
- Yield hectare^{-1}

3.13 Apparatus and instruments used

Petridishes, fine camel hair brush, sweep net, aspirator were used in sample collection. Aspirator was used for collecting small insects. Hand magnifying glass, insect collection box and bottles with ethanol were used for identification, collection and preservation of insect pests. Stereoscopic microscope fitted with camera was used for taking exclusive photograph.

Incidence of major insect pests of wheat was recorded for the entire cropping season and as a major pest aphid, wireworm, dipteral stem maggot and army worm were observed. Data were taken from selected plant at tillering, panicle initiation and grain filling stages to identify the intensity of infestation by the major insect pests of wheat.

3.14 Determination of infestation tiller

The data were collected at tillering, panicle initiation and grain filling stage. The healthy and infested tillers were counted and the percent tiller damage was calculated by using the following formula:

$$\text{Infested tiller (\%)} = \frac{\text{Number of infested tiller}}{\text{Total number of observed tiller}} \times 100$$

3.15 Harvest and post harvest operations

The plants of middle four rows, avoiding border rows, of each plot were harvested. The pods were then threshed; cleaned and dried in bright sunshine. The yield obtained from each plot was subjected to converted into yield per hectare.

3.16 Procedure of data collection of yield contributing characters

3.16.1 Plant height at harvest

The heights of 5 randomly selected plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in centimeter (cm). Data were recorded from the inner rows plant of each plot during harvesting period.

3.16.2 Number of spike hill^{-1}

The total number of spike hill^{-1} was estimated by counting the number of spike from 10 hills and then averaged to have number of spike hill^{-1}.

3.16.3 Number of filled grains spike^{-1}

The total number of filled grains was counted as the number of filled grains from 10 randomly selected spikes in each plot and average value was recorded.

3.16.4 Number of unfilled grains spike^{-1}

The total number of unfilled grains spike^{-1} was counted as the number of unfilled grains from 10 randomly selected spikes from each plot and average value was recorded.

3.16.5 Weight of 1000-grain (g)

One thousand grains were counted randomly from the total cleaned harvested grains of each plot of each treatment area and then weighed in grams.

3.16.6 Yield hectare^{-1}

Grains obtained from 1 m^2 from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area used to record grain yield per m^2 and converted this into ton hectare^{-1}.

3.17 Statistical analysis

The data on different parameters were statistically analyzed to find out the significant differences among the effects of different treatments. The mean values of all the characters were calculated and analyses of variance were performed by the 'F' (variance ratio) test. The significance of the differences among the mean values of treatment in respect of different parameters was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to study the effectiveness of some control options against the infestation of insect pests of wheat and their natural enemies. Data were recorded on number of insect pests tiller^{-1}, number of natural enemies, number of healthy & infested tiller and percentage of plant infestation in number, yield contributing characters and yield of wheat. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Insect pest incidence

4.1.1 Tillering stage

Statistically significant variation was found at tillering stage for aphid, wireworm, stem maggot and army worm as major insect pests of wheat (Table 2). In case of aphid, the lowest number of aphid (1.00) was recorded from T_5 (spraying of Marshal @ 3.0 ml/L of water at 7 days interval + cultural control + mechanical control at 7 days interval) which was statistically similar (1.33 and 1.67) with T_6 (spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + cultural control + mechanical control at 7 days interval) and T_4 (spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + mechanical control). Nevertheless, the highest number of aphid (11.67) was found from T_7 (untreated control) treatment. In consideration of wireworm, no wireworm was recorded from T_5 (0.00) and T_6 (0.00) which was statistically identical. Nonetheless, while the highest number of wireworm was found from T_7 (8.33) treatment. For dipteran stem maggot, no dipteran stem maggot was recorded from T_5 (0.00), T_6 (0.00) and T_4 (0.00), while the highest number was found from T_7 (4.67) treatment. In case of army worm, no army worm was recorded from T_5 (0.00), T_6 (0.00) and T_4 (0.00), whereas the highest number of army worm was found from T_7 (4.67) treatment.

Table 2. Effect of different treatments on number of major insect pests of wheat plot^{-1} at tillering stage

Treatments	Aphid plot^{-1}	Wireworm plot^{-1}	Stem fly plot^{-1}	Army worm plot^{-1}
T_1	4.33 b	2.33 b	1.67 b	2.00 b
T_2	4.33 b	2.00 b	1.33 b	1.67 b
T_3	3.67 b	2.00 b	1.00 b	1.33 b
T_4	1.67 c	1.00 c	0.00 c	0.00 c
T_5	1.00 c	0.00 d	0.00 c	0.00 c
T_6	1.33 c	0.00 d	0.00 c	0.00 c
T_7	11.67 a	8.33 a	4.67 a	6.67 a
$LSD_{(0.05)}$	1.064	0.592	0.736	0.952
CV(%)	8.33	6.89	9.11	10.33

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

Data revealed that spraying of Marshal @ 3.0 ml/L of water at 7 days interval + cultural control + mechanical control at 7 days interval was superior for controlling wheat insect pests which was followed by spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + cultural control + mechanical control at 7 days interval and also the spraying of Suntap 50 SP @ 3.0 ml/L of water at 7 days interval + mechanical control. More or less similar results of other researchers have supported the present study. Joshi and Sharma (2009) reported that mixing of Confidor 200 SL @ 100 ml/ha with Tilt @ 0.01 % was found significantly least effective for wheat aphids control. Iqbal *et al.* (2011) reported that botanical extracts showed varying effect on aphid population and also other insect pests.

4.1.2 Panicle initiation stage

Statistically significant variation was recorded at panicle initiation stage for aphid, wireworm, dipteran stem maggot and army worm as major insect pests of wheat (Table 3). For aphid, the lowest number of aphid was recorded from T_5 (1.33) which was statistically similar with T_6 (1.67) and T_4 (2.00), whereas the highest number of aphid was found from T_7 (13.33) treatment. In case of wireworm, no wireworm was recorded from T_5 (0.00) and T_6 (0.00) but the highest number of wireworm was found from T_7 (9.67) treatment. For dipteran stem maggot, no dipteran stem maggot was recorded from T_5 (0.00) and T_6 (0.00) treatment which was statistically similar, while the highest was found from T_7 (6.00) treatment. Data revealed that, no army worm was recorded from T_5 (0.00), whereas the highest number of army worm was observed in T_7 (6.67) treatment.

Table 3. Effect of different treatments on number of major insect pests of wheat plot^{-1} at panicle initiation stage

Treatments	Aphid plot^{-1}	Wireworm plot^{-1}	Stem fly plot^{-1}	Army worm plot^{-1}
T_1	5.33 b	3.67 b	3.33 b	3.67 b
T_2	5.00 b	3.33 bc	2.67 c	3.00 bc
T_3	4.00 c	2.67 c	2.33 c	2.67 c
T_4	2.00 d	1.33 d	1.00 d	1.33 d
T_5	1.33 d	0.00 e	0.00 e	0.00 e
T_6	1.67 d	0.00 e	0.00 e	1.00 d
T_7	13.33 a	9.67 a	6.00 a	6.67 a
$LSD_{(0.05)}$	0.547	0.495	0.807	0.658
CV(%)	6.78	10.22	7.61	5.06

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

4.1.3 Grain filling stage

Data revealed that a statistically significant variation was recorded at grain filling stage of aphid, wireworm, dipteran stem maggot and army worm (Table 4). The lowest number of aphid was recorded from T_5 (1.67) which was statistically similar with T_6 (2.00), whereas the highest number of aphid was found from T_7 (14.67) treatment. In consideration of wireworm, no wireworm was recorded from T_5 (0.00) which was statistically identical with T_6 (1.00) while the highest number of wireworm was found from T_7 (10.33) treatment. For dipteran stem maggot, no dipteran stem maggot was recorded from T_5 (0.00), T_6 (0.00), whereas the highest number was found from T_7 (6.67) treatment. In case of army warm, no army worm was recorded from T_5 (0.00), while the highest number was found from T_7 (7.33) treatment.

Data revealed that for 1st, 2nd and 3rd times of spraying of Marshal @ 3.0 ml/L of water at 7 days interval + cultural control + mechanical control at 7 days interval showed superior for controlling wheat insect pests followed by spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + cultural control + mechanical control at 7 days interval and also the spraying of Suntap 50 SP @ 3.0 ml/L of water at 7 days interval + mechanical control. Joshi and Sharma (2009) reported that mixing of Confidor 200 SL @ 100 ml/ha with Tilt @ 0.01 % was found significantly least effective for wheat aphids control.

Table 4. Effect of different treatments on number of major insect pests of wheat plot^{-1} at grain filling stage

Treatments	Aphid plot^{-1}	Wireworm plot^{-1}	Stem fly plot^{-1}	Army worm plot^{-1}
T_1	6.67 b	4.00 b	4.33 b	4.00 b
T_2	6.33 b	3.67 b	3.67 c	3.67 bc
T_3	5.33 c	3.00 b	2.67 d	3.33 c
T_4	2.67 d	1.67 c	2.33 d	1.67 d
T_5	1.67 e	0.00 d	0.00 e	0.00 f
T_6	2.00 e	1.00 d	0.00 e	1.00 e
T_7	14.67 a	10.33 a	6.67 a	7.33 a
$LSD_{(0.05)}$	0.849	1.023	0.473	0.518
CV(%)	10.01	7.34	5.69	9.38

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

4.2 Natural enemies of wheat pests

Incidence of natural enemies of wheat pests was recorded for the entire cropping season and found that lady bird beetle, parasitic wasps (parasitoid), syrphid fly and spider were abundantly occurred.

4.2.1 Tillering stage

Statistically significant variation was found at tillering stage for lady bird beetle, parasitic wasps (parasitoid), syrphid fly and spider as major natural enemies of wheat insect pests (Table 5). No lady bird beetle was recorded from T_4 and T_5 treatment, whereas the highest number of lady bird beetle (2.33) was found from T_7 treatment. No parasitic wasps (parasitoid) was recorded from T_4 and T_5 treatment, whereas the highest number (3.67) was found from T_7 treatment. Consideration of syrphid fly, no fly was recorded from T_4 and T_5 treatment, whereas the highest number (2.00) was found from T_7 treatment. Data revealed that, no spider was recorded from T_4 and T_5 treatment, whereas the highest number (3.33) was found from T_7 treatment.

Grainge *et al.*, 1985 reported that lady beetles, lacewings, syrphids, dance flies, and spiders and parasitoids (parasitic wasps) are major natural enemies of insect pests of wheat. Pedigo, 2002 reported that insecticides frequently kill natural enemy populations, and cause resurgence of other pest populations, resistance biotypes development which is also support the findings of the present study.

4.2.2 Panicle initiation stage

Statistically significant variation was found at panicle initiation stage for major natural enemies of wheat pests (Table 6). No lady bird beetle was recorded from the T_4 and T_5 treatment, whereas the highest number (3.00) from T_7. For parasitic wasps (parasitoid), no wasps was recorded from T_4 and T_5, whereas the highest number (4.33) from T_7 treatment. Consideration of syrphid fly, no fly was recorded from T_4 and T_5 treatment, whereas the highest number (3.67) from T_7 treatment. For spider, no spider was recorded from T_4 and T_5 treatment, whereas the highest number (4.33) from T_7 treatment.

Table 5. Effect of different treatments on number of natural enemies of wheat pests per two sweeps at tillering stage

Treatments	Number of natural enemies per two sweeps in each treatment			
	Lady bird beetle	Parasitic wasps (Parasitoid)	Syrphid fly	Spider
T_1	1.67 b	2.67 b	1.67 b	2.67 b
T_2	1.33 bc	2.33 c	1.33 c	2.33 c
T_3	1.00 c	2.00 d	1.33 c	1.67 d
T_4	0.00 d	0.00 f	0.00 e	0.00 e
T_5	0.00 d	0.00 f	0.00 e	0.00 e
T_6	1.00 c	1.67 e	1.00 d	1.67 d
T_7	2.33 a	3.67 a	2.00 a	3.33 a
$LSD_{(0.05)}$	0.542	0.285	0.303	0.291
CV(%)	4.55	7.80	9.11	4.67

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

4.2.3 Grain filling stage

Statistically significant variation was found at grain filling stage for different major natural enemies of wheat pests (Table 7). In case of lady bird beetle, no lady bird beetle was recorded from T_4 and T_5 treatment and, whereas the highest number of lady bird beetle (3.33) was found from T_7. For parasitic wasps (parasitoid), no parasitic wasps (parasitoid) was recorded from T_4 and T_5 treatment, whereas the highest number (5.00) from T_7 treatment. Consideration of syrphid fly, no syrphid fly was recorded from T_4 and T_5, whereas the highest number (3.33) from T_7. For spider, no spider was recorded from T_4 and T_5 treatment, whereas the highest number (3.67) from T_7 treatment.

Number of insects and natural enemies in wheat at tillering, panicle initiation stage and grain filling stage were presented in Graph 1 and found that number of insects was found always greater than that of natural enemies.

Table 6. Effect of different treatments on natural enemies of wheat pests per two sweeps at panicle initiation stage

Treatments	Number of natural enemies per two sweeps in each treatment			
	Lady bird beetle	Parasitic wasps (Parasitoid)	Syrphid fly	Spider
T_1	2.33 b	3.00 b	2.67 b	3.67 b
T_2	2.33 b	2.33 c	2.00 c	3.33 c
T_3	1.67 c	2.00 d	1.67 d	2.67 d
T_4	0.00 e	0.00 e	0.00 f	0.00 f
T_5	0.00 e	0.00 e	0.00 f	0.00 f
T_6	1.00 d	2.33 c	1.33 e	2.00 e
T_7	3.00 a	4.33 a	3.67 a	4.33 a
$LSD_{(0.05)}$	0.529	0.481	0.198	0.265
CV(%)	5.65	9.33	7.89	4.81

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

Table 7. Effect of different treatments on natural enemies of wheat pests per two sweeps at grain filling stage

Treatments	Number of natural enemies per two sweeps in each treatment			
	Lady bird beetle	Parasitic wasps (Parasitoid)	Syrphid fly	Spider
T_1	2.67 b	3.67 b	2.33 b	2.67 b
T_2	2.00 c	3.67 b	2.00 c	2.67 b
T_3	2.00 c	3.33 b	1.67 d	2.33 c
T_4	0.00 e	0.00 d	0.00 f	0.00 e
T_5	0.00 e	0.00 d	0.00 f	0.00 e
T_6	1.67 d	2.67 c	1.33 e	2.00 d
T_7	3.33 a	5.00 a	3.33 a	3.67 a
$LSD_{(0.05)}$	0.272	0.517	0.308	0.254
CV(%)	9.08	6.61	8.94	5.66

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

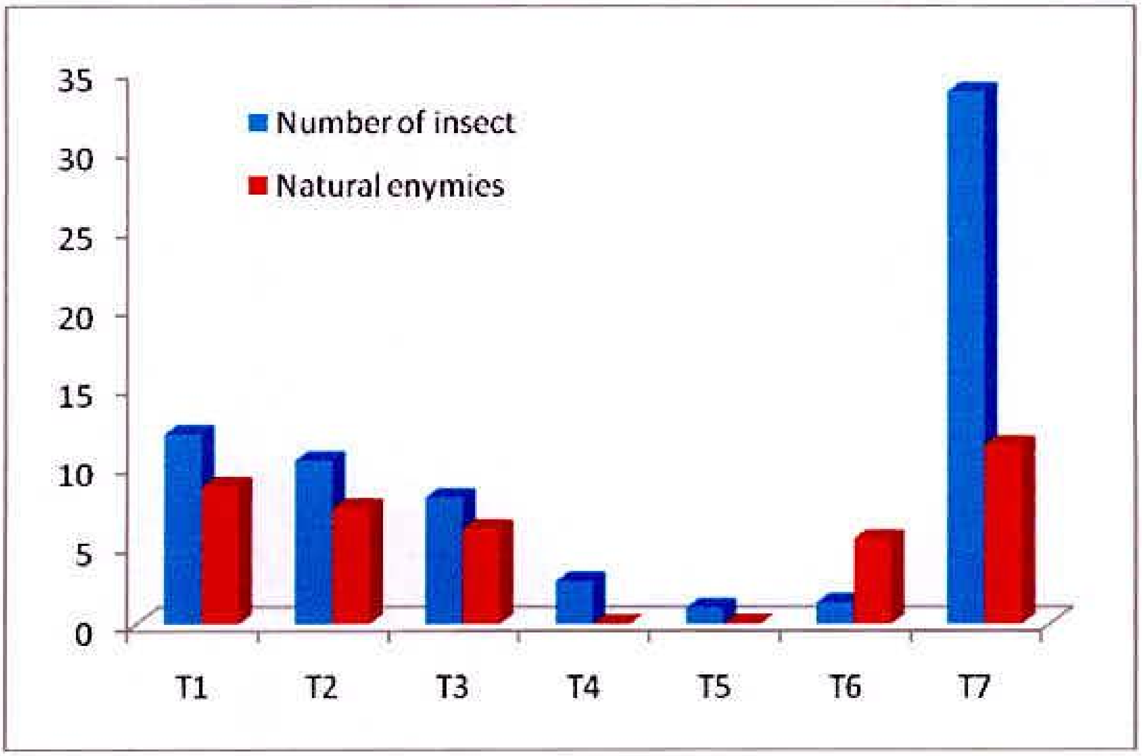
T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control



Treatments

Figure 1. Number of insects and natural enemies in wheat plot^{-1} at tillering stage

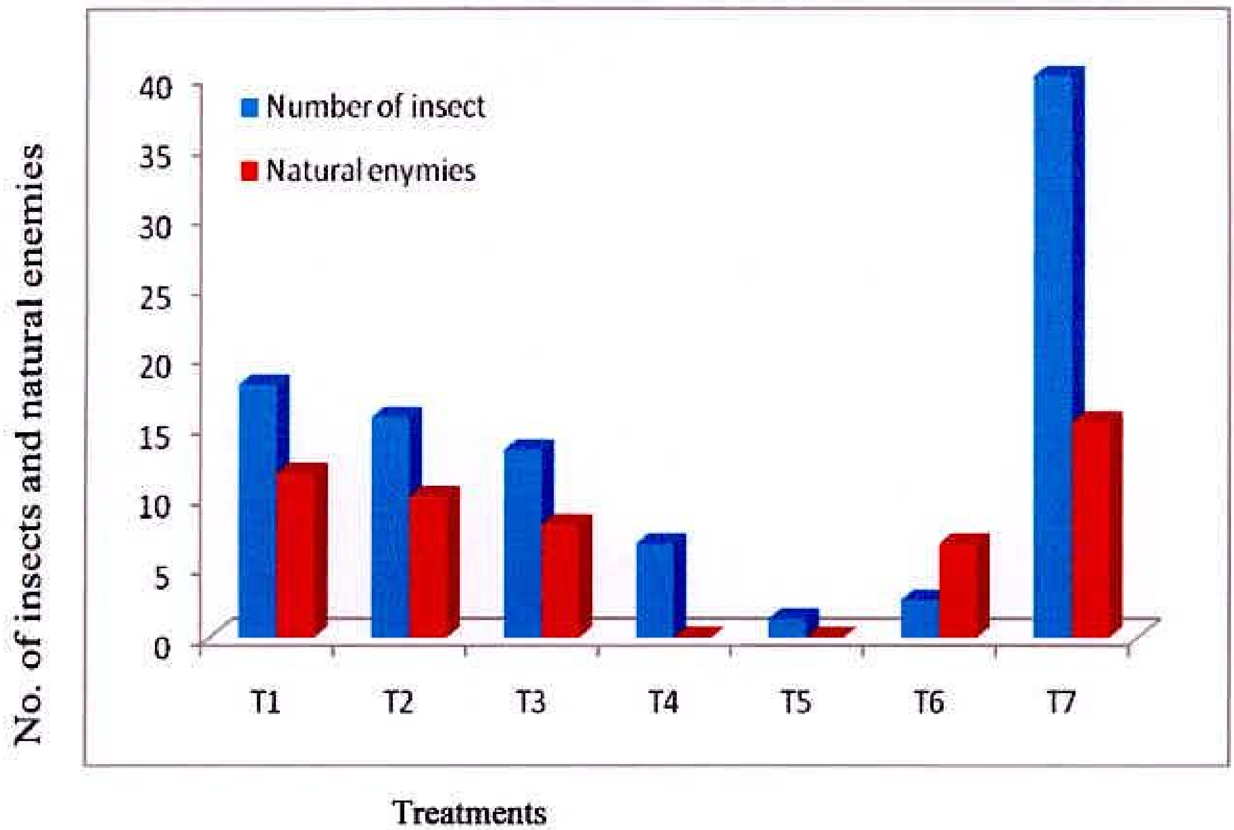
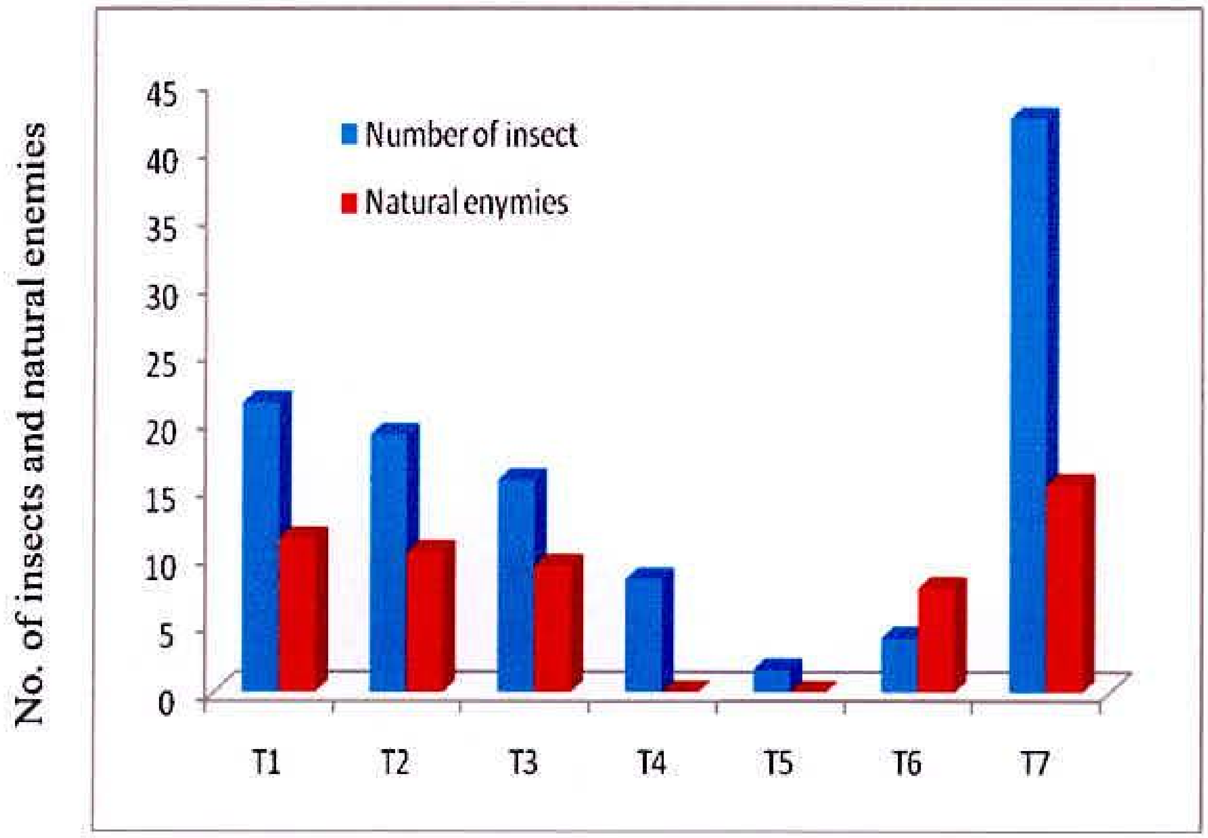


Figure 2. Number of insects and natural enemies in wheat plot^{-1} at panicle initiation stage



Treatments

Figure 3. Number of insects and natural enemies in wheat plot^{-1} at grain filling stage

4.3 Plant infestation by the insect pest

4.3.1 Tillering stage

Significant differences were obtained in number of healthy, infested plant, percent infestation at tillering stage for different treatments (Table 8). The highest number of healthy plants per m^2 was recorded from T_5 (97.33) which was statistically similar with T_6 (96.67), T_4 (96.00), T_3 (94.33) and T_2 (93.00), while the lowest number obtained from T_7 (85.67). The lowest number of infested plant per m^2 was observed from T_5 (1.33). On the other hand, the highest number of infested plant was obtained from T_7 (11.33) treatment. The lowest infested plants per m^2 was observed from T_5 (1.37%) but the highest infested plant was recorded in T_7 (13.23%). Plant infestation reduction over control was estimated and the highest value was found from the treatment T_5 (89.67%) and the lowest was recorded from T_1 (59.05%) treatment. Baloch *et al.*, 1994 earlier reported that the major biotic factors which greatly effect of wheat production are insects.

4.3.2 Panicle initiation stage

Significant differences were obtained in number of healthy, infested plant, percent infestation at panicle initiation stage for different treatments (Table 9). The highest number of healthy plants per m^2 was recorded from T_5 (95.33) which was statistically similar with all treatments, whereas the lowest from T_7 (83.33). The lowest number of infested plant per m^2 was observed from T_5 (1.67), while the highest from T_7 (13.00). In terms of percent plant infestation, the lowest infested plants per m^2 was observed from T_5 (1.75%), while the highest infested plant was recorded in T_7 (15.60%). Plant infestation reduction over control was estimated and the highest value was found from the treatment T_5 (88.77%) and the lowest reduction was found from T_1 (60.35%).

Table 8. Effect of different treatments to combat the infestation of wheat pests plot^{-1} at tillering stage of plant

Treatments	Mean number of plants plot^{-1}			
	Healthy	Infested	Infestation (%)	Reduction over control (%)
T_1	92.33 b	5.00 b	5.42 b	59.05
T_2	93.00 ab	4.33 c	4.66 c	64.80
T_3	94.33 a	3.67 d	3.89 d	70.58
T_4	96.00 a	2.67 e	2.78 e	78.97
T_5	97.33 a	1.33 g	1.37 g	89.67
T_6	96.67 a	2.00 f	2.07 f	84.36
T_7	85.67 c	11.33 a	13.23 a	--
$LSD_{(0.05)}$	1.628	0.485	0.652	--
CV(%)	6.89	10.22	12.68	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

Table 9. Effect of different treatments to combat the infestation of wheat pests plot^{-1} at panicle initiation stage of plant

Treatments	Mean number of plants plot^{-1}			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_1	91.67 a	5.67 b	6.19 b	60.35
T_2	92.33 a	5.33 b	5.77 c	63.00
T_3	93.00 a	4.00 c	4.30 d	72.43
T_4	94.00 a	3.33 c	3.54 e	77.29
T_5	95.33 a	1.67 d	1.75 f	88.77
T_6	94.33 a	3.33 e	3.53 e	77.37
T_7	83.33 b	13.00 a	15.60 a	0.00
$LSD_{(0.05)}$	5.061	0.671	0.689	--
CV(%)	8.55	5.67	10.33	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

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T_7: Untreated control

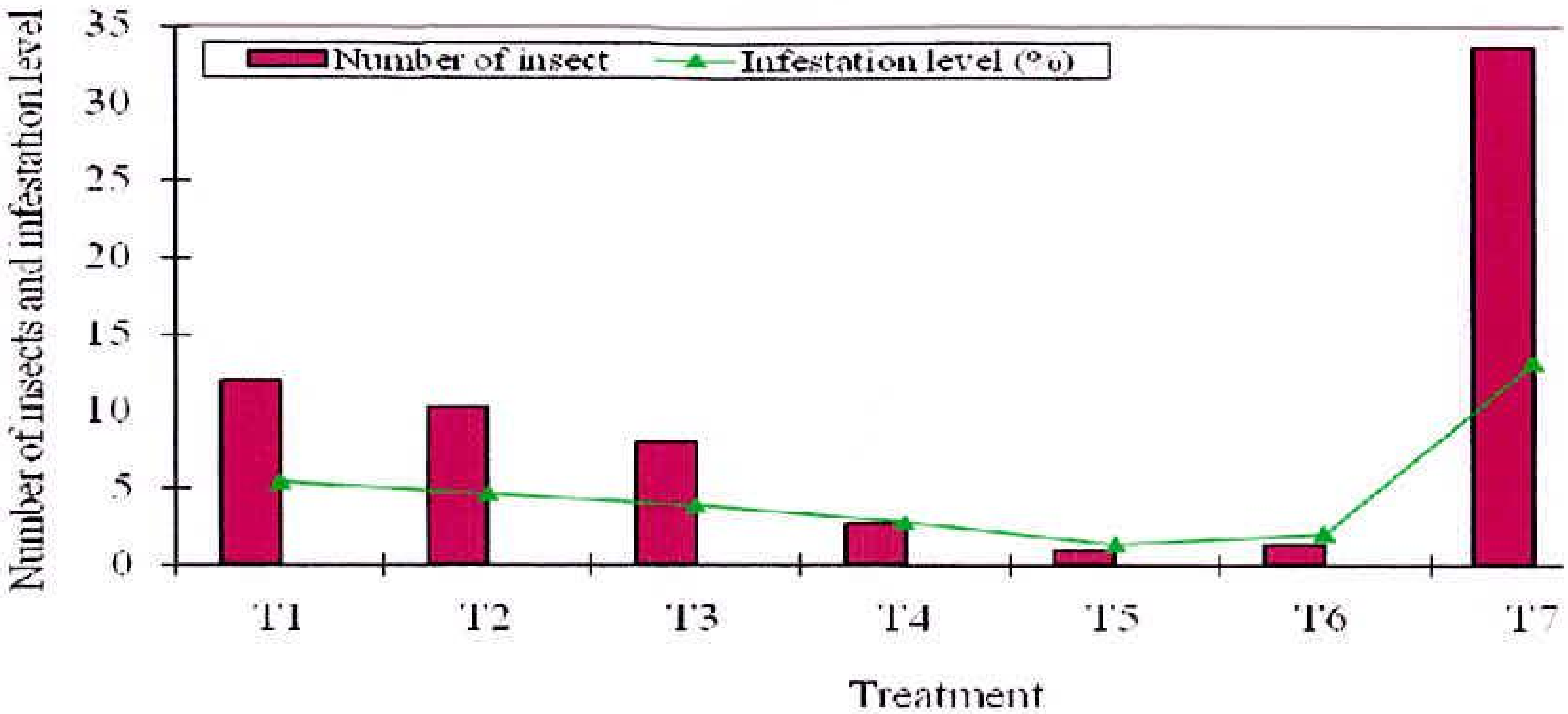

Figure 4. Number of insect pests and infestation level plot^{-1} at tillering stage of wheat

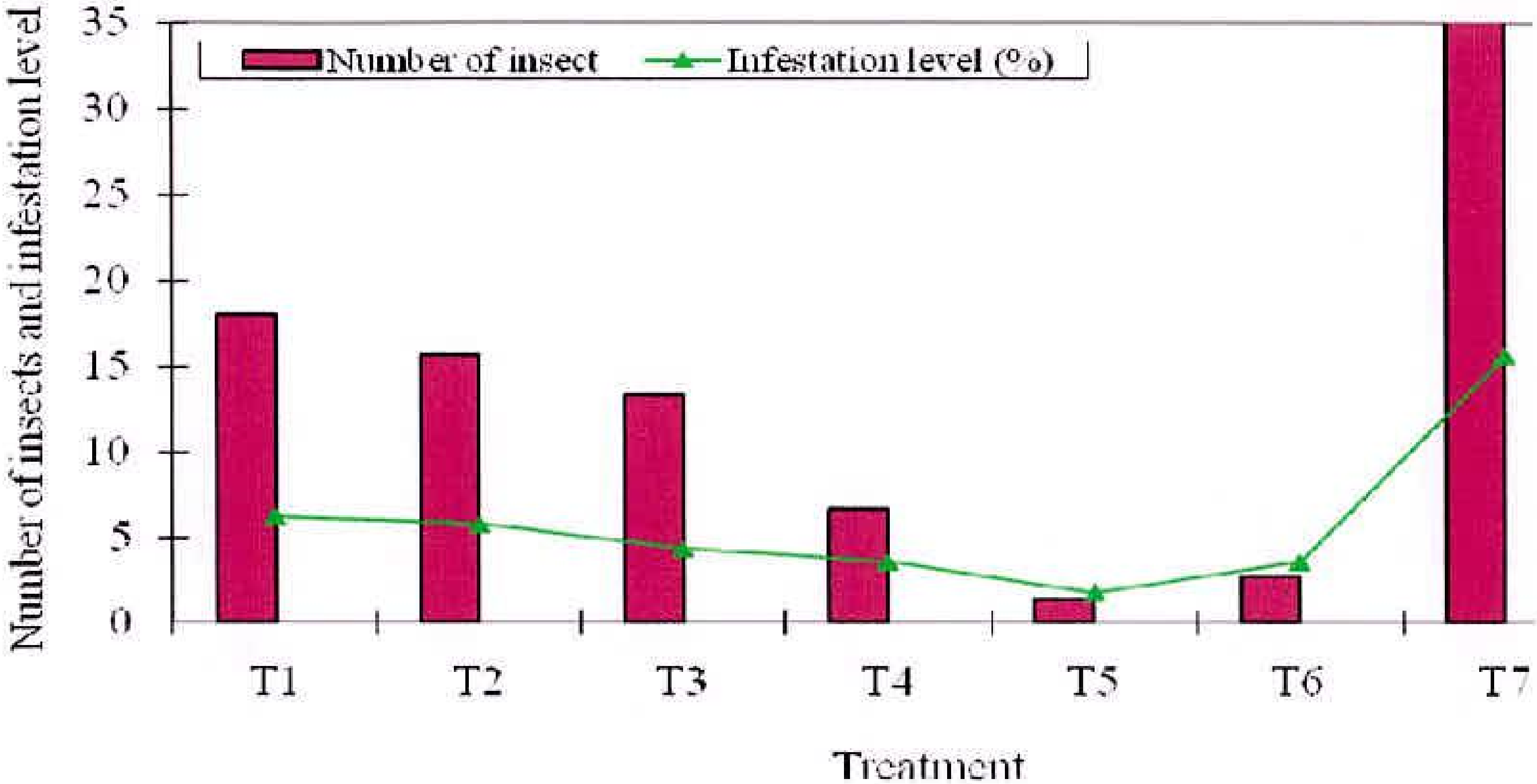

Figure 5. Number of insect pests and infestation level plot^{-1} at panicle initiation stage of wheat

4.3.3 Grain filling stage

Number of healthy, infested plant and percent infestation differed significantly among the treatments at grain filling stage and presented in Table 10. The highest number of healthy plants per m^2 was recorded from T_5 (93.67) which was statistically similar with all treatment except control, whereas the lowest number was obtained from T_7 (81.67). The lowest number of infested plant per m^2 was observed from T_5 (2.33), while the highest number was obtained from T_7 (15.33). The lowest infested plants per m^2 was observed from T_5 (2.49%) while the highest infested plant was recorded in T_7 (18.77%). Plant infestation reduction over control was estimated and the highest value from the treatment T_5 (86.75%) and the lowest from T_1 (60.37%).

4.4 Yield contributing characters and yield of wheat

4.4.1 Plant height at harvest

Plant height of wheat showed statistically significant variation for different treatments (Table 11). The longest plant was measured from T_5 (92.80 cm) which was statistically identical with T_4 (91.45 cm) and T_6 (90.10 cm), while the shortest plant was obtained from T_7 (77.56 cm) treatments.

4.4.2 Number of spike hill^{-1}

Statistically significant variation was recorded for number of spike hill^{-1} for different treatments (Table 11). The maximum number of spike hill^{-1} was measured from T_5 (4.37) which was statistically identical with T_6 (4.19), while the minimum number of spike hill^{-1} was obtained from T_7 (3.60) treatments.

Table 10. Effect of different treatments to combat the infestation of wheat pests $plot^{-1}$ at grain filling stage of plant

Treatments	Mean number of plants $plot^{-1}$			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_1	89.67 a	6.67 b	7.44 b	60.37
T_2	89.33 a	6.00 c	6.72 b	64.22
T_3	90.67 a	4.47 d	4.93 c	73.74
T_4	91.33 a	3.33 e	3.65 d	80.58
T_5	93.67 a	2.33 f	2.49 e	86.75
T_6	92.33 a	3.67 e	3.97 d	78.82
T_7	81.67 b	15.33 a	18.77 a	0.00
$LSD_{(0.05)}$	6.091	0.561	0.591	--
CV(%)	10.11	5.99	11.15	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

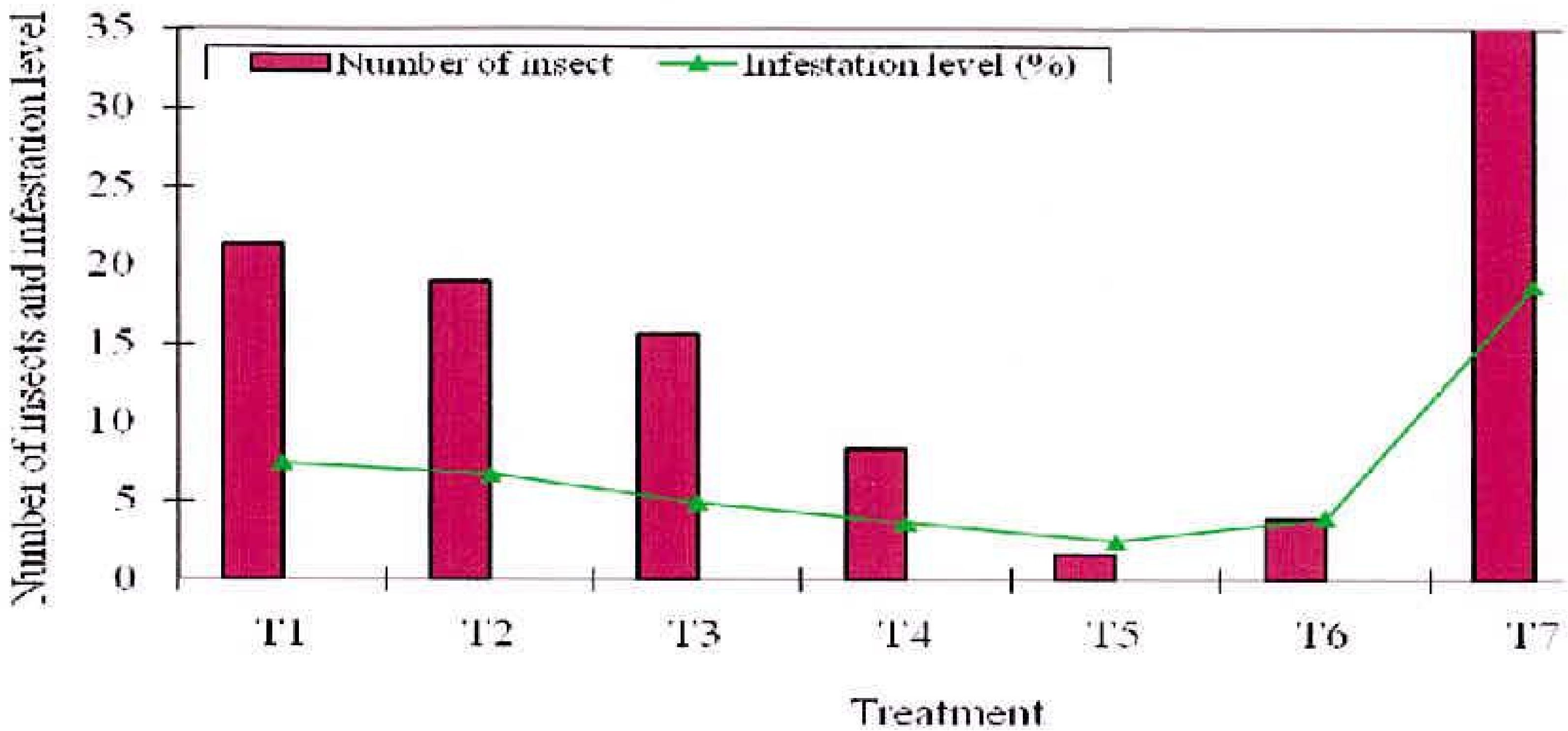

Figure 6. Number of insect pests and infestation level plot^{-1} at grain filling stage of wheat

Table 11. Effect of different treatments on plant height at harvest and number of spike hill^{-1} of wheat

Treatments	Plant height (cm) at harvest	Number of spike hill^{-1}
T_1	84.12 b	3.80 bc
T_2	85.78 b	4.01 ab
T_3	86.22 b	4.05 ab
T_4	91.45 a	4.18 a
T_5	92.80 a	4.37 a
T_6	90.10 a	4.19 a
T_7	77.56 c	3.60 c
$LSD_{(0.05)}$	3.078	0.189
CV(%)	7.88	5.79

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

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T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

4.4.3 Number of filled grains spike^{-1}

Statistically significant variation was recorded for number of filled grains spike^{-1} for different treatments (Figure 5). The maximum number of filled grains spike^{-1} was recorded from T_5 (29.33) which was statistically identical with T_6 (28.61), while the minimum number of filled grains spike^{-1} was obtained from T_7 (23.12) treatments.

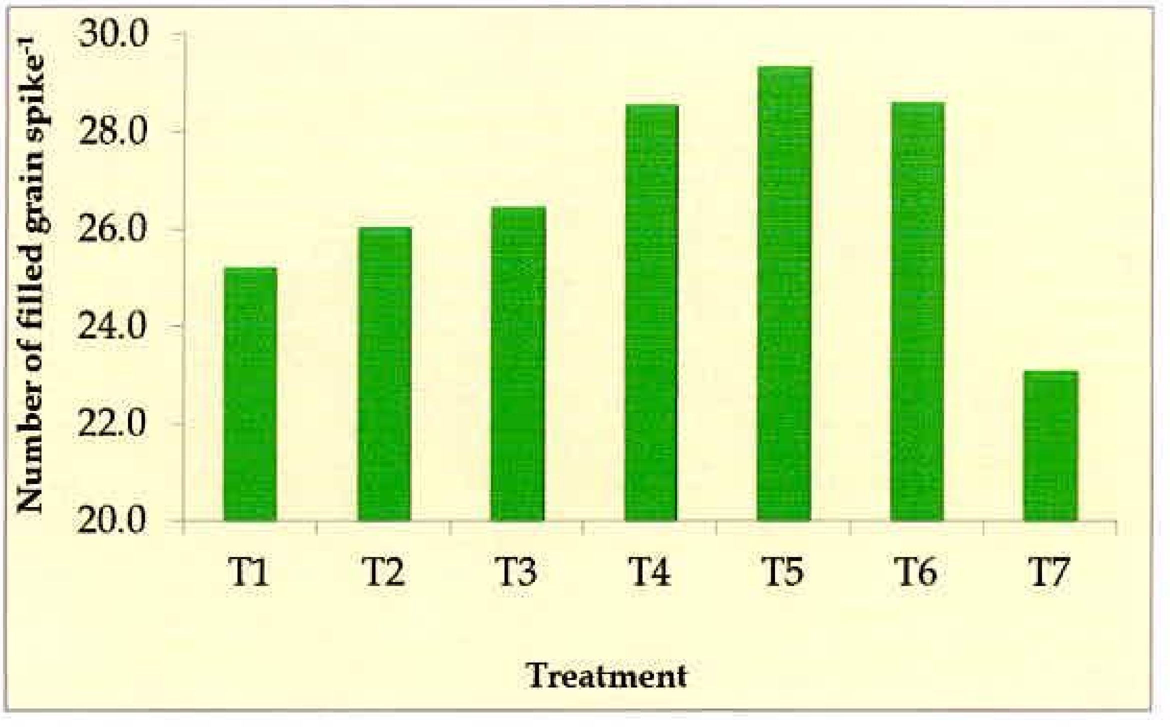

Figure 7. Effect of different treatments on number of filled grains spike^{-1} of wheat

4.4.4 Number of unfilled grains spike^{-1}

Statistically significant variation was recorded among treatments due to (Table 12). The minimum number of unfilled grains spike^{-1} was recorded from T_5 (1.99) which was statistically identical with T_4 (2.24) and T_6 (2.61), while the maximum number of unfilled grains spike^{-1} was obtained from T_7 (4.56) treatments.

4.4.5 Weight of 1000-grains

Statistically significant variation was recorded of weight of 1000 grains of wheat for different treatments (Table 12). Significantly the highest weight of 1000 grains was recorded from T_5 (44.43 g) which was statistically identical with T_6 (44.12 g) and T_4 (43.50 g), while the lowest weight was obtained from T_7 (39.45 g) treatments.

4.4.6 Yield hectare^{-1}

Statistically significant variation was recorded for yield hectare^{-1} of wheat for different treatments (Table 12). The highest yield was recorded from T_5 (3.43 t ha^{-1}) which was statistically identical with T_6 (3.26 t ha^{-1}) and T_4 (3.22 t ha^{-1}), while the lowest from T_7 (2.14 t ha^{-1}) treatments. On average pests cause 20-37% yield losses worldwide that translates to approximately $70 billion annually (Pimentel *et al.*, 1997). The results of the present study are in close proximity with those of Alam *et al.*, (2003), Rahman *et al.*, (2002) and Islam *et al.*, (1999). They reported that mechanical and cultural control in combination with insecticide reduced insect pest infestation and increased yield.

Table 12. Effect of different treatments on number of filled and unfilled grains spike^{-1}, weight of 1000-grains and yield hectare^{-1} of wheat

Treatments	Number of filled grains spike^{-1}	Number of unfilled grains spike^{-1}	Weight of 1000-grain (g)	Yield (t ha^{-1})
T_1	25.22 c	3.62 b	41.01 b	2.61 b
T_2	26.05 b	3.55 b	41.67 b	2.84 b
T_3	26.45 b	3.23 b	42.12 b	2.98 b
T_4	28.54 a	2.24 c	43.50 a	3.22 a
T_5	29.33 a	1.99 c	44.43 a	3.43 a
T_6	28.61 a	2.61 c	44.12 a	3.26 a
T_7	23.12 d	4.56 a	39.45 c	2.14 c
$LSD_{(0.05)}$	0.792	0.392	1.067	0.412
CV(%)	7.21	7.62	4.80	6.84

In a column, numeric data represents the mean value of 3 replications; each replication is derived from the plants of 10 randomly selected hill row^{-1} for each 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.

T_1: Cultural control (removal of weeds at 10 days interval)

T_2: Mechanical control (handpicking of infested tillers) at 7 days interval

T_3: Cultural control + Mechanical control at 7 days interval

T_4: Spraying of Suntap 50 SP @ 3.0 gm/L of water at 7 days interval + Mechanical control

T_5: Spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval

T_7: Untreated control

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted to evaluate of the effectiveness of some control options against the infestation of insect pests of wheat and their natural enemies during the period from November, 2012 to March, 2013 at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. Wheat variety Shatabdi was used as a test crop of this study. The experiment consists of the management practices as; T_1: Cultural control (removal of weeds at 10 days interval); T_2: Mechanical control (handpicking) at 7 days interval; T_3: Cultural control + Mechanical control at 7 days interval; T_4: Spraying of Suntap 50 SP @ 3.0 ml/L of water at 7 days interval + Mechanical control; T_5: Spraying of Marshal @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval; T_6: Spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval and T_7: Untreated control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

At tillering stage, the lowest number of aphid (1.00) was recorded from T_5, whereas the highest number (11.67) from T_7. No wireworm was recorded from T_5 (0.00) and T_6 (0.00), while the highest number from T_7 (8.33) treatment. No dipteran stem maggot was recorded from T_5 (0.00), T_6 (0.00) and T_4 (0.00), while the highest number from T_7 (4.67) treatment. No army worm was recorded from T_5 (0.00), T_6 (0.00) and T_4 (0.00), whereas the highest number from T_7 (4.67) treatment. The lowest number of aphid was recorded from T_5 (1.33), whereas the highest number from T_7 (13.33) treatment. No wireworm was recorded from T_5 (0.00) and T_6 (0.00), again the highest number from T_7 (9.67) treatment. No dipteran stem maggot was recorded from T_5 (0.00), T_6 (0.00), while the highest number from T_7 (6.00) treatment. The lowest number of aphid was recorded from T_5 (1.67), whereas the highest number from T_7 (14.67) treatment. No wireworm was recorded from T_5 (0.00), again the highest number from T_7 (10.33) treatment. No dipteran stem maggot was recorded from T_5 (0.00), T_6 (0.00), whereas the highest number from T_7 (6.67) treatment. No army worm was recorded from T_5 (0.00), while the highest number from T_7 (7.33) treatment.

For natural enemies of wheat, at tillering stage, no lady bird beetle was recorded from T_4 and T_5 treatment, whereas the highest number (2.33) from T_7 treatment. No parasitic wasps (parasitoid) were recorded from T_4 and T_5 treatment, whereas the highest number (3.67) from T_7 treatment. No syrphid fly was recorded from T_4 and T_5 treatment, whereas the highest number (2.00) from T_7 treatment. No spider was recorded from T_4 and T_5 treatment, whereas the highest number (3.33) from T_7 treatment. At panicle initiation stage, no lady bird beetle was recorded from T_4 and T_5 treatment, whereas the highest number (3.00) from T_7. No wasps was recorded from T_4 and T_5, whereas the highest number (4.33) from T_7 treatment. No syrphid fly was recorded from T_4 and T_5 treatment, whereas the highest number (3.67) from T_7 treatment. No spider was recorded from T_4 and T_5 treatment, whereas the highest number (4.33) from T_7 treatment. At grain filling stage, no lady bird beetle was recorded from T_4 and T_5 treatment, whereas the highest number (3.33) from T_7 treatment. No parasitic wasps (parasitoid) was recorded from T_4 and T_5 treatment, whereas the highest number (5.00) from T_7 treatment. No syrphid fly was recorded from T_4 and T_5, whereas the highest number (3.33) from T_7. No spider was recorded from T_4 and T_5 treatment, whereas the highest number (3.67) from T_7 treatment.

At tillering stage, the lowest infested plants per m^2 was observed from T_5 (1.37%), again the highest infested plant was recorded in T_7 (13.23%). At panicle initiation stage, the lowest infested plants per m^2 was observed from T_5 (1.75%), again the highest infested plant was recorded in T_7 (15.60%). At grain filling stage, the lowest infested plants per m^2 was observed from T_5 (2.49%), again the highest in T_7 (18.77%). The longest plant was measured from T_5 (92.80 cm), while the shortest plant from T_7 (77.56 cm) treatments. The highest yield was recorded from T_5 (3.43 t ha^{-1}), while the lowest yield from T_7 (2.14 t ha^{-1}) treatments.

Conclusion and Recommendations

From the above findings it was revealed that Spraying of Marshal @ 3.0 ml/L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval was superior for controlling wheat insect pests but spraying of Neem oil @ 3.0 ml/10 L of water at 7 days interval + Cultural control + Mechanical control at 7 days interval also gave the satisfactory results.

Recommendations

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

1. Though the spraying of neem oil @ 3.0 ml/10 L of water was second highest treatment that could be recommended because using of neem extract eco-friendly and easily affordable by the farmers.
2. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
3. Chemicals and other botanicals with different concentration may be used for further study.

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APPENDICES

Appendix I. Physical properties of the soils of the experimental field

Soil properties	Analytical data
Sand (%)	29.04
Silt (%)	41.80
Clay (%)	29.16

Appendix II. Chemical properties of the soils of the experimental field

Soil properties	Analytical value
pH	5.8
Organic matter (%)	1.34
Total N (%)	0.08
Available P (ppm)	31.15
Exchangeable K (meq/100 g)	0.18
Exchangeable Ca (meq/100 g)	0.12
Exchangeable Mg (meq/100 g)	--
Available S (ppm)	0.02
Zinc (ppm)	--
Boron (ppm)	--

Appendix III. Monthly record of air temperature, relative humidity, rainfall, and sunshine of the experimental site during the period from November 2012 to March 2013

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2012	25.8	16.0	78	00	6.8
December, 2012	22.6	13.3	76	00	6.2
January, 2013	25.2	12.8	69	00	5.8
February, 2013	27.3	16.9	66	39	6.8
March, 2013	31.7	19.2	57	23	8.1

* Monthly average,

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