FARMERS PRACTICES FOR COMBATING INSECT PESTS OF JUTE IN THREE INTENSIVE JUTE GROWING AREAS IN BANGLADESH AND THEIR ON-STATION VALIDATION TO DEVELOP AN IPM PACKAGE UTILIZING BIO-CONTROL AGENT AND NEEM PRODUCTS

BY

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DEDICATED
TO
MY BELOVED PARENTS

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ABSTRACT

The experiments were conducted to study the status of farmers practices for combating insect & mite pests of jute and develop an IPM package utilizing bio- control agent and neem products in three extensive jute growing areas of Bangladesh and the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from March to August 2011. Field survey in three intensive jute growing areas viz., Tangail, Jamalpur and Manikgonj was conducted to identify the present status of farmers practices for combating insect & mite pests of jute. The following treatments were applied during develop an IPM package utilizing bio-control agent and neem product T_1 = Green neem leaf extract @ 1:20 at 7 days interval; T_2 = Dry neem leaf extract @ 1:20 at 7 days; T_3 = Neem oil 5ml/ litre of water at 7 days interval; T_4 = Neem seed karnel @ 200 g/L of water at 7 days interval; T_5 = *Trichogramma evanescense @ 0.5 gm/6m*^{2} at 7 days interval; T_6 = *Trichogramma evanescense @ 0.5 gm/6m*^{2} + Neem oil 5 ml/L of water at 7 days interval; T_7 = Untreated control. According to the opinion of the respondent farmers collected from three intensive growing areas, jute hairy caterpillar, jute semilooper, weevil and mite were recorded as the major insect and mite pests of jute. Survey data revealed that the highest (14.25%) plant infestation was recorded for jute hairy caterpillar and the lowest (5.75%) was for jute weevil. The highest yield loss (23.00%) was recorded for jute hairy cater pillar and the lowest (11.00%) was for jute weevil. Considering economic loss, the highest (31.00%) economic loss was obtained for jute hairy caterpillar, while the lowest (14.00%) was weevil. During the development of IPM package the treatment that applied in consideration of % mortality of Jute hairy caterpillar, Jute semilooper, Jute weevil and Jute mite after 24, 48 and 72 hours where the highest mortality was recorded from T_6 while the lowest mortality was recorded fromT_5. By using bio-control agents and different neem products the highest yield (2.81 t ha^{-1}) was recorded from T_6, while the lowest yield (1.82 t ha^{-1}) from T_7. The highest benefit cost ratio (3.34) was estimated for T_5 treatment and the lowest (2.81) for T_6.

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CERTIFICATE

This is to certify that thesis entitled, **"Farmers practices for combating insect pests of jute in three intensive jute growing areas in Bangladesh and their on-station validation to develop an IPM package utilizing bio-control agent and neem products"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of bona fide research work carried out by **Md. Azizul Haq**, **Registration No. 05-01580** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2011

Place: Dhaka, Bangladesh

Prof. Dr. Md. Mizanur Rahman
Supervisor

CHAPTER I

INTRODUCTION

Jute (*Corchorus capsularis* L. and *Corchorus olitorius* L.) is the most important fibre crop and it is extensively grown in Bangladesh as a cash crop. Bangladesh ranks the second after India in area coverage and production of jute accounting for 62% of the world's production (Sinha *et al*., 2004). In Bangladesh, about 4.72 lac hectares of land are under jute cultivation and the total yield is 821,000 metric ton (BBS, 2006). It has been reported that about 90% of World's jute produced in Bangladesh and India (Atwal, 1976). Though two species of jute are cultivated (*C. capsularis* and *C. olitorius*), the first one is more popular because of its higher productivity. The land and climatic conditions of Bangladesh are congenial for the production of high quality jute. It is worthy to note that 100 thousand traders and 250 thousand industrial labours earn their livelihood from the jute business (Khandaker, 1987). Jute ranks second only to cotton among all the natural fibre in case of production (Talukder *et al*., 1989).

This crop was facing attack by various pests including insects, mites and nematodes, from seedling stage to harvest. All the parts, from the roots to the tip of the plant are ravaged by various pests. It was reported that about 40 species of insects and mites are considered to be the pests of jute in Bangladesh (Kabir, 1975). The pests cause loss in yield and quality of fibres. In Bangladesh, jute semilooper (*Anomis sabulifera* Guen.), jute hairy caterpillar (*Spilarctia obliqua* Wlk.), stem weevil (*Apion corchori* Marshall), grey weevil (*Myllocerus discolor* Bohemus) and yellow mite (*Polyphagotarsonemus latus* Banks) were recorded as the major pests of jute. Most of the previous efforts to

combat the pest problem associated with jute were based on pesticide approaches. Rahman and Khan (2010) reported from a pest complex of *olitorius* jute var. JRO-524 that incidence of *Anomis sabulifera* Guen., *Spilarctia obliqua* Wlk., *Myllocerus discolor* Bohemus, *Apion corchori* Marshall and *Polyphagotarsonemus latus* Banks were found causing a minimum of 6.10, 4.68, 12.38, 5.09, and 10.47 percent plant infestation, respectively.

At present, effective control techniques other than insecticide application against the pest are not available. The poor farmers of Bangladesh cannot always afford to use insecticides. Again, indiscriminate use of insecticides for the management of insect pests has resulted in the development of resistance to insecticides, pest resurgence and appearance of secondary pests (Shengal and Ujagir, 1990; Butter *et al*., 1992). Moreover, continuous use of insecticides leads to the hazardous effects on the pollinators, natural enemies like predators, parasitoids, parasites etc. and also causes the environmental pollution (Nugrar and More, 1998). Banerjee *et al*. (2000) reported that integration of improved cultural management practices, use of bio pesticides and conservation of natural enemies and a need-based use of chemicals could effectively control the insect and mite pest complex problem associated with jute. Efforts were also made for integrated management of insect and mite of olitorius jute (Prasad *et al*., 2002; Hath and Chakraborty, 2004). Such management included: using seed treatment with carbosulfan 25 DS at 3% w/w (Khan, 2004 and Bibha and Bora, 2005).

Therefore, it becomes necessary to find out some eco-friendly alternative methods for the management of jute pests. The manipulation of the cultural practices like changing the dates of sowing, using various levels of different fertilizers, screening of genotypes resistant to pest and using botanical and bio-agents can be eco-friendly components in

formulating the integrated pest management approach. In Bangladesh sufficient information on jute pests for its proper management is not available so far and no in-depth studies have been done. The chemical insecticides still remain the key tools for the management of the pest.

Under the above prospective, bio-control agents and neem products has been thought to be an environment friendly option for the management of insect and mite pests of jute. Therefore present study was planned and designed with the following objectives:

1. To know the present status of farmers practices for combating insect pests of jute;
2. To develop an IPM package utilizing bio control agents and neem products;
3. To find out an effective and suitable control option for suppressing insect & mite pests of jute.

CHAPTER II

REVIEW OF LITERATURE

Jute is one of the important cash crop namely golden fiber of Bangladesh. Jute semilooper, Jute hairy caterpillar, Jute weevil and Jute mite are the most destructive pest of this crop. For combating of these insect pests, it is necessary to have a concept of the pest status and host range, nature of damage, seasonal abundance, bionomics of these insect pests. Farmers mainly control these insect pests through use of different chemicals. But the concept of management of pest employing eco-friendly materials gained momentum as mankind became more safely about environment. Use of neem products and bio-control agents is the recent approaches for pest control that was commonly practiced. Information related to combating insect pests of jute using neem products and bio-control agents is very limited. Nevertheless, some of the important and informative works and research findings related to the control of insect pests through neem products and bio-control agents so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1. Insect pest of jute and their incidence

Rahman and Khan (2010) reported from a pest complex of olitorius jute var. JRO-524 that incidence of *Anomis sabulifera* Guen., *Spilarctia obliqua* Wlk., *Myllocerus discolor* Bohemus, *Apion corchori* Marshall and *Polyphagotarsonemus latus* Banks were found causing a minimum of 6.10, 4.68, 12.38, 5.09, and 10.47 percent plant infestation, respectively.

Seasonal incidence of *Spilosoma obliqua* on JRO 524 and JRO 632 cultivars of jute in Darrang district of Assam, India, during 1999 and 2000 throughout the jute growing season was studied by Sarma and Kalita (2002). The larvae of *Spilosoma obliqua* appeared in the field from first week of May and remained active up to harvesting stage of the crop. Maximum larval population of 20.94 and 19.55 numbers per plant was observed during second to third week of June 1999 on JRO 524 and JRO 632 cultivars, respectively, after which the population declined. The larval population again increased (10.19) on JRO 632 cultivar during second week of August 1999. The maximum numbers of larvae (22.35 no./plant) was observed during first week of July 2000 on JRO 524 cultivar, whereas 20.53 numbers of larvae per plant was recorded during fourth week of July 2000 on JRO 632 cultivar. Temperatures showed positive relationship, however, relative humidity and rainfall were negatively correlated with the larval population build up of jute hairy caterpillar. The results revealed that the number of attracted larvae was highest in jute (26.5 and 50.0 larvae at 12 and 24 h, respectively), followed by sesame (23.5 and 29.5 larvae at 12 and 24 h, respectively).

The advanced jute (*Corchorus olitorius*) cultivars, namely Seln-881, Seln-882, Seln-883, Seln-885 and Seln-887, along with standard varieties, JRO-7835 and JRO-524, were evaluated by Prasad *et al*. (2001) against jute pests, viz. stem weevil (*Apion corchori*), yellow mite (*Polyphagotarsonemus latus*), semilooper (*Anomis sabulifera*) and grey weevil (*Myllocerus discolor*) during the kharif seasons of 1996-99 under field conditions in Uttar Pradesh, India. The results indicated that the cultivar Seln-882 was moderately resistant against stem weevil and yellow mite with average infestation of 15.97 and 11.25%, respectively, whereas the cultivar Seln-887 was moderately resistant against semilooper and grey weevil with average infestation of 14.37 and 9.95%, respectively.

Out of 10 kenaf (*Hibiscus cannabinus*) cultivars evaluated during 1994-97 in Dhaka, Bangladesh against spiral borer (*Agrilus acutus*), one was found to be resistant, one was moderately resistant, one was moderately susceptible, five were susceptible, and two were highly susceptible. Levels of resistance expressed in two cultivars of mesta (*H. sabdariffa*), one of deshi jute (*Corchorus capsularis*), two of tossa jute (*C. olitorius*), one of okra (*Abelmoschus esculentus*), one accession of *H. radiatus,* two of *H. acetosella,* and one of ban-dheras (*Malachra capitata*) ranged from resistant to highly resistant. Among the resistant materials, there were no significant differences in the amount of plant damage. However, where per cent infestation was considered, PI 343128 (one cultivar of kenaf) was found to be significantly different from the other resistant materials. The cultivar CVL-1 (*C. capsularis*) was found to be completely free from borer attack (0% infestation and 0% damage). The presence of significantly high levels of resistance observed in mesta (*H. sabdariffa*) and other related species (*H. radiatus* and *H. acetosella*) indicate a potential use in breeding programs for developing resistant cultivars. High levels of resistance in related genera (*C. capsularis*, *C. olitorius*, *A. esculentus*, and *M. capitata*) indicate that these genera would not act as alternate hosts of *A. acutus*.

A random and fixed plot survey was conducted by Banerjee *et al*. (2000) in the districts of North 24 Parganas, Nadia, Murshidabad and Howrah on insect pest infestation in jute from the seedling stage to the late harvesting stage during 1998-1999. Different insect pests were noted infesting jute in different locations. Recommendations are given for the integrated control of these pests.

Fifty newly identified capsularis jute (*Corchorus capsularis*) genotypes along with standard cultivars JRC-212 and JRC-698 were evaluated by Prasad *et al*. (2010) for resistance to some important insect pests in augmented design during kharif 2005-06 and 2007-08 in

Bahraich, Uttar Pradesh, India. Data on different pests, i.e. semilooper (*Anomis sabulifera*), stem weevil (*Apion corchori*) and yellow mite (*Polyphagotarsonemus latus*), were recorded at peak infestation during the third week of August. The pooled data of 3 seasons on semilooper, stem weevil and yellow mite infestation varied from 4.99 to 12.39, 4.88 to 26.45 and 1.66 to 6.10%, respectively. CIJ-083 with 4.99% infestation was the least infested by the semilooper. It was followed by CIJ-042, CIN-111, CEX-008 and CIJ-100 with 5.36, 6.84, 6.85 and 7.03% semilooper infestation, respectively. Regarding stem weevil infestation, CIJ-042 with 4.85% infestation was the least susceptible. The yellow mite infestation was comparatively low (1.66-5.36%); CIJ-042 and CIJ-083 recorded the least infestation. The infestation of semilooper, stem weevil and yellow mite on JRC-212 and JRC-698 was 10.73, 9.15 and 4.07; and 11.48, 10.28 and 5.55% respectively.

Yadav and Adbhut (2010) evaluated eight jute (*Corchorus capsularis*) cultivars along with standard check (Var. JRC-212 & JRC-321) were evaluated against stem weevil (*Apion corchori*), semilooper (*Anomis sabulifera*) and yellow mite (*Polyphagotarsonemus latus*). Results revealed that the cv. NDC-2005-7 was significantly superior and most promising against stem weevil, semilooper and yellow mite with an average infestation of 9.9, 5.4 and 7.9%, respectively and may be considered as multiple resistant and significantly superior to standard check varieties JRC - 212 and JRC-321.

2.2 Insect pests control by neem products

Islam *et al*. (2009) conducted an experiment at the laboratory, greenhouse and in the field of Bangladesh Jute Research Institute (BJRI) during March to December, 2007. It was observed that the synthetic chemical pesticide such as Acaricide (Kumulus 80 WP) killed all the predators of jute mites tested while, there is no harmful effect of neem products on predators (natural enemies). The highest (88%) percent survival of adult Minute pirate bug

(*Orious insidiosus*), Lady bird beetle (90%), predatory mite (89%), Tarnished bug (85%) and Thrips (87%) was observed in green neem leaf extract and the lowest survival was recorded in chemicals acaricide suggesting that neem products such as green neem leaf extract is not harmful for predators (Natural enemies).

Field studies were conducted by Korat and Dabhi (2009) during three successive wet seasons (1995-97) 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.

Butani and Mittal (1993) studied the efficacy of neem seed kernel suspension and several conventional insecticides against *H. armigera* on chickpea 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 in chickpea. 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* on chickpea.

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 deterrency effect. Reduction of oviposition was highest (60.9%) with 10% NSKE. The hatchability of the laid eggs was also affected on NSKE treated surface.

Bajpai and Sehgal (2000) compared endosulfan with seven botanical insecticides, including neem, karanj (*Pongamia pinnata*) and tobacco formulations for control of pod borer on chickpea at Pantnagar, India. Neem gave the highest pod borer control (40.2% pod damage) and yields. Of the botanicals, pod damage at maturity was lowest with karanj oil followed by the neem product Green Mark or nicotine sulfate and yield was highest with karanj oil.

Visalakshimi *et al*., (2005) reported that application of neem effectively reduced the oviposition of *H. armigera* throughout 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.

Sasikala *et al*. (1999) studied during rabi 1998-99 at the Agricultural College Farm, Bapatla for the management of the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee, involving eco-friendly methods. The treatments included 5% neem seed kernel extract (NSKE), neem oil (0.2%), *Bacillus thuringiensis* var. (B.t.) kurstaki (0.15%), lufenuron (0.02%), carbaryl (0.15%), their combinations (except NSKE), mechanical removal and destruction of infested shoots and fruits with larvae, and release of egg parasitoid, *Trichogramma japonicum* Ashm. Treatment by mechanical destruction of infested shoots and fruits with larvae, neem oil (0.2%) and release of the egg parasitoid, *T. japonicum* resulted in very good control of shoot and fruit borer as compared to control. The respective percentage of shoot infestation and fruit damage (on number basis) in these treatments were

14.46, 20.24; 21.06, 23.35; and 23.36 & 28.00 vis-a-vis 52.60 & 52.55 per cent in control plots. Plots treated with neem oil (0.2%), neem oil (0.1%) + B.t. (0.075%), neem oil (0.1%) + lufenuron (0.01%), and neem oil (0.1%) + carbaryl (0.075%) gave higher fruit yield (40.76, 33.80, 31.35 and 29.07 kg/plot, respectively, compared with 17.5 kg/plot obtained from control plots.

Hossian (2007) observed Efficacy of some synthetic and biopesticides against pod borer, *Helicoverpa armigera* (Hubner) damage in chickpea was studied at the Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh during rabi cropping season of 2004-05. Synthetic and biopesticides reduced pod borer damage significantly. Significantly lowest pod damage was observed in cypermethrin (5.75%) and HNPV (5.86%) sprayed plots followed by carbaryl (6.05%) and dimethoate (7.92%) treated plots. The bio-control agent, HNPV, showed equally the best performance like synthetic insecticides and also showed higher efficacy than neem based insecticides like nimbi-cidine (azadiractin 0.03% EC). Pod damage reduction by synthetic insecticides and bio-pesticides over untreated control ranged from 24.98 to 64.08%. It ranged from 50.53 to 64.08% in synthetic insecticides and 24.98 to 63.40% in bio-pesticides. Significantly the highest yield (1,856 kg/ha) obtained from HNPV sprayed plots which was statistically identical to cyperme-thrin followed by azadiractin 0.03% EC. The highest net income ($ 105/ha) and marginal bene-fit cost ratio (3.35) was recorded from HNPV spray followed by cypermethrin ($ 87/ha) and (2.12), respectively. Hence, it might be concluded that HNPV is the best tool in managing pod borer in chickpea considering efficacy, profitability and environment friendly.

Bhat *et al*. (1988) reported that neem seed extract was the next best treatment tomonocrotophos against the pod borers, *M. testulalis* and *C. ptychora* on cowpea. Kareem *et al*. (1988) evaluated the efficacy of neem seed bitter (NSB) @ 5000 ppm and NSKE 3 per

cent against pod borers (*Etiella* sp., *Maruca* sp. and *Helicoverpa* sp.) in mung bean. The per cent pod damage was significantly reduced by NSB (22%), NSKE (20%) and monocrotophos (16%) as against untreated control (34%).

Ramasubramanian and Babu (1991) reported that neem seed extract and neem oil were on par with each other and were more effective than carbaryl in controlling the spotted pod borer, *Maruca testulalis* in lablab bean.

Jackai and Oyediran (1991) observed that neem oil emulsifiable concentrate (NOEC) at 5, 10 and 20 per cent concentrations exhibited a high degree of insecticidal activity to 3rd instar larvae of pod borer, *M. testulalis* in cowpea.

Bottenberg and Singh (1996) found that, on an average, aqueous neem leaf extracts at 5 and 10 per cent concentrations reduced the *M. testulalis* pod damage by 12 per cent in cowpea cv. 715and by 16 per cent in cultivar 941 compared to untreated control.

Balikai *et al*. (1997) reported the lowest pod damage (39.8%) and highest seed yield (10.2 q/ha) from the plots receiving three sequential sprays of NPV 250 LE/ha, cypermethrin 0.1 per cent and NSKE 5 per cent at 15 days interval starting from 50 per cent flowering on redgram, against *H. armigera.*

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 Gerst and *H. armigera* in pigeonpea.

Chickpea plots treated with leaf extracts of Nicotiana tobacum L. 5 per cent, seed extract of Pongamia glabra (Vent) 5 per cent, indiara (a neem based herbal product) 1 per cent and NSKE 5 per cent, exhibited lower population build up of *H. armigera* (Kulat *et al*., 2001).

2.3 Insect pests control by bio control agents

The efficacy of biological and chemical control agents against Meloidogyne incognita on jute (*Corchorus olitorius* cv. JRO-524) was evaluated by Srivastava *et al*. (2010) in Bahraich, Uttar Pradesh, India, from 2007-08 to 2008-09. The treatments consisted of: *Trichoderma viride*, *Aspergillus niger* or Pseudomonas fluorescens seed dressing and soil application at 15 and 30 days after sowing or DAS (T_1, T_2 and T_3, respectively); seed dressing with fungicide (tebuconazole at 2.5 g/kg of seeds) and *T. viride*, *A. niger* or *Pseudomonas fluorescens* (T_4, T_5 and T_6, respectively); seed dressing with fungicide and *T. viride* + *T. viride* soil application at 15 and 30 DAS (T_7); seed dressing with fungicide and *A. niger* + *A. niger* soil application at 15 and 30 DAS (T_8); seed dressing with fungicide and *P. fluorescens* + *P. fluorescens* soil application at 15 and 30 DAS (T_9); seed dressing with *T. viride* + *A. niger* + *P. fluorescens* and soil application of *T. viride* + *A. niger* + *P. fluorescens* at 15 and 30 DAS (T_{10}); seed dressing with fungicide and *T. viride* + *A. niger* + *P. fluorescens* (T_{11}); seed dressing with fungicide and *T. viride* + *A. niger* + *P. fluorescens* and soil application of *T. viride* + *A. niger* + *P. fluorescens* at 15 and 30 DAS (T12); seed dressing with fungicide (T13); and control (T14). T1 was the most effective among the treatments, as it resulted in the lowest number of galls/10 g of roots (20.3) and greatest reduction in gall formation (92.0%).

Mallik *et al*. (1989) reported that *Trathala flavoorbitalis* cam. is the parasitoid of the BSFB. *Trathala flavoorbitalis* is recorded from *L. orbonalis* in India and also in Srilanka where *L. orbonalis* is its major host and where an average parasitisation level of 36.2% has been reported Sandana, (2001). In Hissar, India, *Trathala* was found as the only parasitoid of *L. orborialis* which attack the larvae of BSFB ranging from 13.2 to 18.21% in winter to 12.9%

in summer when 95.2% of fruits were infested (Naresh *et al.,* 1986). *Trathala flavo-orbitalis* is identified as an effective larval parasitoid against BSFB in Bangladesh. The rate of parasitism varied from 20 to 25%. *Trathala flavoorbitalis* was recorded parasitizing the eggplant pest *L.orbonalis* in Bihar, India in 1986-88. Parasitism increased the host pupal period to 11-18 days, as compared to 6-14 days for healthy pupae. Adult parasitoids lived for 4-7 days in the laboratory.

Tewari and Sandana (1990) reported a larval ectoparasite, *Bracon* sp. on *L.orbonalis* on eggplant in Karnataka, India and stated the possibility of its use in the biological control of the pest. Naresh *et al.*, (1986) reported that the *L. orbonalis* larval population peaked in May and the pest was active throughout the year where *Trathala* sp. caused 12.90-18.18% parasitism of larvae. The parasitoid was active throughout the winter and summer seasons and preferred mature host larvae.

Itamoplex sp. recorded for the first time in the Indian state of Himachal Prodesh parasitizing the pyralid *L. orbonalis* is a serious pest of eggplant there. About 9-15% of pupae of the pyralid that were collected from the field was parasitized (Verma and Lal, 1985). A species of *Phanerotoma* near *P.hendecasisella* and *Campyloneura* sp, are recorded for the first time as parasites of larvae of *L.orbonalis.* The parasites were found attacking larvae infesting eggplant near Bangalore, Karnataka, India in July 1982. Combined parasitism was only 1-2% (Tewari and Moorthy, 1984).

Trichogramma sp.

Trichogramma are extremely tiny wasps in the family Trichogrammatidae. While it is uncommon for an insect's scientific name, especially one so long and unusual as *Trichogramma*, to also become its common name, the commercial development of this natural enemy and the fact that it attacks so many important caterpillar pests has earned it a

place in the popular vocabulary of many pest management advisors and producers.

Trichogramma wasps occur naturally in almost every terrestrial habitat, and some aquatic habitats as well. They parasitize insect eggs, especially eggs of moths and butterflies. Some of the most important caterpillar pests of field crops, forests, and fruit and nut trees are attacked by *Trichogramma* wasps. However, in most crop production systems, the number of caterpillar eggs destroyed by native populations of *Trichogramma* is not sufficient to prevent the pest from reaching damaging levels.

Recognizing the potential of *Trichogramma* species as biological control agents, entomologists in the early 1900s began to mass rear *Trichogramma* for insect control. This was not the case in the Soviet Union and China, both of which developed programs to control several crop pests with *Trichogramma*. In these countries, insectaries were less expensive and less sophisticated than production facilities for synthetic insecticides, and could be located on farms where labor was inexpensive and readily available. Also, control standards were not as stringent, and releasing *Trichogramma* was often better than no control at all (King, 1993).

Species and distribution

The genus *Trichogramma* is one of 80 genera in the family *Trichogrammatidae*. All members of this family are parasites of insect eggs. *Trichogrammatidae* includes the smallest of insects, ranging in size from 0.2 to 1.5 mm. Within the genus *Trichogramma*, there are 145 described species worldwide; 30 species have been identified from North America and an estimated 20 to 30 species remain to be described. The species most commonly collected from crops and orchards are *atopovirilia, brevicapillum, deion, exiguum, fuentesi, minutum, nubilale, platneri, pretiosum,* and *thalense* (O'Neil *et al*., 1998).

Life cycle

The effect of temporary host deprivation on parasitization rates of *T. cacoeciae* [*T. cacaeciae*] and *T. dendrolimi* was investigated by Thakur *et al*. (2000). The insect host in the experiments was *Sitotroga cerealella*. The study was conducted with females that we allowed to engage in 3 days of oviposition after various periods of host deprivation. It seems that the production and management of eggs by the two species is completely different. During the first day of oviposition, parasitization by *T. cacoeciae* was almost unaffected after 1 to 5 days of host deprivation. As deprivation time increased, however, the number of parasitized hosts decreased from an average of 28.6+or-2.0 hosts provided at emergence to an average of 12.5+or-2.3 hosts when the waiting time was 10 days. The number of hosts parasitized on the first day of parasitization by *T. dendrolimi* was not affected whatever the waiting tests period. During the second or third days of oviposition, the lack of suitable hosts for *T. cacoeciae* did not depress egg-laying potentiality, whereas a strong reduction in parasitization rates by *T. dendrolimi* occurred in the next 2 days of oviposition whatever was the waiting period. This leads to ca. 50% reduction in total activity of 3 days of oviposition. Only in *T. cacoeciae* was it possible to distinguish between ageing and host deprivation. The data suggest that *T. dendrolimi* is a typical proovigenic species, while *T. cacoeciae* is neither definitely proovigenic nor synovigenic. A slight decrease in rate of emergence of offspring of *T. cacoeciae* females that had waited 8 to 10 days for their hosts was observed.

The functional response of third generation of the *Trichogramma brassicae* reared in laboratory, was studied by Ahmad and Chandel (2004) at various densities (5, 10, 20, 40, 80, 100, 120) of the *Sitotroga cerealella* eggs under 25±1^{0}C, 60%±5 RH. One day old eggs of Angomous grain moth. *S. cerealella*, in 15 replications for 24 hours were exposed to one-day old female wasps. Functional response of *T. brassicae* was found to be type III.

CHAPTER III

MATERIALS AND METHODS

Two experiments were conducted during the period from March to August 2011 to study the present status of farmers practices for combating insect pests of jute in three intensive areas like Tangail, Jamalpur and Manikgonj and their on-station validation to develop an IPM package utilizing bio-control agents and neem products.

Experiment I: Study on the farmers practices for combating insect pests of jute in three intensive jute growing area

Selection of Farmers

Total 90 jute growers were randomly selected from three intensive growing districts such as Tangail, Jamalpur and Manikgonj districts. Among which 3 villages from each districts and 10 farmers from each village were randomly selected to collect the data. A list (Appendix I) of jute growers of the selected villages was made with the help of the Sub-Assistant Agriculture Officer (SAAO) of the respective areas. The response of each of the selected farmers were collected by administering a pretested questionnaire simple checklist. All the collected data were coded, tabulated, checked and analyzed through descriptive statistical methods using computer-based statistical package SPSS (Rashid *et al*., 2003).

Experiment II: On-station validation to develop an IPM package utilizing bio-control agent and neem products

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from April to

August, 2011 to develop an IPM package utilizing bio-control agent and neem products. 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 has been given below.

3.1 Location

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

3.2 Characteristics of soil

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

3.3 Weather condition of the experimental site

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

3.4 Planting material

The seeds of jute variety O-9897 was used for the study as planting material. This seeds were collected from Bangladesh Jute Research Institute. Before sowing, seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%.

3.5 Land preparation

The experimental field was first opened on April 18, 2011 with the help of a power tiller and prepared by three successive ploughing and cross-ploughing. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally leveled with the help of wooden plank. Finally the experimental plot was prepared at April 23, 2011.

3.6 Fertilizer application

Standard doses of fertilizers comprising N, P and K @ 40 kg, 40 kg and 25 kg per hectare in the form of Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) respectively were applied during the study. The whole amount of TSP and MP were applied as basal dose at the time of seed sowing. Total Urea was broadcasting maintaining two times during seedlings and vegetative stage.

3.7 Sowing of seeds

The seeds were sown in each plot on April 26, 2011 in rows with spacing of 30 cm × 30 cm.

3.8 Treatments

There were seven 7 demarcated treatments. They were as follows:

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

3.9 Description of the treatment

T_1: Green neem leaf extract @ 1:20 at 7 days interval. Leaves of neem were collected from Sher-e-Bangla Agricultural University campus. For preparation of extracts, collected leaves were weighted in an electric balance and then washed in the water. After washing the big leaves were cut into small pieces. For getting extract, weighted plant parts were blended in an electric blender and then distilled water was added into the jug of the blender. The pulverized mass was squeezed through 3 folds of fine cotton cloth. The filter thus obtain was used as a crude extract for spraying. For getting 1:4 (w/v) ratio 1000 ml of distilled water was added with 250 g plant parts.

T_2: Dry neem leaf extract @ 1:20 at 7 days interval. Green neem leaves were collected from Sher-e-Bangla Agricultural University campus then washed in the water and after washing the big leaves were cut into small pieces then dried and make extract as per the description of treatment T_1.

T_3: Neem oil 5 m1/L of water at 7 days interval. Under this treatment, The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the

local market of Agargaon bazaar. Neem oil were applied @ 15ml /3L of water with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. The mixture within the spray machine was shaked well and sprayed on the upper and lower surfaces of the plants of the treatment until the drop runoff from the plant. Three liters spray material was required to spray in three plots of each replication.

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval. Neem seed karnel was collected from from Chawkbazar, Dhaka and then blend and use @ 20 g/L of water.

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval. The inoculums of egg parasitoid *Trichogramma evanescens* were collected from the Safe Agro-Bio Tech Ltd, Mirpur, Dhaka, Bangladesh. The collected *T. evanescens* were reared on the eggs of *S. cerealella* and developed pupa in the laboratory of the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh then pupa was applied in the field.

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval. This treatment was applied as per the combination of treatment T_5 and T_3.

T_7: Untreated control- There were no control measures used in jute cultivation.

3.10 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly assigned in each block. The unit plot size was 3m × 2m with a distance of 50 cm between the plots and 100 cm between the replications.

3.11 Intercultural operations

Irrigation was applied for avoiding moisture stress and ensuring good germination. Intercultural operations like thinning, weeding and mulching were done as and when necessary for proper growth and development of the crop.

3.12 Monitoring and data collection

The growth and development of the jute plant were closely examined at regular intervals commencing from germination to harvest. The following data were collected during conducting the study.

The parameters which were considered during data collection on number of different insect/sq. cm leaf before treatment, average number of infested plant/plot by different insect pests before spray, number of infested plant/plot by different insect pests after spray and yield ton/ha.

3.13 Estimation of mortality

Insect pests population of jute were recorded by examining the leaf before spray and at 24, 48 and 72 hrs after spray for calculating % mortality from 5 plants. Percent mortality was calculated as per following formula:

$$\% \text{ mortality} = 1 - \left(\frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}} \right) \times 100$$

Where: n = Insect population, T = Treatment, Co=control

3.14 Harvest and post harvest operations

The plants of each plot were harvested at August 5, 2011 then the plants were bundle and take it for 5 days and then put into water upto August 24, 2011. Fiber was separate from stick then clean and dried for 5 days and weight was recorded.

3.15 Procedure of data collection

3.15.1 Plant height at harvest

The plant heights of 10 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.

3.15.2 Fibre yield (t ha^{-1})

The fibers collected from 6.0 m^2 of each plot were sun dried properly. The weight of fibre was taken and converted into the yield t ha^{-1}.

3.16 Statistical analysis

The data obtained for different characters were analyzed statistically and analysis of variance was done by the 'F' (variance ratio) test with the help of a complete package program MSTAT-C. The means were separated by using Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Two experiments were conducted to know the present status of farmers practices for combating insect mite pests of jute in three intensive jute growing areas like Tangail, Jamalpur and Manikgonj and their on-station validation to develop an IPM package utilizing bio-control agent and neem products in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from March to August, 2011. The results of different treatments on yield, extent of damage were presented, discussed and interpreted under the following headings-

Experiment I: **Study on the farmers practices for combating insect pests of jute in three intensive jute growing areas**

4.1 Farmers characteristics

A total of 90 farmers were selected for conducting survey in the respective area. Among the respondent farmers, 16.67% were up to 25 years old, 68.89% were 25-40 years olds and 14.44% were above 40 years old. Among them, 71.11% had primary level of education, 14.44% had SSC level and the rest 14.44% were illiterate. On an average, 66.67% of the sample farmers received training whereas 33.33% did not receive any type of training. Among the trained farmers, 91.11% had training on IPM and only 8.89% had training on pest management. The training duration was about 15 days for 97.78% while it was above 15 days for 2.22% farmers. Among the sample farmers, 32.22% cultivated jute during 1-5 years, 43.33% cultivated jute during last 5-10 years, and only 24.44% cultivated jute from more than last 10 years. On an average, 30% of the farmers cultivated jute in own land, 52.22% cultivated in leased-in land where as 17.78% cultivated in leased out land.

4.2 Infestation level, yield and economic loss

According to the response of the farmers, jute hairy caterpillar, jute semilooper, jute weevil and jute mite were recorded as the major insect pests of jute. The infestation of jute plant and yield and economic loss due to these insect pests are presented below-

As per the response of the jute growers, in case of plant infestation the highest (14.25%) infestation was recorded for jute hairy caterpillar which was closely followed (10.50%) by jute mite and the lowest (5.75%) plant infestation was recorded for jute weevil which was followed (8.50%) by jute semilooper (Table 1). In case of yield loss, the highest (23.00%) yield loss was recorded for jute hairy caterpillar which was followed (17.00% and 16.00%) by jute mite and jute semilooper and they were statistically identical, while the lowest (11.00%) yield loss was recorded for jute weevil. In consideration of economic loss, the highest (31.00%) economic loss was recorded for jute hairy caterpillar which was followed (23.00%) by jute semilopper, while the lowest (14.00%) economic loss was recorded for jute weevil, which was followed (19.00%) by jute mite. According to the opinion of jute growers jute hairy caterpillar was the serious pest in consideration of plant infestation, yield and economic loss.

Table 1. Farmers response on the infestation level, yield loss and economic loss by the insect pests of jute

Insect Pests	Plant infestation (%)	Yield loss (%)	Economic loss (%)
Jute hairy caterpillar	14.25	23.00	31.00
Jute semilooper	8.50	16.00	23.00
Jute Weevil	5.75	11.00	14.00
Jute Mite	10.50	17.00	19.00

4.3 Application status of pesticides, hand picking and practicing IPM

For controlling these insect mite pests the farmers use the following control methods and techniques in intensive way. Among the respondents 45.00%, 13.00% and 29.00% replied that they practicing pesticide, hand picking and practicing IPM for controlling jute hairy caterpillar (Table 2), whereas the lowest 10.00%, 4.00% and 24% respondents practiced the same methods of pest control for jute weevil control.

Table 2. Farmers response on the application status of pesticides, hand picking and practicing IPM

Insect Pests	Pesticide (%)	Hand picking (%)	Practicing IPM (%)
Jute hairy caterpillar	45.00	13.00	29.00
Jute semilooper	23.00	7.00	26.00
Jute Weevil	10.00	4.00	24.00
Jute Mite	11.00	9.00	26.00

4.4 Time of application of pesticides in different attacking stages

For controlling insect pests of jute the farmers applied insecticides in different time. According to the respondent opinion, the highest 23.00%, 12.00% and 9.00%, respectively practice application of pesticide after sever attack, after initial attack and without observing pest in case of jute hairy caterpillar, while the lowest was followed for controlling jute mite (Table 3).

Table 3. Farmers response on the application of pesticides in different stages of attack by the jute pests

Insect Pests	After severe attack (%)	After initial attack (%)	Without observing pests (%)
Jute hairy caterpillar	23.00	12.00	9.00
Jute semilooper	16.00	7.00	6.00
Jute Weevil	12.00	8.00	6.00
Jute Mite	6.00	5.00	4.00

4.5 Source of information related to pest control

The farmers received pest control information from the following sources following intensive manner. In case of jute hairy caterpillar, the highest percent of farmers (47.00) informed the related control methods from neighbor and the lowest percent of farmers (13.00) from extension worker (Table 4). In case of Jute semilooper, the highest percent of farmers (35.00) got information from relatives, whereas the lowest percent (11.00) from extension worker. In case of jute weevil, the highest percent of farmers (41.00) informed from neighbor and lowest percent (15.00) informed from dealers. In case of Jute mite, the highest percent of farmers (32.00) informed from extension worker, while the lowest percent (17.00) informed from relatives.

Table 4. Farmers response on the source of information related to jute pest control by the jute growers

Insect Pests	Neighbor (%)	Extension worker (%)	Dealers (%)	Relatives (%)
Jute hairy caterpillar	47.00	13.00	14.00	26.00
Jute semilooper	33.00	11.00	21.00	35.00
Jute Weevil	41.00	20.00	15.00	24.00
Jute Mite	31.00	32.00	20.00	17.00

Experiment II: **On-station validation to development of an IPM package against the attack of insect pests of jute by utilizing bio-control agent and neem products**

4.6 Effect of management practices on jute hairy caterpillar at 24, 48 and 72 hours after application of treatment

Percent mortality and percent infested plant^{-1}plot reduction over control of jute hairy caterpillar for 1st, 2nd and 3rd spray by using bio-control agent and neem products showed statistically significant differences (Table 5-6).

4.6.1 Mortality over control for 24, 48 and 72 hours

After 24 hours of treatment application in consideration of percent mortality of jute hairy caterpillar over control, the highest mortality (92.26%) was recorded for T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) which was followed (85.71%) by T_3 (Neem oil 5 m1/L of water at 7 days interval) and subsequently (80.10%) by T_1 (Green neem leaf extract @ 1:20 at 7 days interval). On the other hand, the lowest (57.79%) mortality of jute hairy caterpillar over control was recorded from T_5 (*Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval) which was closely followed (69.05% and 73.47%) by T_2 (Dry neem leaf extract @ 1:20 at 7 days interval) and T_4 (Neem seed karnel @ 200 g/L of water at 7 interval). After 48 hours of treatment application percent mortality of jute hairy caterpillar over control, the highest mortality (100.00%) was recorded for T_6 which was followed (93.33%) by T_3, while the lowest (68.48%) mortality of jute hairy caterpillar over control was recorded from T_5 which was followed (83.43%, 78.33% and 75.24%) by T_1, T_2 and T_4, respectively and they were statistically identical. After 72 hours of treatment application in consideration of % mortality of jute hairy caterpillar over control the highest mortality (100.00%) was recorded for T_6 and T_3 which was closely followed (94.54%) by T_1, while the lowest (86.10%) mortality of jute hairy caterpillar over control was recorded from T_5 which was statistically identical (89.08%, 87.25% and 86.10%) by T_4, T_2 and T_5, respectively and they were statistically identical (Table 5).

Table 5. Effect of bio-control agent and neem products on percent mortality of jute hairy caterpillar

Treatment	Number of jute hairy caterpillar cm^{-1} leaf before application	% mortality of jute hairy caterpillar over control at		
		24 hours	48 hours	72 hours
T_1	14	80.10 c	81.43 c	94.54 b
T_2	12	69.05 d	78.33 c	87.25 c
T_3	13	85.71 b	93.33 b	100.00 a
T_4	14	73.47 d	75.24 c	89.08 c
T_5	11	57.79 e	68.48 d	86.10 c
T_6	12	92.26 a	100.00 a	100.00 a
T_7	13	--	--	--
$LSD_{(0.05)}$	--	4.614	6.421	3.941
Significance level	NS	0.01	0.01	0.01
CV(%)	5.98	7.11	6.72	9.01

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.6.2 Reduction of infested plant over control for 1st, 2nd and 3rd application

During 1st application of treatment due to jute hairy caterpillar, The reduction of infested plant over control, the highest reduction (86.21%) was recorded from T_6, which was statistically identical (82.76%) with T_3 and followed T_1 (75.86%), T_2 (72.41%) T_4 (68.97%) respectively and they were statistically identical, whereas the lowest (62.07%) was recorded from T_5 (Table 6). After 2nd application due to jute hairy caterpillar, the reduction of infested plant over control, the highest reduction (93.75%) was recorded from T_6, which was statistically identical (90.63%) with T_3 and followed (84.38%) by T_1 and T_2, respectively, whereas the lowest (71.88%) was recorded from T_5. During 3rd application of treatment due to jute hairy caterpillar reduction of infested plant over control, the highest reduction (97.14%) was recorded from T_6, which was followed (94.29%) by T_3, again the lowest (85.71%) was recorded from T_4 and T_5. Korat and Dabhi (2009) reported that although all neem formulations were effective against pests and resulted in an increased yield but none were superior in efficacy to chlorpyrifos with various concentrations of azadirachtin compared to chlorpyrifos for the control of pest. This finding revealed that the neem products had the significant effect on the insect pests of jute.

Table 6. Effect of bio-control agent and neem products on percent reduction of jute hairy caterpillar at different treatment application

Treatment	Jute hairy caterpillar infestation reduction over control (%)		
	1st application	2nd application	3rd application
T_1	75.86 b	84.38 b	91.43 c
T_2	72.41 b	84.38 b	88.57 d
T_3	82.76 a	90.63 a	94.29 b
T_4	68.97 b	78.13 c	85.71 e
T_5	62.07 c	71.88 d	85.71 e
T_6	86.21 a	93.75 a	97.14 a
T_7	--	--	--
$LSD_{(0.05)}$	3.841	4.271	2.091
Significance level	0.01	0.01	0.05
CV(%)	6.09	11.02	5.33

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.7 Effect for management practices on jute semilooper at 24, 48 and 72 hours after application of treatment

Statistically significant variation was recorded for percent mortality at 24, 48 and 72 hours after application of treatment and percent infested plant per plot reduction over control of jute semilooper for 1st, 2nd and 3rd spray by using bio-control agent and neem products (Table 7-8).

4.7.1 Mortality over control for 24, 48 and 72 hours

After 24 hours of treatment application in consideration of percent mortality of jute semilooper over control, the highest mortality (89.06%) was recorded for T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) which was statistically identical (87.50%) by T_3 (Neem oil 5 m1/L of water at 7 days interval) and followed by (78.13%) by T_1 (Green neem leaf extract @ 1:20 at 7 days interval). On the other hand, the lowest (56.25%) mortality of jute semilooper over control was recorded from T_5 (*Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval) and T_4 (Neem seed karnel @ 200 g/L of water at 7 interval) which was followed (70.83%) by T_2 (Dry neem leaf extract @ 1:20 at 7 days interval). After 48 hours of treatment application in consideration of % mortality of jute semilooper over control the highest mortality (100.00%) was recorded for T_6 which was followed (90.00% and 88.33%) by T_3, T_2, T_4 and T_5 and they were statistically similar, again the lowest (82.50%) mortality of jute semilooper over control was recorded from T_1. After 72 hours of treatment application in consideration of percent mortality of jute semilooper over control the highest mortality (100.00%) was recorded for T_6, T_1 and T_3, while the lowest (90.28%) mortality of jute semilooper over control was recorded from T_2, T_4 and T_5 treatment, respectively and they were statistically identical (Table 7). Islam *et al*. (2009) reported from an experiment at the laboratory, greenhouse and in the field of Bangladesh Jute Research Institute (BJRI) similar results.

Table 7. Effect of bio-control agent and neem products on percent mortality of jute semilooper

Treatment	Number of jute semilooper cm^{-1} leaf before application	% mortality of semilooper over control at		
		24 hours	48 hours	72 hours
T_1	8	78.13 b	82.50 c	100.00 a
T_2	6	70.83 c	88.33 b	90.28 b
T_3	7	87.50 a	90.00 b	100.00 a
T_4	6	56.25 d	88.33 b	90.28 b
T_5	6	56.25 d	88.33 b	90.28 b
T_6	8	89.06 a	100.00 a	100.00 a
T_7	7	--	--	--
$LSD_{(0.05)}$	--	2.091	4.132	2.981
Significance level	--	0.05	0.05	0.01
CV(%)	--	7.21	9.12	5.23

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.7.2 Reduction of infested plant over control for 1st, 2nd and 3rd application

For 1st spray reduction of infested plant over control due to jute semilooper, the highest reduction (80.65%) was recorded from T_6, which was closely followed (77.42%) by T_3, whereas the lowest reduction (54.84%) was recorded from T_5, which was followed (67.74% and 64.52%) by T_1, T_2 and T_4, respectively and they were statistically identical (Table 8). For 2nd spray due to jute semilooper reduction of infested plant over control, the highest reduction (88.57%) was recorded from T_6, which was followed (82.86% and 80.00%) by T_3 and T_1 and they were statistically similar, whereas the lowest reduction (65.71%) was recorded from T_5 which was followed (71.43%) by T_4. For 3rd spray due to jute semilooper reduction of infested plant over control, the highest (97.37%) was recorded from T_6, which was closely followed (92.11% and 89.47%) by T_3, T_1 and T_2, again the lowest (81.58%) was recorded from T_5 treatment which was followed (84.21%) by T_4.

Table 8. Effect of bio-control agent and neem products on percent reduction of jute semilooper at different treatment application

Treatment	Jute semilooper infestation reduction over control (%)		
	1st application	2nd application	3rd application
T_1	67.74 c	80.00 b	89.47 b
T_2	67.74 c	77.14 c	89.47 b
T_3	77.42 b	82.86 b	92.11 b
T_4	64.52 c	71.43 d	84.21 c
T_5	54.84 d	65.71 e	81.58 d
T_6	80.65 a	88.57 a	97.37 a
T_7	--	--	--
$LSD_{(0.05)}$	5.321	3.091	3.143
Significance level	0.01	0.01	0.01
CV(%)	4.34	9.09	6.33

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.8 Effect for management practices on the jute weevil at 24, 48 and 72 hours after application of treatment

Percent mortality at 24, 48 and 72 hours after application of treatment and percent infested plant per plot reduction over control of weevil for 1st, 2nd and 3rd spray by using bio-control agent and neem products showed statistically significant differences (Table 9-10).

4.8.1 Mortality over control for 24, 48 and 72 hours

After 24 hours of treatment application in consideration of percent mortality of jute weevil over control the highest mortality (87.99%) was recorded for T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) which was followed (84.16% and 82.58%) by T_3 (Neem oil 5 m1/L of water at 7 days interval) and subsequently (80.10%) by T_1 (Green neem leaf extract @ 1:20 at 7 days interval). On the other hand, the lowest (74.71%) mortality of jute weevil over control was recorded from T_5 (*Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval) which was statistically identical (75.12%) with T_4 (Neem seed karnel @ 200 g/L of water at 7 interval) and followed (78.98%) by T_2 (Dry neem leaf extract @ 1:20 at 7 days interval). After 48 hours of treatment application in consideration of percent mortality of jute weevil over control the highest mortality (94.52%) was recorded for T_6 which was statistically identical (92.78%) by T_3 and closely followed (86.31%, 85.82%, 84.63% and 84.12%) T_2, T_4, T_5 and T_1, respectively and they were statistically identical. After 72 hours of treatment application in consideration of % mortality of jute weevil over control the highest mortality (100.00%) was recorded for T_6 and T_3 which was statistically identical (97.00%) with T_1, while the lowest (94.64%) mortality of weevil over control was recorded from T_4 which was statistically identical (94.83% and 95.16%) by T_2 and T_5, respectively and they were statistically identical (Table 9).

Table 9. Effect of bio-control agent and neem products on percent mortality of jute weevil

Treatment	Number of jute weevil cm^{-1} leaf before treatment application	% mortality of jute weevil over control after application of treatment at		
		24 hours	48 hours	72 hours
T_1	25	82.58 b	84.12 b	97.00 a
T_2	29	78.98 c	86.31 b	94.83 b
T_3	22	84.16 b	92.78 a	100.00 a
T_4	28	75.12 d	85.82 b	94.64 b
T_5	31	74.71 d	84.63 b	95.16 b
T_6	29	87.99 a	94.52 a	100.00 a
T_7	27	--	--	--
$LSD_{(0.05)}$	--	3.123	4.451	3.651
Significance level	--	0.01	0.05	0.01
CV(%)	--	4.98	11.23	

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 $gm/6m^2$ at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 $gm/6m^2$ + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

Islam *et al*. (2009) reported from an experiment at the laboratory, greenhouse and in the field of BJRI that the highest (88%) percent survival of adult Minute pirate bug (*Orious insidiosus*), predatory mite (89%), and Thrips (87%) was observed in green neem leaf extract and the lowest survival was recorded in chemicals acaricide suggesting that neem products such as green neem leaf extract is not harmful for predators.

4.8.2 Reduction of infested plant over control for 1st, 2nd and 3rd application

For 1st spray due to weevil reduction of infested plant over control, the highest (75.00%) was recorded from T_6, which was closely followed (67.86%) by T_3 and subsequently (57.14%) by T_1, whereas the lowest (32.14%) was recorded from T_5 which was closely followed (42.86%) by T_4 (Table 10). For 2nd spray due to weevil reduction of infested plant over control, the highest (90.32%) was recorded from T_6, which was closely followed (83.873%) by T_3 and subsequently (80.65%) by T_1, whereas the lowest (70.97%) was recorded from T_5 which was closely followed (74.19%) by T_4. For 3rd spray due to weevil reduction of infested plant over control, the highest (94.12%) was recorded from T_6, which was closely followed (88.24%) by T_3, again the lowest (79.41%) was recorded from T_5 treatment. Korat and Dabhi (2009) reported that similar results.

Table 10. Effect of bio-control agent and neem products on percent reduction of jute weevil at different treatment application

Treatment	Jute weevil infestation reduction over control (%) at		
	1st application	2nd application	3rd application
T_1	57.14 c	80.65 c	88.24 b
T_2	50.00 d	77.42 d	85.29 c
T_3	67.86 b	83.87 b	88.24 b
T_4	42.86 e	74.19 e	82.35 c
T_5	32.14 f	70.97 f	79.41 d
T_6	75.00 a	90.32 a	94.12 a
T_7	--	--	--
$LSD_{(0.05)}$	5.672	3.561	4.561
Significance level	0.01	0.01	0.01
CV(%)	6.78	8.99	7.96

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.9 Effect of management practices on the jute mite at 24, 48 and 72 hours after application of treatment

Percent mortality at 24, 48 and 72 hours after application of treatment and percent infested plant per plot reduction over control of mite for 1st, 2nd and 3rd spray by using bio-control agent and neem products showed statistically significant differences (Table 11-12).

4.9.1 Mortality over control for 24, 48 and 72 hours

After 24 hours of treatment application in consideration of % mortality of jute mite over control the highest mortality (61.90%) was recorded for T_6 treatment (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) which was followed (53.51%) by T_3 (Neem oil 5 m1/L of water at 7 days interval) and subsequently (48.39%) by the T_1 (Green neem leaf extract @ 1:20 at 7 days interval). On the other hand, the lowest (10.20%) mortality of jute mite over control was recorded from T_5 (*Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval) which was followed (25.06%) by T_4 (Neem seed karnel @ 200 g/L of water at 7 interval). After 48 hours of treatment application in consideration of % mortality of mite over control the highest mortality (98.67%) was recorded for T_6 which was followed (92.77%) by T_3 treatment, while the lowest (54.29%) mortality of jute mite over control was recorded from T_5 which was statistically identical (51.83%) with T_1 and followed (70.57% and 65.03%) by T_2 and T_4 treatment, respectively and they were statistically identical. After 72 hours of treatment application in consideration of % mortality of jute mite over control the highest mortality (100.00%) was recorded for T_6 treatment which was followed (93.62%) by T_3 treatment, while the lowest (73.11%) mortality of jute mite over control was

Table 11. Effect of bio-control agent and neem products on percent mortality of jute mite

Treatment	Number of jute mite cm^{-1} leaf before treatment application	% mortality of jute mite over control after application of treatment at		
		24 hours	48 hours	72 hours
T_1	62	48.39 c	51.83 d	87.86 c
T_2	58	36.95 d	70.57c	80.53 d
T_3	59	53.51 b	92.77 b	93.62 b
T_4	61	25.06 e	65.03 c	81.49 d
T_5	56	10.20 f	54.29 d	73.11 e
T_6	60	61.90 a	98.67 a	100.00 a
T_7	64	--	--	--
$LSD_{(0.05)}$	--	4.091	5.091	6.143
Significance level	--	0.01	0.05	0.01
CV(%)	--	4.89	11.12	9.91

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

recorded from T_5 which was followed (81.49% and 80.53%) by T_4 and T_2 treatment, respectively and they were statistically identical (Table 11). Islam *et al*. (2009) reported from an experiment at the laboratory, greenhouse and reported that in chemicals acaricide suggesting that neem products such as green neem leaf extract is not harmful for predators.

4.9.2 Reduction of infested plant over control for 1st, 2nd and 3rd application

For 1st spray due to mite reduction of infested plant over control, the highest (90.00%) was recorded from T_6, which was followed (86.67%) with T_3 and subsequently (83.33% and 80.00%) by T_1 and T_2, respectively and they were statistically identical, whereas the lowest (70.00%) was recorded from T_5 treatment and followed (76.67%) by T_4 (Table 12). For 2nd spray due to jute mite reduction of infested plant over control, the highest (96.88%) was recorded from T_6, which was statistically identical (93.75%) with T_3 and followed (87.50%) by T_1 and T_2, respectively, whereas the lowest (78.13%) was recorded from T_5 treatment. For 3rd spray due to jute mite reduction of infested plant over control, the highest (97.22%) was recorded from T_6 and T_3, which was followed (88.89%) by T_2 and T_4 and they were statistically similar, again the lowest (86.11%) from T_5 treatment. Korat and Dabhi (2009) reported that that although all neem formulations were effective against pests.

Table 12. Effect of bio-control agent and neem products on percent reduction of jute mite at different treatment application

Treatment	Jute mite infestation reduction over control (%) at		
	1st application	2nd application	3rd application
T_1	83.33 c	87.50 b	94.44 a
T_2	80.00 c	87.50 b	88.89 b
T_3	86.67 b	93.75 a	97.22 a
T_4	76.67 d	84.38 c	88.89 b
T_5	70.00 e	78.13 d	86.11 b
T_6	90.00a	96.88 a	97.22 a
T_7	--	--	--
$LSD_{(0.05)}$	3.091	3.078	4.091
Significance level	0.01	0.05	0.01
CV(%)	10.12	14.09	8.88

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.10 Yield contributing characters and yield

Plant height and yield per hectare of jute and increase over control showed significant differences for bio-control agent and neem products (Table 13).

4.10.1 Plant height (m)

By using bio control agent and different neem products the longest plant (3.34 m) was recorded from T_6 treatment which was statistically identical (3.22 m) with T_3 treatment and followed (3.18 m and 3.06 m) by T_1 and T_2 treatment and they were statistically similar. On the other hand, the lowest plant (2.42 m) was recorded from T_7 which was followed (2.95 m and 2.96) by T_5 and T_4, respectively and they were statistically identical (Table 13). Plant height increase over control revealed that the highest (38.02%) was recorded from T_6 and the lowest (21.90%) was recorded from T_5.

4.10.2 Yield (t ha^{-1})

By using bio-control agent and different neem products the highest yield (2.81 t ha^{-1}) was recorded from T_6 treatment which was statistically identical (2.74 t ha^{-1}) with T_3 treatment and followed (2.62 t ha^{-1} and 2.51 t ha^{-1}) by T_1 and T_2 treatment and they were statistically similar. On the other hand, the lowest yield (1.82 t ha^{-1}) was recorded from T_7 which was followed (2.33 t ha^{-1} and 2.25 t ha^{-1}) by T_5 and T_4, respectively and they were statistically identical (Table 13). Plant height increase over control revealed that the highest (54.40%) was recorded from T_6 and the lowest (23.63%) was recorded from T_5. Korat and Dabhi (2009) reported that that although all neem formulations were effective against pests and resulted in an increased yield.

Table 13. Effect of bio-control agent and neem products on plant height and yield of jute

Treatment	Plant height (m)	Increase over control (%)	Yield (t ha^{-1})	Increase over control (%)
T_1	3.18 b	31.40 b	2.62 b	43.96 c
T_2	3.06 b	26.45 c	2.51 b	37.91 d
T_3	3.22 a	33.06 b	2.74 a	50.55 b
T_4	2.96 c	22.31 d	2.33 c	28.02 e
T_5	2.95 c	21.90 d	2.25 c	23.63 f
T_6	3.34 a	38.02 a	2.81 a	54.40 a
T_7	2.42 d	--	1.82 d	--
$LSD_{(0.05)}$	0.134	3.142	0.093	3.671
Significance level	0.05	0.01	0.05	0.01
CV(%)	7.33	7.45	8.09	7.91

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

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

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/$6m^2$ + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

4.11 Economic analysis

The analysis was done in order to find out the most profitable bio-control agent and neem products based on cost and benefit of various components. The results of economic analysis of jute cultivation showed that the highest net benefit of Tk. 454,200 ha^{-1} was obtained in T_1 and the second highest net benefit was found Tk. 438,100 ha^{-1} in T_2 (Table 14). The highest benefit cost ratio (3.34) was estimated for T_5 and the lowest (2.81) benefit cost ration for T_6 under the trial. The highest BCR was found in the T_1 may be due to the minimum infestation cost compared to the other treatment components and highest yield.

Table 14. Cost of production of jute for the application of bio-chemical agent and neem products

Treatments	Cost of pest Management (Tk.)	Yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
T_1	45000	2.62	314400	269400	51000	1.13
T_2	45000	2.51	301200	256200	37800	0.84
T_3	45000	2.74	328800	283800	65400	1.45
T_4	40000	2.33	279600	239600	21200	0.53
T_5	30000	2.25	270000	240000	21600	0.72
T_6	45000	2.81	337200	292200	73800	1.64
T_7	0	1.82	218400	218400	--	--

T_1: Green neem leaf extract @ 1:20 at 7 days interval

T_2: Dry neem leaf extract @ 1:20 at 7 days interval

T_3: Neem oil 5 m1/L of water at 7 days interval

T_4: Neem seed karnel @ 20 g/L of water at 7days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval

T_7: Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

Two experiments were conducted to know the present status of farmers practices for combating insect pests of jute and development of an IPM package by utilizing bio-control agents and neem products in three intensive jute growing areas like as Tangail, Jamalpur and Manikgonj and the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from March to August 2011. The results of different treatments on yield, extent of damage were presented, discussed and interpreted under the following.

During conducting the field survey, according to the response of the respondent farmers, jute hairy caterpillar, jute semilooper, jute weevil and jute mite were recorded as the major insect pests of jute. As per the opinion of the respondent jute growers, in case of plant infestation the highest (14.25%) plant infestation was recorded for jute hairy caterpillar and the lowest (5.75%) was for jute weevil. In case of yield loss, the highest (23.00%) yield loss was recorded for jute hairy cater pillar, while the lowest (11.00%) was for jute weevil. In consideration of economic loss, the highest (31.00%) economic loss was for jute hairy caterpillar, while the lowest (14.00%) was for jute weevil. Among the respondents 45.00%, 13.00% and 29.00% replied that they practicing pesticide, hand picking and practicing IPM for controlling jute hairy caterpillar, whereas the lowest 10.00%, 4.00% and 24% respondents practiced the same methods of pest control for jute weevil control. According to the respondent the highest 23.00%, 12.00% and 9.00%, respectively practice application of pesticide after sever attack, after initial attack and without observing pest in case of jute hairy caterpillar, while the lowest was followed for controlling jute mite. In case of jute hairy caterpillar, the highest 47.00% informed the related control methods from neighbor and the lowest (13.00%) from extension worker. In case jute semilooper, the highest (35.00%) informed from relatives, whereas the lowest (11.00%) from extension worker. In

case of jute weevil, the highest (41.00%) informed from neighbor and lowest (15.00%) informed from dealers. In case of jute mite, the highest (32.00%) informed from extension worker, while the lowest (17.00%) informed from relatives.

During conducting on station where the following results were obtained, data on application of treatment at different time interval after 24 hours of treatment application in consideration of % mortality of jute hairy caterpillar over control the highest mortality (92.26%) was recorded for T_6 treatment and the lowest (57.79%) mortality of jute hairy caterpillar over control was recorded from T_5. After 48 hours of treatment application in consideration of percent mortality of jute hairy caterpillar over control the highest mortality (100.00%) was recorded for T_6, while the lowest (68.48%) mortality of jute hairy caterpillar over control was recorded from T_5. After 72 hours of treatment application in consideration of percent mortality of jute hairy caterpillar over control the highest mortality (100.00%) was recorded for T_6 and T_3, while the lowest (86.10%) was recorded from T_5. For 1st spray due to jute hairy caterpillar reduction of infested plant over control, the highest (86.21%) was recorded from T_6, whereas the lowest (62.07%) from T_5 (Table 2). For 2nd spray due to jute hairy caterpillar reduction of infested plant over control, the highest (93.75%) was recorded from T_6, whereas the lowest (71.88%) from T_5. For 3rd spray due to jute hairy caterpillar reduction of infested plant over control, the highest (97.14%) was recorded from T_6, again the lowest (85.71%) from T_4 and T_5.

After 24 hours of treatment application in consideration of % mortality of jute semilooper over control the highest mortality (89.06%) was recorded for T_6 and, the lowest (56.25%) mortality was recorded from T_5. After 48 hours of treatment application in consideration of % mortality of jute semilooper over control the highest mortality (100.00%) was recorded for T_6, again the lowest (82.50%) mortality of jute semilooper over control was recorded from T_1. After 72 hours of treatment application in consideration of % mortality of jute

semilooper over control the highest mortality (100.00%) was recorded for T_6, T_1 and T_3 while the lowest (90.28%) mortality of jute semilooper over control was recorded from T_2, T_4 and T_5, respectively. For 1st spray reduction of infested plant over control due to jute semilooper, the highest (80.65%) was recorded from T_6, whereas the lowest (54.84%) was recorded from T_5. For 2nd spray due to jute semilooper reduction of infested plant over control, the highest (88.57%) was recorded from T_6, whereas the lowest (65.71%) was recorded from T_5. For 3rd spray due to jute semilooper reduction of infested plant over control, the highest (97.37%) was recorded from T_6, again the lowest (81.58%) was recorded from T_5.

After 24 hours of treatment application in consideration of percent mortality of jute weevil over control the highest mortality (87.99%) was recorded for T_6 and the lowest (74.71%) mortality of jute weevil over control was recorded from T_5. After 48 hours of treatment application in consideration of % mortality of jute weevil over control the highest mortality (94.52%) for T_6. After 72 hours of treatment application in consideration of % mortality of jute weevil over control the highest mortality (100.00%) was recorded for T_6 and T_3, while the lowest (94.64%) mortality of jute weevil over control was recorded from T_4.

For 1st spray due to jute weevil reduction of infested plant over control, the highest (75.00%) was recorded from T_6, whereas the lowest (32.14%) was recorded from T_5 treatment. For 2nd spray due to jute weevil reduction of infested plant over control, the highest (90.32%) was recorded from T_6, whereas the lowest (70.97%) from T_5 treatment. For 3rd spray due to jute weevil reduction of infested plant over control, the highest (94.12%) was recorded from T_6, again the lowest (79.41%) from T_5.

After 24 hours of treatment application in consideration of percent mortality of jute mite over control the highest mortality (61.90%) was recorded for T_6 and the lowest (10.20%)

was recorded from T_5. After 48 hours of treatment application in consideration of percent mortality of jute mite over control the highest mortality (98.67%) was recorded for T_6, while the lowest (54.29%) mortality of jute mite over control was recorded from T_5. After 72 hours of treatment application in consideration of % mortality of jute mite over control the highest mortality (100.00%) was recorded for T_6, while the lowest (73.11%) mortality of jute mite over control was recorded from T_5. For 1st spray due to jute mite reduction of infested plant over control, the highest (90.00%) was recorded from T_6 treatment, whereas the lowest (70.00%) from T_5. For 2nd spray due to jute mite reduction of infested plant over control, the highest (96.88%) was recorded from T_6, whereas the lowest (78.13%) from T_5. For 3rd spray due to jute mite reduction of infested plant over control, the highest (97.22%) was recorded from T_6 and T_3 treatment, again the lowest (86.11%) from T_5 treatment.

Regarding plant length bio-control agents and different neem products the longest plant (3.34 m), Which was recorded from T_6 and the lowest plant length (2.42 m), which was recorded from T_7 treatment, Plant height increase over control revealed that the highest (38.02%) was recorded from T_6 treatment and the lowest (21.90%) from T_5 treatment. In case of jute yields, the highest yield (2.81 t ha^{-1}) was recorded from T_6 treatment, while the lowest yield (1.82 t ha^{-1}) from T_7. The highest benefit cost ratio (3.34) was estimated for T_5 and the lowest (2.81) from T_6.

The present study revealed that the increased yield per hectare of Jute with the highest % mortality of jute hairy caterpillar after 24, 48 and 72 hours of treatment application, highest reduction of infested plant due to jute hairy caterpillar after 1st spray, 2nd and 3rd Spray was recorded from T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval**)** treatment. In case of jute semilooper, the highest % mortality of semilooper after 24, 48 and 72 hours of treatment application, highest reduction of infested

plant due to semilooper after 1st spray, 2nd and 3rd Spray was recorded from T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) treatment. Similarly in case of jute weevil, the highest % mortality of weevil after 24, 48 and 72 hours of treatment application, highest reduction of infested plant due to weevil after 1st spray, 2nd and 3rd Spray was recorded from T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) treatment. In case of Jute mite, the T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) treatment gives the best results in respect of the above parameters among all treatments used in present study.

From the above description, it can be concluded that, T_6 (*Trichogramma evanescense* @ 0.5 gm/6m^2 + Neem oil 5 m1/L of water at 7 days interval) treatment significantly reduced the infestation of jute hairy caterpillar, jute semilooper, jute weevil and jute mite of jute cultivation with resulting satisfactory yield per hectare.

Considering the findings of the present study, further studies in the following areas may be recommended:

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

2. Other recommended management practices may be included in future study.

CHAPTER VI

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APPENDICES

Appendix I. List of jute growers of the selected villages

Name of District	Name of village	Name of farmer
Jamalpur	Pingna	Shahjahan Ali
		Moti Mia
		Hanif Ali
		Salam Ali
		Azim Mia
		Harun Mia
		Benjamin Ali
		Md.Mamun
		Ganda Sheikh
		Dullah Mia
	Kabaria Bari	Abdul Gafur
		Hamid Ali
		Karim Ali
		Md. Arif
		Rustom Ali
		Akbar Mia
		BarekAli
		Abdur Razzak
		Kala Chan
		Akkash Ali
	Kawa Mara	Rintu Mia
		Mintu Ali
		Hira Mia
		Nantu Sheikh
		Indu Mia
		Binda Ali
		Ataur Rahman
		Rasel Rahman
		Intus Ali
		Abul Hai
Tangail	Vengula bazaar	Musa Sheikh
		Sohrab Ali
		Sadek Ali
		Anaet kabir
		Suman Mia
		Kabir Ali
		Sahed Ali
		Mizanur Rahman
		Sanuar Hossain
		Rajib Mia
	Soyani para	Tangsu Sheikh
		Pear Ali
		Bachchu Sheikh
		Jamilur rahman
		Abdul Jalil

Name of District	Name of village	Name of farmer
		Khalilur Rahman
		Hayat Ali
		Kunu Mondal
		Dudu Mia
		Saman Ali
		Alauddin Mia
	Horisha	Abdul Majid
		Abdul Samad
		Nuru Mia
		Nazrul Mia
		Mukul Ali
		Yakub Ali
		Sayad Ali Sarkar
		Abdul Halim
		Faruque Mia
		Liakat Ali
Manikgonj	Gheor	Baharulla pandith
		Nazu Sarkar
		Idrish Ali
		Jazu Mia
		Arshad Ali
		Hossain Mia
		Julhash Uddin
		Kanchu Sheikh
		Lal Mia
		Monu Mia
	Nabinagar	Abjal Hossain
		Fakir Ali
		Keramat Ali
		Azizur Rahman
		Md. Nuruzzaman
		Md. Nizam Atikullah
		Ohab Ali
		Babon Ali
		Lucky Sarkar
		Abdul Fajal
	Shaturia	Niranjan Saha
		Gonesh
		Kartrik
		Gata Babu
		Anil Kumar
		Komol Sarker
		Sunil
		Jhantu
		Montu
		Bimol kumar

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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from March to August 2011

Month (2011)	*Air temperature (^{o}c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
March	31.4	19.6	54	11	8.2
April	33.6	23.6	69	163	6.4
May	34.7	25.9	70	185	7.8
June	34.5	26.8	76	213	7.1
July	36.4	25.2	82	165	7.5
August	33.5	26.3	84	123	7.4

* Monthly average,
Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka