USE OF NEEM PRODUCTS FOR THE CONTROL OF JUTE YELLOW MITE, *Polyphagotarsonemus latus* (Banks) AND RED MITE, *Tetranychus bioculatus* (Wood–Mason)

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This is to certify that the thesis entitled, "**USE OF NEEM PRODUCTS FOR THE CONTROL OF JUTE YELLOW MITE, *Polyphagotarsonemus latus* (Banks) AND RED MITE, *Tetranychus bioculatus* (Wood–Mason)**" 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. NAZRUL ISLAM** Roll No. **2187** Registration No.**02187** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

PROF. DR. MD. SERAJUL ISLAM BHUIYAN
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DEDICATED TO
MY
BELOVED PARRENTS

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ABSTRACT

In order to study the efficacy of different neem products for the control of jute mites (yellow mite, *Polyphagotarsonemus latus* Banks and red mite, *Tetranychus bioculatus* Wood- Mason), and its effect on predators, several experiments were conducted at laboratory, greenhouse and in the field of Bangladesh Jute Research Institute during the period from March to December 2007. In the greenhouse condition, the highest % mortality (67.37) was observed in the plot treated with 3% neem oil but it had some phytotoxic effect on jute leaves, therefore from the green house experiment, 2% neem oil was selected as most appropriate dose for field experiment as higher dose cause phytotoxicity on plant. In field experiment, highest % reduction of infestation over control (79.23), lowest number of nodes per plant (53.25), highest plant height (3.28 m), and highest % of yield increased (39.33%) over control were observed in the plot treated with 2% neem oil. Benefit cost ratio was also found highest (16.55) from 2% neem oil treated plot. In late jute seed crop, the highest % reduction of infestation by red mite (75.17%) and yellow mite (75.28), maximum 1000 seed weight (2.53 g), % germination (86%) and seed vigour (56) was recorded from 2% neem oil treated plots. It was observed that Acaricide such as Sulphur, Chlorinated hydrocarbon, Organophosphate and Abamectin killed all the predators of jute mites tested while; there is no harmful effect of neem products on predators.

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ACRONYMS

% = Percent

AEZ = Agro-Ecological Zone

BBS = Bangladesh Bureau of Statistics

BJRI = Bangladesh Jute Research Institute

BPH = Brown Plant Hopper

cm = Centimeter

cm^2 = Centimeter Square

CV = Coefficient of Variation

DAS = Days After Sowing

DF = Degree of Freedom

DMRT = Duncan's Multiple Range Test

et al. = And others

g = Gram

GLH = Green Leaf Hopper

Hr = Hour

IPM = Integrated Pest Management

JAES = Jute Agriculture Experimental Station

Kg = Kilogram

L = Liter

LC_{50} = = Median Lethal Concentration

LD_{50} = Median Lethal Dose

LSD = Least Significant Difference

m = Meter

ml = Milliliter

NLP = Neem Leaf Powder

No. = Number

NSKE = Neem Seed Kernel Extract

NSO = Neem Seed Oil

°C = Degree Celsius

RCBD = Randomized Complete Block Design

SCA = Seed Certification Agency

WBHP = White Backed Plant Hopper

WP = Wettable Powder

ISTA= International Seed Testing Agency

NC= Neem Cake

RH= Relative Humidity

DAT = Days After Treatment

INTRODUCTION

INTRODUCTION

Jute (*Corchorus capsularis* L. and *Corchorus olitorius* L.) is the most important cash crop and one of the major foreign currency earners of Bangladesh. It is cultivated for bast of phloem fibre. Jute fibre is extensively used all over the world for its versatility, durability and fineness. It is used for the production of newsprint paper, carpet, hessians, gunny bags, ropes, juton etc. Now a days, jute sticks are used in making partex. Nevertheless, our agricultural community is dependent to a large extent on jute and jute products.

Jute is mostly grown in the Indo-Bangladesh region and in some countries of Southeast Asia. It has been reported that about 90% of world's jute is produced in Bangladesh and India (Atwal 1976). In respect to the production, Bangladesh ranks second among the jute growing countries of the world. The land and climatic conditions of Bangladesh are congenial for the production of high quality jute. In Bangladesh, about 4.72 lac hectares of land are under jute cultivation and the total yield is 821000 m.ton (BBS 2006). 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).

Jute is liable to damage by various insect and mite pests at all growth stages. All parts of the plants including flowers and seed pods are subjected to attack,

leading to reduce yield and lessen quality of fibre. It was reported that about 40 species of insects and mites are considered to be the pests of jute in Bangladesh (Kabir 1975). Among them, yellow mite, *Polyphagotarsonemus latus* (Banks) and red mite, *Tetranychus bioculatus* (Wood–Mason) are the most common and destructive.

The yellow mite of jute is commonly known as "yellow tea mite", a very destructive pest and cause damage to both fibre and seed crops. The damage is often termed as 'Telenga' or 'Telchita' disease in Bangladesh. It appears at the end of April but more active in mid May (Kabir 1975). Generally, they suck the sap from the apical leaves of the plants, as a result, the young leaves crinkle and curl down, color changes to copper or purplish, finally dry up and fall down (Siddique and Kabir 1979) . Due to the attack of this pest, the vertical growth of the internodes is suppressed thereby side branches are enhanced (Kabir 1975). Moreover, they attack flower buds, thus, flowers can not bloom properly, and infested pods fail to form seeds (Kabir 1975). Both yield and quantity of fibre are reduced due to the attack of this pest. It was reported that about 38% of fibre yield is decreased by the attack of yellow mite under field condition (Anon. 1990).

The red mite has a very wide range of host plants. It appears on jute in the month of July and populations reached at the maximum level during mid August as many as 816 to 986 mites per leaf (Kabir 1975). The red mite mainly attacks the

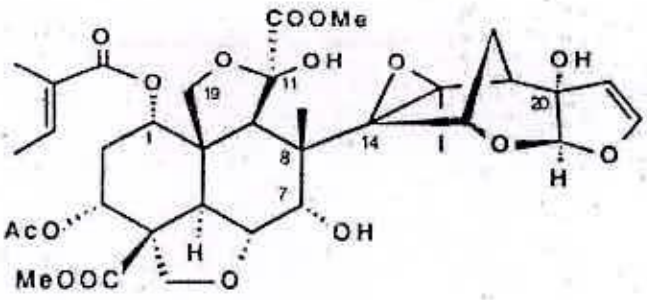
older leaves and they also attacks apical leaves. Severely infested leaves are turned into yellow then dropped off (Kabir 1975).

Generally, mite pests are controlled by chemical acaricides. The non-judicious use of synthetic chemicals for the control of mite pests creates several problems in agro-ecosystem, such as direct toxicity to beneficial insects, fishes and human (Goodland *et al.* 1985, Pimentel 1981, Munakata 1977) gain resistance to chemicals (Schmutterer *et al.* 1983, Waiss and Chen 1981, Georghiou and Taylor 1977, Brown 1968, Fukuda 1966) out breaks of secondary pests (Hagen and Franz 1973), health hazarads (Bhaduri *et al.* 1989), environmental pollution (Fishwick 1988, Kavadia 1986,), susceptibility of crop plants to insect pests (Pimentel 1977) and increases environmental and social cost (Pimentel *et al.*, 1980). In general, chemical control of pests by different pesticides is a very health hazardous, costly and they kill not only the pests but also their parasite, predators and create imbalance in environment. Therefore, scientist's in the world are being are trying to find out suitable eco-friendly pest control measures.

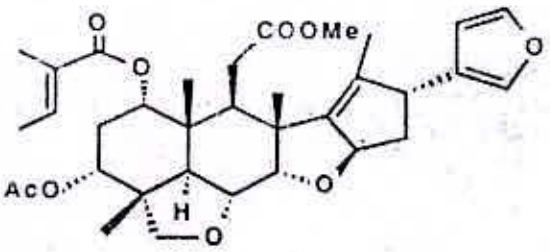
To minimize the use of synthetic chemicals in mite control programmes, alternative or biodegradable substitutes are now strongly felt in many developed countries. The biologically active natural plant products can play a significant role in this regard. These products may help to keep the drawbacks of conventional methods within bounds. An appreciable amount of works has been carried out by different researchers in the world and found that natural plant

products are environment friendly, less health hazardous, less expensive, biodegradable and readily available. The costs of production of indigenous plant products are likely to be less than that of chemical insecticides (Saxena *et al.* 1980).

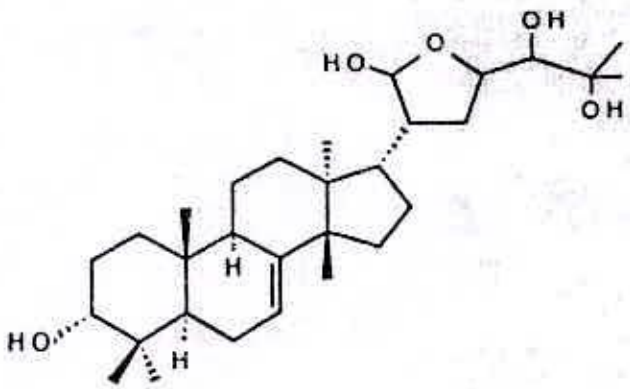
Naturally occurring feeding deterrents or antifeedants decrease pest infestation in the field crops and in the storage. A number of researchers have isolated and identified several chemical compounds from leaves and seeds of numerous plants and screened out for insect feeding deterrents and growth inhibitors (Jurd and Manners 1980, Menn 1980, Carpenter 1979, Warthen 1979, Bernays and Chapman 1977, Jacobson *et al.* 1975). Among them, neem tree (*Azadirachta indica* A. Juss) contains several promising pest control substances. These substances are short lived in the environment, as they are broken down rapidly in the presence of light and air and found to be very effective in many economically important pests. Neem affects more than 200 insect pest species belonging to the orders Coleoptera, Diptera, Heteroptera, Homoptera, Hymenoptera, Lepidoptera, Orthoptera and also some species of mites (Schmutterer 1992). The major ingredients of neem are: (a) Azadirachtin (b) Salannin (c) Meliantriol (d) Nimbin and (e) Nimbidin. Chemical structure of main neem ingredients are:



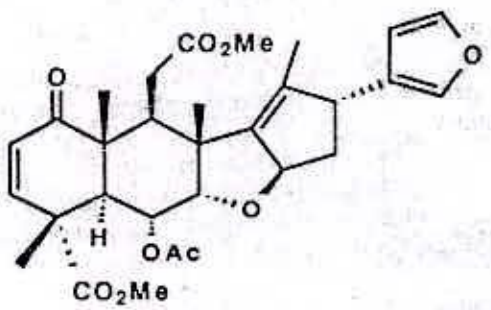
azadirachtin



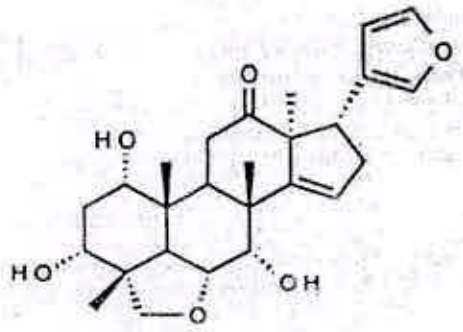
salannin



meliantriol



nimbin



nimbidin

Azadirachtin is the active principle compound and act as a feeding deterrent, repellent, toxicant sterilant and growth disrupter for insects and mites. It also acts principally as an insect ecdysis inhibitor (Saxena 1989). Products derived from the seeds of neem tree, including azadirachtin and neem oil, are more selective and have low mammalian toxicity. The interferences of the azadirachtin is too insects specific endocrine control system, which is so different from the mammalian system that no toxic effect have been found even after application of gram amounts of azadirachtin per kilogram of body weight

Neem seed kernel extracts containing azadirachtin, salanin and meliontrial have extensively been studied and demonstrated the pest control efficacy against several insect pests (Haque and Islam 1988, Heyde *et al.* 1983, Mariappan and saxena 1983, Saxena *et al.* 1981a). Its biological efficiency has been proved against a number of agricultural pests since more than 20 years (Ostermann 1983). The potential antifeedant and growth regulating effects of azadirachtin and crude neem oil have been reported in several rice insect pests (Heyde *et al.*

1983, Saxena *et al.* 1981b). However, utilization of neem oil for the control of jute pests is very scanty (Schmutterer 1984). It should be pointed out that some works have been carried out by Pest Management Division of Bangladesh Jute Research Institute (BJRI), Dhaka, Bangladesh to control jute yellow mite by neem. Only green neem leaf extract @ 1:20 has been found to be suitable giving about 60% mortality control. However, there is no report available to control of red mite by using natural plant products in Bangladesh. The present study was, therefore, designed to investigate the use of neem products for the control of jute mites (*Polyphagotarsonemous latus* and *Tetranychus bioculatus*) with the following objectives:

I. To study the effectiveness of different neem extracts/ products on jute mites.

II. Evaluation of the effect of neem products on the natural enemies of jute mites.

III. Determination of the economic doses of neem products; and

IV. Proper suggestion for suitable dose(s) of neem products for farmer's to control jute mites.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In the world, the botanical pesticides have now been recognized as potential pest control measures. Several species of insect pests both in the field as well as in the storage have been reported to be controlled by the application of neem oil a potential source of antifeedant and inhibitor. Works with the neem and other plant based pesticides or their derivative for the control of jute mites in Bangladesh is very scanty. Literatures cited below reveal some information about the use of different plant extract in Bangladesh and other countries against important insect pests and mites.

2.1 Use of different plant extracts for controlling mite pest.

Banu *et al.* (2007) conducted an experiment to compare some non-chemical approaches to control jute yellow mite and jute hairy caterpillar in greenhouse and field condition during 2004-2006. In greenhouse condition, double spray of green neem leaf extract @ 1:20 and dry neem leaf @ 1:50 was found to be effective and gave 74.63% and 70.83% mortality 72 h after treatment on potted plants. However, in field condition, double spray of green neem leaf extract and dry neem leaf extract gave 67.70 % and 72.20% reduction of infestation 7^{th} day after spray. The fibre yield was also increased by 19.9% (880.1 kg/acre) for green leaf extract and 35.9% (892.1 kg/acre) for dry neem leaf over the control

treatment, respectively. In addition, hand picking method was found to be effective, easiest, economic and eco-friendly.

Banu *et al.* (2007) studied the effect of neem leaf extracts (dry and green) in green house and field condition during the period from 2003-05 against jute yellow mite. Dry neem leaf @ 1:50 and green neem leaf @ 1:20 gave 62% and 64% mortality, respectively. Fibre yield was increased by 39.95% and 35.93% over the control treatment.

Pasini *et al.* (2003) studied the effect of a commercially formulated neem oil (Azadirachtin) at different stages of the life cycle of the red mite of Paragua tea. They found that formulation was efficient in controlling adults. Azadirachtin also affected the fecundity of the female mites.

Palaniswamy and Ragini (2000) sprayed 5% aqueous extracts of *Adathoda vasica, Vitex neegundo, Azodirachta indica, Aristolochia bracteata, Lippia nodiflora, Argemone mexicana sansevieria* sp. and *Aloe* sp. on chillies 30 days after transplanting in Tamil Nadu, India. The *Polyphagotarsonemus latus* populations were reduced and *Aloe* sp. were also recorded to be the lowest.

Sanguanpong and Schmutterer (1992) found that pentane extract and cold pressed neem oil reduced the fecundity of the mites on treated plants and the survival of nymph hatched from treated eggs. Application of pentane extract or

neem oil in sub lethal concentration caused growth disrupting effects on the nymphal stages and ovicidal effects.

Pande *et al.* (1987) reported that neem leaf extract (1%) and neem seed kernel (5%) was very effective against *Tetranychus neocaledonicus* and *Tetranychus urticae* respectively. This result was also supported by Devraj (1990).

2.2 Use of different plant extracts for controlling other insect pests

Doolittle *et al.* (2007) tested the effect of some natural products on gut microbes in Farmosan subterranean termite (*Coptotermes formosanus*). They used three natural products (neem extract, capsaicin and gleditschia) to reduce the number of Formosan subterranean termite (FST) hindgut microbes (*Pseudotrichonympha grassii*, *Spirotrichonympha leidyi* and *Holomastigotoides hartmanni)* and found neem extract was capable of reducing the population of *Pseudotrichonympha grassii* and spirochaetes.

Singh (2006) tested the efficacy of some spices and plant products on the incidence of rice gundhi bug, *Leptocorisa* spp. (Alydidae: Hemiptera). He found neem oil, neem seed kernel and neem seed kernel powder were effective to protect the rice crop by reducing bug population as per conventional insecticide treatment.

Prabhat Kumar and Poehiling (2006) studied persistence of soil and foliar azadirachtin (neem based product) treatments to control sweet potato whitefly *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) on tomatoes under controlled (laboratory) and field (netted greenhouse) conditions in the humid tropics. Two commercial neem products, NeemAzalReg.-T/S (1% azadirachtin) and NeemAzalReg.-U (17% azadirachtin) were used. Foliar application, under room conditions at dose-rates of 7 and 10 ml NeemAzalReg.-T/S, induced an immature mortality of 32 and 44%, respectively. Systemic application by soil drenching with solutions of 3.0 g NeemAzalReg.-U until 7 day, immature mortality declined from 88% for the first day to almost half (45%) by day-7 in the GH, and from 90% on first day to 64% by day-7 under laboratory condition. Similar response trends for *B. tabaci* were obtained for other parameters such as adult colonization, egg deposition, and egg hatch.

Abdullah *et al.* (2006) evaluated neem cake, Nembicidine, neem leaf powder and Bishkatali (*Polygonum hydropiper*) plant powder and tobacco plant powder against some major insect pests of sugarcane. They found that all botanical products reduced larval population and infestation caused by top shoot borers (*Scirpophaga excerptalis*), stem borer (*Chilo tumidicostatis*) and rootstock borer (*Emmalocera depressella*[*Polyocha depressella*]).

Gonzalez-Gomez *et al.* (2006) conducted an experiment to evaluate the acute toxicity of crude neem seed extract and neem based commercial product (0, 1, 2,

3 and 4%) on Varroa destructor (Aceri: Varroidae) and *Apis mellifera* and repellence of varroa mites. They found neem based products had a persistent repellency effect that lasted approximately 48 h.

Islam *et al.* (2006) studied the effect of neem oil and neem leaf extract on mortality, growth and food consumption of jute hairy caterpillar, *Spilarctia obliqua* (Walker) in the laboratory of Department of Entomology, Bangladesh Jute Research Institute, during April to August 2005. To evaluate the efficacy of neem products on the larval mortality, third, fourth and fifth instar larvae were allowed to feed on jute leaves treated with neem extract (1:20) and neem oil at 0.5, 1.0, 2.5 and 5.0% emulsified with 0.1% Nikalin. Their mortality was recorded at different days after treatment. Larval mortality was greater at the higher two concentrations (2.5 and 5.0%) of neem products at each instar. Neem leaf extract (1:20) and lower concentrations (0.5 and 1.0%) of neem oil, also markedly reduced the survival of the larvae as compared to control treatment. The median lethal dose (LD_{50}) of neem oil against different larval varied with exposure time and it was the lowest at 14 days after treatment applied against all larval instars.

Islam (2006) conducted the experiment on the exploration of plant materials extracts for the control of jute yellow mite, *Polyphagotarsonemus latus* (Banks) was conducted at the Department of Entomology, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka, during the period from May to August,

2005. The treatments were green neem leaf extract (1:10), green neem leaf extract (1:20), neem oil 1%, neem oil 0.5%, onion bulb extract (1:10), onion bulb extract (1:20), green mahua leaf extract (1:10), green mahua leaf extract (1:20), green nayantara leaf extract (1:10), green nayantara leaf extract (1:20), green karabi leaf extract (1:10), green karabi leaf extract (1:20) and untreated control. Neem oil was emulsified at 0.5 & 1.0% with 0.1% Nikalin. The minimum number of yellow mite was observed in T_3 (neem oil at 1%) during all stages of the plant and it reduced the height percent of mite population over control. Neem oil (1%) significantly reduced the population of yellow mite, increased plant height and numbers of leaves per plant and decreased the number of increased leaves and nodes per plant.

Jagjeet *et al.* (2005) treated pigeon pea seeds with 11 seed protectants, i.e. neem seed kernel powder at 20 g, neem oil at 10 ml, mustard oil and groundnut oil each at 7.5 ml, turmeric powder at 3.5 g, mustard oil + turmeric powder at 3.7 ml + 1.75 g, groundnut oil + turmeric powder at 3.7 ml + 1.75 g each per kg of seed. All the seed protectants, expect sawdust and turmeric powder, recorded significantly higher adult mortality than the control after the first day of treatment. Neem oil was found most effective (64.33% adult mortality) up to 35 DAT and it were followed by mustard oil + turmeric powder, giving 16.33% adult mortality.

Zhu *et al.* (2004) studied the biological activity of azadirachtin on rice stem borer, *Chilo suppressalis*. After feeding on water oats treated with 0.75 and 0.50 mg azadirachtin/litre, the third instar larvae had completely died after 3 and 6 days, respectively. Mortality of the newly hatched *C. suppressalis* reached 100% within 24 h after treatment.

Manju and David (2004) studied the effect of soil and foliar application of neem products on densities of egg masses of the yellow stem borer, *Scirpophaga incertulas* infesting rice, and on the extent of egg parasitism by *Telenomus dignus* and *Tetrastichus scoenobil.* NPK fertilizers and organophorphate insecticides were included for comparison. The egg masses were higher in NPK plots ($2.16/m^2$) than in neem cake plots ($1.10/m^2$), whereas parasitism was higher on plants sprayed with neem products + fish oil rosin soap (26.28%) in neem cake plots than on plants with no plant protection in NPK plots (20.92%).

Prasad *et al.* (2004) evaluated neem products against yellow stem borer, *Scirpophaga incertulas* on deep water rice and found significantly better than the untreated control. Neemgold Liquid at 2.0% was the most effective neem product and was at par with the standard insecticide, as it recorded very low damage percentage (1.4, 1.6 and 3.8%) and higher yield (13.86, 11.89 and 24.24 q/ha) in 1995, 1996 and 1997, respectively.

Mudathir and Basedow (2004) conducted an experiment to study the effect of neem products on pests and yields of okra (*Abelmoschus exculentus*), tomato (*Lycopersicum esculentum*) and onion (*Allium cepa*) in the Sudan. In okra, the neem preparations were significantly reduced the attack of the 4 pests studied i.e. *Aphis gossypii*, *Bemisia tabaci*, *Earias vittella* and *Podagrica puncticollis*, in 1998. In tomato, *Lirimyza trifolii* was significantly reduced by both neem preparations, while *A. gossypii* and *B. tabaci* were controlled only by NKWE and Neemazal, respectively. However, there was no effect of neem preparations on pest and yield of onion.

Maisary and Rahawi (2004) conducted an experiment to examine the effect of neem oil on the 2^{nd} and 4^{th} instars and eggs of *Culex pipiens* under laboratory condition. They observed that 46.98% of *C. pipiens* were killed upon exposure to 1000 ppm of neem oil. However, the lower concentration (10 ppm, 100 ppm) showed little efficiency on the eggs. The continuous treatment of the 2^{nd} and 4^{th} instars with neem oil (100 ppm) caused high mortality and complete inhibition of the formation of mature instars. Based on these results, they concluded exposure to neem oil for a short period (24 and 48 h) is less effective as compared with continuous.

Dayal *et al.* (2003) carried out an experiment to evaluate the efficacy of some botanicals as protectants against *Sitophilus oryzae* infesting stored rice. The treatments were mentha oil (0.5 ml/kg), clove oil (0.5 ml/kg), salt (1.0 ml/kg),

mustard oil (1.0 ml/kg), tulsi seed oil (0.5 ml/kg), turmeric powder (1.0 g/kg), mercury tablet (0.25 tablet/kg), DDVP [dichlorvos] (0.05 ml/kg; encapsulated), camphor (0.5 g/kg) and control. Based on the cumulative percent mortality of adults, all treatment showed significantly superior over the untreated control.

Neerja and Saroj (2003) studied the efficacy of fresh neem oil in controlling *A. proxima* on Indian mustard. Mustard leaves were dipped in fresh neem oil at 2, 1, 0.5, 0.25 and 0.125% and fed to the larvae. Mortality was observed after 24 h of exposure. They observed that pupation and adult emergence was decreased with increasing neem oil concentration. Minimum pupation was observed with 2% neem oil.

Pasini *et al.* (2003) showed that the 2% formulation of neem oil was efficient in controlling the adults of red mite of Paraguay tea. Azadirachtin also affected the fecundity of the female mites.

Ogemah *et al.* (2003) observed that neem seed oil at high doses caused more than 80% mortality compared with 4% in the control. Insect population increase was completely inhibited by the doses of more than 7.5 ml/kg (Approx. 22.5 mg azadirachtin /kg maize) of neem oil. Neem oil caused promising larval mortality in their early developmental stages within the grains.

Rahman *et al.* (2003) conducted an experiment to evaluated five indigenous plant seed oils viz. Castor, Neem, Pithraj, Safflower and Sesame at concentration of 1, 2, 3, 4 and 5%. They found that all the plant seed oils have grain protectant value against lesser meal worm, *A. diaperinus*. The results also showed that sesame and neem oil were more effective than Castor, Pithraj and Safflower oils. However, the tested seed oils provided good protection for wheat grains.

Gupta (2003) examined the efficacy of neem products viz., neem kernel extract in water or cow urine, neem leaf extract in cow urine and neem oil in controlling the major pests (*Antigastra catalaunalis* and *Dasineura seasami*) of sesame cv. Fower. The capsule damage was the lowest with the application of neem oil and endosulfan, respectively. Application of neem oil resulted lowest bud and flower damage (13.3%) and highest grain yield (6.55 kg/ha) gave net profit (Rs. 2633/ha).

Jyothi and Sannaveerappanavar (2003) conducted an experiment on contact toxicity of aqueous neem seed kernel extract and neem seed oil emulsion to egg, larval, pupal and adult stages of *Chellomenes sexmaculata* (Fabricius) (Coleoptera: Coccinellidae) under laboratoryt condition. Neem oil emulsion at 2 and 4% and NSKE at 2 and 4% significantly affected the egg hatching (80.0, 75.0 and 82.5%, respectively) compared to the control (95.0%). Aqueous NSKE at 4% was relatively more toxic (22.0% mortality) to the 3rd instar larvae.

Eungwijarupanga *et al.* (2002) tested neem extracts containing 0.185% azadirachtin at 3 concentrations 100 ml, 200 ml and 300 ml, diluted in 5 litres of water. These were applied using a thermal fogger to a 15 years old teak (*Tectona grandis*) for control of teak defoliator, *Hybiaea puera*. After application larvae were collected and reared in the laboratory to observed mortality. One day after fogging mortality started to increase for these treated with 200 ml and 300 ml/5L concentrations and all larvae died within 6 days when treated with 300 ml/5L.

Padmashecla and Delvi (2002) tested a commercial formulation of neem oil (Nimbex, 0.3%) at different concentration viz. 25 ppm, 50 ppm, 75 ppm and 100 ppm for mortality effects against grubs of *O. rhinoceros* (a coconut pest) at laboratory conditions. In feeding toxicity test, neem oil at concentrations of 50 ppm, 75 ppm and 100 ppm caused 20%, 45% and 90% mortality, respectively on exposure up to 96th day/100 ppm caused 90.67% mortality.

Malinowaki (2002) studied the activity of azadirachtin @10 g/litre against 3rd instar *Neodiprion serlifen* larvae, using aqueous emulsion at four different azadirachtin concentration (0.01%, 0.001%, 0.0001% and 0.00001%) larvae were fed with treated pine twigs for 3 days and then reared on untreated foliage until pupation. Mortality was significantly increased up to 100%, even at the lowest concentration of azadirachtin (0.00001%).

Qureshi *et al.* (2002) investigated the direct effect of neem extracts on the adult glass beetle, *Costelytra zealandica.* Laboratory bioassay showed that neem caused only low mortality even at the highest dose.

Karmakar and Bhole (2001) observed the efficacy and persistent toxicity of some neem products neem oil and Nimbicidine against adult of *Epilachna dodecastigma*. The treatments of 2% neem oil and 2% Nimbicidine resulted 90.69% and 71.90% mortality, respectively.

Imtiaz *et al.* (2001) studied the effects of neem leaf extracts on adult rice weevil, *Sitophilus oryze*. Glass film method was adopted to determine the LC_{50} rate. After plotting a graph between mortality and concentration, the LC_{50} was found to be 0.44 µg/sq. cm.

Shaminathan and Jayaraj (2001) conducted two experiments to evaluated botanical pesticides like Ipomoea and vitavex, leaf extracts, neem oil and madhuca oil (at 0.3% or 3.0% each) against *Perrisia virgata.* The leaf dip method was used in both experiments and pest mortality was recorded at 24th, 48th and 72th after treatments. In experiment 1, treatments with 3% neem oil recorded the highest mortality (43.13%). Neem resulted 50% mortality at 72th and in experiment 2, at 48 h fortified (0.3%) neem oil recorded a maximum mortality of 49.3% and at 72 h, fortified neem recorded 63.6% mortality.

Arcos *et al.* (2001) evaluated the effect of different concentration (0.2, 1, 1.5, 2 and 3%) of neem oil on *I. marginipennis*. Mortality recorded by ingestion was attributed to starvation.

The effect of neem (*Azadirachta indica*) oil at 0.25, 0.5 and 1.5% on larvae of *Epilachna vigintioctopunctata* was investigated by Shanmugapriyan and Kingsly (2001). The effects of quinalphos (0.025%) and monocrotophos (0.025%) were also determined for comparison. Neem oil at 1.5% gave the highest mortality of 2^{nd} and 3^{rd} instars (95.23%) and 4^{th} instars (76.19%). Neem oil at 0.25 and 0.5% concentrations resulted in 57.1 and 85.75% mortality in 2^{nd} instars, 47.6 and 85.7% in 3^{rd} instars and 57.1 and 80.9% in 4^{th} instars. Monocrotophos and qunalphos resulted in 95.24% larval mortality.

Rani *et al.* (2000) investigated the efficacy of cotton seed, neem, palm, rice bran and soybean oils as seed coating against pulse beetle, *Callosobruchus chinensis* infesting Chickpea and found that neem oil at 1 ml/kg of seeds gave the promising adult mortality (65%) 3 days after treatment.

Ranjana *et al.* (2000) tested five plant extracts from *Azadirachta indica* kernels, *Allium sativum* bulbs, *Citrus sinensis* rech, *Citrus limm* peels and *Mangifera indica* leaves each having three concentration (1%, 1.5% and 2%) against pulse beetle, *C. maculantus*. The petroleum extraction of neem kernel was most

effective at concentration of 1.5% and 2% level showed 50% and 61.11% mortality, respectively.

Menhajul (1999) observed that the effect of neem oil on the 3rd, 4th and 5th instar larvae of Jute hairy caterpillar. He found 30% to 100% larval mortality up to 10% concentration of neem oil.

Sharma (1999) reported that neem seed (*Azadirachta indica*), kernel powder (NSKP) at 4% and neem leaf powder (NLP) at 5% protected maize for 5 months against *Sitophilus oryzae*, *Sitotroga cerealella*, *Rhyzopertha dominica* and *Trogoderma granarium*. Neem oil (Nembicidine, 2%) effectively reduced the emergence of F_1 and F_2 progeny of all the pests and completely protected maize up to 9 months and suggested that neem products can be mixed with stored maize to protect the grains up to 9 months the attack of these major pests.

Reddy *et al.* (1999) stated that application of four plant neem oil (Azadirachtin), karanja oil (*Pongamia glubra*), Mahua oil (*(Madhuca lalifolia*) and palmolein oil (*Elaeis gaineenis*) at dosages of 0.5% and 1.0% level effectively protector green gram from *C. chinensis*. Neem oil at 1% level was the best protector followed by Palmolein, Karanja and Mahua oils. These oils also exhibited contact toxicity and no adults could survive in neem treated green gram at 5% concentration.

Tabassum *et al.* (1999) reported that the toxicity of neem compound (Nfc and NC) and an insect growth regulator dimilin (diflubenzuron) were determined against adult of the pulse beetle, *Callosobruchus analis* using filter paper impregnation and glass film method. The LC_{50} values of Nfc, NC and dimilin were 39.20 $\mu m/cm^2$, 7.17$\mu m/cm^2$ and 13.5 $\mu m/cm^2$ respectively, using the filter paper impregnation method, while 10.0 $\mu m/cm^2$ and 4.9 $\mu m/cm^2$, respectively, for NC and dimilin using the glass film method.

Mahapatro and Umakanda (1998) found that the green leaf hopper (*Nephotettix virescens*) population can be better managed by integrating neem derivatives (neem oil and neem seed extract 0.2% along with 0.1% teepol) at 20 and 70 days after transplanting (DAT) with chemicals such as monocrotophos (0.4 kg a.i./ha) as an intermediate spray at 40 DAT.

Sudipta and Sanjib (1998) reported that larvae of rice moth, *Corcyra cephalonica* were maintained in neem oil (Azadirachtin, 0.03%) absorbed crushed jowar grains in four doses (0.25, 0.5., 0.75 and 1.0 ml; each dose in 20g of food), with an initial population of 50 newly hatched larvae/ 100 g of neem absorbed food in each replication. Deformed adults with a prolonged period of development were obtained. Growth inhibition, development distribution and mortality increased markedly with increased doses.

Mayabini (1997) studied the efficacy of neem bark decoction, neem based chemicals and neem derivatives (neem oil, leaf extract and leaf decoction) against rice folder *Cnaphalocrosis medinalis*. All were applied as foliar sprays to pot-grown rice plants. Leaf area fed by the larvae was recorded after 48 h. Neem bark decoction appeared to be a very effective botanicals for controlling the rate of feeding and reducing the rate of population.

Naganagouda *et al.* (1997) conducted a field study to determine the efficacy of various insecticides and neem products for the control of *Nilaparvata lugens*, *Sogatella furcifera*, *Cnaphalocrosis medinalis* and *Scirpophaga incertulas* on rice. Monocrotophos was the most effective insecticide in terms of giving the highest yield followed by neem oil and nembicidin.

Deka and Hazarika (1997) observed that neem (*Azadirachta indica*) seed oil (NSO) acted as a potential antifeedant against adult of the chrysomelid, *Dicladispa armigera*. Under laboratory conditions, daily consumption of fresh rice larvae was 1.05 g, 0.08 mg which was reduced by 50% when leaves were treated with 6.46% NSO.

Jeyakumar and Uthamasamy (1997) carried out an experiment in the laboratory to study the efficiency of some botanicals against *Liriomyza trifoli* on cotton. Application of some botanicals insecticides such as neem oil (3%) and neem seed kernel extract (5%) resulted higher larval mortality. Whereas *Pongamia*

pinnata oil (3%), neem oil (2%), neem seed kernel extract (2.5%) were found least effective.

Hiremath *et al.* (1997) tested methanol extracts of 84 samples of 49 Indian plant species for insecticidal activities against *Nilaparvata lugens* by topical application method at a dose of 0.5 µg/female. The identified significant and toxic plants species were *Adahota vasica* leaves (100% mortality), *Annanosa squamosa* seeds (100%), *Nerium indicum* stem (100%), *Clerodendrum inerme* whole plant (90%), *Azadirachta indica* seeds (89%), *Azadirachta indica stem* (85%), *Aegel marmelos* leaves (88%) and *Madhuca indica* seed oil (88%).

Raguraman and Rajasekaran (1997) stated the effect of neem oil and neem seed bitters applied at different concentrations as either high volume, low volume or ultra volume sprays to the rice brown plants hopper, *Nilaparavata lugens*. All neem products affected the orientation, probing and feeding time, food ingested and growth and development of *N. lugens*.

Lowery *et al.* (1996) reported that neem *(Azadirachta indica*) seed oil (NSO) added to meridic diet at concentration as low as 0.0016% NSO reduced the firness of *C. rosaceana* resulting in longer developmental times, lower adult emergence rates and reduced egg production compared with controls. Pupation was completely inhibited at concentration of 0.25 and 1.0% for larvae exposed in the 5^{th} or 6^{th} instar, respectively; rates as low as 0.016% reduced pupal weights

and elution rates. For larvae transferred to treated diet in the 5th instar, physical abnormalities in the wings of adults occurred at a rate of 0.004% NSO and increased with increasing treatment rates.

Aktharuzzaman (1996) were tested four concentrations of neem oil viz. 1.0, 2.0, 4.0 and 8.0% by leaf spraying method allowing 5th instar larvae of *Spilosoma oblique* to feed on treated food for 48 h. The percent reduction of food consumption at 1.0, 2.0, 4.0 and 8.0% were 41.92, 46.22, 51.29 and 55.63% in 46 h and 47.16, 49.72, 56.56 and 67.48% in 48 h. growth inhibition indicated by mortality was 100% at the 4.0% and 8.0% concentration of neem oil.

In a laboratory study Haque *et al.* (1996) found that when 1st and 3rd instars larvae and adult of *Epilachna dodecastigma* were exposed to 0.25, 0.50, 1.0 or 2.0% neem (*Azadirachta indica*) oil applied on brinjal leaf discs, all the 1st instar larvae were killed at the concentrations before feeding and the feeding activity of 3rd instar larvae and adults decreased with increasing oil concentration.

Singh *et al.* (1996) reported that *A. indica, Lantana camara* and *Vitex negundo* were the most effective to adult mortality of *R. dominica* on wheat.

Behera and Satapathy (1996) evaluated 7 plant materials viz. *Azadirachta indica Armona reticulate, Dutura anoxia, Callophyllum inophyllum, P. pinnata, Calotropis gigantean, Thevetia peruviana.* They found that aqueous extract of

neem seed kernel was the most effective causing 100% mortality of *Spodoptera litura* at 10 days after treatment among other 6 indigenous plant extract.

Nauman and Islam (1995) found that applications of 3 concentrations of neem seed extracts to cabbage plates in cages did not deter oviposition by individuals of 3 species of noctuid months, *Trichoplusia ni*, *Peridroma saucia* and *Spodoptera litura*. They found that 1% crude oil emulsion significantly reduced the proportion of eggs laid by *S. litura* on treated plants.

Lowery *et al.* (1994) reported that application of neem seed oil effectively controlled several of aphids infesting plants both in laboratory and field. Neem seed oil (NSO) was equally deterrent to 1st and 3rd instar nymphs and adult strawberry aphids, *Chactosiphon fragaefolii* (Cockerell). Concentration on NSO resulting in 50% feeding deterrence was approximately 1.1% for this species.

Barman (1993) observed antifeedant effects of azadirachtin in nymphal tawny mole crickets, *Scapteriscus vicinus* Scudder, in laboratory tests. Crickets surviving treatments grow more slowly and tunneled less than their untreated counterparts.

Dey and Sarup (1993) tested eight vegetables oils viz. mustard, soybean, coconut, neem, groundnut, cotton, sesame and castor at 5 doses against adults,

Sitophilus oryzae in three varieties of stored maize in India and showed that highest weevil mortality was on 24 hrs day after treatment.

Azmi *et al.* (1993) observed in laboratory studies that the toxicity of a compound containing 10% cyfluthrin (Slofac) and a neem formulation containing crude extract from fruits of *Azadirachta indica* against *S. orzae*. The tests were carried out by releasing the curculionids on filter papers treated with different concentration of the compounds. A mortality rate of 90% was obtained with 0.5% concentration of cyfluthrin and 1% concentration of the neem compound.

An experiment was conducted by Durairaj and Venugopal (1993) at National Pulses Research Centre, India with several extracts of neem and *V. negundo* for their effectiveness to compared with that of malathion, against *Leptocorisa acuta* on rice in the field, resulted reduction in pest incidence of 86.2% (0.5% Malathion), 82.8% (0.5% neem bark), 69.0% (2.0 neem oil), 50.7% and 38.0% (2.5% and 5.0% *V. negundo* leaf extract, respectively) and 39.0% (5.0% neem seed kernel extract).

Islam (1993) studied the efficacy of azadirachtin, the major active ingredient in neem, as a feeding deterrent for six species of noctuids of economics importance; the black armyworm, *Actebia fennica* Tansch, bertha armyworm, *Manestra configweata* Walker, variegated cutworm, *Peridroma sancia* Hubner, Zebra caterpillar, *Melancra picta* Harr, Asian armyworm, *S. litura* Fab. And the

cabbage looper, *Trichoplusia ni* Hubner. Fourth instar larvae of *S. litura* was the most sensitive to the antifeedant effects of azadirachtin whereas *A. fennica* was the least.

Matter *et al.* (1993) tested oil from *A. indica, M. azadirach, Cymbopogon citrates* and *Geranium* in the laboratory to evaluate their effect on *Coccinella undecimpunctata* and *Aphis gossypii, Geranium* sp. Neem oil was more repellent to *A. gossypii* than the others for antifeedant.

Nesseh *et al.* (1993) tested the repellent effect of neem oil on adults of *Schistocerca gregaria.* They found that *S. gregraria* consumed 100% of the leaves of the untreated plant, while the adults started feeding on treated plant after 24 h of the application.

Freisewinkel (1993) found the contact effects of neem oil topically sprayed on 3rd instar nymph of *Locusta migratoria migratorioides.* In parallel experiment neem oil was applied directly to the abdomen of the nymphs. The effectiveness of neem oil given orally was tested by feeding larvae at the beginning of the 3rd instar with maize leaves treated with neem oil. The mortality in feeding experiments was much higher than in spraying or direct application experiments. Treated locusts showed prolonged nymphal development and reduced increase in weight.

Nicol (1993) studies the effects the neem seed oil in 3rd instar nymphs of *Schistocerca gregraria*. In cages which were sprayed with neem oil, the locust showed higher mortality rates, delayed nymphal development and morphogenetic effects of antennae, eyes and wings.

Venkateswarlu *et al.* (1993) studied the effect of neem oil (0.1, 0.25, 0.50, 1.0 and 1.25%) on growth and development of *Lipaphis erysimi* in laboratories. At concentration of 1.0, 1.25 and 1.50% all the nymphs reared on treated Indian mustard leaves diet before reaching the adult stages. At the lower concentration nymphal survival, fecundity and growth index of the aphid decreased with increased development period.

Rao *et al.* (1993) tested, Neemark, Biosol, Repelin and neem oil at 0.5-3.0% against larvae of *Spodoptera litura* in the laboratory. Repellency, anifeedant activity and developmental period increased with increase in concentration of all pesticides. Adult's emergence, growth, survival, larval and pupal weight, number of eggs laid and hatchability of eggs decreased with increase in concentration. Neem oil had the greatest effect followed by Neemark, Biosol and Repelin.

Solsoloy and Embuido (1992) evaluated neem oil for its insecticidal action on cotton bollworm, *Helicoverpa armigera* Hubner. The oil applied along sprayed

on cotton and the effects were compared. Neem oil sprayed on cotton gave poor control of the pest.

Becker *et al.* (1992) observed that natural insecticides, neem contains the active chemical azadirachtin, which disrupt the hormonal changes in *Bemisia tabaci* causing death during moulting.

In laboratory experiments Schmutterer (1992) applied concentration of 10 and 20 ppm/litre of azadirachtin, of an azadirachtin-free fraction and of 100 ppm/litre or an enriched, formulated seed kernel extract of *A. indica*, against the 5^{th} larval of *Pieries brassicae*. Application of neem products against young (1^{st}–3^{rd}) larval instar of *P. brassica*, which may be typical under practical conditions, led to the death of the caterpillars.

Freisewinkel and Schmutterer (1991) showed that the topical application of neem extract at 0.25 to 1.0 ml/m^2 to the 5 nymphal instars of the gregarious phase of *Locusta migratoria migratorioides* led to increased mortality during moults, prolonged development and reduced fitness. Morphogenetic effects were observed on the legs, wings and antennae. A reduction in weight corresponded to reduced feeding activity. Color changes and supernumerary moults suggested tendencies towards soliterization. The earlier the nymphs treated and the higher the amounts applied the more distinct the effects.

Salem (1991a) tested pure neem seed oil against the cotton bollworms, *Pectinophora gossypiella* saund and *Earias insulana* Boisd. The most active concentration caused reduction in the percentage of infestation nearest to 150 ppm. The percentage of infestation decreased with the increase of neem seed oil concentrations.

Salem (1991b) found that larval mortality ranged between 14.28% to 78.57% and the percent of eggs hatching ranged between 57.5% and 89.4%, when different concentration from neem seed oil extract were tested against the potato tuber moth, *Phthorimaea operculella* Zell and also stated that 100 ppm concentration of neem oil extract was the most effective extract against larval feeding of potato tuber moth, *Phthorimaea operculella* Zell.

Loke *et al.* (1990) evaluated six concentrations (1.25, 2.25, 5, 10, 20 and 40%) of neem oil in acetone, for contact toxicity against 2nd and 3rd larval instars of *Plutella xylostella* L. significant mortalities of both larval stages were observed with neem oil concentration of 10 percent and above. Although the lower concentration of neem oil appeared to be sublethal with regard to contact toxicity effect, physiological and growth disruptive effects, such as retardation of growth (prolonged), delayed adult emergence and abnormal adults but the effects were more pronounced in the younger instar. Subsequent treatment of pupae and adults of *P. xylostella* with neem oil concentrations of 1.25, 2.25, 5 and 10% showed that pupae were not affected by the concentrations tested. However,

male and female adult moths treated with 2.5% and higher concentrations of neem oil had significantly higher mortalities in 48 h and shorter longevities than the adults in control.

Mishra *et al.* (1990) reported that feed brinjal leaves treated with 0.025 and 0.05% neem oil to *Epilachna vigintioctopunctata* increased the duration of life stages in the subsequent generation.

Karel (1989) evaluated various formulations of neem extracts under field condition to examine the effects on foliar beetle, *Ootheca bennigseni* Weise, a serious pest of beans and other legumes. At concentrations of 2 and 4%, neem formulations from seed kernels deterred *O. bennigseni*, from feeding on bean leaves. None of the neem formulations protected bean plots completely. In green house studies, 1.0% aqueous leaf and kernel extracts were highly active as an antifeedant against *O. bennigseni*, which consumed little or none of the leaves. In free choice experiments, bean seedlings treated with 1 and 2% neem seed kernel extracts were well protected.

Kareem and Durairaj (1987) showed that extracts of Neem Seed Kernel (NSK) when evaluated at field, 4% NSK significantly reduced Green Leaf Hopper (GLH), Brown Plant Hopper (BPH) and White Backed Plant Hopper (WBPH) population and Leaf Folder (LF) damage. This crude water extract caused greater BPH and LF feeding inhibitor and WBPH nymphal emergence.

Solsoloy and Solsoloy (1987) stated that cottons bolls treated with 2% neem oil emulsified with 1% surfactant inhibited the feeding of even starved larvae of cotton bollworm. The amount of frass they excreted was significantly lower than the control which was sprayed with acetone. Similarly, the larvae were relatively lighter and smaller. These results showed the antifeedant effect of the oil.

Unchalle (1987) observed the efficacy of neem oil on rice leaf hopper, *Nephoteti virscens*. The repellent property of neem oil was found to increase along with the increasing oils concentration. Neem oil at 7% concentration and above was observed to reduce the population density to treated 3rd instar nymphs of green leaf hopper to more than 50%. Twenty five percent neem oil was found to decrease mortality of female green leafhopper to lower than 50% after 6 days of spraying.

Kareem and Durairaj (1987) evaluated crude extracts of neem seed kernel (NSK) and neem cake (NC) in water and neem oil (NO) emulsion along with two synthetic insecticides in fields as foliar sprays for the control of major insect pests of rice. NSK 4% significantly reduced green leaf hopper (GLH), Brown Plant Hopper (BPH) and White Backed Plant Hopper (WBPH) populations and leaf folder (LF) damages in two fields trials proving either as per with or next in efficacy to fethion and phosphamidon spraying.

Saxena (1987) reported that neem seed derivatives were promising against sucking insects the green leaf hopper, *N. virescens* Distant, the brown plant hopper, *Nilaparvata luigens* Stal, the white backed plant hopper, *Sogatella fercifera* Horvath and the rice bug, *L. oratorius* Fbricus and foliage feeders the rice leaf folder, *C. medinalis* Guenee, the ear cutting caterpillar *Mythima separate* Walker and the rice army worm, *S. maurita acronynctoides* Boisduval. Insect growths were inhibited on neem treated plants. Contact with or ingestion of neem derivatives disrupted growth of insect pests but emergence of parasite was not affected.

Chiu-Shin–Foon (1987) evaluated the potential of *Azadirachta indica, M toosendan* and *M. azadirach, Tripterygium wilfordii* and *T. hypoglaucum* and regulators, in laboratory and field experiments. Fifth instar *Pieris rapae* larvae topically treated with 20% neem oil at 2 micro litre/larvae developed properly and died after population. In field trials, spray application of a 0.3% neem seed extract of commercial product (ATZ-VR-K) was effective against *P. rapae* larvae for almost 21 days. The extract was also effective against *Pluella xylostella.* Azadirachtin disrupted the growth of corn borers and other pests.

Saxena and Khan (1986) monitored feeding behavior of *N. virescens* on rice plants kept in an arena permeated with the odour of neem seed oil. The garlicky odour of neem oil disrupted the normal feeding behavior of Cicadellids. Phloem

feeding by *N. virescens* on rice plants kept in an arena permeated with odour of 6, 12 or 25% neem oil was significantly reduced.

Saxena (1985) found that insects fed far les, grew poorly and laid fewer eggs on rice plants treated with the oil, cake, extracts such as azadirachtin and their formulation. Contact with or ingestion of neem seed derivatives with seed oil of clustered apple (*Annona squamosa* L.) was effective in reducing the survival of *N. virescens* and its transmission of grassy and ragged stunt viruses.

Jotwani and Srivastava (1984) reported that antifeeding properties of neem seed kernel suspensions against desert locust, *Schitocerca gregaris* Forsk; Castor hairy caterpillar, *Cuproctis lunata* W., Tobacco caterpillar, *Spodoptera litura* F., Bihar hairy caterpillar, *Utethesia pulchella* L. Grasshoppers, *Acrida exaltata* W. Antifeedant properties of *A. indica*, *M. azadirach*, *M. toosendan* were investigated by Shin-Foon and Zhang (1984) on fifth instar larvae of *S. litura* and were sensitive to neem treated leaf discs in choice tests.

Shin- Foon and Zhang (1984) observed that the leaf discs treated with neem oil was protected more than 97.5% when offered to 5^{th} instar off the fall army worm, *Spodoptera litura* F.

Ladd *et al.* (1984) stated that the application if azadirachtin from seeds of Indian neem tree to larvae of Japanese beetle, *Popilla japonica* Newnam, completely

disrupted subsequent normal development to the adult stages. Calculated LD_{50} and LD_{90} values of topically applied azadirachtin were 0.1 and 0.4 µg/ larvae, respectively. Azadirachtin also increased in duration of immature stages.

Schmutterer *et al.* (1984) investigated that topical application of neem oil on last instars *N. lugens*, *S. furcifera* and *N. virescens* nymphs resulted in their premature death. Seventy seven to 100% mortality of *S. furcifera* was resulted by neem oil.

Islam (1993) revealed that oil neem, extracts of leaves and seeds of *A. indica*, *M. azedirach*, *A. ruhituka* and *A. reticulate* with haxen diethyl ether, 95% ethanol and acetone showed potential as antifeedant or feeding deterrents for the control of brown rice plant hopper (BPH), rice green leaf hopper (RGLH), rice hispa (RH) and lesser rice weevil (LRW). The young seedling of rice sprayed with 8-12% of crude and emulsified neem oil also significantly reduced feeding in brown hopper and green rice leaf hopper. Aqueous and methanol extracts of neem and chinaberry also deterred feeding in adult pulse beetle and early instar larvae of jute hairy caterpillar.

Mariappan and Saxena (1983) reported that custard-apple oil, neem oil and their mixtures were effective in reducing the survival of the green leaf hooper, *N. virescens* distant and its transmission of the rice tungro virus (RTV).

Heyde *et al.* (1983) found that 2 to 4 days exposure of *Sogatella furcifera* to plants treated with 500 ppm of neem seed kernel extracts resulted in 75% mortality where as in the control, mortality was only 5%. On third instar, *N. lugens* nymphs, a combination of foliar and topical application induced higher mortality (75%) than either application alone (30%).

Schmutterer *et al.* (1983) studied the morphogenetic effects of four partially purified fractions of neem seed extracts and two methanolic seed extracts on larvae of rice ear cutting caterpillar, *Mythimna separeta* walker and the rice leaf folder, *C. medinalis* larvae fed for 24 h. On rice leaf cuts dipped in different solution of the partially purified fractions and methanolic extracts exhibited pronounced development abnormalities and mortalities in succeeding larval instars and in pupal and adults stages.

In the laboratory and green house tests, Reed *et al.* (1982) reported that suspension containing low concentrations of azadirachtin and salanin compounds isolated from extracts of neem seeds, (*A. indica*) possessed feeding deterrents against the spotted cucumber beetle, *Acalyma vittatum* F.

Feuerhake *et al.* (1982) dissolved neem seed extract in water by means of emulsifier and these formulations were tested against *Leptinotarsa decemlineata; Pieries brassica* and *Mamestra brassicae*. A concentration of 100

mg/kg was the most effective extract that caused 100% mortality in all the pest species.

Redknap (1981) found various neem suspensions to control the leaf eating larvae of *Epilachna chrysomelina* on cucumber, *Cucumis sativus* and leaf eating flea beetles, *Prodagica niforma* and *P. syastedti* on sorrel, *Hibiscus sabdariffa*. In addition, citrus seedlings sprayed with neem suspension were protected from the larvae of *Papilio demoleous*.

Kareem (1981) observed the neem oil as an antifeedant for certain phytophagous insects and bruchid of pulses. Feeding and gallery formation by *Nephantis serinopa* Meyer. and their larvae were inhibited by 1% neem seed kernel extract. Seed extract had significant antifeedant effect on *Spodoptera litura* F. larvae on sweet potato. A 3% aqueous neem seed kernel extract reduced the damage by *Crocidolomia binotalis* Zell and *Phyllotreta downsii* on radish whereas 2% neem seed kernel powder mixed with seeds of pigeon pea and green gram effectively checked *Callosobruchus chinensis* L. He also reported that 25% mortality in *Plutella xylostella* larvae fed in leaves treated with 3% neem oil. High mortality was induced at higher concentrations.

Saxena *et al.* (1981a) observed that neem oil acted as a potent antifedant for controlling brown plant hopper, *Nilaparvata lugens* both in the laboratory and field when plants were sprayed with 12% neem oil. The quantity of food

ingested/ female/day was significantly reduced. Feeding duration decreased by 0.93 min/h for every 0.1% increase in oil concentration. Later Heyde *et al.* (1983) further confirmed the antifeeding properties of neem oil against *N. lugens*, white backed plant hopper, *Sogatella furicifera* Horvath and rice green leaf hopper, *Nephotettix virescens* Distant. Another observation he found that neem oil caused high mortality of the first instar larvae of *N. lugens*.

Saxena *et al.* (1981b) found that 5th instar larvae of *C. medinalis* treated topically with neem oil or confined on treated rice leaves showed high developmental abnormalities and mortality.

Saxena *et al.* (1980) revealed that food consumption by the larvae of rice leaf roller, *Cnaphalocrosis medinalis* Guenee was significantly reduced when they fed rice leaves sprayed with 12% or higher concentration of crude emulsified neem oil.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiments were carried out in laboratory, greenhouse and in the field during March to December, 2007. The details of different materials used and methodology followed during the experimental period are described below.

3.1 Experimental site:

The research work was carried out at laboratory and Greenhouse premises of BJRI, Dhaka and in the experimental field of Jute Agriculture Experimental Station (JAES), Manikganj.

3.2 Soil:

The experimental area belonging to the Agro-Ecological Zone (AEZ-7) "Active Brahmaputra and Jamuna Floodplain". The soil texture was sandy loam.

3.3 Climate:

The experimental area was under the subtropical climate. Usually the rainfall was heavy during Kharif season and scantly in Rabi season. The atmospheric temperatures increased as the growing period proceeded towards Kharif season. The weather conditions of crop growth period such as monthly mean rainfall (mm), mean temperature (^{0}C), sunshine hours and humidity (%) were collected from weather center of JAES, Manikganj and presented in (Appendix- 1).

3.4 Land preparation:

The land was prepared at 'JOE' condition by deep ploughing and harrowing followed by laddering and leveled properly. The seeds were sown after final preparation of land.

3.5 Experimental design and layout:

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications following the methods described by Gomez and Gomez, (1984).

3.6 Plot size:

The size of the individual plot was 3 m × 2.1 m. The space between plot to plot and line to line was 0.75 m and 0.3 m, respectively.

3.7 Fertilizer Application:

The following fertilizers (As prescribed fertilizer recommendation of Soil science department of BJRI) were used.

Name of the fertilizers	Rate (kg/ha)
Urea	200
TSP	50
MP	60
Gypsum	95
$ZnSO_4$	11

The total amount of TSP, MP, Gypsum, Zinc sulphate and the half of urea were applied at the time of final land preparation. The remaining half of the urea was applied after 45 days of seed sowing.

3.8 Planting materials:

The variety O-9897 of *Corchorus olitorius* L. was used. The seeds were collected from the Breeder Seed Department of BJRI. Before sowing, seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%.

3.9 Pot preparation:

Earthen pots (10'' diameter) were brought from the market and filled with dairy soil and sand.

3.10 Inter cultural operation:

Weeding, mulching and irrigation were done as and when necessary but no plant protection measures were taken.

3.11 The test pests:

Test pests were jute yellow mite, *Polyphagotarsonemus latus* (Order: Acarina Family: Tarsonemidae) and red mite, *Tetranychus bioculatus* (Order: Acarina Family: Tetranychidae).

Plate 1. A view of the field experiment

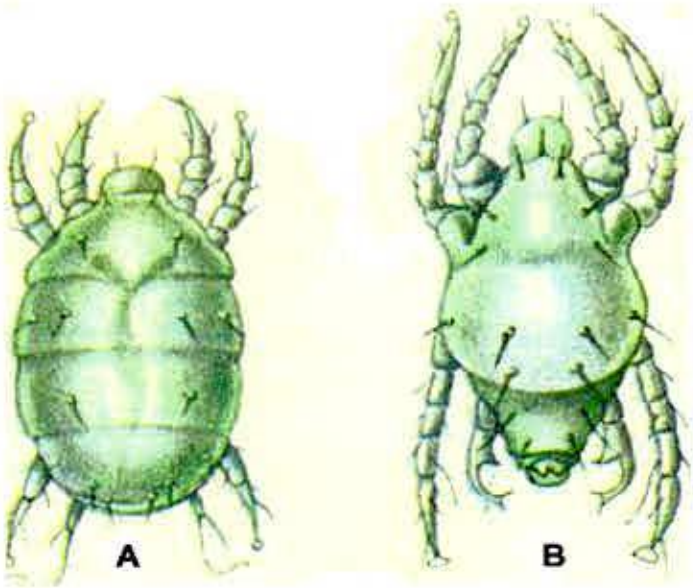


Plate 2. Adult female (A) and male (B) yellow mite

Plate 3. Yellow mite infested plant

Plate 4. Adult red mites

Plate 5. Red mite infested plant

3.12 Details of the treatments:

Effectiveness of different neem products were evaluated against yellow and red mite of jute.

A) Preliminary dose selection (Aqueous and Methanolic extraction) was done as per following treatments:

T_1 = Green neem leaf extract @ 1:10

T_2 = Green neem leaf extract @ 1:20

T_3 = Green neem leaf extract @ 1:30

T_4 = Dry neem leaf extract @ 1:30

T_5 = Dry neem leaf extract @ 1:40

T_6 = Dry neem leaf extract @ 1:50

T_7 = Neem oil 1%

T_8 = Neem oil 2%

T_9 = Neem oil 3%

T_{10} = Neem seed kernel extract @ 1:10

T_{11} = Neem seed kernel extract @ 1:20

T_{12} = Neem seed kernel extract @ 1:30

T_{13} = Nembicidine @ 1.5 ml/lit water

T_{14} = Control

B) Field experiments of both fibre and seed crops were conducted with the following treatments:

T_1 = Green neem leaf extract @ 1:20

T_2 = Dry neem leaf extract @ 1:50

T_3 = Neem oil 2%

T_4 = Neem seed kernel extract @ 1:10

T_5 = Nembicidine @ 1.5 ml/lit water

T_6 = Control (Untreated)

3.13 Extraction and formulation of neem and neem products:

Neem leaves and neem seed kernels were extracted by the following methods:

3.13.1 Aqueous extraction:

Aqueous extraction of neem seed and neem leaves were prepared as described by Zebitz (1986) with few modifications. Ground neem seed kernels or leaves were stirred for 16 h at room temperature. Then solution was filtered twice through linen cloths.

3.13.2 Methanolic extraction:

Methanolic extraction of neem seed kernels and neem leaves were made as described previously (Adhikary, 1984). One part of neem products (leaf, seed) crushed to powder, were mixed with 9X methanol and agitated for 3 hours and then kept undisturbed for 24 hours. The extracts were filtered through Whatman filter paper (no. 1). The methanol was evaporated by using a rotary evaporator at 40^0C. This experiment was conducted to compare the efficacy with aqueous extraction.

3.13.3 Preparation of green neem leaf extract:

Fresh green neem leaves were collected from the campus of BJRI, Dhaka. The collected leaves were washed under running tap water. Air dried fresh 10 g of green leaves were taken into an electric blender with 100 ml of water. After blending, the mixture was filtered through fine cloth and the extracts were considered as 1:10 neem leaf extract. Similarly 1:20 and 1:30 neem leaf extract were prepared by adding 200 ml and 300 ml of water with 10 g of leaves, respectively.

3.13.4 Preparation of dry neem leaf extract:

Green neem leaves were shed dried for 7 days to obtain dry neem leaves. Ten gram of dry neem leaves were soaked in 300 ml of water for over night and the extracts were filtered through fine lilen cloth to get 1:30 dry neem leaf extract. Similarly 1:40 and 1:50 dry neem leaf extract were prepared by adding 400 ml and 500 ml of water with 10 g of leaves, respectively.

3.13.5 Preparation of neem seed extract:

Matured neem fruits were collected from BJRI campus. Neem fruits were deep in water for 48 hours for de-pulping. Then cleaned seeds were dried in air. Ten gram of seeds were crushed and dissolved in 100ml, 200ml and 300ml of water separately for over night to get 1:10, 1:20 and 1:30 of neem seed extract. The suspensions were filtered through lilen cloth.

3.13.6 Preparation of different neem oil concentration:

Neem oil used in this experiment was collected from National Tree Fair, 2006 Sher-e-Bangla Nagar, Dhaka. The concentration of the collected neem oil was 100%. From this stock, a series of concentrations (1, 2 and 3%) were prepared (eg. for 1% neem oil , 99 parts water + 1 part oil) with adding required amount of distilled water. The emulsion of neem oil in water were prepared by adding 1% liquid Nikalin detergent (emulsifier) as described by Mariappan and Saxena (1983).

Plate 6. Green neem leaf

Plate 7. Green neem leaf extract

Plate 8. Dry neem leaf extract

Plate 9. Neem seed kernel

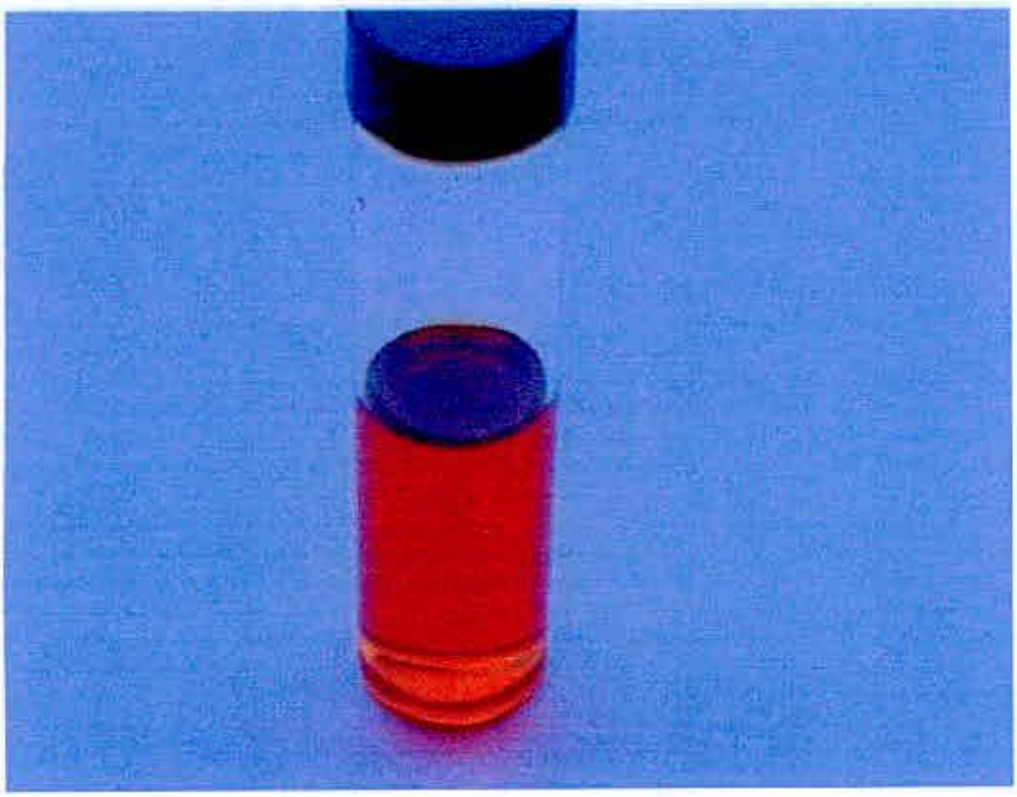


Plate 10. Neem oil

3.13.7 Nembicidine:

The commercial botanical pesticide "Nembicidine" was collected from National Tree Fair, Sher-e-Bangla Nagor, Dhaka. It contains 0.3% azadirachtin. One percent nembicidine was prepared by mixing 1 ml of nembicidine with 99 ml of distilled water.

3.14 Natural enemies of jute mites:

There are five natural enemies of jute mites such as *Orious insidiosus*, *Amblyseius longispinosus*, *Stethorus* sp., *Adelphocoris* sp., *Scolothrips* sp. (Iftekher 2006). The effects of plant materials on survival of natural enemies of jute mites was carried out following the methods described by Flavia *et al.* (2004) in the laboratory of Entomology Department of BJRI at temperature 30± 2^0 C and 70± 10% RH.

Adult predators were collected from the jute field of Central station, BJRI and JAES, Manikganj. Jute leaves containing individual predators were placed in separate glass petridishes. Then aqueous extraction of neem products and an acaricide, Kumulus 80WP were sprayed. Control petridish was treated with water only. Mortality counts were recorded under binocular microscope after 24, 48 and 72 hours of treatments.

Plate 11. Jute leaves containing predators

3.15 Experimental details:

3.15.1 At greenhouse premises :

Greenhouse experiment was conducted to determine the optimum dose for field experiment with Aqueous extraction of neem and neem products . When sufficient infestations of yellow mite infestation were built up in all the pots, then extracts of green neem leaves, dry neem leaves, neem seed kernel were sprayed on the infested plants. Each treatment was replicated four times. Yellow mite population were recorded by examining the leaf samples under binocular microscope before spray and at 24, 48 and 72 hrs. after spray for calculating % mortality. 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

Similarly Methanolic extraction of green neem leaves, dry neem leaves, neem seed kernel were evaluated against on yellow mite.

3.15.2 In field:

The efficacy of neem (aqueous extraction) products were evaluated at JAES. After sufficient natural infestations built up in all the plots, green neem leaf, dry neem leaf, neem seed kernel extracts, emulsified concentration of neem oil and along with bio pesticide, nembicidine were sprayed on the infested plots with a

repetition of 2nd spray after 20 days of 1st spray. The control plots were kept untreated and each treatment was replicated 4 times. Number of infested plants were recorded before spray and at 7th day after spray for calculation of % reduction of infestation over control.

Percent reduction was calculated as per following formula:

$$\% \text{ Reduction} = \frac{\text{No. of infested plants in control plot} - \text{No. of infested plants in treated plot}}{\text{No. of infested plants in control plot}} \times 100$$

3.15.3 Seed crop:

Aqueous extraction of different neem products were sprayed on late jute seed crop plots at JAES, Manikganj. The percent reduction of yellow and red mite was calculated with the above mentioned formula.

3.15.4 Seed quality:

Seeds collected from healthy and infested plants were assessed in the laboratory for determining moisture content, % germination, vigour, and 1000 seed weight.

3.15.4.1 Moisture test

Moisture content was determined by using grain moisture meter (Model no. 303 RS) in the Agronomy laboratory of BJRI according to standard procedure.

3.15.4.2 Germination test

Germination test was done according to ISTA rules (ISTA, 1996). Germination percentage was calculated using the following formula.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

3.15.4.3 Vigour test:

The level of seed vigour was tested by using the formula described by Jain and Saha (1971). During the progress of germination the protrusion of the radical up to 1 cm was recorded from the germinating seeds in the following tabular form:

Acc. No.	Number of germination seeds				
	1st day (a)	2nd day (b)	3rd day (c)	4th day (d)	Total S_1

The vigour value of the accession or seed samples may be calculated from the same table:

Calculation of vigour value and its interpretation:

$$\text{Vigour value (\%)} = \frac{(\ a/1 + b/2 + c/3 + d/4\ ) \times 100}{S_1}$$

Where a, b, c and d are seeds germination after 1, 2, 3 and 4 days from the start of the germination and S_1 is the total number of seeds germinated before critical seedling evaluation.

Plate 12 . Germinated jute seeds on blotter paper

3.15.4.4 Thousand seed weight:

Thousand seeds were counted randomly and measured in an electric balance (Model- PC-180). Thousand seed weight was also calculated at specific moisture content (SCA testing manual).

$$1000 \text{ seed weight} = \frac{\text{Weight of 1000 seeds} \times (100 \times \text{moisture content at counting})}{100 - \text{weight at which moisture content is required}}$$

3.16 Statistical analysis:

The data were statistically analyzed to obtain the level of significance using the MSTAT software for analysis of variance developed by Russel (1986). The treatment means were separated by Duncan's Multiple Range Test (DMRT).

3.17 Benefit Cost Ratio (BCR):

Benefit Cost Ratio (BCR) was calculated by adopting the following formula:

$$\text{BCR} = \frac{\text{Value of the yield save by pest control}}{\text{Value of cost of pest control}}$$

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Effect of aqueous extraction of different neem products on jute yellow mite.

Experiments were conducted to study the effect of different concentrations of neem products such as neem oil, green neem leaf extract, dry neem leaf extract and extract of neem seed karnel on percent mortality of yellow mite in green house condition. Results are shown in Table 1. Among the three different concentrations of neem oil viz. 1%, 2% and 3%, the highest percent mortality (67.37%) was recorded in 3% neem oil followed by 2% neem oil (63.87%) at 72 hours after treatment. However, these treatments were found to be equally significant. It is worthy to note that 3% neem oil showed phytotoxic effect to jute leaves. Therefore, the 3% neem oil was not used for the subsequent field trial. Similar phytotoxic effect was reported by Anonymous (1984). From the three doses of neem seed kernel extract, the highest percent mortality (59.95%) was recorded in neem seed kernel extract @ 1:10 followed by 1:20 (56.06%) and 1:30 (53.85%), respectively. In case of green neem leaf extract, the highest percent mortality (56.87%) was recorded at the dose 1:20 followed by 1:10 (55.28%) and 1:30 (54.60%) respectively. Dry neem leaf extract @ 1:50 provided the highest mortality (51.73%) followed by 1:40 (50.12%). The lowest percent mortality (45.74%) was observed in dry neem leaf extract @ 1:30. It was reported that pentane extract and cold pressed neem oil reduced the fecundity of mites and survival of nymph hatched from treated eggs and thus, reduced the mite population Sanguanpong and Schmutterer (1992). Accordingly, Pande *et al.*

(1987) reported 1% neem leaf extract and 5% neem seed kernel which were very much effective against *Tetranychus neocaledonicus* and *Tetranychus urticae*.

Based on the above findings, 2% neem oil, neem seed kernel extract @ 1:10, green neem leaf extract @ 1:20 and dry neem leaf extract @ 1:50 were selected for field trial.

4.2 Effect of methanolic extraction of different neem products on yellow mite.

This experiment was conducted to study the efficacy of different concentrations of neem products on percent mortality over control of yellow mite on potted plants. Results are given in Table 2. Green neem leaf extract @ 1:20 showed the highest mortality (62.53%) which was significantly different from other two concentrations (1:30; 1:10). On the other hand, from the three different concentrations of dry neem leaf extracts, the highest mortality (58.63%) was recorded in 1:50 followed by 1:40 (57.51%) and 1:30 (55.13%). Among the three different doses of neem seed kernel extract, the highest mortality (67.13%) was recorded in 1:10, which was significantly different from the other two concentrations (1:20 and 1:30).

Moreover, methanolic extractions were applied to compare the efficacy of aqueous extraction of various neem products. The methanolic extraction was found to be effective than aqueous extraction (data not shown). It would be wise to mention here that methanolic extraction is costly, time consuming, and the procedure is not easy to farmers, therefore, it was not selected for field trial.

Table 1: Effect of neem products (aqueous extraction) on % mortality of jute yellow mite under green house condition

Treatment	No. of mite/sq. cm leaf before treatment	% Mortality over control at		
		24 hrs	48 hrs	72 hrs
T_1	81	51.72 bcd	53.52 bcd	55.28 bcd
T_2	78	51.05 bcd	52.96 bcd	56.87 bc
T_3	83	52.93 bcd	54.17 bc	54.60 bcd
T_4	69	43.26 e	44.75 d	45.74 d
T_5	75	45.93 de	48.03 cd	50.12 cd
T_6	85	48.78 cde	51.03 bcd	51.73 cd
T_7	80	54.80 bc	58.66 b	58.56 abc
T_8	81	56.16 bc	59.44 ab	63.87 ab
T_9	78	63.75 a	67.35 a	67.37 a
T_{10}	73	56.97 ab	58.90 b	59.95 abc
T_{11}	83	53.96 bc	56.85 bc	56.06 bc
T_{12}	67	51.38 bcd	52.15 bcd	53.85 cd
T_{13}	77	-	-	-
LSD (0.05)	-	6.82	7.9	8.53
% CV	-	9.02	10.03	10.55

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:10, T_2 = Green neem leaf extract @ 1:20, T_3 = Green neem leaf extract @ 1:30, T_4 = Dry neem leaf extract @ 1:30, T_5 = Dry neem leaf extract @ 1:40, T_6 = Dry neem leaf extract @ 1:50, T_7 = 1% Neem oil, T_8 = 2% Neem oil, T_9 = 3% Neem oil, T_{10} = Neem seed kernel extract @ 1:10, T_{11} = Neem seed kernel extract @ 1:20, T_{12} = Neem seed kernel extract @ 1:30, T_{13} = Control (untreated).

Table 2: Effect of neem products (methanolic extraction) on % mortality of jute yellow mite under green house condition

Treatment	No. of mite/ sq.cm leaf before treatment	% Mortality over control at		
		24 hrs	48 hrs	72 hrs
T_1	69	48.90 d	51.26 c	55.47 d
T_2	75	54.85 bc	58.63 b	62.53 b
T_3	80	50.37 cd	55.89 bc	57.56 cd
T_4	69	47.75 d	52.43 bc	55.13 d
T_5	81	51.53 bcd	54.56 bc	57.51 cd
T_6	83	52.80 bcd	55.59 bc	58.63 bcd
T_7	75	60.25 a	65.63 a	67.13 a
T_8	78	56.67 ab	57.28 bc	60.50 bc
T_9	72	50.27 cd	52.98 bc	54.85 d
T_{10}	77	-	-	-
LSD (0.05)		4.84	5.84	4.51
% CV		6.31	7.15	5.26

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:10
T_2 = Green neem leaf extract @ 1:20
T_3 = Green neem leaf extract @ 1:30
T_4 = Dry neem leaf extract @ 1:30
T_5 = Dry neem leaf extract @ 1:40
T_6 = Dry neem leaf extract @ 1:50
T_7 = Neem seed kernel extract @ 1:10
T_8 = Neem seed kernel extract @ 1:20
T_9 = Neem seed kernel extract @ 1:30
T_{10} = Control (untreated)

4.3 Effect of neem products on yellow mite (1st spray) under field condition.

The effect of different neem product on percent reduction over control of plant infestation by yellow mite was determined in the field. Results of Table 3 indicated that after 1st spray, all neem products reduced considerable amount of plant infestation. The highest reduction of plant infestation was 70.26% recorded in 2% neem oil treated plots followed by nembicidine (65.36%) and neem seed kernel extract (64.61%) treated plots. The lowest plant infestation reduction 53.98% was recorded in dry neem leaf extract, followed by green neem leaf extract (57.37%) having no significantly difference between them. The results indicated that neem oil, nembicidine and neem seed kernel extract were most effective, while green neem leaf extract and dry neem leaf extract were moderately effective against jute yellow mite. Recently, Banu *et al.* (2007) reported that green leaf extract and dry neem leaf extract reducing yellow mite infestation over control in jute. It has also been reported that neem products were controlled various insect pests (Pasini *et al.* 2003, Karmakar and Bhole, 2001, Kareem and Durairaj, 1987, Naganagouda *et al.* 1987).

4.4 Effect of neem product on yellow mite (2nd spray) under field condition.

After 2nd spray in the field (20 days after 1st spray) the effect of different neem products of percent reduction of plant infestation over control was studied and results are shown in Table 4. It was found that all neem products reduced remarkable amount of plant infestation significantly over control. The highest reduction of plant infestation (79.23%) was recorded from 2% neem oil followed

by nembicidine (75.45%) and neem seed kernel extract (73.22%) treated plot, which were statistically similar. Green neem leaf extract treated plots provided 60.99% reduction, followed by dry neen leaf extract (58.86% reduction). These results indicated that 2% neem oil, nembicidine and neem seed kernel extract were most effective followed by Green neem leaf extract and dry neem leaf extract, respectively. Islam (2006) showed 1% neem oil and green neem leaf at the dose 1:20 is very much effective for reducing mite population in jute.

4.5 Effect of different neem products on internodes of jute plant.

The effect of different neem products on number of nodes per plant at three growth stages of jute plant are presented in (Table 5). At early stage, the lowest number of nodes/plant (20.25) was recorded in T_3 (Neem oil 2%) followed by 21.25 (T_5) and 23.25 (T_4) which were statistically similar but significantly different from other treatment. The untreated control, T_6 (35.25) had the highest number of nodes per plant, which was significantly different from other treatments. At the middle stage, the lowest number of nodes per plant 34.75 was recorded from treatment (T_3) neem oil 2%, followed by 36.50 (T_5)and 38.50 (T_4) which were statistically similar but different from other treatment. The highest number (77.25) of nodes per plant was observed in untreated control (T_6), which was significantly different from other treatments.

Table 3: Effect of neem product on % reduction of yellow mite in field condition (First spray) over control

Treatment	Average no. of mite infested plant/plot before spray	No. of mite infested plant after 7days of spray	% reduction over control
T_1	91.75	33.00	57.37b
T_2	85.50	37.00	53.98b
T_3	87.00	25.00	70.26a
T_4	100.00	29.75	64.61ab
T_5	56.25	29.00	65.36ab
T_6	87.00	83.75	00
LSD (0.05)	-	-	11.87
% CV	-	-	12.36

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

Table 4: Effect of neem product on % reduction of yellow mite in field condition (2nd spray) over control

Treatment	No. of mite infested plant/plot before spray	No. of mite infested plant after 7 days of spray	% reduction over control
T_1	50.00	23.75	60.99bc
T_2	46.75	27.50	58.86c
T_3	46.75	15.50	79.23a
T_4	38.25	21.25	73.22abc
T_5	52.50	19.25	75.46ab
T_6	82.50	79.75	00
LSD (0.05)	-	-	15.14
% CV	-	-	14.13

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (Untreated).

Table 5: Effect of neem products on number of nodes of jute plant

Treatment	No. of nodes at		
	Early stage (35 DAS)	Middle stage (80 DAS)	Late stage (120 DAS)
T_1	25.25c	47.25b	61.50b
T_2	28.50b	48.25b	65.50b
T_3	20.25e	34.75c	53.25c
T_4	23.25cd	38.50c	57.25c
T_5	21.25de	36.50c	55.00c
T_6	35.25a	77.25a	94.50a
LSD (0.05)	2.76	4.23	4.13
% CV	9.03	5.96	4.25

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

On the other hand, the late stage of plant, the lowest 53.23 number of nodes per plant was recorded in treatment T_3 (2% neem oil) which was statistically similar to 55.00 (T_5) and 57.25 (T_4). The highest 94.50 number of nodes per plant was observed in treatment T_6 (untreated control), which was significantly different from other treatments. The results indicate that neem oil (2%) was most effective followed by nembicidine, neem seed kernel extract, green neem leaf extract and dry neem leaf extract. It was also clear that neem products showed the better performance on reducing the number of nodes per plant at all stages of jute plant growth than untreated control plant. It should be noted that severe infestation of mite on jute plant causes defoliation, stunting of plant growth, increased the number of nodes per plant (Plate 13) and decreased the fibre quality. Because application of neem products reduced mite infestation and increased plant height that decreased the number of nodes with in an unit area. The effect of neem products in the present study was in accordance with the findings observed by Pande *et al.* (1987) and Devraj (1990). They found that, neem leaf extract 1% and neem seed kernel extract at 5% were effective against mites. So the effectiveness of neem products against mites proved promising in the present study. Therefore neem products can be used for the control of yellow mite on jute.

Plate 13: Severely infested jute plant showing short internodes and increased number of nodes

4.6 Effect of neem products on plant height.

The effect of different neem products on height of jute is presented in Table 6. At the time of harvest, the highest plant height 3.28 m. was recorded in the treatment 2% neem oil followed by nembicidine (3.14 m), neem seed kernel extract (3.05 m) and green neem leaf extract (2.99 m), respectively. These are statistically similar. The lowest plant height was recorded from untreated control plot which was significantly lower than all other treatments treated plots. The above results indicate that neem products had significant effect on increasing height of jute plant.

Mite infestation causes growth stunting and finally reduces the plant height. Application of neem products decreased mite infestation and ultimately increased plant height. Therefore, neem products were reduced yellow mite infestation are increased plant height. The effect of neem oil on increasing plant height as observed in the present study was in conformity with finding reported by Palaniswamy and Ragini (2000) against yellow mite on chili. They observed that 5% aqueous extract of neem leaf reduced mite population on chili and increased height.

4.7 Effect of neem products on fibre yield of jute.

Effect of neem products on yellow mite has influence on yield of jute fibre. The plot treated with 2% neem oil, 39.33% yield was increased over untreated control as shown in Table 7. The lowest (19.85%) fibre yield was recorded from

dry neem leaf extract treated plots, which were significantly different from other treatment. Nembicidine and neem seed kernel extract significantly increased fibre yield by 34.59% and 33.02%, respectively over control having no significant difference between them. The results indicate that neem products performed increased fibre yield over control. Similar findings were reported by Banu *et al.* (2007). They reported that the use of green neem leaf extract and dry neem leaf extract against yellow mite gave increased yield over control.

4.8 Benefit Cost Ratio.

Economic analysis revealed that the highest benefit cost ratio 16.55 was obtained from the T_3 (neem oil 2%) treatment followed by T_4 (neem seed extract), T_1 (green neem leaf extract @1:20) and T_2 (Dry neem leaf extract @1:10) giving 15.77, 13.43 and 11.70, respectively. The lowest benefit cost ratio (10.74) was found in T_5 (nembicidine). Detailed results are given in Table 8.

Price :

Jute fibre =18tk/kg; Nembicidine = 600tk/lit; Neem oil = 300tk/lit;

Neem seed = 50tk/kg ; Labour cost =120tk/labour/day

Table 6: Effect of neem products on plant height

Treatment	Plant height (m.)
T_1	2.99 ab
T_2	2.69 bc
T_3	3.28 a
T_4	3.05 ab
T_5	3.14 ab
T_6	2.50 c
LSD (0.05)	0.44
% CV	10.84

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

Table 7: Effect of neem product on fibre yield

Treatment	Yield (t/ha)	% Increase yield over control
T_1	2.41	22.79c
T_2	2.36	19.85d
T_3	2.74	39.33a
T_4	2.61	33.02b
T_5	2.65	34.59b
T_6	1.97	00
LSD (0.05)	-	2.717
% CV	-	5.89

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

Table 8: Effect of neem product on the fibre yield of jute and Benefit Cost Ratio (BCR)

Treatment	Dose/ha	Yield (t/ha)	Increase yield over control	Value of yield saved by pest control (Tk)	Value of cost for pest control (Tk)	Gross margin (Tk)	BCR
T_1	1:20	2.41	0.45	8055	600	7455	13.43
T_2	1:50	2.36	0.39	7020	600	6420	11.70
T_3	2 L	2.74	0.77	13905	840	13065	16.55
T_4	10 kg	2.61	0.65	11673	740	10933	15.77
T_5	1.5 L	2.65	0.68	12240	1140	11100	10.74
T_6	0	1.97	00	00	00	00	00

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

Cost of pest control/ha. :

T_1 (Green neem leaf 1:20) = Labour- 5 (preparation + double spray of green neem leaf) = Tk 600.00

T_2 (Dry neem leaf 1:50) = Labour- 5 (preparation + double spray of dry neem leaf) = Tk 600.00

T_3 (Neem oil 2%) = Neem oil(2 lit.) + 2 labour = 600/- + 240/- = Tk 840.00

T_4 (Neem seed extract 1:10) = Neem seed (10 kg)+ 2 labour =500/- + 240/- = Tk 740.00

T_5 (Nembicidine) = Nembicidine (1.5 lit.) + 2 labour = 900/- + 240/- = Tk 1140.00

T_6 (Control) = Tk 00.00

4.9 Effect of neem products on red mite of late jute seed crop.

Effect of neem products on percent plant infestation by red mite on late jute seed production shown in Table 9. Percent reduction of plant infestation over control was achieved by all neem products. The highest reduction of plant infestation (75.17%) was recorded in 2% neem oil treated plots followed by nembicidine (70.50%) and neem seed kernel extract (69.09%) treated plots which were statistically similar. Green neem leaf extract and dry neem leaf extract also significantly reduced plant infestation by 59.91% and 57.78%, respectively over control having no significant difference between them.

Table 9: Effect of neem product on % reduction of red mite in late jute seed crop

Treatment	No. of mite infested plant/plot before spray	No. of mite infested plant after 7days of spray	% reduction over control
T_1	74.25	22.50	59.91bc
T_2	74.25	30.00	57.78c
T_3	75.75	16.00	75.17a
T_4	74.00	20.25	69.09ab
T_5	73.75	19.25	70.50a
T_6	75.75	65.50	00
LSD (0.05)	-	-	9.822
% CV	-	-	9.59

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated).

Plate 14. Red mite infested late jute seed plants

The results indicate that neem oil (2%), nembicidine and neem seed kernel extract were most effective, followed by green neem leaf extract and dry neem leaf extract against red mite in late jute seed production. Pasini *et al.* (2003) reported the efficacy of neem oil against red mite on paragua tea.

4.10 Effect of neem products on yellow mite of late jute seed crop.

The Table 10 shows the effect of different neem product on percent plant infestation by yellow mite in late jute seed crops. Neem oil (2%) provided the highest (75.28%) percent reduction of plant infestation over control, followed by nembicidine (70.22%) and neem seed karnel extract (68.39%), which were statistically similar but significantly different from other treatments. The lowest plant infestation reduction (56.06%) was recorded from dry neem leaf extract followed by green neem leaf extract 1:20 (58.40%), where there was no significant difference between them. The results indicate that neem oil, nembicidine, neem seed kernel extracts were most effective followed by green neem leaf extract and dry neem leaf extract against yellow mite of late jute seed production.

Table 10: Effect of neem product on % reduction of yellow mite in seed crop over control

Treatment	No. of mite infested plant/plot before spray	No. of mite infested plant after 7 days of spray	% reduction over control
T_1	54	16.50	58.40bc
T_2	54	16.25	56.06c
T_3	51.75	10.25	75.28a
T_4	49.75	13	68.39ab
T_5	60.25	12.25	70.22a
T_6	48.50	41	00
LSD (0.05)	-	-	10.24
% CV	-	-	10.12

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated).

Plate 15. Yellow mite infested seed crop

Plate 16. Yellow mite free seed crop

4.11 Effect of neem products on survival of adult *Orious insidiosus.*

The Figure 1 shows the effect of different neem products on adult predator *Orious insidiosus*. The highest (88%) percent survival of adult *O. insidiosus* was recorded in green neem leaf extract at 72 hours followed by dry neem leaf extract (85%), neem seed kernel (70%), nembicidine (65%) and neem oil (62%). However, the lowest (3%) adult survival was recorded in kumulus 80 WP (acaricide). In control experiment, the percent survival of adult *O. insidiosus* was 97%. The above results indicate that green leaf extract, dry neem leaf extract, neem seed kernel extract, nembicidine and neem oil were not harmful on adult *O. insidiosus*.

It has been reported that insecticides seriously affected the beneficial insect lady bird beetle population which help to control aphid biologically in the field but was less affected by botanical pesticide (Dutta *et al.* 2003).

4.12 Effect of neem products on survival of *Stethorus* sp.

The effect of different neem products on adult predator *Stethorus* sp. showed that highest percent of survival (90%) was recorded in green neem leaf extract followed by (88%) dry neem leaf extract, (72%) neem seed kernel extract, (71%) nembicidine and (66%) neem oil as shown in Figure 2. The lowest 10% was observed in acaricide (Kumulus 80 WP). In control the adult percent survival was 97%. Banken and Stark (1998) showed that populations of *Coccinella septempunctata* adults sprayed with neemix were not reduced. They claimed that neem products are not harmful.

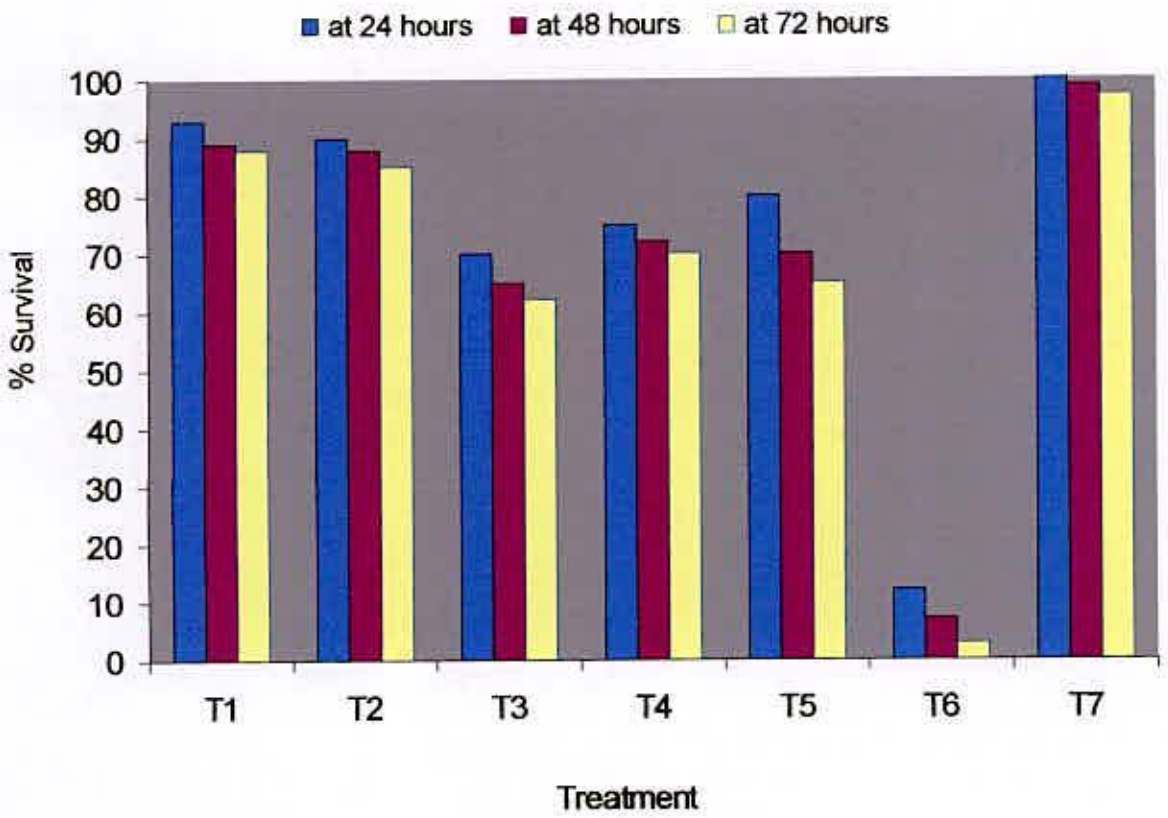


Figure 1: Effect of neem products on survival of *Orious insidiosus*

Plate 17. Adult of Minute pirate bug; *Orious insidiosus*

Plate 18. Nymph of Minute pirate bug, *Orious insidiosus* predating on red mite

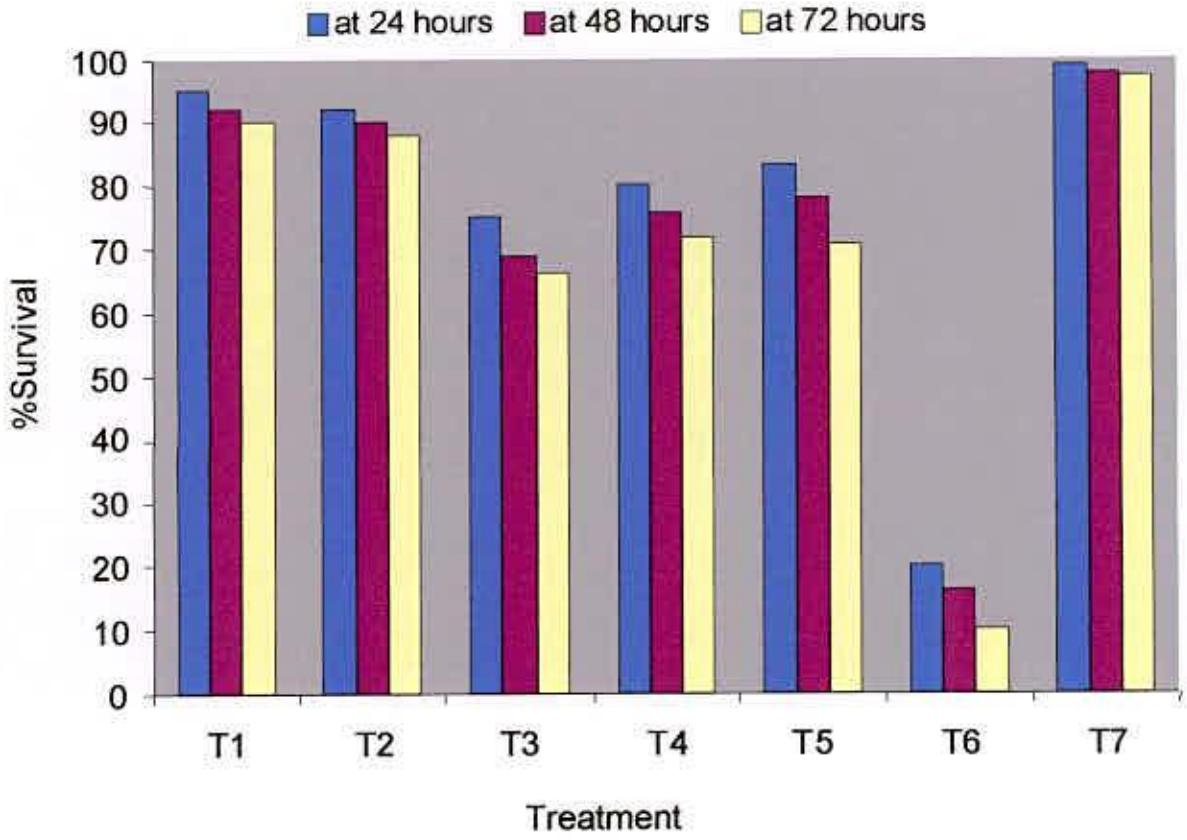


Figure 2: Effect of neem products on survival of *Stethorus* sp.

Plate 19. Adult of *Stethorus* sp.

4.13 Effect of neem products on survival of *Amblyseius longispinosus*.

Comparative effects of neem products and chemical acaricide were presented in Figure 3. The highest percent of adult survival (89%) was in green neem leaf extract followed by dry neem leaf extract (87%), neem seed kernel extract (70%), nembicidine (70%) and neem oil (67%). No adult survival was recorded in the treatment with acaricide (kumulus 80 WP). However, the percent adult survival was 96% in the untreated control. Similar results were also reported by Fernandez *et al.* (1992). They showed that adults of the predator *Cyrtohinus lividipenis* were not reduced when rice plants sprayed with 0.3% neem oil and 5% aqueous extract of seed. This result again proved that neem products are not harmful against natural predator.

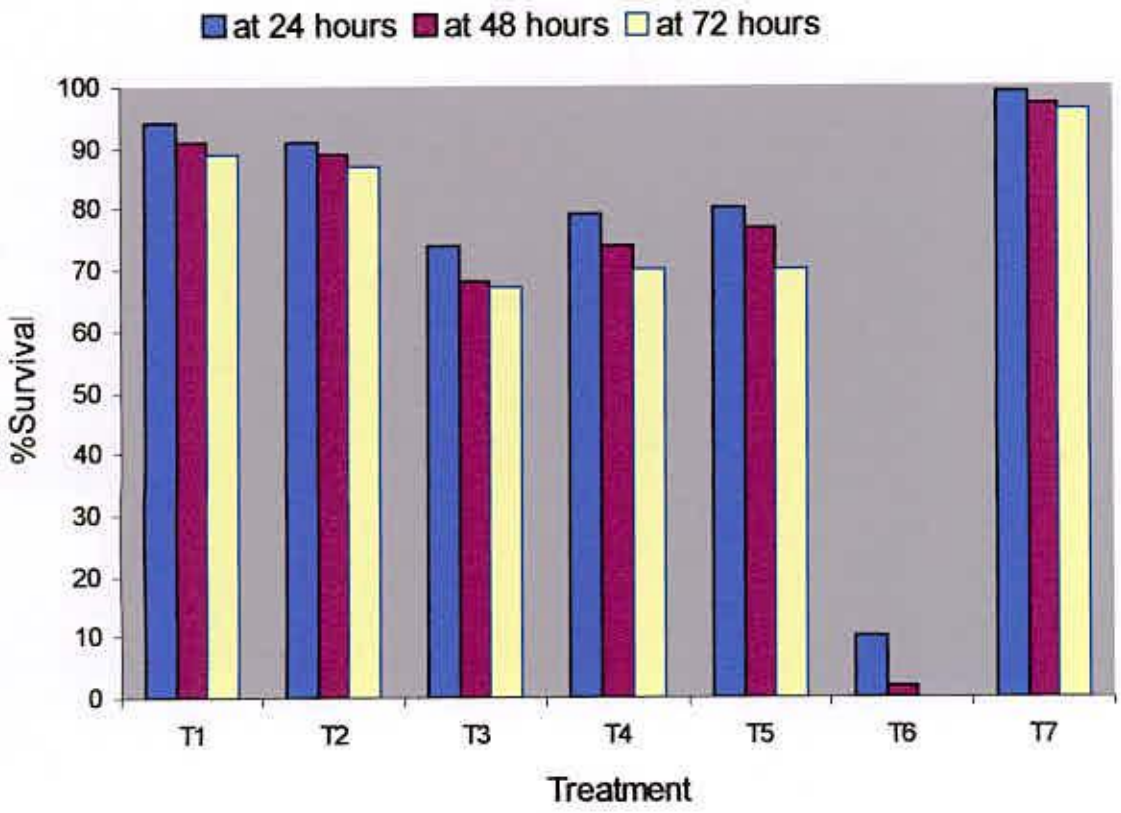


Figure 3: Effect of neem product on % survival of *Amblysieus longispinosus*

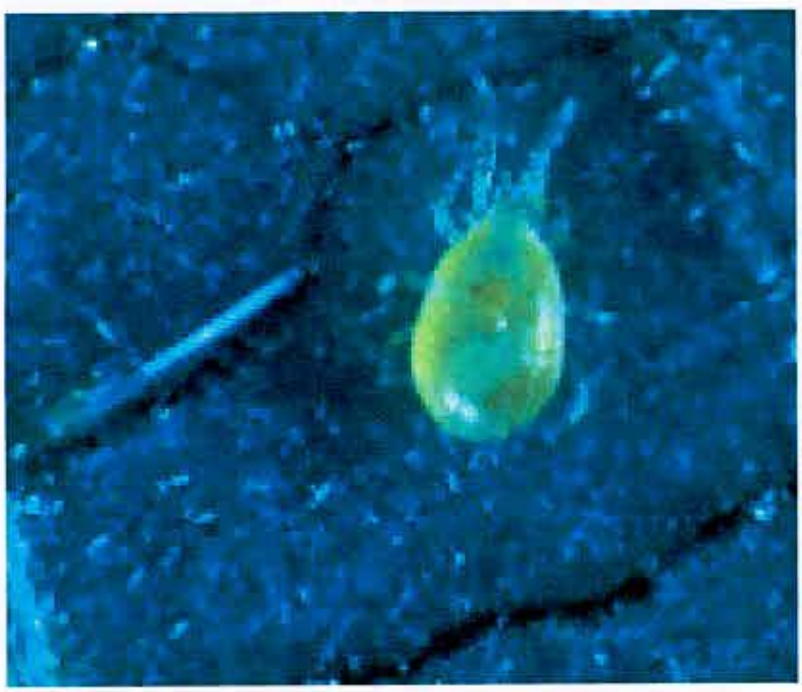


Plate 20. Adult of predatory mite: *Amblyseius* sp.

4.14 Effect of neem products on adult survival of *Adelphocoris* sp.

Comparative effect of neem products and chemical acaricide on adult *Adelphocoris* sp. are presented in Figure 4. The highest adult survival (85%) was recorded in green neem leaf extract followed by dry neem leaf extract (82%), neem seed kernel extract (68%), nembicidine (69%) and neem oil (60%). The lowest survival (2%) was observed in the treatment with acaricide (Kumulus 80 WP). In control the adult percent survival was 93%. This result also suggested that neem products are not harmful against natural predators jute mites but the negative impact of chemical on mites.

4.15 Effect of neem products on survival of *Scolothrips* sp.

Effects of neem products on percent survival of *Scolothrips* sp. are shown in Figure 5. The highest adult survival (87%) was observed in green neem leaf extract followed by dry neem leaf extract (85%), neem seed kernel extract (69%), nembicidine (68%) and neem oil (63%). The lowest adult survival 7% was observed in the treatment with chemical acaricide (kumulus 80 WP). In control, the percent adult survival was 93%. Mani (1996) reported that mortality of adults predator was not reduced when sprayed with 0.2% neem oil.

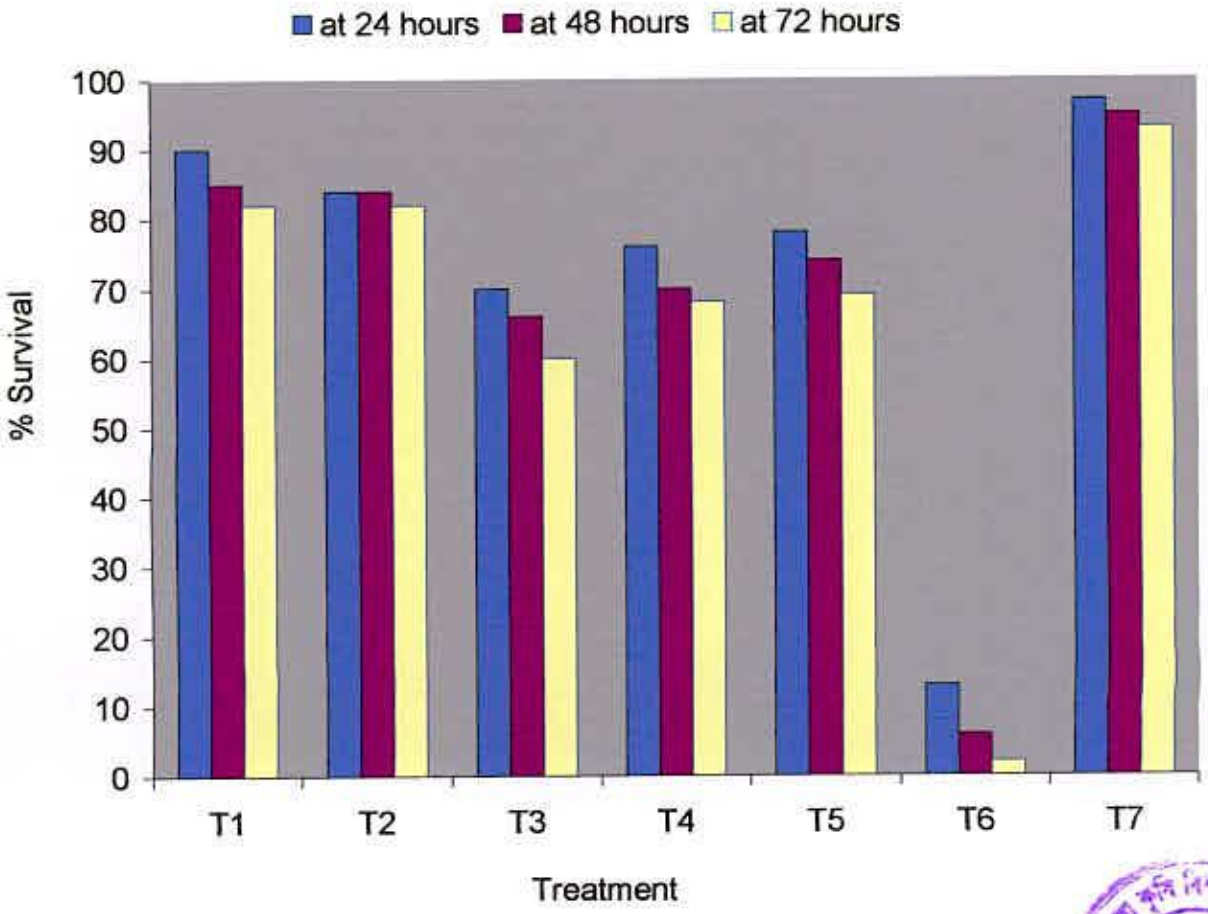


Figure 4 : Effect of neem products on survival of *Adelphocoris* sp.

Plate 21. Ventral view of adult of *Adelphocoris* sp.

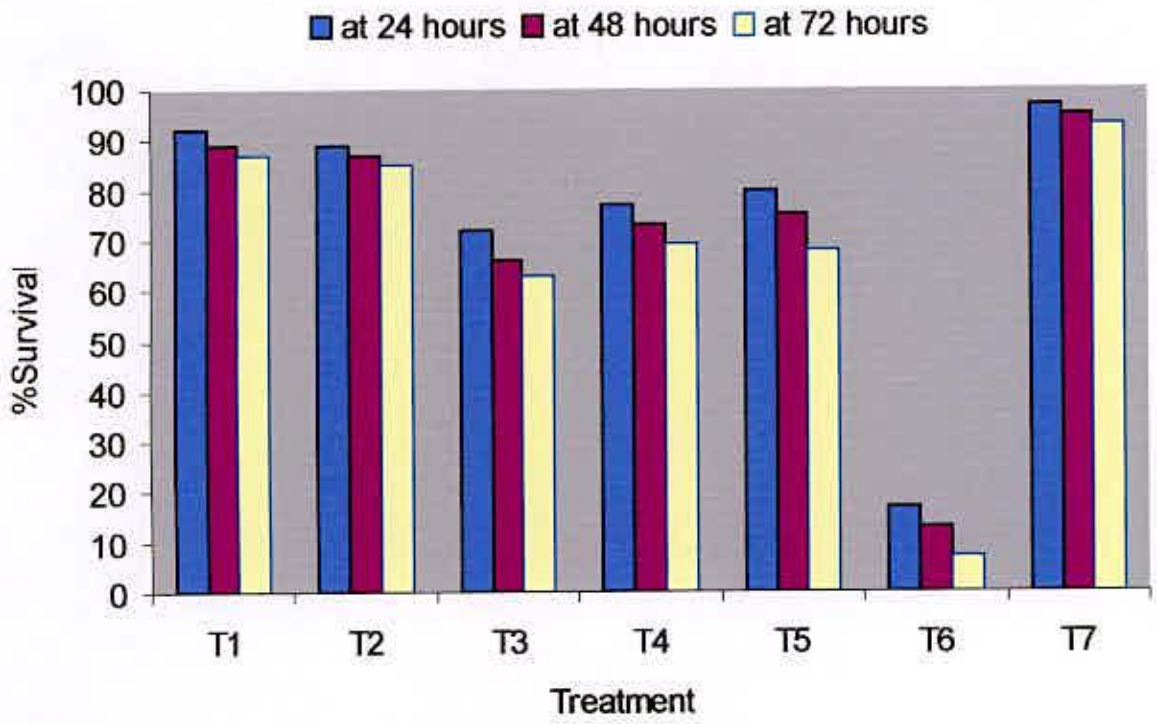


Figure 5: Effect of neem products on % survival of *Scolothrips* sp.

Plate 22. Adult of *Scolothrips* sp.

Plate 23. Nymph of *Scolothrips* sp. feeding on egg of red mites

4.16 Effect of neem products on seed quality.

The highest weight of 1000 seeds 2.53 g was recorded from neem oil (2%) treated plots followed by Nembicidine (2.36 g), neem seed kernel extract (2.33 g). The lowest weight of 1000 seeds 1.91 g from untreated control plot.

The seed quality was significantly influenced by the application of neem products. The highest percent germination (86%) was recorded from neem oil treated plots followed by nembicidine (84%) and neem seed kernel extract (83.75%) treated plots. However no significant difference was found among them. Green neem leaf extract and dry neem leaf extract provided germination 77% and 76% respectively with no significant difference between them. The lowest percent germination (65%) was recorded from untreated control plots, which was significantly different from all other treatments.

In terms of seed vigour, the highest vigour (56) was recorded from neem oil treated plots followed by nembicidine (53) and neem seed kernel extract (52), which were statistically similar. The lowest seed vigour (35.25) was observed in untreated control plots, which was significantly different from other plots.

From the above results that the best seed quality was found in 2% neem oil, nembicidine, neem seed kernel extract and green neem leaf extract.

Table 11: Effect of neem products on quality of seed

Treatment	1000 seed weight (g)	Germination (%)	Vigour
T_1	2.17 bc	77.00b	47.25b
T_2	2.14 bc	76.00b	46.50b
T_3	2.53 a	86.00a	56.00a
T_4	2.33 ab	83.75a	52.00ab
T_5	2.36 ab	84.00a	53.00a
T_6	1.91 c	65.00c	35.25c
LSD (0.05)	0.26	6.12	5.35
% CV	7.79	5.16	7.35

Means within a column followed by same letter(s) are not significantly different at 5% level.

T_1 = Green neem leaf extract @ 1:20
T_2 = Dry neem leaf extract @ 1:50
T_3 = Neem oil 2%
T_4 = Neem seed kernel extract @ 1:10
T_5 = Nembicidine @ 1.5 ml/L
T_6 = Control (untreated)

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

In order to study the effectiveness of neem products against yellow mite and red mite of jute, several experiments were conducted under laboratory, greenhouse and field condition of Bangladesh Jute Research Institute during the period of March 2007 to December 2007.

Initially, aqueous extraction of different doses of neem products including green neem leaf, dry neem leaf, neem oil and neem seed kernel were evaluated against yellow mite in greenhouse condition to find out suitable dose for the field experiment. The highest % mortality (67.37) was recorded in 3% neem oil followed by 2% neem oil. However, phytotoxic effect was appeared in jute leaves due to spraying of 3% neem oil, therefore, 2% neem oil was chosen. Furthermore, green neem leaf extract @ 1:20, dry neem leaf extract @ 1:50 and neem seed kernel extract @ 1:10 were found to be the most effective to control yellow mite of jute.

Comparative effectiveness of aqueous extraction and methanolic extraction of neem products were also studied. It was found that the methanolic extracted neem products showed better performance than aqueous extracted neem products. Preparation of neem products by aqueous extraction method is very easy and economic than methanolic extraction method.

In case of first and second spray (field experiment), the highest percent reductions over control (70.26 and 79.23) were secured by 2% neem oil. However, they were statistically different than other treatments. The lowest percent reductions over control (53.98 and 58.86) were recorded by dry neem leaf extract (1:50) which were statistically similar to green neem leaf extract.

At the late stage of plants, highest number of nodes (94.50) per plant was found in control plots due to shortening of internodes caused by severe mite infestation which was statistically different than other treatments. The lowest number of nodes (53.25) per plant was found in neem oil, which was statistically similar with neem seed kernel and nembicidine. Plant height was found to be the highest (3.28 meter) in the plot treated by 2% neem oil and the lowest (2.50 meter) in control plot. Maximum percent yield increase over control (39.33) was found in the plot treated with 2% neem oil and the lowest percent yield increase over control (19.85) was found in the plot treated with dry neem leaf extract (1:50). Cost benefit ratio was highest (16.55) from 2% neem oil and lowest (10.74) was in nembicidine.

The highest survival of *Orious insidiosus* (88%), *Stethorus* sp. (90%), *Amblyseius longispinosus* (89%), *Adelphocoris* sp. (85%) and *Scolothrips* sp. (87%) was observed in green neem leaf extract and the lowest survival was recorded in acaricide (kumulus 80 WP) suggesting that neem products such as green neem leaf extract is not harmful for predators.

In late jute seed crop, the highest percent reduction (75.17) of red mite was recoded in 2% neem oil and the lowest (57.78) was in dry neem leaf extract (1:50). Similar trend was also observed in yellow mite. The maximum weight of 1000 seeds (2.53g) was recorded from neem oil (2%) and the lowest weight of 1000 seeds 1.91g was recorded from untreated control plot. The height percent germination (86%) was recorded from neem oil (2%) treated plots and the lowest percent germination (65%) was recorded from untreated control plot. The height seed vigour (56) was observed from neem oil (2%) treated plots and the lowest seed vigour (35.25%) was observed in untreated control plot. Thus, neem products play an important role in quality jute seed production.

The longer persistence and extensive use of the synthetics resulted in number of problems such as the development of resistance in target pests, elimination of predator and parasites resulting in secondary pest out break, toxicity to higher animals and environmental population. Neem oil 2%, neem seed kernel extract @ 1:10, green neem leaf extract @1:20 and dry neem leaf extract @1:50 can be safely used by the farmers as components of IPM are indigenous plant product, a low cost alternative and a promising known botanical pest control agent and to save the crops from different insect pests effectively and economically without hampering the ecological balance agro-ecosystem. The present study will presumably help in future research to improve the effectiveness of botanical products as pesticides for the benefit of farmers and it can be used as a components of IPM programme.

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APPENDICES

APPENDICES

Appendix 1. Data on rainfall and temperature (year 2007) recorded from JAES, Manikganj

Month	Rainfall (mm)	Temperature	
		Min. (^{0}C)	Max. (^{0}C)
January	000	10.76	25.02
February	028	15.52	27.15
March	056	17.39	31.83
April	026	23.35	34.42
May	079	25.50	35.30
June	638	26.11	32.81
July	833	26.21	31.62
August	252	27.34	32.31
September	114	26.96	32.33
October	398	23.90	31.80
November	071	19.12	29.66
December	000	13.10	25.69

Appendix 2. Area and production of jute in Bangladesh

Year	Area in '000' acre	Production in '000' m. tons
1994-95	1383	961
1995-96	1133	737
1996-97	1253	883
1997-98	1427	1057
1998-99	1181	812
1999-2000	1008	711
2000-01	1107	821
2001-02	1128	859
2002-03	1079	800
2003-04	1008	794
2004-05	965	732
2005-06	1165	821

Source: BBS, 2006