EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA, *Abelmoschus esculentus* (L). Moench

by

ANU THOMAS

(2017-11-073)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA, *Abelmoschus esculentus* (L). Moench"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Padannakkad
Date: 29/08/2019

Anu Thomas
(2017-11-073)

CERTIFICATE

Certified that this thesis entitled **"EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA, *Abelmoschus esculentus* (L). Moench"** is a record of research work done independently by Ms. Anu Thomas under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place: Padannakkad

Date: 29/08/2019

Dr. K. M. Sreekumar
(Major Advisor)
Professor and Head
Department of Agricultural Entomology
College of Agriculture
Padannakkad- 671314

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Anu Thomas, a candidate for the degree of **Master of Science in Agriculture** with major in Agricultural Entomology, agree that the thesis entitled **"EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA, Abelmoschus esculentus (L). Moench"** may be submitted by Ms. Anu Thomas, in partial fulfilment of the requirement for the degree.

29/8/19

Dr. K. M. Sreekumar
(Major Advisor)
Professor and Head
Department of Agricultural Entomology
College of Agriculture
Padannakkad- 671314

29/8/2019

Dr. B. Ramesha
(Member, Advisory Committee)
Associate Professor
Department of Agricultural Entomology
College of Agriculture
Padannakkad- 671314

29/8/2019

Dr. Faizal M. H.
(Member, Advisory Committee)
Professor
Department of Agricultural Entomology
College of Agriculture,
Vellayani - 695522

29/8/2019

Dr. Yamini Varma C.K.
(Member, Advisory Committee)
Associate Professor (Plant Pathology)
AICRP on spices
Pepper Research Station,
Panniyur - 670142

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Anu Thomas

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Introduction

1. INTRODUCTION

Okra, *Abelmoschus esculentus* (L). Moench also known as lady's finger native to West Africa is a warm season vegetable crop cultivated in many subtropical, tropical and warm temperate regions of the world. Rich source of dietary fibre (3.2g), vitamin C (23 mg) and vitamin K (31.3 mg) along with moderate contents of thiamine (0.2 mg), folate (60 micrograms) and magnesium (57 mg) makes okra an important vegetable crop offering high health benefits. Okra is cultivated for its fibrous, tender and delicious fruits which remains productive even in the long summers of South East.

India stands first in okra production (6094.94 MT during 2018-19) which contribute with 62 per cent share of world production. It is cultivated in 509.02 ha of area with a productivity of 11.97MT/ha. West Bengal is the leading okra producing state in India. In Kerala okra is grown throughout the year occupying an area of 2.48 ha with a production of 34.65 MT and productivity of 13.96 MT/ ha which is much lower than many other states (National Horticultural Board, 2018).

One of the major constraints for okra production is heavy infestations of several insect pests which exert both quantitative and qualitative loss. The marketable fruit yield recorded from protected and unprotected plots of okra indicated that insect pests caused 48.97 per cent loss in fruit yield, equivalent to the loss of 77.78 q/ha (Kanwar and Ameta, 2007). Among the insect pests, the important and the destructive ones are the shoot and fruit borer, *Earias vitella* (Fb.) (Lepidoptera: Noctuidae); fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae); leaf roller, *Sylepta derogata* (Lepidoptera: Pyralidae); leaf hopper, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae); red bug, *Dysdercus cingulatus* (F.) (Hemiptera: Pyrrhocoridae); green semilooper, *Anomis flava* Fab. (Lepidoptera: Noctuidae); semilooper caterpillar, *Xanthodes groellsi* Fsth.

(Lepidoptera: Noctuidae); leaf caterpillar, *Spodoptera litura* (Lepidoptera: Noctuidae) and aphid, *Aphis malvae* Koch. (Hemiptera: Aphididae).

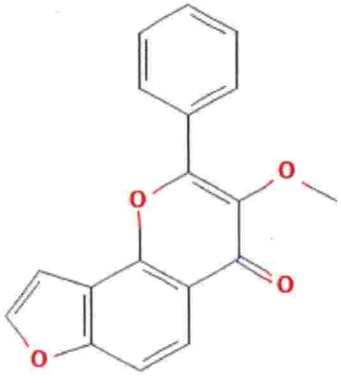
Early stages of crop is infested by sucking pests like leafhoppers, aphids and whiteflies that cause huge economic loss due to sucking of the cell sap and making the plant weak. Krishnaiah (1980) reported that leafhoppers alone can cause a yield loss of 54.04 per cent in okra. Okra shoot and fruit borer infest the crop both during vegetative and reproductive stage causing 3.5 to 90 per cent of crop damage (Mandal *et al.,* 2006). During the initial stages the larvae bore into the top shoots and results in withering and drooping of the shoots. Later on during the reproductive stage it bores in to the newly formed buds, flowers and fruits causing deformed and stunted fruits resulting in huge yield loss. *H. armigera* is an important pest infesting okra during the later stages of the crop. It damage the flower buds and fruits by boring circular holes thus rendering the fruit unfit for human consumption. Mandal *et al.* (2006) reported that fruit borers alone can cause upto 90 per cent of damage to okra. The larvae of okra leaf roller, *S. derogata* feed by remaining inside the rolled up funnel shaped leaves and can cause complete defoliation in case of heavy infestation resulting in huge yield loss. Ahmed *et al.* (2006) stated that the pest lowered the yield of soybean to a greater extent due to its damage on tender leaves of soybean.

Okra being harvested at frequent intervals, application of synthetic insecticides may lead to toxic residues in fruits causing health hazards. Non judicious use of synthetic pesticides over the last four to five decades have resulted in many negative consequences like resurgence and resistance of pests and pesticide residues in farm products (Kabir *et al.,* 1994; Mahapatro, 1999). Hence, to control these pests and to reduce such risks, alternative environmentally safe methods like bio pesticides, botanicals *etc.*, are to be adopted (Khade *et al.*, 2014). More over organic agriculture movement is gaining in momentum in the state.

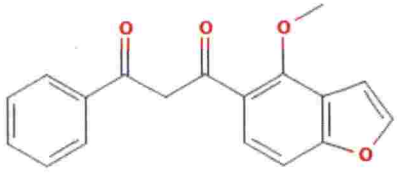
Pongamia pinnata (L.) is a multipurpose tree species of pea family Fabaceae which is widely distributed in India, China, Bangladesh and Australia. It is commonly called as Indian Beech Tree or Karanj. Pongamia oil is thick yellowish red/brown non edible fixed oil, extracted from seed with a saponification value in the range of 186 - 196 mg KOH/ g of oil. It is used for the treatment of rheumatism and skin diseases, in soap industry, as a fuel, lubricant and pesticide. The secondary metabolites like flavanoids, chalcones, steroids and terpenoids in pongamia oil serve as natural pest repellents (Pavela, 2009). The presence of karanjin and pongamol make pongamia oil effective against several insect pests (Mathur *et al.,* 1990). Karanjin and pongamol (National Centre for Biotechnology Information, 2005) is chemically a furanoflavanol, a type of flavonoid which possess pesticidal (Rangaswamy and Seshadri, 1941) and insecticidal (Parmar and Gulati, 1969) properties. It has antifeedent properties similar to neem oil and act against a number of insect pests. Tripathi *et al.* (2012) stated that pongamia oil is safe to humans and other mammals.

The proposed study, "evaluation of pongamia oil soap against major pests of okra, *Abelmoschus esculentus* (L). Moench" is aimed at evaluating the efficacy of a new product made of pongamia oil - pongamia oil soap at different concentrations in combating the major pests of okra.

Fig. 1 Chemical structure



(a) Karanjin - 3-methoxy-2-phenylfuro [2,3-h]chromen-4-one



(b) Pongamol - 1-(4-methoxy-1-benzofuran-5-yl)-3-phenylpropane-1,3-dione

Review of Literature

2. REVIEW OF LITERATURE

The work pertaining to the effect of different botanical insecticides on some insect pests of okra published in scientific literature in India and abroad have been reviewed and presented here in this chapter.

2.1. Effect of pongamia oil in controlling major Lepidopteran pests

Kushram *et al.* (2017) tested the effectiveness of botanical insecticides against tobacco caterpillar *Spodoptera litura* infesting soybean and revealed that per cent reduction of *S. litura* population was the highest with triazophos @ 750 ml/ha (68.64 %) while among the plant products, maximum reduction was shown with plot treated with garlic + green chilli @ 8.75 kg/ha (63.56 %) followed by NSKE @ 5 per cent (57.63 %), pongamia seed extract @ 2.5 per cent (51.69 %), pongamia oil @ 2 per cent (46.61 %), neem oil @ 2 per cent (40.67 %) and green chilli @ 9kg/ha (34.75 %). He also studied the effect of botanical insecticides on green semilooper, *Chrysodeixis acuta* infesting soybean and found that the mean larval population of green semilooper after first spray was recorded minimum in plot treated with triazophos 40 EC @ 750 ml/ha (0.40 larva/meter row length) and among the plant products, garlic + green chilli @ 8.75 kg/ha recorded minimum larval population with 0.52 larva/meter row length, followed by NSKE @ 5 per cent (0.53), pongamia seed extract @ 2.5 per cent (0.65), pongamia oil @ 2 per cent (0.68), neem oil @ 2 per cent (0.73) and green chilli @ 9kg/ha (0.77).

Sahana and Tayde (2017) reported that the lowest percentage infestation of brinjal shoot and fruit was lowest in spinosad treatment (4.78 %, 6.38 %), while the next effective treatments were neem oil (8.47 %, 9.68 %) and pongamia oil (9.85 %, 10.28 %). Also the highest marketable fruit yield was recorded from spinosad (222.0 q/ha) followed by pongamia oil (213.5 q/ha) and neem oil (180.5 q/ha).

Feeding deterrancy of extracts (*Acacia arabica, Eucalyptus globulus, Lantana camara, Nicotiana tabacum,* and *Pongamia pinnata* and seed kernel extracts of *Pongamia pinnata* and *Azadirachta indica* at 2, 3 and 4 % concentrations) was evaluated on fourth instar larvae of *Spodoptera litura.* It indicated that NSKE treatment had more deterrancy and the larvae consumed 46.12 per cent followed by *A. arabica* (48.12 %), *N. tabacum* (56 %) and PSKE (Pongamia seed kernel extract) (57.20 %) (Sasvihalli *et al.,* 2017).

In a choice assay mature seed extract of *Pongamia pinnata* exhibited oviposition detterrancy on *Helicoverpa armigera* when applied on to the substrate at 2.5 per cent concentration. One day old eggs failed to hatch (Reena *et al.,* 2012).

Neem oil (3%) caused 100 per cent mortality on fourth instar larvae of *Spodoptera litura* after 12 days of treatment while at 1 per cent, it caused 98.2 per cent mortality. Chrysanthemum oil (3 %) and pongamia oil (3 %) showed 98.3 per cent and 98.8 per cent larval mortality, respectively (Pavela, 2009).

Kumar *et al.* (2006) evaluated the efficiency of different extracts of *P. pinnata* against the first and second instar larvae of *S. litura.* He reported that application of methanolic extracts of pongamia oil resulted in maximum growth reduction (EC_{50}: 0.11 %) followed by karanj bark (EC_{50}: 1.49 %), crude seed oil (EC_{50}: 2.72 %), hexane fraction of oil (EC_{50}:3.41 %) and methanolic extract of karanj leaves (EC_{50}: 5.44 %). He also stated that methanolic extracts of pongamia oil showed maximum antifeedent (EC_{50}: 0.21 %) activity followed by crude seed oil (EC_{50}: 2.42 %) and methanolic extract of karanj bark (EC_{50}: 2.51 %) and leaves (EC_{50}:2.63 %).

Singh and Kalidhar (2005) reported that the biology and food consumption utilization indices of first instar larvae of *Plutella xylostella* under laboratory

condition were adversely affected when the larvae were allowed to feed on cabbage leaves treated with 1 per cent pongamia oil for 48 h.

Eswarareddy and Shrinivasa (2004) reported that spraying of neem oil 2 per cent was highly effective in reducing the brinjal shoot and fruit borer damage (19.61 %) followed by pongamia oil 2 per cent (20.26 %) after three applications during summer season.

Joint action potential of neem (N), sweet-flag (S) and pungam (P) at 1:1:1 (NSP I), 2:1:1 (NSP II) and 3:1:1 (NSP III) ratios (v/v) was examined by Rao *et al.* (2002) for antifeedant and growth inhibitory effects on *Earias vitella*. He revealed that all the treatments compared to control showed reduced food intake by *E. vitella*. Third instar larvae of *E. vitella* showed 80 per cent feeding when treated with NSP (I) 60EC @ 0.3 per cent over control.

Rosaiah (2001) found that borer damage on bhendi was very less (14.87 %) with neemazal 0.5 per cent treatment. When treated with pongamia seed extract (5%) it was less (18.34% damage) which was superior over 5% NSKE (19.53% damage) and reported the lowest borer damage of 14.87 per cent followed by pongamia seed extract 5 per cent (18.34 %), NSKE 5 per cent (19.53 %) and 2 per cent mineral oil treatments (21.62 % damage).

Pongamia oil at 1 per cent concentration showed significant effects on fecundity, larval period and larval mortality of *H. armigera* infesting cotton (Morale *et al.*, 2000).

Katole *et al.* 1993 reported that pongamia oil (1 %) as one of the superior treatments for the management of citrus leaf miner *Phyllocnistis* followed by Dimethoate, mahua oil and neem oil, while castor oil and Neemark were ineffective.

In a laboratory assay it was observed that survival, feeding and oviposition of spotted stalk borer *Chilo partellus* were highly reduced by the application of neem and pongamia oils, while mahua and castor oils were less effective (Sharma and Bhatnagar, 1993).

Studies on the antifeedant activity of various plant extracts was carried out by Koshiya and Ghelani (1993) against 3rd-instar larvae of *Spodoptera litura* in the laboratory at 26°C on groundnut leaves. Results showed the superiority of neem leaf (75.5 %) and seed extracts (88.96 %) and extracts of seeds of *Pongamia glabra* (66.4 %) at 15 per cent concentration.

Jothi *et al.* (1990) observed that neem, mahua and pongamia oils each at 2 per cent and 4 per cent concentration and neem and pongamia seed extracts at 2 per cent reduced the incidence of citrus leaf miner *Phyllocnistis citrella* on lime.

Seed extract of 0.62 per cent of *Psoralea corylifolia*, 0.80 per cent of *Pongamia pinnata* and 1.50 per cent of lentil gave 50 per cent feeding inhibition to Bihar hairy caterpillar on castsor (Chakraborty and Roy, 1988).

Verma and Singh (1985) reported that neem-seed oil (1 %) as an effective antifeedant against fourth instar larvae of *Amsacta moorei* in laboratory conditions followed by pongamia oil (1 %).

The above cited reviews state that pongamia oil at varying concentrations (1-15 %) is a potential botanical showing feeding deterrence, growth reduction and insecticidal properties on lepidopteran caterpillars and have similar properties as that of neem.

2.2. Effect of pongamia oil in controlling major Hemipteran pests

Dehariya *et al.* (2018) conducted an experiment to evaluate the efficacy of some botanical products including neem oil 1 per cent, eucalyptus oil 1 per cent, Achook 5 per cent, NSKE 5 per cent and pongamia oil 1 per cent along with a standard check triazophos 40 EC (0.04 %) against aphids infesting brinjal. Triazophos 40 per cent EC was found to be the superior treatment (7.00 mean aphid population/15 leaves), while among the botanicals, neem oil 1 per cent (13.00/15 leaves) was found to be superior followed by pongamia oil 1 per cent (13.50/ 15 leaves) and NSKP 5 per cent (16.00 /15 leaves). The efficacy of certain botanicals against jassids, *Amrasca biguttula* infesting brinjal was also studied by him and found that, triazophos 40 per cent followed by neem oil 1 per cent (13.25/15 leaves) and pongamia oil 1 per cent (14.25/ 15 leaves) was the most effective in controlling the jassid. Among the botanicals, neem oil 1 per cent treated plots gave the highest yield (20.54q/ha) followed by eucalyptus oil 1 per cent (19.57q/ha) and pongamia oil 1 per cent (17.81q/ha).

According to Sridhar *et al.* (2017), the use of neem oil (5ml/l), pongamia oil (5ml/l) and fish oil (5 ml/l) as synergists with insecticides for the control of whitefly, *Bemisia tabaci* (Gennadius) infesting tomato showed an additional mortality up to 16 per cent as compared with insecticides along. The highest synergist effect was observed with neem oil followed by fish oil and pongamia oil.

Efficacy of biopesticides and synthetic insecticides was studied by Bopche (2015) against aphid, *Uroleucon compositae* (Theobald) infesting safflower and reported that the lowest aphid population was found with the treatment *Metarhizium anisopliae* (17.93) followed by *Verticillium lecanii* (19.02), NSKE (26.10), hinganbet fruit extract (27.46), pongamia oil (28.34) and ritha fruit extract (29.81) when the precount of aphid population was in the range of 51.73 to 54.13 aphids / twig.

Ghosh and Chakraborty (2015) conducted a study during post kharif season to determine the efficacy of some microbial pesticide *Beauveria bassiana,* the microbial toxin *Saccharopolyspora spinosa*, and plant extracts of *Polygonum hydropiper* and *Pongamia pinnata* against jassids infesting okra. From the study it was revealed that extracts of *Polygonum* plant and pongamia leaf at higher concentrations (7 %) gave more than 50 per cent jassid suppression.

Tran *et al.* (2015) reported that pongam leaf extract (5 ml/l) showed acute toxicity to the turnip aphid with the LC_{50} value 0.585 per cent, 0.151 per cent and 0.113 per cent at 24, 48 and 72 hours respectively, in laboratory conditions. Laboratory observations also indicated that low concentrations of pongam leaf extract caused significant reduction of vitality and fertility of the turnip aphids of the subsequent generation and thus caused an indirect reduction of overall pest numbers in the next generation.

An experiment was laid out during 2011-12 by Madhuri *et al.* (2014) at UAS, GKVK, Bangalore to test the efficacy of different botanicals *viz*., seed kernel extracts of neem, pongamia and mahua (at 2 and 4 %) and leaf extracts of neem, pongamia, mahua, lantana and adathoda (at 8 and 10 %) against pink mealy bug in mulberry. NSKE @ 4 per cent showed 76.09 per cent protection over control followed by NSKE @ 2 per cent (64.16 %), PSKE @ 4 per cent (50.66 %) and MSKE @ 4 per cent (40.18 %).

According to Akashe *et al.* (2013), 83.6 per cent decline in aphid population was recorded with 1 per cent pongamia oil treatment in safflower which was statistically at par with 1 per cent neem oil (81.03) and 1 per cent castor oil (74.59) after second spray. Pongamia oil was thus found effective in checking safflower aphid resulting in highest seed yield (914.76 kg/ha) followed by neem oil (776.48 kg/ha) and castor oil (637.15 kg/ha).

Shrinivas (2012) carried out a field experiment to evaluate the efficacy of organic products via margosom 0.15 EC (0.3 %), neemazal-T/S 1.0 EC (0.2 %), neem seed kernel extract (5.0 %), neem oil (1.0 %), pongamia oil (1.0 %), fish oil rosin soap (1.0 %), *M. anisopliae* (0.1 %) and *V. lecanii* (0.5 %) in alternation with *B. bassiana* (0.5 %) against sucking pests of brinjal and reported that the average survival population of aphids in the plot treated with pongamia oil 1 per cent was 11.45 aphids/plant while the untreated plot showed an average of 25.06 aphids/ plant. The average survival population of jassids in the plot treated with pongamia oil 1 per cent showed 6.38 jassids/plant while the untreated plot showed an average of 16.00 jassids/ plant and the average survival population of whitefly in the plot treated with pongamia oil 1 per cent was 4.69 whiteflies/plant while the untreated plot showed an average of 15.77 whiteflies/ plant.

Field experiments were carried to study the effectiveness of pongam oil, neem oil and chrysanthemum oil against *Myzus persicae* at concentrations of 3 per cent, 1 per cent and 0.5 per cent by Pavela (2009). For aphids, 100 per cent mortality was recorded in all the tested botanicals at its highest concentration on day 12 after application. But in other tested concentrations the highest efficiency was determined in pongam oil on the day 12 after application ranging from 96-96 per cent for 1 per cent concentration and 76-82 per cent for 0.5 per cent concentration while neem oil at 0.5 per cent showed only 57 per cent mortality.

The impact of botanicals and mycopathogens on the incidence of sucking pests of okra was evaluated by Anitha (2007) in Dharwad. She observed that among botanicals and mycopathogens, neem oil (2 %) recorded least leafhopper population (2.90 leafhoppers / 3 leaves) followed by pongamia oil (2%) (3.44 leafhoppers / 3 leaves) and *V. negundo* (5%). The least aphid population was recorded in the block treated with NSKE (5%) (4.28 aphids / 3 leaves) followed by neem oil (5.03 aphids / 3 leaves), azadirachtin (1ml/l) (5.43 aphids / 3 leaves), pongamia oil (5.82 aphids / 3

leaves), *V. negundo* leaf extract (6.13 aphids / 3 leaves), *V. lecanii* (1g/l) (6.97 aphids / 3 leaves) and *M. anisopliae* (1g/l) (8.32 aphids / 3 leaves). The lowest incidence of whiteflies were reported in the plot treated with oxydemeton methyl (1.80 whiteflies / 3 leaves) and neem oil (2.52 whiteflies / 3 leaves) followed by *V. lecanii* (2.69 whiteflies / 3 leaves), NSKE (3.14 whiteflies / 3 leaves) and pongamia oil 2 per cent (3.46 whiteflies / 3 leaves).

A study was conducted by Pavela and Herda (2007) to test the efficacy of pongamia oil on whiteflies (*Trialeurodes vaporariorum*) infesting chrysanthemum plants under greenhouse conditions in insect proof-cages. The experiment included a choice test using treated and untreated plants, a no-choice test and direct application on adult whiteflies on plants. The choice and no-choice test of pongam oil suspension at different concentrations of 2.0 per cent, 1.0 per cent and 0.5 per cent were evaluated on the 4th, 8th and 12th day after the application. The study revealed that the plants treated with pongamia oil @ 2 per cent and 1 per cent reduced both, the number of adult whiteflies and eggs.

The efficacy of the botanical pesticides for the management of aphids in safflower was studied by Patidar (2007) under field conditions. He reported that among the botanicals, NSKE 5 per cent, neem oil 1 per cent and pongamia oil 0.5 per cent were found to be more effective in reducing the aphid population with a mean population of 12.92, 22.36 and 23.69 per five cm apical twig respectively as compared to control (36.70 per five cm apical twig).

Kharian (2004) tested the efficiency of different plant oils of palmarosa, menthe, java citronella, lemon grass, karanj and neem at 1 per cent against different stages of *Bemisia tabaci.* Results indicated that neem oil and pongamia oil was superior among the treatments in terms of adult, pupal and nymphal mortality. Adult mortality of 24.2 and 20.2 was recorded in case of neem and karanj respectively.

A greenhouse study was carried out by Mariappan *et al.* (1988) on the efficiency of nonedible oils extracted from seeds of *Pongamia pinnata* Pierre, *Madhuca longifolia* Koen. Macbr. var. *latifolia* Roxb. Cheval, *Azadirachta indica, Annona squamosa* L and *Calophyllum inophyllum* L., trees against *Nephotettix virescens*. He revealed that the oils of karanj, mahua and pinnai were as effective as oil of custard-apple and even more effective than that of neem in reducing the survival of the rice green leafhopper, and its transmission of the rice tungro viruses. A mortality of 100 per cent was observed after 4 days of spray treatment on rice plants sprayed with oils at 5 per cent concentration in contrast to 69 per cent insect survival on control plants.

Hussain *et al.,* 1996 tested various plant oils against lantana bug, *Orthezia insignis* infesting the ornamental crop *Crossandra* sp. in Karnataka and they recommended Neem and Pongamia oils at 4 per cent, for controlling this pest. They also stated that the two oils were even effective than quinalphos and monocrotophos.

According to Jothi *et al.* (1990), the treatments with mahua and pongamia oils at 1 per cent and neem and pongamia seed extracts at 2 per cent were recommended for control of *Toxoptera citricidus* on lime at the time of emergence of new flush, when infestation begins in the field in Karnataka.

Sardana and Krishnakumar (1989) tested the effectiveness of neem (0.5 to 2 %), karanj (0.5 to 2 %) and garlic (0.25 to 1 %) oils against leafhopper, *A. biguttula biguttula* on okra and revealed that all the oils under test failed to provide any significant control of the hopper population compared to check insecticide monocrotophos (0.05 %). However, maximum reduction in hopper population to the extent of 17.51 and 18.51 leafhoppers per plant was recorded in case of pongamia oil (2 %) and garlic oil (0.5 to 1 %) respectively.

Subramaniam (1934) stated that hongay (*Pongamia glabra*) oil resin soap at 2 per cent was effective against mango hopper, *Idiocerus* spp. and aphids infesting cabage.

Subramaniam (1932) reported that pongamia oil resin soap when sprayed at 2 per cent killed all the nymphs of *Coccus viridis* infesting coffee within 24 h of spraying and adults in 48 h after spraying.

The works carried out on the management of different sucking pests revealed that pongamia oil soap can significantly reduce the pest population and can be incorporated along with other tools of IPM to control both the adults and nymphs even up to 10 days after treatment.

2.3. Effect of pongamia oil in controlling major storage pests

Srilakshmi and Virant (2018) studied the efficacy of edible and non-edible plants oil on the infestation of *Rhizopertha dominica* at 5 and 10 ml/kg of wheat grains. They reported that the grains treated with neem oil @ 10 and 5 ml/kg showed the lowest adult emergence with 1.00 and 1.16 adults @ 40 DAS(days after spraying), 2.06 and 2.36 adults @ 80 DAS and 2.26 and 2.63 adults @ 120 DAS. It was followed by pongamia oil at 10 and 5 ml/kg with adult emergence of 1.33 and 1.50 adults @ 40 DAS, 3.33 and 3.53 adults @ 80 DAS and 3.66 and 4.06 adults @ 120 DAS.

Kuldipake *et al.* (2016) carried out an investigation during 2014-2015 in order to study the insecticidal actions of some locally available plant materials against *Sitophilus oryzae* including *Azadirachta indica, Annona Squamosa, Glyricidia sepium, Ocimum tenuiflorum, Justicia adhatoda, Thevetia peruviana, Eucalyptus oblique* and *Pongamia pinnata*. *Pongamia pinnata* leaf powder (10.00 %) @ 5 g/kg seed of wheat showed superior over all other treatments with 13.3 per cent mortality

and 76.67 per cent repellency. Treatments with neem and custard apple leaf powder were also found to be at par with it showing 9.33 per cent mortality and 66.7 per cent repellency.

The greatest reduction in larval weight and increase in larval mortality of *Oryzaephilus surinamensis* and *Tribolium castaneum* were observed when the grains were treated with extracts of *P. pinnata*, followed by extracts of neem, *Acorus calamus* and *Cliestanthus collinus* at the rate of 2ml/l in that order (Prakash *et al.*, 2008).

Kumar *et al.* (2006) checked the toxic effect of different extracts of *Pongamia pinnata* on *Tribolium castaneum* and reported that karanj leaves (EC50 : 19.9 µg/insect) showed the maximum toxicity followed by bark extract (EC50 : 28.8 µg/insect), methanolic fraction of the oil (EC50: 47.8 µg/insect) and hexane fraction of the oil (EC50 : 129.4 µg/insect).

Babu *et al.* (1989) tested the efficiency of karanj, neem, mustard, groundnut and castor oils as a pre-storage treatment on mungbean at 2.5, 5 and 10 ml/kg seed against *Callosobruchus chinensis.* Under artificial conditions, the ovipositional deterrence was found highest in treatments with pongamia oil (5 and 10 ml/kg) and castor oil (10ml/kg) as compared to other treatments.

Shelke *et al.* (1987) evaluated the efficacy of 7 plant oils or extracts against *Phthorimaea operculella* infesting stored seed potatoes. He concluded that extracts of *Jatropha cureas, Pongamia glabra* and *Ipomoea carnea* leaves at 0.05 and 0.1 per cent and neem oil at 0.03 - 0.1 per cent were highly effective, with only 1.39-2.50 tunnels per potato up to 30 days, as compared with 4.04 tunnels per potato for control.

2.4. Effect of pongamia oil in controlling mites

Roy *et al.* (2018) tried to manage red spider mite on tea with non-conventional plant based oils *viz.* karanja oil, olive oil, castor oil, groundnut oil, mustard oil and sesame oil with the standard check ethion. They revealed that the application of pongamia oil (LC_{50}: 117.24 ppm) showed the lowest LC value on adulticide bioassay followed by mustard oil (345.70 ppm) as compared with ethion (441.891 ppm), while rose oil (5622.5 ppm) showed the lowest LC value on ovicidal action on eggs followed by karanja oil (6927.6 ppm) as compared to the standard check ethion (LC_{50}: 2270 ppm).

Efficacy of methanolic leaf extract of *Pongamia pinnata* against *Tyrophagus putrescentiae* was studied by direct spray and treated bioassay under laboratory conditions at different concentrations (0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 %) by Malik *et al.* (2018). They observed that with increase in concentrations, efficacy against mites also increased significantly causing high reduction of population in direct spray (41.33 to 76.00 %) and treated bioassay (28.00 to 63.33 %).

Rahman *et al.* (2016) evaluated the efficacy of three botanical oils of neem, nahogany and karanja at 1 % and an acaricide (Ambush 1.8 EC) against yellow mite, *Polyphagotarsonemus latus* infesting jute plants and assessed their effect on the population of the pest at 24, 48 and 72 hours after treatment and the reduction of yellow mite infested plant after 7 and 10 days of spraying. The effectiveness was shown highest with the plants treated with acaricide ambush 1.8 EC (80.25 %) while among the botanicals, neem oil, mahogany oil and pongamia oil caused 60.55 per cent, 55.89 per cent and 35.0 per cent reduction of mite infestation.

The impact of botanicals and mycopathogens on the incidence of sucking pests of okra was evaluated by Anitha (2007) in Dharwad. She reported that among botanicals and mycopathogens, lowest mite population was recorded in NSKE (5 %)

(9.82 mites/ 3 leaves) followed by neem oil 2 per cent (10.29 mites/3 leaves) and pongamia oil 2 per cent (10.83 mites/ 3 leaves).

Efficacy of dicofol @ 0.04 per cent along with different plant oils of pongamia, neem, castor, sesame and *Hibiscus cannabinus* @ 0.026 per cent was studied by Smitha and Girradi (2001) and revealed that the lowest mite population was observed in dicofol + castor oil treatment followed by dicofol + pongamia oil. They also stated that the plots treated with dicofol + castor oil recorded highest dry chilli yield followed by dicofol + pongamia oil.

2.5. Effect of pongamia oil in controlling other pests

Singh and Goswami (2017) reported that leaves and their respective oil seed cakes of mustard, neem, karanj and castor at 50g/l showed nematicidal properties on infective second stage juveniles of *Meloidogyne incognita* infesting okra and they also exhibited better plant growth parameters.

A field study was conducted by Dwivedi *et al.* (2016), to study the effectiveness of some botanicals and insecticide against onion thrips. The results indicated that Profenophos @ 1 ml/l and neem crude oil @ 4 per cent showed the highest reduction of thrips population by 3.35 and 10.45 thrips / plant as compared to that of control (48.48 thrips / plant) while pongam crude oil @ 4 per cent also showed a reduction of 23.33 thrips /plant.

Mandal *et al.* (2016) tried to manage the thrips infesting leaves of *Machilus bombycina* King with some bio-pesticides and certain insecticides. They revealed that among the seven pesticides, the application of imidacloprid 17.8 SL was found to be the most effective against thrips by giving a population suppression of 75.18 per cent, followed by azadirachtin (64.94 %), extracts of garlic (53.33 %), extracts of

tobacco (48.55 %), extracts of spilanthes (47.24 %), extracts of polygonum plant (46.71 %) and from pongamia leaf extracts (33.01 %).

In vitro trials of herbal and chemical acaricides was conducted by Thakur *et al.* (2007) against *Boophilus microplus* ticks. They reported that neem oil, pongamia oil and eucalyptus oil at 1 per cent showed 100 per cent mortality after 48 hours of treatment. They also stated that pongamia oil in 1 per cent teepol gave a uniform emulsification solution compared to neem oil I per cent.

George and Vincent (2005) reported that the results from 24 h bioassay studies of the petroleum ether extracts (100 %) of the seeds of *Annona squamosal* and *Pongamia glabra* independently and their combinations against mosquitoes showed a greater larvicidal effect for *P. glabra*.

As per the report of Mathur *et al.* (1990), third instar larvae of flesh fly, *Sarcophaga ruficornis* when treated with karanjin (3500 - 1000 ppm) manifested three types of morphogenetic forms *viz.*, larval-pupal intermediates, pupal-adult intermediates and deformed adults. An increase in the concentration of karanjin (2000 - 3500 ppm), resulted in more larval mortality whereas at lower concentrations (1000 - 2000 ppm) the percentage of pupal-adult intermediates and deformed adults was more pronounced.

2.6. Effect of pongamia oil on crops and natural enemies

Sahana and Tayde (2017), conducted an experiment to study the effect of certain botanicals *viz.* neem oil 3 per cent, NSKE 5 per cent, neem leaf extract 50ml/L, pongamia oil 3 per cent, garlic extract 50ml/L and papaya leaf extract 50ml/L along with Spinosad 0.1ml/L on the population of predatory coccinellid beetles and spider. They observed that all the treatments had a uniform population

count of coccinellid predators (0.66 to 1.00/ plant) and (0.46 to 0.63/ plant) indicating their safety to the natural enemies.

Bopche (2015) stated that bio pesticides tested against safflower aphids including hingan bet fruit extract (*Balanites aegyptiaca*) @ 5 per cent, neem seed extract (*Azadirachta indica* A. Juss.) @ 5 per cent, pongamia oil (pongamia sp.) @1 per cent, ritha fruit extract (*Sapindus sp.*) @5 per cent and *Metarhizium anisopliae* (1x108 cfu /ml) and *Verticillium lecanii* (1x108 cfu/ml) @ 2.5 kg/ha did not show any phytotoxic symptoms on safflower plants and the coccinellid beetles even after three sprays.

According to Stephanycheva *et al.* (2014), field treatments with 1 per cent pongamia oil did not have any negative impact on insect pollinators like Hymenopterans (*Apis florea, Apis dorsata*), dipterans (Muscidae, Syrphidae) or other natural enemies. Pongamia oil also did not cause any phytotoxicity to plants like beans and peppers when applied at a concentration of 3 per cent, where practically 0.5 – 1 per cent concentrations are commonly used as insecticides.

A study was conducted by Krishnamoorthy *et al.* (2007) to determine the compatibility of ten pesticides *viz.*, endosulfan, dinocap, acephate, chlorothalonil, abamectin, ethion, carbendazim, pongamia oil (*Pongamia glabra* Vent. Jard. Malm.), iprodion + carbendazim (a combination of two fungicides, marketed as Quintol) and thiophanate methyl on *Lecanicillium lecanii.* Pongamia oil showed the maximum conidial germination (99.3 %) and maximum sporulation of 47.2x106 conidia/ml which indicates that pongamia oil has synergistic effect with *L. lecanii.*

The impact of biopesticides on egg parasitoid, *Trichogramma chilonis* was evaluated by Basappa (2007) in Directorate of oilseeds Research, Rajendranagar, Hyderabad. He observed that all the bio pesticides were safe to *T. chilonis.* Percentage of adult emergence from one day old parasitized egg was recorded

maximum in untreated plot (95.33) followed by NSKE 5 per cent (82.66), neem oil 2 per cent (79.33), pongamia seed extract 5 per cent (74), pongamia oil @ 2 per cent (70.66) and custard apple seed extract 5 per cent (70) while commercial neem formulation showed only 58.66 per cent adult emergence.

It can be concluded that pongamia oil soap is safer to natural enemies like *Trichogramma*, coccinellid beetles and hymenopteran pollinators. It is also clear that the oil did not show any phytotoxic effect even at 3 per cent when other botanicals are usually used at a concentration of 0.5 - 1 per cent.

Material and Methods

3. MATERIAL AND METHODS

The material used and the methods carried out for evaluating the efficacy of pongamia oil soap against major pests of bhindi, *viz.*, shoot and fruit borer, leaf roller and leaf hopper are included in this chapter.

3.1. LABORATORY BIOASSAY OF PONGAMIA OIL SOAP

Laboratory bioassay was carried out in the Department of Entomology, College of Agriculture, Padannakkad, during 2018-19. Pongamia oil required for the preparation of soap was obtained from Tamil Nadu Agricultural University, and the saponification value of the oil was determined (194 mg KOH/ g of oil) in Soil Science and Agricultural Chemistry lab, COA, Padannakkad, to check the purity of the oil (Horowitz, 1975).

3.1.1 Laboratory bioassay

Laboratory bioassay was carried out to evaluate the feeding deterrency of pongamia oil soap against fourth instar larvae of okra leaf roller, *Sylepta derogata.* Growth retardation property of pongamia oil soap was studied against first instar larvae of bhendi leaf roller *S. derogata* by computing the Growth Index (GI) and Relative growth index (RGI). The effect of pongamia oil soap on the bhendi leaf hopper, *Amrasca biguttula biguttula* was studied using nymphal stages of the insect. The test organisms were exposed to various treatments as three replications and the data recorded were assessed using completely randomised design (CRD). The details of the experiment carried out is given below:

Experimental design : Completely Randomised Design (CRD)
No. of treatments : Six
No. of replications : Three
Variety : Arka Anamika

Crop : Okra

Treatment details : As per table 1

Table 1. Treatments imposed at Laboratory level

Sl.no.	Treatment details	Concentration
T_1	Pongamia oil soap 0.6%	6g/L
T_2	Pongamia oil soap 1%	10g/L
T_3	Pongamia oil soap 2%	20g/L
T_4	Neem oil soap 0.6%	6g/L
T_5	Soap solution 0.5%	5ml/L
T_6	Control	

3.1.2. Preparation of pongamia oil soap

Pongamia oil soap was prepared according to the technology used for the preparation of Ready To Use neem oil garlic soap, the first botanical of KAU, approved by Kerala Agricultural University (Varma, 2018).

pH of the prepared pongamia oil soap solution (10.5) was determined using a pH meter from Soil Science and Agricultural Chemistry lab, COA, Padannakkad.

3.1.3. Collection of egg mass

Egg mass of *Sylepta derogata* were collected from the fields of different farmers and rearing started from egg stage. Different instars were separated based on the head capsule size. Presence of brown spots on the dorsal aspect of prothorasic segment and the size and shape of the prothoracic shields were also taken into consideration while grouping the larvae instar wise.

Plate 1. Pongamia oil soap

(a) Pongamia oil soap

(b) Pongamia oil soap solution

3.1.4. Feeding deterrency index

Okra leaf discs of 5 cm diameter were prepared and dipped in different treatments and air dried for 10 minutes. Then two fourth instar larvae (av. weight : 0.058 g) of *S. derogata* starved for 4 h were introduced into the centre of each petri dish (140 mm Internal Diameter × 20 mm Height) lined with moistened filter paper containing treated leaves. The dishes were then transferred into a climatic chamber maintained at a temperature of 25°C ± 2°C, relative Humidity (60% - 70%) and 16L: 8D. After 10 h of feeding, the larvae were removed and the quantity fed was calculated by measuring the area of leaf eaten by larvae using a graph paper. The feeding deterrency index (FDI) was calculated by the formula (Li *et al.*, 2014).

$$\mathbf{FDI= (C-T)\ x100/(C+T)}$$

Where,

C = average consumed area of controlled leaf disc.

T = average consumed area of treated leaf disc.

3.1.5 Growth index and Relative growth index

Five first instar larvae of *S. derogata* were introduced into rearing covers containing treated leaves which were air dried for 10 minutes. Observations were taken daily and when 100 per cent of the larvae present in the control underwent pupation, both dead and live larvae present in other treatments were checked and separated into different stages (5 larval instars) and counted, based on which Growth Index (GI) and Relative Growth Index (RGI) were calculated using the formula (Zhang *et al.*,1993) given below:

$$\mathbf{GI} = \sum_{i=1}^{i_{max}} [n_{(i)} \times i\,] + \sum_{i=1}^{i_{max}} [n_i' \times (i-1)] \div \mathbf{N\ x}\ i_{\mathbf{max}}$$

Where,

i = stage number

n_i = no. of live larvae at i

n'_i= no. of dead larvae at i

i_{max} = total number of stages

N = total no. of larvae in the group

Relative growth index = GI of tested group / GI of control group.

3.1.6 Mortality study of leaf hoppers

Mortality study of okra leaf hopper, *Amrasca biguttula biguttula* was done according to the standard *Bemisia tabaci* susceptibility test, method no. 8 recommended by Insecticide Resistance Action Committee (IRAC) with slight modifications (IRAC, 2009).

The materials used for conducting the study are listed below:

Plastic cups of 300 ml capacity, scissors, perforated plastic covers, rubber bands, metal rod and fresh uncontaminated okra leaves.

The experimental set up was made of two plastic cups of 300 ml capacity with one kept inside the other thus forming an inner and outer chamber and kept vertically. A hole was made at the base of the inner cup using a metal rod. Fresh uncontaminated okra leaves were plucked from the field and cleaned with a wet cotton swab. The petiole of the leaf was cut to a length of 4 cm and placed in the inner plastic chamber with 1 cm of the petiole protruding out in to the lower cup touching the water surface. Ten nymphs collected from the experimental field was exposed to different treatments using a hand sprayer and released in to the inner chamber which was covered with perforated plastic cover. Observations were taken at 2 h interval for 48 h and the percentage of mortality was calculated for each treatment.

Percentage of mortality = (Dead nymphs in treatment/total nymphs in treatment) x 100

3.2 FIELD EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA FOR TWO SEASONS

A field study was carried out in the instructional farm, College of Agriculture, Padannakkad for two seasons (rabi and summer) during 2018 – 2019 and the details are given below:

3.2.1. Details of the experiment

Crop	: Okra
Variety	: Arka Anamika
Design	: Randomized Block Design (RBD)
Replications	: 4
Treatments	: 7
Sowing method	: Dibbling
First season	: October – January
Second season	: Febraury - May
Seed rate	: 8.5 kg/ ha
Spacing	: 60 cm x 45 cm
Area of a single plot	: 2.4x1.8 m^2, with 8 plants

3.2.2 Details of the treatments imposed

Table 2. Treatments imposed at field level

Sl.no	Treatment details	Application rate
T_1	Pongamia oil soap 0.6%	6g/L
T_2	Pongamia oil soap 1%	10g/L
T_3	Pongamia oil soap 2%	20g/L
T_4	Neem oil soap 0.6%	6g/L
T_5	Soap solution 0.5%	5ml/L
T_6	Quinalphos 25 EC (0.05%) – Standard check	2ml/L
T_7	Control	

Plate 2. Experimental plot

(a) Field view - two weeks after sowing

(b) Field view - 35 days after sowing

Treatments were applied at vegetative and reproductive stages as soon as the pest infestation was seen.

3.2.3 Preparation of main field

Land preparations were carried out one week prior to planting by taking eight long trenches. Farm yard manure (FYM) and lime were applied immediately. Seeds, obtained from IIHR, Bengaluru were sown by dibbling method at a spacing of 0.6 m x 0.45 m with eight plants per treatment and each treatment was replicated four times after land preparation. Seven days later the basal dose of NPK fertilizers, recommended in the KAU Package of Practices: Crops 2016 (POP, KAU) were applied.

Irrigation was given at 2 days interval during rabi season and daily during summer season. Other cultural practices including fertilizer application, weeding and earthing up were carried out as per the recommendation of the KAU Package of Practices: Crops 2016 (POP, KAU)

3.2.4 Treatment allocation

First round spraying of pongamia oil soap solution (Table 2.) was done at 30 days after sowing (DAS) during vegetative phase, second application during the reproductive stage at 55 DAS and third application at 80 DAS using 16 L Knapsack sprayer. Spraying was carried out during evening hours and precautions were taken to avoid drift.

3.2.5 Method of recording observation

Four plants out of eight were randomly selected and tagged in each plot for recording the observations. Observations were taken one day prior to treatment and 1, 3, 5, 7 and 14 days after application (DAA) for sucking pests. Damage symptoms caused by lepidopteran pests were observed at one day prior to and 7 and 14 DAA.

3.2.5.1 Shoot and fruit borer (Earias vitella) and fruit borer (Helicoverpa armigera)

Shoot infestation was recorded by counting total number of shoots and number of infested shoots from the tagged plants, whereas fruit infestation was recorded on number basis by recording the total number of fruits and number of damaged fruits from each plot at 7 and 14 DAT and percentage of infestation was calculated by the formula,

% of Shoot infestation = (No. of infested shoots ÷ Total no. of shoots observed) X 100

% of Fruit damage = (No. of damaged fruits ÷ Total no. of fruits) X100

3.2.5.2 Leaf roller (Sylepta derogata)

Total number of leaves and number of damaged leaves were counted from the tagged plants and percentage infestation of leaf roller was calculated by using the formula,

% of leaf infestation = (No. of damaged leaves ÷ Total no. of leaves) X 100

3.2.5.3 Sucking pests

Population density of leaf hopper was recorded by counting the number of nymphs and adults from five leaves (one top, two middle and two lower) of selected four plants on one day before, 1, 3, 5, 7 and 14 days after allocation of treatments. Per cent reduction in leaf hopper population was calculated using Henderson and Tilton formula, and were analyze (Henderson and Tilton, 1955).

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

Where,

n = Insect population
Co = Control
T = Treatment

3.2.6 Yield parameters

The effect of any treatment applied on crops will be finally reflected in the yield obtained and hence yield parameters are also important to compare the efficacy of each treatment. First harvesting was done at 40 DAS and later at every alternate day. Total 15 harvests was taken during rabi season and 14 harvests during summer season. Yield was recorded seperately on g / plant basis. Length of ten randomly selected fruits from each plot was measured and recorded. Fresh weight of fruit (g / plant), total yield obtained (g / plant) and marketable yield (g / plant) were also recorded and the benefit-cost ratio was calculated.

3.2.7 Statistical analysis

Data on per cent damage was analysed after arc sine transformation while population count was analysed after square root transformation. Yield parameters and cost – benefit ratio were analysed after square root transformation. Pooled analysis was worked out to compare the efficacy of the soap for both the season. The data were analysed using analysis of variance (ANOVA). Web Agri Stat Package (WASP) was used to compare the significance of each treatment.

Results

4. RESULTS

The present investigations on the evaluation of pongamia oil soap against major pests of okra, *Abelmoschus esculentus* (L). Moench was carried out to evaluate the efficacy of a new product made of pongamia oil - pongamia oil soap at different concentrations in combating the major pests of okra. The results of the investigation carried out during 2017-19 are presented below:

4.1 LABORATORY BIOASSAY OF PONGAMIA OIL SOAP

Bioassay studies were conducted in the laboratory of Department of Entomology, College of Agriculture, Padannakkad, to evaluate the efficacy of pongamia oil soap at different concentrations.

4.1.1 Feeding deterrency of pongamia oil soap against okra leaf roller *Sylepta derogata*

Based on the results from the leaf area consumed by the fourth instar larvae of *S. derogata* antifeedent properties of different concentrations of pongamia oil soap at 0.6 per cent, 1 per cent and 2 per cent along with neem oil soap 0.6 per cent, soap solution 0.5 per cent and control were evaluated. The experiment was repeated two times and the feeding deterrency of various treatments were computed from the observed data and presented in Table 3.

Pongamia oil soap 2 per cent showed the highest antifeedent activity with 97.33 and 98.33 per cent of feeding deterrency during both the experiments which was significantly superior to all other treatments as compared to that of control with zero per cent feeding deterrency. Soap solution 0.5 per cent was statistically on par with control with 3.33 and 2.33 per cent of feeding deterrency. Pongamia oil soap 1 per showed the next best result of 82.33 and 83.67 per cent of feeding deterrency followed by pongamia oil soap 0.6 per cent (72.33 %) and neem oil soap 0.6 per cent (52 and 54.33 %).

Table 3. Feeding deterrency in the fourth instar larvae of *Sylepta derogata* under different treatments

Treatments	Feeding deterrency	
	First Experiment	Second Experiment
Pongamia oil soap 0.6%	72.33^{c}	72.33^{c}
Pongamia oil soap 1%	82.33^{b}	83.67^{b}
Pongamia oil soap 2%	97.33^{a}	98.33^{a}
Neem oil soap 0.6%	52.00^{d}	54.33^{d}
Soap solution 0.5%	3.33^{e}	2.33^{e}
Control	0.00^{e}	0.00^{e}
C.D (0.05)	**5.64**	**5.56**

Means superscripted by similar letters are not significantly different at 5% level of DMRT

4.1.2 Growth index and Relative growth index

Growth retardation properties of pongamia oil soap was evaluated against first instar larvae of *Sylepta derogata* after conducting two experiments and Growth Index (GI) was calculated and presented in Table 4. The relative growth index (RGI) of each treatment was calculated from GI and is presented in the Table 5.

The ratio of rate of increase in size of larvae in treatment to that of the larvae in control was noted the lowest in pongamia oil soap 2 per cent with 0.16 RGI during first experiment which was significantly different from other treatments. It was followed by pongamia oil soap 1 per cent with a RGI of 0.42. Control (1.00) and soap solution 0.5 per cent (1.00) was on par with each other. Pongamia oil soap 0.6 per cent was on par with neem oil soap 0.6 per cent with a RGI of 0.57.

Pongamia oil soap 2 per cent recorded the lowest RGI with 0.16 RGI during second experiment also followed by pongamia oil soap 1 per cent with a RGI of 0.45. Control (1.00) and soap solution 0.5 per cent (1.00) was on par with each other. Neem oil soap 0.6 per cent showed better growth retardation properties in the second experiment (0.54) as compared to that of pongamia oil soap 0.6 per cent (0.6).

4.1.3 Mortality of leaf hopper

The data on mortality of leaf hopper nymphs taken at 2, 4, 6, 8, 10, 12, 16, 20, 24 and 48 h after treatment is presented in Table 6.

None of the treatment inflicted any mortality on leaf hopper upto 8 h of treatment. Pongamia oil soap (2%) caused 40% and 60% of cumulative mortality at 10 and 12 h of treatment, respectively. At 16 h of treatment cent percent mortality was recorded, whereas pongamia oil soap (1%) caused 30% mortality only at 12 h of treatment which was increased to 80% at 16 h of treatment. Cent per cent mortality was obtained at 20h of treatment.

Table 4. Growth index of *Sylepta derogata* larvae under different treatments

Treatments	No. of Ist instar larvae at the beginning of the experiment	No. of live larvae present in different instars							No. of dead larvae present in different instars							Growth index	No. of live larvae present in different instars							No. of dead larvae present in different instars							Growth index
		1	2	3	4	5	6	Pupa	1	2	3	4	5	6	Pupa		1	2	3	4	5	6	Pupa	1	2	3	4	5	6	Pupa	
Pongamia oil soap 0.6%	5	-	-	-	4	-	-	-	-	-	-	1	-	-	-	0.57	-	-	-	3	-	-	-	-	-	-	1	1		-	0.60
Pongamia oil soap 1%	5	-	-	3	-	-	-	-	-	-	2	-	-	-	-	0.42	-	-	2	-	-	-	-	-	-	2	1	-		-	0.45
Pongamia oil soap 2%	5	-	-	-	-	-	-	-	-	5	-	-	-	-	-	0.16	-	-	-	-	-	-	-	-	5	-	-	-		-	0.16
Neem oil soap 0.6%	5	-	-	-	3	-	-	-	-	-	-	2	-	-	-	0.57	-	-	-	2	1	-	-	-	-	2	-	-		-	0.54
Soap solution 0.5%	5	-	-	-	-	-	-	5	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	5	-	-	-	-	-		-	1.00
Control	5	-	-	-	-	-	-	5	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	5	-	-	-	-	-		-	1.00

Table 5. Relative growth index of *Sylepta derogata* larvae under different treatments after two experiments

Treatments	Relative growth index	
	First Experiment	Second Experiment
Pongamia oil soap 0.6%	0.57[b]	0.60[b]
Pongamia oil soap 1%	0.42[c]	0.45[d]
Pongamia oil soap 2%	0.16[d]	0.16[e]
Neem oil soap 0.6%	0.57[b]	0.54[c]
Soap solution 0.5%	1.00[a]	1.00[a]
Control	1.00[a]	1.00[a]
C.D (0.05)	**0.025**	**0.026**

Means superscripted by similar letters are not significantly different at 5% level of DMRT

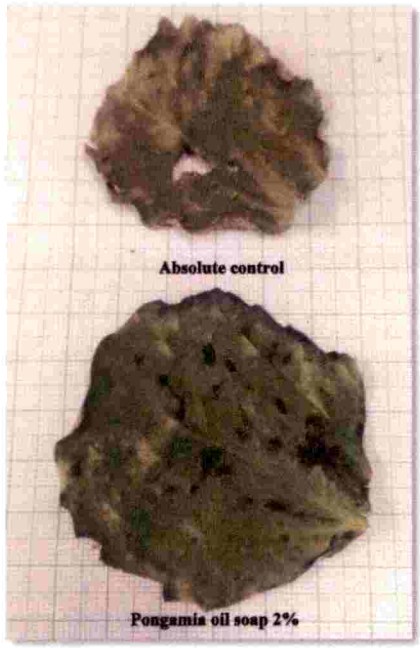
Neem oil soap 0.6 per cent showed a mortality of 20 per cent by 16 h of treatment. 20 hours after treatment pongamia oil soap (0.6 %) and neem oil soap (0.6 %) showed a cumulative mortality of 50 and 70 per cent respectively. 24 hours after the treatment, all the treatments showed cent per cent mortality except control and soap solution 0.5 per cent. No mortality was observed even after forty eight hours of treatments in control and soap solution 0.5 per cent.

Table 6. Percentage mortality of leafhoppers under different treatments

Treatments	Percentage mortality of leaf hoppers after					
	10 h	**12 h**	**16 h**	**20 h**	**24 h**	**48 h**
Pongamia oil soap 0.6%	0	0	0	50	100	-
Pongamia oil soap 1%	0	30	80	100	-	-
Pongamia oil soap 2%	40	60	100	-	-	-
Neem oil soap 0.6%	0	0	20	70	100	-
Soap solution 0.5%	0	0	0	0	0	0
Control	0	0	0	0	0	0

After cent percent mortality "-" denotes no value since 100 per cent mortality occurred in the previous observation. The experiments were commenced with 10 nymphs in each treatment.

Plate 3. Laboratory bioassay



(a) Leaf are consumed by fourth instar larvae of *Sylepta derogata*

(b) Experimental set up for mortality study of leaf hoppers

Plate 4. Laboratory bioassay of Relative growth Index against first instar larvae of *Sylepta derogata*

(a) Larvae fed with pongamia oil soap treated leaf

(b) Larvae fed with untreated leaves underwent pupation

4.2 EVALUATION OF FIELD EFFICACY OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA (RABI AND SUMMER 2018-19)

The present experiment was carried out to study the efficacy of pongamia oil soap at different concentrations for the management of pests infesting okra in field conditions during two consecutive seasons: rabi and summer, 2018 - 2019 at College of Agriculture, Kerala Agricultural University, Padannakkad. The results obtained from the study are presented below under the following main headings:

4.2.1 Field efficacy of pongamia oil soap against leaf hopper, *Amrasca biguttula biguttula* infesting okra

The field efficacy of pongamia oil soap at different concentrations was evaluated on okra during rabi (October 2018 – January 2019) by three rounds of spraing at 30, 55 and 80 days after sowing. Obervations taken at one day prior, 1, 3, 5, 7 and 14 days after treatment is presented in the Table 7. Leaf hopper population during summer was not recorded as the incidence was very less.

First application

Precount of leaf hopper population was not significantly different among the treatments, indicating a homogenous population which ranged from 4.00 – 5.06 leaf hoppers / 5 leaves / plant.

A day after the first application, the plot treated with quinalphos 25 EC at 0.05 per cent (standard check) recorded the least count of 1.75 leaf hopper / 5 leaves, followed by pongamia oil soap 2 per cent (2.81 leaf hopper / 5 leaves) and pongamia oil soap 1 per cent (3.75 leaf hopper / 5 leaves) which were on par with the standard check. All the treatments stood significantly superior over the control (5.38 leaf hopper / 5 leaves) whereas soap solution 0.5 per cent (5.19 leaf hopper / 5 leaves) was on par with control. Pongamia oil soap 0.6 per cent (4.31 leaf hopper / 5 leaves) and neem oil soap 0.6 per cent (4.06 leaf hopper / 5 leaves) was on par with each other.

After three days of application, among the botanicals, pongamia oil soap 2 per cent showed lowest population of 1.19 leaf hopper / 5 leaves which was at par with standard check (1.00 leaf hopper / 5 leaves). It was followed by pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent (2.81, 3.00 and 3.69 leaf hopper / 5 leaves) respectively which was at par with each other. Soap solution 0.5 per cent and control showed highest population count of 5.31 and 5.56 leaf hopper / 5 leaves which was at par with each other.

Observations after five days of first application indicated that the standard check was highly effective treatment with lowest hopper population of 0.31 leaf hopper / 5 leaves which was immediately followed by pongamia oil soap 2 per cent (0.81 leaf hopper / 5 leaves) and pongamia oil soap 1 per cent (1.63 leaf hopper / 5 leaves). Neem oil soap 0.6 per cent (2.06 leaf hopper / 5 leaves) was at par with pongamia oil soap 0.6 per cent (2.50 leaf hopper / 5 leaves). Soap solution 0.5 per cent and control showed highest population count of 6.00 and 6.25 leaf hopper / 5 leaves which was at par with each other.

A gradual decrease in the population was observed in all the treatments except control and soap solution 0.5 per cent on the seventh day after first application with minimum population recorded in standard check (0.13 leaf hopper / 5 leaves) which was on par with pongamia oil soap 2 per cent (0.44 leaf hopper / 5 leaves). The highest population recorded was 6.81 leaf hopper / 5 leaves in control which was on par with soap solution 0.5 per cent (6.63 leaf hopper / 5 leaves). Pongamia oil soap 1 per cent was at par with neem oil soap 0.6 per cent with a population count of 1.00 and 1.25 leaf hopper / 5 leaves respectively which was followed by pongamia oil soap 0.6 per cent with 2.38 leaf hopper / 5 leaves.

There was a gradual increase in leaf hopper population in all the treatments on fourteenth day after first application and among the botanicals pongamia oil soap 2 per cent recorded the lowest leaf hopper population of 0.75 leaf hopper / 5 leaves

which was at par with standard check 0.31 leaf hopper / 5 leaves. Soap solution 0.5 per cent and control showed the highest population count of 7.44 and 7.50 leaf hopper / 5 leaves which was at par with each other. Pongamia oil soap 1 per cent was at par with neem oil soap 0.6 per cent with a population count of 1.56 and 1.69 leaf hopper / 5 leaves respectively which was followed by pongamia oil soap 0.6 per cent with 3.31 leaf hopper / 5 leaves.

Second application

Precount of leaf hopper population prior to second application was at a range of 5.37 - 8 leaf hopper / 5 leaves /plant.

A day after the second application, a reduction in the leaf hopper population was observed in all the treatments except in soap solution 0.5 per cent (8.06 leaf hopper / 5 leaves) and control (8.1 leaf hopper / 5 leaves) which were on par with each other. Quinalphos 0.05 per cent (standard check) recorded the least count of 3.13 leaf hopper / 5 leaves, followed by pongamia oil soap 2 per cent (4.63 leaf hopper / 5 leaves). Pongamia oil soap 1 per cent (5.81 leaf hopper / 5 leaves), neem oil soap 0.6 per cent (6.06 leaf hopper / 5 leaves) and pongamia oil soap 0.6 per cent (6.19 leaf hopper / 5 leaves) were found on par with each other.

After 3 days of second application significantly lowest population was recorded in standard check (1.00 leaf hopper / 5 leaves) followed by pongamia oil soap 2 per cent (2.50 leaf hopper / 5 leaves), while highest number of leaf hopper was recorded in treatment with soap solution 0.5 per cent (8.44 leaf hopper / 5 leaves) which was on par with control (8.38 leaf hopper / 5 leaves). Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent (3.88, 4.25 and 4.50 leaf hopper / 5 leaves) respectively were found on par with each other.

Five days after application, standard check showed the lowest hopper population of 0.19 leaf hopper / 5 leaves followed by pongamia oil soap 2 per cent

(0.94 leaf hopper / 5 leaves), pongamia oil soap 1 per cent (1.88 leaf hopper / 5 leaves), neem oil soap 0.6 per cent (2.94 leaf hopper / 5 leaves) and pongamia oil soap 0.6 per cent (3.06 leaf hopper / 5 leaves). Soap solution 0.5 per cent and control showed the maximum leaf hopper population with 9.00 and 9.31 leaf hopper / 5 leaves.

Observations at seventh day after second application during rabi season revealed standard check with 0.00 leaf hopper population as significantly superior treatment followed by pongamia oil soap 2 per cent (0.56 leaf hopper / 5 leaves) and pongamia oil soap 1 per cent (1.69 leaf hopper / 5 leaves). Neem oil soap 0.6 per cent was at par with pongamia oil soap 0.6 per cent with a population count of 2.81 and 3.38 leaf hopper / 5 leaves respectively. While the maximum population was recorded in soap solution 0.5 per cent and control with 9.63 and 10.00 leaf hopper / 5 leaves respectively which was found to be on par.

A gradual increase in leaf hopper population was observed in all the treatments at 14 days after application with standard check showing the lowest population count of 0.56 leaf hopper / 5 leaves, while among the botanicals pongamia oil soap 2 per cent recorded the lowest leaf hopper population of 1.06 leaf hopper / 5 leaves followed by pongamia oil soap 1 per cent (2.06 leaf hopper / 5 leaves). Neem oil soap 0.6 per cent (3.94 leaf hopper / 5 leaves) and pongamia oil soap 0.6 per cent (4.06 leaf hopper / 5 leaves) were the next best treatments which were on par with each other. However, all treatments were significantly superior over control (11.00 leaf hopper / 5 leaves) and soap solution treatment (10.25 leaf hopper / 5 leaves).

Third application

Precount of leaf hopper population prior to third application was at a range of 7.93 – 11.25 leaf hopper / 5 leaves /plant.

The data collected a day after the third application revealed that the pest population ranged from 4.69 leaf hopper / 5 leaves in standard check to 11.94 leaf hopper / 5 leaves in control. However among the botanicals pongamia oil soap 2 per cent showed least population of 5.50 leaf hopper / 5 leaves which was on par with standard check. Pongamia oil soap 1 per cent (7.00 leaf hopper / 5 leaves) was the next best treatment followed by neem oil soap 0.6 per cent (7.75 leaf hopper / 5 leaves) which was on par with pongamia oil soap 0.6 per cent (8.31 leaf hopper / 5 leaves). Soap solution 0.5 per cent (11.19 leaf hopper / 5 leaves) was at par with control.

Third day count of leaf hopper population recorded the lowest population of 2.00 leaf hopper / 5 leaves in standard check followed by pongamia oil soap 2 per cent, pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent with 3.38, 4.44, 5.00 and 5.44 leaf hopper / 5 leaves respectively. Soap solution 0.5 per cent and control showed the maximum population count of 11.63 and 12.19 leaf hopper / 5 leaves respectively.

Five days after application, standard check showed the lowest hopper population of 1.19 leaf hopper / 5 leaves and control showed the maximum population of 12.75 leaf hopper / 5 leaves which was on par with soap solution 0.5 per cent (12.06 leaf hopper / 5 leaves). Pongamia oil soap 2 per cent showed the least population count of 2.38 leaf hopper / 5 leaves among the botanicals followed by pongamia oil soap 1 per cent (3.63 leaf hopper / 5 leaves), neem oil soap 0.6 per cent (4.44 leaf hopper / 5 leaves) and pongamia oil soap 0.6 per cent (4.94 leaf hopper / 5 leaves).

Seven days after third application, standard check with 0.81 leaf hopper / 5 leaves showed the lowest population followed by pongamia oil soap 2 per cent with 2.13 leaf hopper / 5 leaves. Pongamia oil soap 1 per cent was the next best treatment followed by neem oil soap 0.6 per cent which was on par with pongamia oil soap 0.6

per cent with 3.19, 4.00 and 4.44 leaf hopper / 5 leaves respectively. While the population was 12.50 and 13.00 leaf hopper / 5 leaves in soap solution 0.5 per cent and control respectively which was on par with each other.

There was a gradual increase in leaf hopper population in all the treatments at 14 days after application while among the botanicals pongamia oil soap 2 per cent recorded the lowest leaf hopper population of 2.81 leaf hopper / 5 leaves after the standard check 1.25 leaf hopper / 5 leaves which was followed by pongamia oil soap 1 per cent, neem oil soap 0.6 per cent which was on par with pongamia oil soap 0.6 per cent with 4.19, 4.75 and 5.06 leaf hopper / 5 leaves respectively. Soap solution 0.5 per cent and control showed the highest count of 13.19 and 14.06 leaf hopper / 5 leaves respectively.

Percentage reduction in leaf hopper population under various treatmnets after three spray application is presented in Table 8. Pongamia oil soap (2%) (48.24%), pongamia oil soap (1%) (25.53%) and pongamia oil soap (0.6%) (20.86%) were statistically on par with standard check (61.59%) on one day after first spray application in reducing the leaf hopper population. Soap solution (0.5%) showed an increase in hopper population indicated by negative sign (-31.22%) which was on par with control (0.00%). Three days after first treatment also pongamia oil soap (2%) (82.94%), pongamia oil soap (1%) (42.86%, pongamia oil soap (0.6%) (41.22%) and neem oil soap (0.6 %) were statistically on par with standard check (75.18%). A gradual increase in percentage reduction of leaf hoppers on cumulative basis was observed in all the treatments except soap solution (0.5%) and control plots. The effectiveness increased upto seven days after the spray application which reached upto 91.71 per cent of leaf hopper reduction in pongamia oil soap (2%) treated plot followed by pongamia oil soap (1%) (81.69%), neem oil soap (0.6%) (79.18%) and pongamia oil soap (0.6%) (65.79%) which were on par with the standard check (93.37%). Fourteen days after first spray application a decrease in percentage reduction on cumulative basis was observed in all the treatments.

Table 7. Average population density of leaf hoppers during rabi season from October 2018 to January 2019

Treatments	Number of leaf hopper / 5 leaves*																	
	First application						Second application						Third application					
	1 DBA	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA	1 DBA	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA	1 DBA	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA
Pongamia oil soap 0.6%	4.94 (2.21)	4.31 (2.07)^{ab}	3.69 (2.02)^{ab}	2.50 (1.56)^{b}	2.38 (1.68)^{b}	3.31 (1.94)^{b}	7.75 (2.87)^{a}	6.19 (2.48)^{b}	4.50 (2.23)^{b}	3.06 (1.88)^{b}	3.38 (1.96)^{b}	4.06 (2.01)^{b}	10.37 (3.21)^{ab}	8.31 (2.88)^{b}	5.44 (2.33)^{b}	4.94 (2.22)^{b}	4.44 (2.10)^{b}	5.06 (2.24)^{b}
Pongamia oil soap 1%	4.44 (2.07)	3.75 (1.90)^{abc}	2.81 (1.81)^{b}	1.63 (1.27)^{c}	1.00 (1.22)^{c}	1.56 (1.42)^{c}	7.06 (2.73)^{ab}	5.81 (2.40)^{b}	3.88 (2.08)^{b}	1.88 (1.53)^{c}	1.69 (1.46)^{c}	2.06 (1.43)^{c}	10 (3.16)^{b}	7.00 (2.63)^{b}	4.44 (2.09)^{bc}	3.63 (1.90)^{c}	3.19 (1.78)^{c}	4.19 (2.04)^{c}
Pongamia oil soap 2%	5.06 (2.22)	2.81 (1.58)^{bc}	1.19 (1.25)^{c}	0.81 (0.89)^{d}	0.44 (0.96)^{d}	0.75 (1.11)^{d}	6.31 (2.60)^{bc}	4.63 (2.15)^{c}	2.50 (1.72)^{c}	0.94 (1.18)^{d}	0.56 (1.02)^{d}	1.06 (1.02)^{d}	8.75 (2.95)^{c}	5.50 (2.34)^{c}	3.38 (1.82)^{c}	2.38 (1.52)^{d}	2.13 (1.45)^{d}	2.81 (1.67)^{d}
Neem oil soap 0.6%	4.13 (2.01)	4.06 (2.00)^{ab}	3.00 (1.86)^{b}	2.06 (1.43)^{bc}	1.25 (1.31)^{c}	1.69 (1.46)^{c}	7.18 (2.77)^{ab}	6.06 (2.45)^{b}	4.25 (2.17)^{b}	2.94 (1.85)^{b}	2.81 (1.81)^{b}	3.94 (1.97)^{b}	10.25 (3.20)^{ab}	7.75 (2.78)^{b}	5.0 (2.23)^{b}	4.44 (2.10)^{bc}	4.00 (1.99)^{b}	4.75 (2.17)^{b}
Soap solution 0.5%	4.25 (1.97)	5.19 (2.25)^{a}	5.31 (2.40)^{a}	6.00 (2.43)^{a}	6.63 (2.65)^{a}	7.44 (2.81)^{a}	7.87 (2.89)^{a}	8.06 (2.83)^{a}	8.44 (2.98)^{a}	9.00 3.08)^{a}	9.63 (3.18)^{a}	10.25 (3.19)^{a}	11 (3.31)^{a}	11.19 (3.34)^{a}	11.63 (3.40)^{a}	12.06 (3.47)^{a}	12.50 (3.53)^{a}	13.19 (3.63)^{a}
Quinalphos 25 EC 0.05%	4.00 (1.97)	1.75 (1.27)^{c}	1.00 (1.17)^{c}	0.31 (0.55)^{e}	0.13 (0.78)^{d}	0.31 (0.88)^{d}	5.37 (2.41)^{c}	3.13 (1.76)^{d}	1.00 (1.19)^{d}	0.19 (0.82)^{e}	0.0 (0.70)^{e}	0.56 (0.72)^{e}	7.93 (2.81)^{c}	4.69 (2.14)^{c}	2.0 (1.38)^{d}	1.19 (1.08)^{e}	0.81 (0.89)^{e}	1.25 (1.11)^{e}
Control	4.69 (2.10)	5.38 (2.25)^{a}	5.56 (2.41)^{a}	6.25 (2.49)^{a}	6.81 (2.70)^{a}	7.50 (2.82)^{a}	8 (2.91)^{a}	8.1 (2.92)^{a}	8.38 (2.97)^{a}	9.31 (3.13)^{a}	10.0 (3.23)^{a}	11.0 (3.31)^{a}	11.25 (3.35)^{a}	11.94 (3.45)^{a}	12.19 (3.48)^{a}	12.75 (3.56)^{a}	13.0 (3.60)^{a}	14.06 (3.74)^{a}
C.D. (0.05)	**NS**	**0.62**	**0.49**	**0.28**	**0.25**	**0.25**	**0.24**	**0.17**	**0.24**	**0.19**	**0.23**	**0.22**	**0.15**	**0.25**	**0.29**	**0.20**	**0.14**	**0.13**

* Mean of observations of four plants.
Figures in parentheses denotes square root transformed values. Means superscripted by similar letters are not significantly different at 5% level of DMRT
DBA- Day before application; DAA- Days after application: NS- Non significant

Pongamia oil soap 2 per cent (26.06 % reduction of leaf hopper) was found to be on par with standard check (39.52 %) on first day after second spray application. Pongamia oil soap 2 per cent was also on par with pongamia oil soap 1 per cent (20.08 %), pongamia oil soap 0.6 per cent (13.61 %) and neem oil soap 0.6 per cent (15.55 %). Soap solution showed an increase in hopper population (-2.61 %) which was on par with the control (0.00%). On three and five days after second spray standard check (79.61 and 96.61) showed maximum reduction in leaf hopper population which was immediately followed by pongamia oil soap (2 %) with 62.13 and 86.87 per cent reduction respectively. Pongamia oil soap 2 per cent (92.89 % and 87.44%) was found to be on par with standard check (100.00 % and 92.03%)) at seven and fourteen days after second application. In all these days soap solution (0.5%) was statistically on par with control and pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent also showed statistically similar results through out the second spray application.

One day after third spray application the percentage reduction in leaf hopper population was observed to be on par with pongamia oil soap (2 %) (40.83 %), pongamia oil soap (1 %) (34.08 %) and standard check (76.07 %) treated plots. Standard check treated plots showed the maximum reduction in leaf hopper population during three, five, seven and fourteen days after third spray application with 76.07, 86.64, 91.26 and 87.30 percentage redction. It was immediately followed by pongamia oil soap (2 %) treated plot with 64.92, 74.91 and 78.62 percentage reduction in leaf hopper population. Pongamia oil soap 2 per cent was found to be on par with pongamia oil soap 1 per cent on third (59.04 %), fifth (68.05 %) and seventh (72.23 %) day after treatment. Pongamia oil soap (0.6 %) and neem oil soap (0.6 %) treated plots gave statistically similar results through out the third application, while soap solution (0.5 %) and control also gave similar results through out the experiment.

However, all the treatments showed significantly better reduction in leaf hopper population as compared to control and soap solution (0.5 %).

Table 8. Percentage reduction of leaf hopper population during rabi season from October 2018 to January 2019

Treatments	Percentage reduction in leaf hopper population*														
	First application					Second application					Third application				
	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA	1 DAA	3 DAA	5 DAA	7 DAA	14 DAA
Pongamia oil soap 0.6%	20.86^{abc}	41.22^{ab}	65.06^{a}	65.79^{a}	56.30^{ab}	13.61^{bcd}	44.08^{c}	65.91^{d}	64.09^{c}	61.51^{c}	23.00^{c}	51.15^{c}	57.25^{d}	62.25^{d}	60.28^{c}
Pongamia oil soap 1%	25.53^{abc}	42.86^{ab}	69.10^{a}	81.69^{a}	70.61^{a}	20.08^{b}	44.89^{c}	77.35^{c}	78.74^{b}	76.99^{b}	34.08^{abc}	59.04^{bc}	68.05^{bc}	72.23^{bc}	66.52^{c}
Pongamia oil soap 2%	48.24^{ab}	82.94^{a}	85.64^{a}	91.71^{a}	88.24^{a}	26.06^{ab}	62.13^{b}	86.87^{b}	92.89^{a}	87.44^{ab}	40.83^{ab}	64.92^{b}	74.91^{b}	78.62^{b}	74.25^{b}
Neem oil soap 0.6%	10.35^{bcd}	39.20^{ab}	60.30^{a}	79.18^{a}	74.69^{a}	15.55^{bc}	43.07^{c}	64.83^{d}	68.49^{bc}	59.76^{c}	28.25^{bc}	55.02^{bc}	61.93^{cd}	66.22^{cd}	62.77^{c}
Soap solution 0.5%	-31.22^{d}	-53.89^{c}	-25.13^{b}	-42.09^{b}	-49.57^{c}	-2.61^{d}	-3.32^{d}	1.73^{e}	1.59^{d}	4.44^{d}	3.71^{d}	1.95^{d}	2.49^{e}	1.09^{e}	3.65^{d}
Quinalphos 25 EC 0.05%	61.59^{a}	75.18^{a}	92.95^{a}	93.37^{a}	89.92^{a}	39.82^{a}	79.61^{a}	96.61^{a}	100.0^{a}	92.03^{a}	45.51^{a}	76.07^{a}	86.64^{a}	91.26^{a}	87.30^{a}
Control	0.00^{cd}	0.00^{bc}	0.00^{b}	0.00^{b}	0.00^{bc}	0.00^{cd}	0.00^{d}	0.00^{e}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{e}	0.00^{e}	0.00^{d}
C.D. (0.05)	**41.87**	**73.16**	**33.76**	**49.21**	**58.19**	**17.05**	**12.77**	**6.70**	**10.37**	**11.17**	**15.45**	**10.97**	**10.60**	**8.38**	**7.24**

* Mean of observations of four plants.
Means superscripted by similar letters are not significantly different at 5% level of DMRT
DAA- Days after application: NS- Non significant

4.2.2 Efficacy of pongamia oil soap as foliar application against leaf roller, *Sylepta derogata* infesting okra

The following data furnished below provide the results of the observations made on the efficacy of various treatments in the reduction of leaf damage. The damage caused by okra leaf roller *Sylepta derogata* was evaluated by taking the mean number of leaves damaged at weekly intervals after the application during rabi season and the data obtained was statistically analysed and presented in the Table 9. The incidence of leaf roller was absent during summer season.

First application

Per cent of leaves damaged by leaf roller was uniform in all the treatments prior to first application at a range of 20.12 to 25.48 per cent.

Plot treated with quinalphos 25 EC (0.05 %)(standard check) was the superior treatment with zero per cent of leaf damage at seventh day after the first application. The percent leaf damage was maximum (26.63) in soap solution (0.5 %) which was
on par with control (24.16 %). Pongamia oil soap (2 %) treated plant exhibited 1.99 per cent of leaf damage accounted as the next best treatment. Per cent damage observed in pongamia oil soap (1 %) (6.17) was statistically on par with that of pongamia oil soap (0.6 %)(7.61) and neem oil soap (0.6 %)(8.88) treatments.

Fourteen days after the first application, the leaf roller damage was found to be increased in all the treatments. The lowest damage per cent is observed in standard check (0.36 %), followed by pongamia oil soap 2 per cent (3.75 %) < pongamia oil soap 1 per cent (7.77 %) < pongamia oil soap 0.6 per cent (8.73 %) < neem oil soap 0.6 per cent (10.18 %) in that order. Soap solution 0.5 per cent showed the maximum leaf damage of 28.31 per cent which was on par with control (26.93 %). The treatments pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %) were on par with pongamia oil soap (2 %) treatment.

Second application

Damage caused by leaf roller prior to second spray was in a range of 10.95 to 22.28 per cent. The percentage leaf damage observed at seventh day after treatment in 2 % pongamia oil soap treated plants (2.32 %) and in standard check (0.65 %) were on par. The damage observed on soap solution 0.5 per cent (23.75 %) was on par with that of control (25.5 %). Pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 7.62, 8.49 and 9.52 per cent of leaf damage respectively, while pongamia oil soap 2 per cent and pongamia oil soap 1 per cent gave statistically similar results.

On fourteenth day after second application, per cent of damaged leaves was found to be the lowest (2.48 %) in pongamia oil soap (2 %) treated plants among the botanicals which was on par with standard check (0.77 %). Maximum leaf damage was observed in control (28.93 %) and soap solution (0.5 %) (24.0 %) and that were on par with each other. The leaf damage observed in pongamia oil soap (1 %), neem oil soap (0.6 %) and pongamia oil soap (0.6 %) treated plants were on par with each other and that are 5.81, 9 and 10.23 per cent, respectively.

Third application

Damage caused by leaf roller prior to third spray was in a range of 2.63 to 28.27 per cent.

The per cent of leaf damage was reduced to 0.39 per cent on seventh day after third application in 0.05% quinalphos treated plants. Maximum leaf infestation was observed in control (31.14 %) which was significantly higher than the population observed on rest of the treatments other than soap solution (0.5 %) (26.93 %). Pongamia oil soap (2 %) was the best treatment among the botanicals with only 2.15 per cent leaf damage. The treatments, pongamia oil soap (1 %), neem oil soap (0.6 %) and pongamia oil soap (0.6 %) were statistically on par

with each other, where the plants exhibited 6.85, 7.64 and 9.64 per cent leaf damages respectively.

Pongamia oil soap (2 %) with 1.43 per cent of leaf damage showed the best results among the botanicals which was on par with standard check (0.39 %). Pongamia oil soap (1 %), neem oil soap (0.6 %) and pongamia oil soap (0.6 %) was statistically on par with each other with 7.47, 7.92 and 10.39 per cent leaf damage respectively. A decrease in damage percent was observed from a day prior to first application to fourteenth day after third application in all the treatments except in the case of control (31.41 %) and soap solution (0.5 %) (26.75 %).

A reduction in percentage of damaged leaves was observed in all the treatments by the seventh day after application except in soap solution 0.5 per cent and control during rabi season. By fourteenth day after application an increase in per cent damaged leaves was observed in all the treatments. However standard check showed lowest percentage of damaged leaves followed by pongamia oil soap 2 per cent, pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent. Control and soap solution 0.5 per cent showed an increase in percent damaged leaves by the fourteenth day.

4.2.3 Efficacy of pongama oil soap as foliar application against shoot and fruit borers, *Earias vitella and Helivoverpa armigera* infesting okra

The following data furnished below provide the results of the observations made on the efficacy of various treatments in the reduction of shoot and fruit damage.

4.2.3.1 Mean per cent of shoot borer (Earias vitella) infestation on shoots during rabi season from October 2018 to January 2019

The effect of treatments like pongamia oil soap @ 0.6 per cent, 1 per cent and 2 per cent, neem oil 0.6 per cent, soap solution 0.5 per cent, quinalphos 0.05 per cent and control against shoot borer *Earias vitella,* was analyzed by

Table 9. Mean per cent of leaves damaged by larvae of *Sylepta derogata* at weekly intervals during rabi season from October 2018 to January 2019

Treatments	Percentage of damaged leaves *								
	First application			Second application			Third application		
	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA	1 DBS	7 DAA	14 DAA
Pongamia oil soap 0.6%	20.12 (27.02)	7.61 (15.99)^{b}	8.73 (17.07)^{b}	16.31 (23.72)^{ab}	8.49 (16.82)^{b}	10.23 (18.31)^{b}	14.29 (22.20)^{b}	9.64 (18.07)^{b}	10.39 (18.11)^{b}
Pongamia oil soap 1%	19.70 (26.20)	6.17 (14.17)^{b}	7.77 (14.98)^{b}	15.74 (23.02)^{bc}	7.62 (15.43)^{bc}	5.81 (13.52)^{bc}	10.37 (18.76)^{c}	6.85 (14.71)^{b}	7.47 (14.79)^{b}
Pongamia oil soap 2%	21.54 (27.54)	1.99 (8.02)^{c}	3.75 (11.07)^{b}	13.20 (21.28)^{bc}	2.32 (8.50)^{cd}	2.48 (8.83)^{cd}	5.71 (13.77)^{d}	2.15 (8.33)^{c}	1.43 (6.83)^{c}
Neem oil soap 0.6%	23.10 (28.68)	8.88 (17.31)^{b}	10.18 (17.91)^{b}	14.53 (22.38)^{bc}	9.52 (17.75)^{b}	9.0 (16.97)^{b}	11.69 (19.80)^{bc}	7.64 (15.82)^{b}	7.92 (15.45)^{b}
Soap solution 0.5%	25.48 (30.212)	26.63 (30.88)^{a}	28.31 (32.02)^{a}	21.49 (27.54)^{a}	23.75 (29.13)^{a}	24.0 (29.12)^{a}	28.27 (32.07)^{a}	26.93 (31.20)^{a}	26.75 (31.14)^{a}
Quinalphos 25 EC 0.05%	21.36 (27.45)	0.00 (.54)^{d}	0.36 (2.13)^{c}	10.95 (19.27)^{c}	0.65 (3.58)^{d}	0.77 (3.85)^{d}	2.63 (9.06)^{e}	0.39 (2.19)^{d}	0.39 (2.21)^{c}
Control	23.61 (29.03)	24.16 (29.39)^{a}	26.93 (31.20)^{a}	22.28 (28.09)^{a}	25.5 (30.32)^{a}	28.93 (32.20)^{a}	28.19 (32.06)^{a}	31.14 (33.90)^{a}	31.41 (33.07)^{a}
C.D. (0.05)	NS	**3.91**	**8.38**	**4.37**	**7.44**	**6.54**	**3.21**	**3.60**	**6.18**

* Mean of four observations.
Means superscripted by similar letters are not significantly different at 5% level of DMRT.
Figures in parentheses denotes arc sine transformed values.
DBA- Day before application; DAA- Days after application. NS – Non significant.

calculating the mean per cent of shoots damaged and the data are recorded at weekly intervals during rabi season from October 2018 to January 2019 and are presented in the Table 10.

First application

Mean percent of shoot damage under different treatments were ranged between 36.46 to 45.835 per cent prior to the treatment which was not significant.

There was a significant reduction in shoot damage in the plot treated with quinalphos 0.05 per cent (standard check) with only 15 per cent of damaged shoots after seven days of first application. The maximum per cent of shoot damage was recorded in control (50 %) which was at par with soap solution 0.5 per cent treated plants (50 %). Pongamia oil soap (2 %) showed the lowest shoot damage among botanicals with 22.91 per cent of damaged shoots, followed by pongamia oil soap 1 per cent (25 %) > pongamia oil soap 0.6 per cent (32.29 %) > neem oil soap 0.6 per cent (36.45 %). The reduction in shoot damage due to pongamia oil soap 2 per cent and pongamia oil soap 1 per cent was statistically on par with standard check. At the same time the per cent reduction in shoot damage due to pongamia oil soap (0.6 %) was on par with pongamia oil soap (2 %) and pongamia oil soap (1 %).

Observations recorded on fourteenth day after first round spray revealed that the standard check as the best treatment (12.5 % shoot damage) followed by pongamia oil soap 2 per cent (31.24 %) > pongamia oil soap 1 per cent (33.33 %) > neem oil soap 0.6 per cent (38.5 %) > pongamia oil soap 0.6 per cent (39.58 %) in the order. Highest percentage of shoot damage (55.62 %) was observed in soap solution (0.5 %) treatment which was at par with control (54.16 % shoot damage). The per cent shoot damage in pongamia oil soap (2 %), pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %) treatments were statistically on par with each other.

Second application

Mean percent of shoot damage under different treatments were found to be at a range of 25 to 54.17 per cent prior to the second application.

Infestation of shoot borer was reduced in all the treatments with pongamia oil soap (2 %) showing minimum per cent of shoot damage (11.56 %) among botanicals which was on par with standard check (9.37 %) while soap solution 0.5 per cent had the highest shoot damage of 38.54 per cent which was on par with control with 34.37 per cent of shoot damage. Neem oil soap (0.6 %) showed the next best result which was followed by pongamia oil soap (1 %) > pongamia oil soap 0.6 per cent with 19.27, 21.35 and 25 per cent of shoot damage respectively. Pongamia oil soap 2 per cent, pongamia oil soap 1 per cent and neem oil soap 0.6 per cent was on par with standard check while pongamia oil soap 0.6 per cent, neem oil soap 0.6 per cent and pongamia oil soap 1 per cent showed statistically similar results. Pongamia oil soap 0.6 per cent showed the maximum per cent of shoot damage among botanicals which was on par with pongamia oil soap 1 per cent and also with soap solution 0.5 per cent and control.

Pongamia oil soap 2 per cent (15.72 %) showed best results among botanicals at fourteen days after second application which was on par with standard check (12.5 %). Per cent of infestation was increased in all the treatments at fourteen days after second application. Soap solution 0.5 per cent showed maximum shoot damage of 42.18 per cent which was on par with control (40.10). Pongamia oil soap 2 per cent, neem oil soap 0.6 per cent and pongamia oil soap 1 per cent was on par with standard check while pongamia oil soap 0.6 per cent also showed similar results as that of pongamia oil soap 2 per cent, neem oil soap 0.6 per cent and pongamia oil soap 1 per cent. Pongamia oil soap 0.6 per cent showed a damage per cent of 26.56 which was also on par with control.

Third application

Mean percent of shoot damage under different treatments were found to be at a range of 14.58 to 43.75 per cent prior to the second application. Due to

profuse branching and reduction in shoot infestation, per cent of shoot damage was reduced at seventh day in all the treatments. Pongamia oil soap (2 %) with only 10.52 per cent of damaged shoots was on par with standard check (7.70 %). Soap solution 0.5 per cent treated plants (43.12 %) showed the maximum shoot damage which was at par with control (39.79 %). Neem oil soap (0.6 %) showed results similar to pongamia oil soap (2 %), pongamia oil soap (1 %) and pongamia oil soap (0.6 %).

Fourteen days after third application standard check showed 9.58 per cent of shoot damage indicating the most superior treatment followed by pongamia oil soap 2 per cent (12.60 %) > pongamia oil soap 1 per cent (19.27 %) in the order. Soap solution 0.5 per cent showed maximum per cent of shoot damage (45.93 %) which was at par with control (44.68 %). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent were at par with each other which marked 25.31 and 22.81 per cent of shoot damage, respectively. That was also on par with pongamia oil soap 1 per cent treatment.

4.2.3.2 Mean percent of shoot borer (Earias vitella) infestation on shoots during summer season from February to May 2019

Treatments like pongamia oil soap @ 0.6 per cent, 1 per cent and 2 per cent, neem oil 0.6 per cent, soap solution 0.5 per cent, quinalphos 0.05 per cent and control were tested to study their efficacy against shoot borer *Earias vitella* during summer season from February to May 2019 and the mean per cent of damaged shoots were obtained after statistical analysis and is presented in the Table 11.

First application

Shoot damage per cent under different treatments were ranged between 43.75 to 47.91 per cent which were statistically not significant.

Table 10. Mean per cent of shoots damaged by larvae of *Earias vitella* taken at weekly intervals during rabi season from October 2018 to January 2019

Treatments	Percentage of damaged shoots *								
	First application			Second application			Third application		
	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA
Pongamia oil soap 0.6%	39.58 (38.81)	32.29 (33.69)^{bc}	39.58 (38.98)^{b}	42.70 (40.79)^{ab}	25 (30.0)^{ab}	26.56 (30.99)^{bc}	27.08 (31.31)^{bc}	22.81 (28.33)^{b}	25.31 (30.13)^{b}
Pongamia oil soap 1%	36.46 (37.04)	25 (30.00)^{bcd}	33.33 (33.94)^{b}	37.50 (37.69)^{b}	21.35 (27.43)^{abc}	23.95 (29.28)^{cd}	24.47 (29.52)^{c}	17.70 (24.64)^{bc}	19.27 (25.88)^{bc}
Pongamia oil soap 2%	43.75 (41.36)	22.91 (28.52)^{cd}	31.24 (35.26)^{b}	41.67 (40.13)^{ab}	11.56 (19.53)^{c}	15.72 (22.32)^{cd}	17.81 (23.56)^{c}	10.52 (18.44)^{cd}	12.60 (20.27)^{cd}
Neem oil soap 0.6%	42.70 (40.75)	36.45 (37.13)^{b}	38.5 (38.98)^{b}	42.70 (40.79)^{ab}	19.27 (22.86)^{bc}	25.41 (29.65)^{cd}	28.22 (31.74)^{abc}	20.31 (25.86)^{bc}	22.81 (28.10)^{b}
Soap solution 0.5%	42.70 (40.75)	50 (45.00)^{a}	55.62 (48.25)^{a}	46.88 (43.19)^{ab}	38.54 (36.09)^{a}	42.18 (40.43)^{a}	43.75 (41.34)^{a}	41.12 (41.0)^{a}	45.93 (42.66)^{a}
Quinalphos 25 EC 0.05%	40.83 (39.65)	15 (22.32)^{d}	12.5 (18.20)^{c}	25.00 (29.24)^{c}	9.37 (17.45)^{c}	12.5 (20.57)^{d}	14.58 (22.39)^{c}	7.70 (16.04)^{d}	9.58 (17.45)^{d}
Control	45.83 (46.18)	50 (45.00)^{a}	54.16 (47.39)^{a}	54.17 (47.39)^{a}	34.37 (35.86)^{a}	40.10 (39.23)^{ab}	41.66 (40.18)^{ab}	39.79 (39.04)^{a}	44.68 (41.92)^{a}
C.D. (0.05)	**NS**	**7.73**	**6.63**	**7.80**	**10.12**	**9.40**	**9.72**	**8.17**	**6.91**

* Mean of observations on four plants.
Figures in parentheses denotes arc sine transformed values.
Means superscripted by similar letters are not significantly different at 5% level of DMRT.
DBA- Day before application; DAA- Days after application.
NS – Non significant.

A significant reduction in shoot damage was observed in the plot treated with quinalphos 0.05 per cent (standard check) with 21.35 per cent of damaged shoots after seven days of first application while the maximum per cent of shoot damage was recorded in control (45 %) which was at par with soap solution 0.5 per cent (43.83 %) treatment. Pongamia oil soap (2 %) showed lowest shoot damage among botanicals with 28.12 per cent of damaged shoots followed by pongamia oil soap (1 %) (34.89 % shoot damage), pongamia oil soap (0.6 %) (34.37 %) and neem oil soap 0.6 per cent (35.41 %). Pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %) were statistically similar to each other.

Fourteen days after first application, standard check was observed as the best treatment (23.43 %) followed by pongamia oil soap 2 per cent (29.16 % shoot damage) > neem oil soap 0.6 per cent (36.97 %) > pongamia oil soap 1 per cent (38.54 %) > pongamia oil soap 0.6 per cent (40.10 %). Soap solution 0.5 per cent with 44.43 per cent of shoot damage showed similar results with control 46.43 per cent. Pongamia oil soap 2 per cent was on par with standard check and it also showed results close to neem oil soap 0.6 per cent and pongamia oil soap 1 per cent. Pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other. Pongamia oil soap 1 per cent and pongamia oil soap 0.6 per cent was on par with control also.

Second application

Prior to the second application non significant damage percent was recorded between all the treatments that range between 32.29 to 44.28.

Observations taken at seven days after the second application also showed similar trends as that of first application with standard check showing the minimum per cent of shoot damage (8.02 %) and maximum per cent of shoot damage in control and soap solution (0.5 %) with 41.35 per cent and 42.81 per cent of shoot damage respectively which was on par with each other. Efficacy level of other treatments against shoot damage was in an order of pongamia oil

soap 2 per cent (14.58 %) > pongamia oil soap 1 per cent (25 %) > neem oil soap 0.6 per cent (27.5 %) > pongamia oil soap 0.6 per cent (29.68 per cent of shoot damage). Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent were on par with each other.

Fourteen days after second application there was an increase in shoot damage in all the treatments and among the treatments standard check (9.27 %) showed significant difference while soap solution 0.5 per cent showed maximum per cent of shoot damage of 45.935 which was on par with control (44.16). Pongamia oil soap (2 %) was the next better treatment followed by pongamia oil soap (1 %), neem oil soap (0.6 %) and pongamia oil soap (0.6 %) with 17.70, 26.56, 30.62 and 31.77 per cent of shoot damage. Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent were on par with each other.

Third application

Prior to the third application damage percent was recorded at a range of 10.83 to 45.94 per cent of shoot damage. Percentage of shoot borer infestation decreased drastically in all the treatments during the seventh day after the third application and the observations revealed that standard check as the most superior treatment with 3.54 per cent of shoot damage which was immediately followed by pongamia oil soap 2 per cent with only 10.31 per cent of damaged shoots. Soap solution 0.5 per cent showed the maximum shoot damage of 37.08 per cent which was at par with control (35.52 %). Neem oil soap 0.6 per cent, pongamia oil soap 0.6 per cent and pongamia oil soap 1 per cent with 21.97, 23.95 and 18.02 per cent of shoot damage respectively was at par with each other.

Even fourteen days after third application standard check showed only 5.10 per cent of shoot damage indicating quinalphos 25 EC as the most superior treatment followed by pongamia oil soap 2 per cent (13.12 %) > pongamia oil soap 1 per cent (20.62 %) > neem oil soap 0.6 per cent (24.79 %) > pongamia oil soap 0.6 per cent (26.45 %). Soap solution 0.5 per cent showed maximum per cent

of shoot damage (39.58 %) which was at par with control (38.12 %). Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent was on par with each other.

A reduction in percentage of damaged shoots was observed in all the treatments by the seventh day after application during both the season except in soap solution 0.5 per cent and control during rabi season. The maximum reduction was observed with standard check followed by pongamia oil soap 2 per cent, pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent.

By fourteenth day after application an increase in per cent of damaged shoots was observed in all the treatments. Standard check showed the maximum percentage reduction followed by pongamia oil soap (2 %) > pongamia oil sopa (1 %) > neem oil soap (0.6 %) > pongamia oil soap (0.6 %). Control and soap solution 0.5 per cent showed an increase in percent damaged leaves by the fourteenth day.

4.2.3.3 Pooled analysis of the per cent shoot damage caused by shoot and fruit borer, Earias vitella during rabi and summer season.

Per cent of shoot damage during both the season were analysed and is presented in Table 12.

Seven days after the first spray standard check (18.18 %) was recorded as the effective treatment against shoot and fruit borer during both the seasons which was immediately followed by pongamia oil soap 2 per cent (25.52 %) which was on par with pongamia oil soap 1 per cent (29.95 %). Soap solution 0.5 per cent was least effective (47.92 %) which was on par with control (48.96 %). Pongamia

Table 11. Mean per cent of shoots damaged by larvae of *Earias vitella* taken at weekly intervals during summer season from February to May 2019

Treatments	Percentage of damaged shoots *								
	First application			Second application			Third application		
	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA
Pongamia oil soap 0.6%	45.83 (42.60)	34.37 (35.88) ^{b}	40.10 (39.23) ^{ab}	43.22 (41.04) ^{ab}	29.68 (32.93) ^{b}	31.77 (34.25) ^{b}	31.45 (34.11) ^{b}	23.95 (29.23) ^{b}	26.45 (30.85) ^{b}
Pongamia oil soap 1%	44.79 (41.99)	34.89 (36.19) ^{b}	38.54 (38.37) ^{abc}	41.67 (40.18) ^{ab}	25 (30.0) ^{b}	26.56 (30.99) ^{b}	26.57 (30.83) ^{b}	18.02 (25.02) ^{b}	20.62 (26.97) ^{b}
Pongamia oil soap 2%	43.75 (41.36)	28.12 (31.94) ^{c}	29.16 (32.27) ^{cd}	33.33 (34.90) ^{bc}	14.58 (22.20) ^{c}	17.70 (24.52) ^{c}	19.80 (26.19) ^{c}	10.31 (18.53) ^{c}	13.12 (21.17) ^{c}
Neem oil soap 0.6%	47.91 (43.93)	35.41 (36.51) ^{b}	36.97 (37.42) ^{bc}	44.28 (41.66) ^{ab}	27.5 (31.56) ^{b}	30.62 (33.50) ^{b}	30.63 (33.56) ^{b}	21.97 (27.78) ^{b}	24.79 (29.67) ^{b}
Soap solution 0.5%	43.75 (41.25)	43.83 (40.74) ^{a}	44.43 (40.45) ^{a}	41.35 (38.27) ^{a}	42.81 (40.86) ^{a}	45.93 (42.66) ^{a}	45.94 (42.66) ^{a}	37.08 (37.49) ^{a}	39.58 (38.94) ^{a}
Quinalphos 25 EC 0.05%	46.87 (43.05)	21.35 (27.43) ^{d}	23.43 (28.91) ^{d}	28 (32.31) ^{c}	8.02 (16.22) ^{d}	9.27 (17.59) ^{d}	10.83 (19.15) ^{d}	3.54 (9.54) ^{d}	5.10 (13.02) ^{d}
Control	44.83 (42.56)	45.0 (41.00) ^{a}	46.43 (42.27) ^{a}	40.85 (37.65) ^{a}	41.35 (40.01) ^{a}	44.16 (41.64) ^{a}	42.60 (40.74) ^{a}	35.52 (36.56) ^{a}	38.12 (38.11) ^{a}
C.D. (0.05)	**NS**	**3.70**	**6.12**	**7.24**	**4.27**	**4.721**	**4.35**	**5.13**	**4.74**

* Mean of observations on four plants

Figures in parentheses denotes arc sine transformed values.

Means superscripted by similar letters are not significantly different at 5% level of DMRT

DBA- Day before application; DAA- Days after application.

NS – Non significant.

oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other. Per cent shoot damage during rabi season (33.10 %) was on par with summer season (35.42 %).

Pongamia oil soap 2 per cent, pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent showed statistically similar results at fourteen days after first application during both the season, while standard check recorded the lowest per cent of shoot damage (17.97 %). Soap solution 0.5 per cent (52.03 %) showed the maximum shoot damage which was on par with control. Percent shoot damage during both the season was statistically similar.

Pongamia oil soap 2 per cent (13.07 %) was on par with standard check (8.70 %) on seventh day after second application, while pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other with 23.18, 27.34 and 23.39 per cent of shoot damage respectively. Soap solution 0.5 per cent (38.85 %) showed the highest shoot damage which was on par with control. Per cent shoot damage was recorded significantly high during summer season (26.99 %) as compared to that of rabi season (22.26 %).

Standard check was effective in controlling shoot damage at fourteen days after second spray with only 10.89 per cent of damaged shoot followed by pongamia oil soap 2 per cent (16.72 %). Pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other with 25.26, 27.17 and 28.02 per cent of shoot damage respectively. Soap solution 0.5 per cent (44.06 %) showed the highest shoot damage which was on par with control. Per cent shoot damage was recorded significantly during summer season (29.43 %) as compared to that of rabi season (26.64 %).

Seven days after the third spray standard check (5.63 %) was recorded as the effective treatment against shoot and fruit borer during both the seasons which was immediately followed by pongamia oil soap 2 per cent (10.42 %) which was

followed by pongamia oil soap 1 per cent (17.86 %). Soap solution 0.5 per cent was least effective (40.10 %) which was on par with control (37.66 %). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other. Per cent shoot damage during rabi season (23.14 %) was on par with summer season (21.49 %).

Pongamia oil soap 2 per cent (12.86 %) was on par with standard check (7.34 %) on fourteenth day after third application, while pongamia oil soap 1 per cent and neem oil soap 0.6 per cent was statistically on par with each other. Neem oil soap 0.6 per cent was also on par with pongamia oil soap 0.6 per cent. Soap solution 0.5 per cent (42.76 %) showed the highest shoot damage which was on par with control. Per cent shoot damage was recorded statistically similar during summer season (23.97 %) and rabi season (25.74 %).

4.2.3.4 Mean percent of fruits damaged by larvae of Helicoverpa armigera and Earias vitella during rabi season from October 2018 to January 2019

Observations on percentage of fruits damaged by larvae of *Helicoverpa armigera* and *Earias vitella* were taken at weekly intervals during rabi season from October 2018 to January 2019 and the data was statistically analyzed and presented in Table 13. Pongamia oil soap was evaluated at various concentrations *viz.* 0.6 per cent, 1 per cent and 2 per cent along with neem oil soap 0.6 per cent, soap solution 0.5 per cent, quinalphos 0.05 per cent and control.

Second application

Observations taken one day prior to treatment application revealed that the infestation by fruit borers did not differ significantly between the treatments. Fruit damage on number basis was observed to be at a range of 7.81 to 10.11 percentage.

Table 12. Pooled analysis of per cent shoot damage caused by *Earias vitella* during rabi and summer season

Treatments	PER CENT SHOOT DAMAGE																	
	FIRST APPLICATION						SECOND APPLICATION						THIRD APPLICATION					
	7 DAA			14 DAA			7 DAA			14 DAA			7 DAA			14 DATA		
	S1	S2	Avg.	S1	S2	Avg.	S1	S2	Avg.	S1	S2	Avg.	S1	S2	Avg.	S1	S2	Avg.
T1	32.29	34.38	33.33^{b}	39.58	40.10	39.84^{b}	25.00	29.69	27.34^{b}	26.56	31.77	29.17^{b}	22.81	23.96	23.39^{b}	25.31	26.46	25.89^{b}
T2	25.00	34.90	29.95^{bc}	31.25	38.54	34.90^{b}	21.35	25.00	23.18^{b}	23.96	26.56	25.26^{b}	17.71	18.02	17.86^{c}	19.27	20.63	19.95^{c}
T3	22.92	28.13	25.52^{c}	33.33	29.17	31.25^{b}	11.56	14.58	13.07^{c}	15.73	17.71	16.72^{c}	10.52	10.31	10.42^{d}	12.60	13.13	12.86^{d}
T4	36.46	35.42	35.94^{b}	39.58	36.98	38.28^{b}	19.27	27.50	23.39^{b}	25.42	30.63	28.02^{b}	20.31	21.98	21.15^{b}	22.81	24.79	23.80^{bc}
T5	50.00	45.83	47.92^{a}	55.63	48.44	52.03^{a}	34.90	42.81	38.85^{a}	42.19	45.94	44.06^{a}	43.13	37.08	40.10^{a}	45.94	39.58	42.76^{a}
T6	15.00	21.35	18.18^{d}	12.50	23.44	17.97^{c}	9.38	8.02	8.70^{c}	12.50	9.27	10.89^{d}	7.71	3.54	5.63^{e}	9.58	5.10	7.34^{d}
T7	50.00	47.92	48.96^{a}	54.17	48.44	51.30^{a}	34.38	41.35	37.86^{a}	40.10	44.17	42.14^{a}	39.79	35.52	37.66^{a}	44.69	38.13	41.41^{a}
Average	**33.10^{a}**	**35.42^{a}**		**38.01^{a}**	**37.87^{a}**		**22.26^{b}**	**26.99^{a}**		**26.64^{b}**	**29.43^{a}**		**23.14^{a}**	**21.49^{a}**		**25.74^{a}**	**23.97^{a}**	
CD (5%) Trt	**7.28**			**9.82**			**4.85**			**4.19**			**4.43**			**5.52**		
CD (5%) S	**3.89**			**5.25**			**2.59**			**2.24**			**2.37**			**2.95**		
CD(5%)T x S	**8.52**			**8.02**			**8.37**			**10.54**			**8.64**			**8.21**		

Means superscripted by similar letters are not significantly different at 5% level of DMRT. S1- Season 1; S2- Season 2; Avg. Average. DAA- Days after application.

All the treatments were significantly superior over the control (12.91) except soap solution 0.5 per cent with 11.87 per cent of fruit damage respectively at seven days after the second application during the rabi season. Among the different treatments quinalphos 25 EC @ 0.05 per cent (standard check) recorded the lowest per cent of fruits infested by fruit borers (3.54 %). The next to follow were pongamia oil soap (2 %), pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %) with 4.38, 5.96, 6.97 and 7.49 per cent of fruit damage, respectively. Pongamia oil soap 2 per cent showed results similar to standard check, while pongamia oil soap 2 per cent, pongamia oil soap 1 per, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent were statistically on par with each other. Standard check recorded minimum per cent of fruit damage (3.60 %) and control and soap solution 0.5 per cent recorded the maximum per cent of fruit damage (12.5 %) at fourteen days after the second application. Pongamia oil soap 2 per cent showed significant difference from other botanicals (5.31 %) which was followed by pongamia oil soap 1 per cent (6.47 %). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was at par with each other with 8.33 per cent of fruit damage.

Third application

Pre count of damage caused by *Earias vitella* and *Helicoverpa armigera* to fruits were recorded prior to third application during the first season and were at a range of 9.04 to 20.31 per cent of fruit damage.

Seventh day after third application also showed a similar trend with the per cent fruit damage observed lowest in standard check (4.37 %) followed by pongamia oil soap 2 per cent (6.25 %) and pongamia oil soap 1 per cent (8.33 %). Pongamia oil soap 0.6 per cent (9.94 %) and neem oil soap 0.6 per cent (11.42 %) was on par with each other. The fruit damage was maximum in soap solution 0.5 per cent (27.5 %) which was at par with control (26.56 %). Pongamia oil soap 0.6 per cent also showed results statistically similar to pongamia oil soap 1 per cent.

Mean per cent of fruit borer infestion increased in all the treatments at fourteenth day after the third application. Infested fruits were minimum in standard check (4.79 %) followed by pongamia oil soap (2 %), pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %) with 6.69, 9.58, 12.5 and 12.5 per cent of fruit damage, respectively. Maximum per cent of fruit damage was found in control (29.79 %) which was at par with soap solution 0.5 per cent (27.5 %). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other.

4.2.3.5 Mean per cent of fruits damaged by larvae of Helicoverpa armigera and Earias vitella during summer season from February to May 2019

Percentage damage of fruits caused by larvae of *Helicoverpa armigera* and *Earias vitella* during summer season from February to May 2019 is presented in Table 14.

Second application

Pre count of damage caused by *Earias vitella* and *Helicoverpa armigera* to fruits were recorded and the results showed not significant difference between the treatments prior to second application during the second season at a range of 13.98 to 15.31 per cent of fruit damage.

Seven days after second application during summer season revealed that quinalphos 0.05 per cent (standard check) recorded the lowest per cent of fruits infested by fruit borers (4.37 %) which stood significantly superior to all other treatments. Pongamia oil soap 2 per cent was the next best treatment followed by pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent with a fruit damage of 6.47 per cent, 8.33 per cent, 9.847 per cent and 10.351 per cent respectively. Maximum per cent of fruit infestation was recorded in soap solution 0.5 per cent and control with 14.796 per cent of fruit damage.

Table 13. Mean per cent of fruits damaged by larvae of *Earias vitella* and *Helicoverpa armigera* taken at weekly intervals during rabi season from October 2018 to January 2019.

Treatments	Percentage of damaged fruits *					
	Second application			Third application		
	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA
Pongamia oil soap 0.6%	9.49 (17.85)	6.97 (15.23)^{b}	8.33 (16.77)^{b}	14.58 (22.39)^{abc}	9.94 (18.35)^{bc}	12.5 (20.70)^{c}
Pongamia oil soap 1%	7.81 (16.20)	5.93 (13.98)^{b}	6.47 (14.73)^{c}	12.05 (20.30)^{bcd}	8.33 (16.77)^{c}	9.58 (18.02)^{d}
Pongamia oil soap 2%	8.82 (17.19)	4.38 (11.91)^{bc}	5.31 (13.31)^{d}	10.62 (19.00)^{cd}	6.25 (14.47)^{d}	6.69 (14.98)^{e}
Neem oil soap 0.6%	9.16 (17.60)	7.49 (15.82)^{b}	8.33 (16.77)^{b}	16.66 (24.09)^{ab}	11.42 (19.73)^{b}	12.5 (20.70)^{c}
Soap solution 0.5%	8.74 (17.19)	11.87 (20.13)^{a}	12.5 (20.70)^{a}	18.75 (25.35)^{a}	27.5 (31.60)^{a}	27.5 (31.60)^{a}
Quinalphos 25 EC 0.05%	10.11 (18.42)	3.54 (9.54)^{c}	3.60 (10.93)^{e}	9.04 (17.38)^{d}	4.37 (12.06)^{e}	4.79 (12.63)^{f}
Control	9.07 (17.44)	12.91 (20.98)^{a}	12.5 (20.70)^{a}	20.31 (26.59)^{a}	26.56 (30.99)^{a}	29.79 (33.08)^{a}
C.D. (0.05)	**NS**	**4.17**	**0.62**	**4.27**	**1.72**	**1.27**

*Mean of observations on four plants.
Figures in parentheses denotes arc sine transformed values.
Means superscripted by similar letters are not significantly different at 5% level of DMRT
DBA- Day before application; DAA- Days after application. NS – Non significant

A significant difference in mean per cent of fruit borer infested fruits was observed in standard check (4.58 %) fourteen days after second application. Maximum per cent of fruit damage was found in soap solution 0.5 per cent (17.70 %) which was at par with control (16.25 %). Pongamia oil soap (2 %) and pongamia oil soap (1 %) exhibited the best control after the standard check with 8.33 and 10.46 per cent of fruit damage. Neem oil soap (0.6 %) with 11.08 per cent of fruit damage was statistically on par with pongamia oil soap (1 %), while pongamia oil soap 0.6 per cent showed the highest per cent of fruit damage (12.15 %) among the botanicals.

Third application

Pre count of damage caused by *Earias vitella* and *Helicoverpa armigera* to fruits were recorded prior to third application during the second season and were at a range of 10.20 to 23.95 per cent of fruit damage.

A significant increase in the fruit borer infestation was observed by the end of the crop season in all the treatments. However the increase in fruit damage was observed minimum in standard check (6.25 %) on seventh day after third application followed by pongamia oil soap 2 per cent (11.25 %) > pongamia oil soap 1 per cent (12.50 %) > pongamia oil soap 0.6 per cent (13.75 %) > neem oil soap 0.6 per cent (14.79 %) in the order. The fruit damage was maximum in soap solution 0.5 per cent (33.75 %) which was at par with control (33.54 %). Pongamia oil soap 1 per cent was on par with pongamia oil soap 2 per cent, while pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other.

Results obtained fourteen days after third application showed that minimum per cent of fruit damage (8.03 %) was recorded on standard check and soap solution 0.5 per cent recorded the maximum per cent of fruit damage (33.74 %) which was at par with control (33.64 %). Pongamia oil soap 2 per cent and pongamia oil soap 1 per cent gave similar results with 12.5 and 12.57 per cent of

fruit damage respectively which was followed by pongamia oil soap 0.6 per cent (15.62 %) and neem oil soap 0.6 per cent (19.27 %).

A reduction in percentage of damaged fruits was observed in all the treatments by the seventh day after application during both the season except in soap solution 0.5 per cent and control during rabi season. The maximum reduction was observed with standard check followed by pongamia oil soap 2 per cent, pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent.

By fourteenth day after application an increase in per cent of damaged fruits was observed in all the treatments. Standard check showed the maximum percentage reduction followed by pongamia oil soap (2 %) > pongamia oil soap (1 %) > neem oil soap (0.6 %) > pongamia oil soap (0.6 %). Control and soap solution 0.5 per cent showed an increase in per cent damaged leaves by the fourteenth day.

4.2.3.6 ***Pooled analysis of the per cent fruit damage caused by Helicoverpa armigera and Earias vitella during rabi and summer season.***

Per cent of fruit damage during both the season were analysed and is presented in Table 15.

Seven days after the second spray standard check (3.96 %) was recorded as the effective treatment against fruit borers during both the seasons which was immediately followed by pongamia oil soap 2 per cent (5.43 %) and pongamia oil soap 1 per cent (7.14 %). Soap solution 0.5 per cent was least effective (13.33 %) which was on par with control (13.85 %). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was statistically on par with each other. Per cent fruit damage during rabi season (7.59 %) was significantly low as compared to summer season (9.85 %).

Table 14. Mean per cent of fruits damaged by larvae of *Earias vitella* and *Helicoverpa armigera* taken at weekly intervals during summer season from February 2019 to May 2019.

Treatments	Percentage of damaged fruits *					
	Second application			Third application		
	1 DBA	7 DAA	14 DAA	1 DBA	7 DAA	14 DAA
Pongamia oil soap 0.6%	14.58 (22.26)	10.35 (18.77)^{b}	12.15 (20.39)^{b}	17.70 (24.87)^{c}	13.75 (21.74)^{b}	15.62 (23.24)^{c}
Pongamia oil soap 1%	14.61 (22.44)	8.33 (16.77)^{c}	10.46 (18.85)^{d}	17.65 (24.71)^{c}	12.50 (20.70)^{bc}	12.57 (20.71)^{d}
Pongamia oil soap 2%	15.20 (22.92)	6.47 (14.73)^{d}	8.33 (16.77)^{e}	14.58 (22.39)^{c}	11.25 (19.56)^{c}	12.5 (20.70)^{d}
Neem oil soap 0.6%	15.31 (22.98)	9.84 (18.28)^{b}	11.08 (19.42)^{cd}	18.64 (25.46)^{bc}	14.79 (22.59)^{b}	19.27 (25.96)^{b}
Soap solution 0.5%	13.98 (21.92)	14.79 (22.59)^{a}	17.70 (24.87)^{a}	23.95 (29.28)^{a}	33.75 (35.49)^{a}	33.74 (35.51)^{a}
Quinalphos 25 EC 0.05%	14.16 (22.07)	4.37 (12.06)^{e}	4.58 (12.34)^{f}	10.20 (18.58)^{d}	6.25 (14.47)^{d}	8.03 (16.45)^{e}
Control	14.06 (21.91)	14.79 (22.59)^{a}	16.25 (22.59)^{a}	22.70 (28.43)^{ab}	33.54 (35.37)^{a}	33.64 (35.44)^{a}
C.D. (0.05)	**NS**	**1.26**	**1.39**	**3.55**	**2.02**	**1.99**

*Mean of observations on four plants.
Figures in parentheses denotes arc sine transformed values.
Means superscripted by similar letters are not significantly different at 5% level of DMRT
DBA- Day before application; DAA- Days after application. NS – Non significant

Fourteen days after the second spray standard check (4.10 %) was recorded as the effective treatment against fruit borers during both the seasons which was immediately followed by pongamia oil soap 2 per cent (6.82 %) which was on par with pongamia oil soap 1 per cent (8.47 %). Soap solution 0.5 per cent was least effective (15.10 %) which was on par with control (13.65 %). Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent was statistically on par with each other. Per cent fruit damage during rabi season (8.15 %) was significantly low as compared to summer season (11.30 %).

Seven days after the third spray standard check (5.31 %) was recorded as the effective treatment against fruit borers during both the seasons which was immediately followed by pongamia oil soap 2 per cent (8.75 %) which was on par with pongamia oil soap 1 per cent (10.42 %). Soap solution 0.5 per cent was least effective (30.63 %) which was on par with control (30.05 %). Pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent was statistically on par with each other. Per cent fruit damage during rabi season (13.48 %) was significantly low as compared to summer season (17.98 %).

Fourteen days after the third spray standard check (6.41 %) was recorded as the effective treatment against fruit borers during both the seasons which was immediately followed by pongamia oil soap 2 per cent (9.60 %) which was on par with pongamia oil soap 1 per cent (11.04 %). Soap solution 0.5 per cent was least effective (30.63 %) which was on par with control (31.72 %). Neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent was statistically on par with each other. Per cent fruit damage during rabi season (14.77 %) was significantly low as compared to summer season (19.33 %).

Table 15. Pooled analysis of fruit damage caused by *Helicoverpa armigera* and *Earias vitella* for rabi and summer season.

Treatments	PER CENT FRUIT DAMAGED											
	SECOND APPLICATION						THIRD APPLICATION					
	7 DAA			14 DAA			7 DAA			14 DAA		
	Season 1	Season 2	Average	Season 1	Season 2	Average	Season 1	Season 2	Average	Season 1	Season 2	Average
Pongamia oil soap 0.6%	6.98	10.36	8.67[b]	8.33	12.15	10.24[b]	9.94	13.75	11.85[b]	12.50	15.63	14.06[b]
Pongamia oil soap 1%	5.94	8.33	7.14[c]	6.47	10.47	8.47[bc]	8.33	12.50	10.42[bc]	9.58	12.50	11.04[c]
Pongamia oil soap 2%	4.39	6.47	5.43[d]	5.31	8.33	6.82[c]	6.25	11.25	8.75[c]	6.70	12.50	9.60[c]
Neem oil soap 0.6%	7.50	9.84	8.67[b]	8.33	11.08	9.71[b]	11.43	14.79	13.11[b]	12.50	19.27	15.89[b]
Soap solution 0.5%	11.88	14.79	13.33[a]	12.50	17.71	15.10[a]	27.50	33.75	30.63[a]	27.50	33.75	30.63[a]
Quinalphos 25 EC 0.05%	3.54	4.38	3.96[e]	3.61	4.58	4.10[d]	4.38	6.25	5.31[d]	4.79	8.04	6.41[d]
Control	12.92	14.79	13.85[a]	12.50	14.79	13.65[a]	26.56	33.54	30.05[a]	29.79	33.65	31.72[a]
Average	7.59[b]	9.85[a]		8.15[b]	11.30[a]		13.48[b]	17.98[a]		14.77[b]	19.33[a]	
CD-Treatment	1.16			1.95			2.50			2.36		
CD-Season	0.62			1.04			1.34			1.26		
CD-T x S	2.13			1.14			2.65			2.26		

Means superscripted by similar letters are not significantly different at 5% level of DMRT.
DAA- Days after second application

Plate 5. Incidence of leaf hopper and shoot borer in okra

(a) Leaf hopper – *Amrasca biguttula biguttula*

(b) Okra shoot and fruit borer infestation – *Earias vitella*

Plate 6. Infestation of fruit by fruit borers

(a) Fruit infested by okra shoot and fruit borer –*Earias vitella*

(b) Fruit infested by okra fruit borer – *Helicoverpa armigera*

4.3 BIOMETRIC OBSERVATIONS

Influence of various treatments on the length of okra fruits were recorded by taking the average fruit length of 10 fruits per treatment during each harvest and were then statistically analyzed and presented in the Table 16.

During rabi season maximum fruit length was observed in quinalphos 25 EC @ 0.05 per cent (standard check) treated plants with an average fruit length of 19.25 cm. Minimum length was observed in control which was 14.75 cm. Among the botanicals, pongamia oil soap (2 5) showed the maximum fruit length of 19 cm. Neem oil soap (0.6 %) and pongamia oil soap(0.6 %) treated plants had fruits of average length of 18.25 cm and 18 cm respectively was found on par with each other.

During summer season standard check recorded the maximum fruit length of 18.5 cm followed by pongamia oil soap 2 per cent (17.72 cm) while soap solution 0.5 per cent observed the minimum fruit length of 13.2 cm. Pongamia oil soap 0.6 per cent with 16.82 cm fruit length was on par with neem oil soap 0.6 per cent with 16.47 cm fruit length.

4.4 YIELD ATTRIBUTES OF OKRA TAKEN DURING RABI (OCTOBER 2018 TO JANUARY 2019) AND SUMMER SEASON (FEBRUARY TO MAY 2019)

4.4.1 Assessment of yield attributes like fresh weight, total yield and marketable yield obtained during rabi season.

Harvesting was done at every alternate day and a total of fifteen harvests were done during the rabi season. Fresh weight of fruits were taken after each harvest and the total yield and marketable yield was calculated. The data was subjected to statistical analysis and presented in the Table 17.

From the first harvest quinalphos 25 EC @ 0.05 per cent (standard check) recorded the highest fresh yield of 21.42 g/plant followed by pongamia oil soap 2 per cent (17.40 g/plant).

Table 16. Mean length of ten pods per treatment taken during rabi season (October 2018 to January 2019) and summer season (February to May 2019)

Treatment	Average length of pods (cm)*	
	Rabi season	**Summer season**
Pongamia oil soap 0.6%	18 ± 2.35	16.82 ± 1.09
Pongamia oil soap 1%	18.75 ± 1.09	16.95 ± 0.52
Pongamia oil soap 2%	19 ± 2.55	17.72 ± 0.73
Neem oil soap 0.6%	18.25 ± 1.92	16.47 ± 0.97
Soap solution 0.5%	15.5 ± 1.12	13.2 ± 2.51
Quinalphos 25 EC 0.05%	19.25 ± 1.92	18.5 ± 1.12
Control	14.75 ± 1.58	14.75 ± 1.09
C.D. (0.05)	**1.79**	**2.28**

* Average of ten observations

Minimum yield was recorded in control plot (21.30 g/plant) which was on par with soap solution 0.5 per cent (11.41 g/plant). The yield on pongamia oil soap (0.5 %) and neem oil soap (0.6 %) treated plants were on par with each other with 14.20 and 13.73 g/plant of fresh weight. The yield recorded in quinalphos treated was the maximum with 28.31 g/plant. Soap solution (0.5 %) treated plants gave the minimum yield (14.56 g/plant). Among the botanicals, pongamia oil soap (2 %) treated plants gave highest fruit yield (22.96 g/plant) followed by pongamia oil soap 1 per cent (21.34 g/plant) > pongamia oil soap 0.5 per cent (19.05 g/plant) > neem oil soap (18.23 g/plant). Soap solution 0.5 per cent was on par with control with 14.75 g/plant of fresh yield. Third harvest also gave a similar result with standard check recording the maximum fresh fruit yield (24.85 g/plant) followed by pongamia oil soap 2 per cent (19.70 g/plant). Control recorded minimum of 11.47 g/plant of fruit yield. At the time of fourth harvest, standard check gave the maximum yield of 31.61 g/plant and control gave the minimum yield of 21.30 g/plant which was on par with soap solution 0.5 per cent (21.32 g/plant). Pongamia oil soap 2 per cent (29.19 g/plant) was on par with pongamia oil soap 1 per cent (28.52 g/plant). Pongamia oil soap 0.5 per cent (26.33 g/plant) was on par with neem oil soap (26.62 g/plant). During the fifth harvest standard check gave the maximum fruit yield (23.34 g/plant) followed by pongamia oil soap 2 per cent (19.71 g/plant), pongamia oil soap 1 per cent (18.41 g/plant). Pongamia oil soap 0.5 per cent (16.16 g/plant) and neem oil soap (15.86 g/plant) was on par with each other. Control gave the minimum yield of 10.92 g/plant which was on par with soap solution 0.5 per cent (11.71 g/plant).

Standard check again gave the highest fresh fruit yield of 54.08 g/plant followed by pongamia oil soap 2 per cent (46.96 g/plant), pongamia oil soap 1 per cent (43.63 g/plant) during the sixth harvest. Pongamia oil soap 0.6 per cent (39.92 g/plant) was on par with neem oil soap 0.6 per cent (39.56 g/plant). Minimum fruit yield was recorded in soap solution 0.5 per cent (29.14 g/plant). On the seventh harvest standard check recorded the maximum yield of 55.37 g/plant and minimum fruit yield was recorded in soap solution 0.5 per cent (31.17

g/plant) which was on par with control (31.90 g/plant). Neem oil soap 0.6 per cent was on par with pongamia oil soap 0.6 per cent with 39.73 and 41.14 g/plant of fresh yield respectively. Standard check recorded highest yield of 54.04 g/plant and control gave the lowest yield of 33.25 g/plant during eighth harvest, while pongamia oil soap 2 per cent gave the best result among botanicals (50.57 g/plant) which was on par with pongamia oil soap 1 per cent (49.44 g/plant). During the ninth harvest pongamia oil soap 2 per cent gave 50.57 g/plant of fruit yield while the standard check showed significantly higher yield of 58.37 g/plant of fresh fruit. Pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 53.17, 51.82 and 52.61 g/plant of fruit yield respectively. However control gave the lowest yield of 34.58 g/plant which was on par with soap solution 0.5 per cent (35.31g/plant). On the tenth harvest control gave the lowest yield of 41.50 g/plant which was on par with soap solution 0.5 per cent (42.89 g/plant). While the highest yield was recorded in standard check 57.57 g/plant. Pongamia oil soap 2 per cent and pongamia oil soap 1 per cent was on par with each other with 55.40 and 55.26 g/plant of fresh fruit yield while neem oil soap 2 per cent with 52.58 g/plant fruit yield was on par with pongamia oil soap 0.6 per cent (53.62 g/plant).

On eleventh and twelfth harvest standard check showed the maximum fruit yield of 58.25 and 45.43 g/plant respectively followed by pongamia oil soap 2 per cent (50.64 and 41.12 g/plant). Pongamia oil soap 0.6 per cent with 44.46 and 36.78 g/plant of fruit yield respectively on eleventh and twelfth harvest was statistically on par with neem oil soap 0.6 per cent (44.58 and 35.84 g/plant). Control showed the lowest yield of 34.10 and 30.04 g/plant which was on par with soap solution 0.5 per cent (33.48 and 29.54 g/plant respectively). Standard check recorded the maximum yield (35.24 g/plant) followed by pongamia oil soap 2 per cent (32.76 g/plant) during the thirteenth harvest. Soap solution 0.5 per cent with 19.70 g/plant of fruit yield showed the lowest yield which was on par with control with 20.04 g/plant of fruit yield. Fourteenth harvest also showed maximum fruit yield in standard check (29.28 g/plant) followed by pongamia oil soap 2 per cent

(25.29 g/plant). Lowest yield was recorded on control with 16.67 g/plant of fresh fruit which was on par with soap solution 0.5 per cent with 16.69 g/plant of fruit yield. During the last harvest soap solution 0.5 per cent showed the lowest yield of 13.54 g/plant which was on par with control (13.59 g/plant). Standard check showed the maximum fruit yield of 26.92 g/plant followed by pongamia oil soap 2 per cent (21.22 g/plant).

From the total yield calculated standard check recorded the highest fruit yield of 602.7 g/plant followed by pongamia oil soap 2 per cent (536.0 g/plant). The lowest yield was obtained in control 357.4 g/plant which was on par with soap solution 0.5 per cent (360.1 g/plant).

Maximum marketable yield was obtained in standard check (587.8 g/plant), followed by pongamia oil soap 2 per cent (505.4 g/plant). The lowest yield was recorded in control 294.2 g/plant which was on par with soap solution 0.5 per cent (302.7 g/plant). While pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 424.3 and 434.9 g/plant of marketable fruit yield.

4.4.2 Assessment of yield attributes like fresh weight, total yield and marketable yield obtained during summer season.

Dueinf summer season fourteen harvests were done and the fresh weight of fruits were taken after each harvest and the total yield and marketable yield was calculated. The data was subjected to statistical analysis and presented in the Table 18.

First harvest was taken at 40 DAS and subsequent harvests at once in two days. Total 14 harvests were done. During the first harvest quinalphos 25 EC @ 0.05 per cent (standard check) recorded the highest fresh yield of 37.46 g/plant followed by pongamia oil soap 2 per cent (33.75 g/plant). Minimum yield was recorded in soap solution 0.5 per cent (20.58 g/plant) which was on par with control (21.30). Standard check gave the maximum fruit yield during the second harvest with 20.15 g/plant and control gave the minimum yield (9.99 g/plant).

Table 17. Effect of treatments on the yield attributes of okra during rabi season from October 2018 to January 2019

Treatments	Fresh weight of pods (g/plant)*															Total yield (g/plant)	Marketable yield (g/plant)	Difference
	First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest	Sixth harvest	Seventh harvest	Eighth harvest	Ninth harvest	Tenth harvest	Eleventh harvest	Twelfth harvest	Thirteenth harvest	Fourteenth harvest	Fifteenth harvest			
T_1	14.20	19.05	17.15	26.33	16.16	39.92	41.14	48.91	51.82	53.62	44.46	36.78	29.74	21.15	17.51	478.7	424.3	54.4
T_2	16.05	21.34	18.15	28.52	18.41	43.63	43.86	49.44	53.17	55.26	47.85	39.15	31.55	23.68	19.72	510.3	474.3	36
T_3	17.40	22.96	19.70	29.19	19.71	46.96	47.41	50.57	55.32	55.40	50.64	41.12	32.76	25.29	21.22	536.0	505.4	30.6
T_4	13.73	18.23	15.83	26.62	15.86	39.56	39.73	47.11	52.61	52.58	44.58	35.84	28.22	22.53	16.44	469.6	434.9	34.7
T_5	11.41	14.56	12.91	21.32	11.71	29.14	31.17	37.34	35.31	42.89	33.48	29.54	19.70	16.69	13.54	360.1	302.7	57.4
T_6	21.42	28.31	24.85	31.61	23.34	54.08	55.37	54.04	58.37	57.57	58.25	45.43	35.24	29.28	26.92	602.7	587.8	14.9
T_7	10.93	14.75	11.47	21.30	10.92	31.86	31.90	33.25	34.58	41.50	34.10	30.04	20.04	16.67	13.59	357.4	294.2	63.2
C.D. 0.05	**0.54**	**0.81**	**0.47**	**1.12**	**0.49**	**0.73**	**1.69**	**1.22**	**1.46**	**1.77**	**1.60**	**1.03**	**0.57**	**0.90**	**0.56**	**7.38**	**20.90**	

*Mean of observations of eight plants

T1: Pongamia oil soap 0.6%; T2: Pongamia oil soap 1%; T3: Pongamia oil soap 2%; T4: Neem oil soap 0.6%; T5: Soap solution 0.5%; T6: Quinalphos 0.05% - Standard check; T7: Control

Among the botanicals pongamia oil soap 2 per cent gave the highest fruit yield of 16.21 g/plant. Pongamia oil soap 0.5 per cent and neem oil soap was on par with each other with 13.15 and 12.83 g/plant of fresh yield. Third harvest also gave a similar result with standard check recording the maximum fresh fruit yield (27.16 g/plant) followed by pongamia oil soap 2 per cent (16.21 g/plant). Control and soap solution 0.5 per cent was at par with each with 14.25 and 14.02 g/plant of fruit yield respectively. At the time of fourth harvest and fifth harvest standard check gave the maximum yield of 23.84 and 28.85 g/plant respectively followed by pongamia oil soap 2 per cent (18.75 and 23.61 g/plant). Minimum yield was recorded on control (10.53 and 15.50 g/plant) which was on par with soap solution 0.5 per cent (10.82 and 15.61 g/plant) respectively.

Standard check again gave the highest fresh fruit yield of 26.54 g/plant followed by pongamia oil soap 2 per cent (22.60 g/plant), pongamia oil soap 1 per cent (20.34 g/plant), pongamia oil soap 0.6 per cent (19.61 g/plant) and neem oil soap 0.6 per cent (18.92 g/plant) during the sixth harvest. Minimum fruit yield was recorded in soap solution 0.5 per cent (9.97 g/plant). On the seventh harvest standard check recorded the maximum yield of 26.54 g/plant and minimum fruit yield was recorded on control (21.71 g/plant) which was on par with soap solution 0.5 per cent (22.41 g/plant). Pongamia oil soap 2 per cent (29.33 g/plant) was on par with pongamia oil 1 per cent (29.17 g/plant). Neem oil soap 0.6 per cent was on par with pongamia oil soap 0.6 per cent with 27.70 and 27.08 g/plant of fresh yield. Standard check recorded highest yield of 22.89 g/plant and control gave the lowest yield of 9.55 g/plant during eight harvest, while pongamia oil soap 2 per cent gave the best result among botanicals (18.93 g/plant). During the ninth harvest pongamia oil soap 2 per cent gave 47.86 g/plant of fruit yield while the standard check showed significant yield of 55.29 g/plant of fruit yield. Pongamia oil soap 0.6 per cent was on par with neem oil soap 0.6 per cent with 41.12 and 40.53 g/plant of fruit yield respectively. However soap solution 0.5 per cent gave the lowest yield of 30.22 g/plant. On the tenth harvest control gave the lowest yield of 34.32 g/plant while highest yield was recorded in standard check 57.45

g/plant. Pongamia oil soap 0.6 per cent and pongamia oil soap 1 per cent was on par with pongamia oil soap 2 per cent with 52.89, 53.58 and 54.26 g/plant of fresh fruit yield.

On eleventh harvest standard check showed the maximum fruit yield of 54.82 g/plant followed by pongamia oil soap 1 per cent (51.48 g/plant) which was on par with pongamia oil soap 1 per cent (50.44 g/plant). Pongamia oil soap 0.6 per cent with 49.82 g/plant of fruit yield was statistically on par with neem oil soap 0.6 per cent (48.05 g/plant). Control showed the lowest yield of 34.32 g/plant. Control and soap solution 0.5 per cent was on par with each other with lowest fruit yield of 33.48 and 34.25 g/plant respectively during twelfth harvest. Standard check recorded the maximum yield (56.91 g/plant) followed by pongamia oil soap 2 per cent (54.47 g/plant) while pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 52.0., 50.58 and 51.67 g/plant fruit yield. Thirteenth and fourteenth harvest also showed maximum fruit yield on standard check (42.52 and 33.48 g/plant) followed by pongamia oil soap 2 per cent (38.68 and 30.82 g/plant). Lowest yield was recorded on control with 29.46 and 21.77 g/plant of fruit yield.

From the total yield calculated standard check recorded the highest fruit yield of 521.2 g/plant followed by pongamia oil soap 2 per cent (464.3 g/plant). Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 416.6 and 409.7 g/plant. The lowest yield was obtained in control 298 g/plant which was on par with soap solution 0.5 per cent (312.8 g/plant).

Maximum marketable yield was obtained in standard check (502.2 g/plant), followed by pongamia oil soap 2 per cent (430.1 g/plant). The lowest yield was recorded in control 231.3 g/plant which was on par with soap solution 0.5 per cent (243.3 g/plant). While pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent was on par with each other with 366.1 and 363.4 g/plant of fruit yield.

Table 18. Effect of treatments on the yield attributes of okra during summer season from February to May 2019

Treatments	Fresh weight of pods (g/plant)*														Total yield (g/plant)	Marketable yield (g/plant)	Difference
	First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest	Sixth harvest	Seventh harvest	Eighth harvest	Ninth harvest	Tenth harvest	Eleventh harvest	Twelfth harvest	Thirteenth harvest	Fourteenth harvest			
T_1	30.78	13.15	18.53	16.11	20.70	19.61	27.08	15.63	41.12	52.89	49.82	50.58	34.79	24.98	416.6	366.1	50.5
T_2	32.48	14.93	20.73	17.36	22.74	20.34	29.17	17.57	44.81	53.85	50.44	52.01	36.85	28.42	445.8	404.1	41.7
T_3	33.75	16.21	22.47	18.75	23.61	22.60	29.33	18.93	47.86	54.26	51.48	54.47	38.68	30.82	464.3	430.1	34.2
T_4	29.03	12.83	17.73	15.88	21.54	18.92	27.70	14.50	40.53	51.61	48.05	51.67	33.61	26.48	409.7	363.4	46.3
T_5	20.58	10.47	14.02	10.82	15.61	9.97	22.41	11.28	30.22	41.21	38.46	34.25	30.48	20.46	312.8	243.3	69.5
T_6	37.46	20.15	27.61	23.84	28.85	26.54	32.36	22.89	55.29	57.45	54.82	56.91	42.52	33.48	521.2	502.2	19
T_7	21.30	9.99	14.25	10.53	15.50	12.48	21.71	9.55	32.08	34.32	34.32	33.48	29.46	21.77	298.0	231.3	66.7
C.D. 0.05	**1.20**	**0.40**	**0.64**	**0.72**	**0.73**	**0.42**	**1.14**	**0.50**	**1.65**	**1.57**	**1.33**	**1.57**	**0.96**	**0.45**	**16.87**	**13.13**	

*Mean of observations of eight plants

T1: Pongamia oil soap 0.6%; T2: Pongamia oil soap 1%; T3: Pongamia oil soap 2%; T4: Neem oil soap 0.6%; T5: Soap solution 0.5%; T6: Quinalphos 0.05% - Standard check; T7: Control

4.5 ECONOMIC ANALYSIS

The economics of different treatments on production of okra was worked out based on the total production cost including cost of fertilizers, manures and labour charge, total marketable yield and prevailing market price and B:C ratio was calculated for each treatments.

4.5.1 Economics of production of okra during rabi season from October 2018 to January 2019

Economics of production of okra during rabi season were calculated and presented in Table 19.

During rabi season the net returns was recorded maximum in standard check (Rs.299695/ha) with a B: C ratio of 3.21 followed by pongamia oil soap 2 per cent with a net return of Rs.234308/ha and B: C ratio of 2.67. However lowest B: C was observed in control with only 1.61 rupees for every one rupee expenditure.

4.5.2 Economics of production of okra during summer season from February to May 2019

Economics of production of okra during summer season were calculated and presented in Table 20.

From the results obtained, the maximum net income was obtained in standard check (Rs.236288/ha) followed by pongamia oil soap 2 per cent (Rs.178530/ha) and pongamia oil soap 1 per cent (Rs.161771/ha). For every one rupee invested an amount of Rs.2.74 was obtained in standard check while only Rs.1.27 was obtained in control. Pongamia oil soap 2 per cent earned a return of Rs.2.27 giving the highest cost benefit ratio among the botanicals.

Table 19. Economics of cultivation of okra during rabi season from October 2018 to January 2019

Treatments	Economics of okra					
	Production cost excluding insecticides (Rs. / ha)	Cost of insecticdes (Rs. / ha)	Total expenditure (Rs / ha)	Gross income (Rs / ha)	Net income (Rs/ ha)	B : C ratio
Pongamia oil soap 0.6%	135062.00	1500.00	136562	314296	177734	2.30
Pongamia oil soap 1%	135062.00	2500.00	137562	351333	213771	2.55
Pongamia oil soap 2%	135062.00	5000.00	140062	374370	234308	2.67
Neem oil soap 0.6%	135062.00	1800.00	136862	322148	185286	2.35
Soap solution 0.5%	135062.00	100.00	135162	224222	89060	1.66
Quinalphos 25 EC 0.05%	135062.00	650.00	135712	435407	299695	3.21
Control	135062.00	0.00	135062	217926	82864	1.61

Table 20. Economics of cultivation of okra during summer season from February to May 2019

Treatments	Economics of okra					
	Production cost excluding insecticides (Rs. / ha)	**Cost of insecticdes (Rs. / ha)**	**Total expenditure (Rs / ha)**	**Gross income (Rs / ha)**	**Net income (Rs/ ha)**	**B : C ratio**
Pongamia oil soap 0.6%	135062.00	1500.00	136562	271185	134623	1.99
Pongamia oil soap 1%	135062.00	2500.00	137562	299333	161771	2.18
Pongamia oil soap 2%	135062.00	5000.00	140062	318592	178530	2.27
Neem oil soap 0.6%	135062.00	1800.00	136862	269185	132323	1.97
Soap solution 0.5%	135062.00	100.00	135162	180222	45060	1.33
Quinalphos 25 EC 0.05%	135062.00	650.00	135712	372000	236288	2.74
Control	135062.00	0.00	135062	171333	36271	1.27

Discussion

5. DISCUSSION

The studies on the evaluation of pongamia oil soap against major pests of okra, *Abelmoschus esculentus* (L). Moench were carried out as per the technical programme and the results are discussed in this chapter. The research on efficacy of pongamia oil soap on major pests of okra is not available in literature for comparison and hence the results obtained is compared with studies carried out with pongamia oil on different pests.

5.1 LABORATORY BIOASSAY OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA

Laboratory bioassay was carried out to study the efficacy of pongamia oil soap against okra leaf hopper *Amrasca biguttula biuttula* and leaf roller *Sylepta derogata* and the results obtained are discussed here.

5.1.1 Feeding deterrency of pongamia oil soap against okra leaf roller *Sylepta derogata*

Among the different treatments pongamia oil 2 per cent showed the maximum antifeedent activity against fourth instar larvae of *S. derogata* followed by pongamia oil 1 per cent, 0.6 per cent and neem oil soap 0.6 per cent. The antifeedent property of pongamia oil might be due to the presence of high concentration of karanjin, pongamol and other active components present in the oil. Similar statement was given by Kumar *et al.* (2006) that methanolic extract of crude seed oil of pongamia followed by crude pongamia oil showed maximum antifeedant and growth reduction activity against *S. litura*, due to presence of high concentration of karanjin, pongamol, glabarin, pinnatin and other active compounds. Mathur *et al.* (1990) stated that karanjin and pongamol are effective against several insect pests. Pramod *et al.* (2014) reported that leaf area consumed by fourth instar larvae of *Spodoptera litura* recorded minimum in NSKE (46.12 %), followed by *Acacia arabica* (48.12 %), *Nicotiana. tabacum* (56 %) and PSKE (Pongamia seed kernel extract) (57.20 %). The present results are in agreement with the findings of Verma and Singh (1985) where he stated that

0.1 per cent neem-seed oil was the most effective antifeedant, followed by 0.1per cent pongamia oil.

Soap solution 0.5 per cent showed results similar to control indicating that soap solution as component of pongamia oil soap did not have any insecticidal effect and the antifeedent property of pongamia oil soap was caused due to the pongamia oil only.

5.1.2 Growth index and Relative growth index

The results obtained from the evaluation of growth retardation properties of pongamia oil soap against first instar larvae of *Sylepta derogata,* it was concluded that pongamia oil soap (2 %) caused the maximum growth retardation properties as compared to other treatments followed by pongamia oil soap (1 %), pongamia oil soap (0.6 %) and neem oil soap (0.6 %). Growth retardation properties of pongamia oil soap may be due to the presence of high concentration of karanjin, pongamol and other active components present in the oil. Similar statement was given by Kumar *et al.* (2006) that methanolic extract of Pongamia oil followed by crude pongamia oil showed maximum antifeedant and growth reduction activity on *S. litura*, due to the presence of high concentration of karanjin, pongamol, glabarin, pinnatin and other active compounds present in the oil.

Control was statistically on par with soap solution 0.5 per cent indicating that soap solution which is a component of pongamia oil soap did not have any insecticidal effect and the growth retardation property of pongamia oil soap was due to the pongamia oil only.

5.1.3 Mortality of leaf hoppers

Pongamia oil soap (2 %) showed 100 per cent mortality of leaf hoppers by 16 h after the treatment. Neem oil soap (0.6 %) and pongamia oil soap (0.6 %) showed cent per cent mortality only by 24 h after treatment. Mortality of leaf hoppers may be due to lack of feeding by the nymphs because of the repellent activity of oil. Kumar *et al.* (2006) have stated that crude oil as most effective repellent compared to other extracts of oil due to the physical characteristics of

the oil. Sharma and Summarwar (2017) stated that neem oil + liquid soap ranked second in the reduction of jassid population in RCH-134 Bt cotton which was on par with Pest guard 5 percentage.

However soap solution 0.5 per cent and control gave statistically similar results with no mortality even after 48 h of treatment. This indicate that the repellent activities of pongamia oil was responsible for the mortality of leaf hoppers rather than the soap solution.

5.2 EVALUATION OF FIELD EFFICACY OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA

Investigations on field efficacy of pongamia oil soap against major pests of okra *viz.*, shoot and fruit borers, leaf roller and leaf hoppers were carried out during two seasons, rabi (October to January) and summer (February to May), during 2018-2019 at the instructional farm of College of Agriculture, Padannakkad and the results thus obtained are discussed here under this chapter.

5.2.1 Efficacy of pongamia oil soap against leaf hopper during rabi season (October to January 2018-19)

From the data observed during the rabi season, it is evident that all the treatments except soap solution 0.5 per cent was effective in reducing the leaf hopper population significantly as compared to that of control. In general the efficacy of pongamia oil soap at 0.6, 1 and 2 per cent and neem oil soap 0.6 per cent were significantly superior over control. However, the standard check (quinalphos 25 EC @ 0.05 %) was superior to pongamia and neem oil soap. Similar findings were reported by Kumar (2013), where he stated that chemical (imidacloprid followed by triazophos, quinalphos) and neem based insecticides were effective in reducing jassid population as compared to that of control.

After three sprays, pongamia oil soap 2 per cent was effective in reducing the leaf hopper population followed by pongamia oil soap (1 %), neem oil soap (0.6 %) and pongamia oil soap (0.6 %). Efficacy of pongamia oil soap was reduced with the reduction in concentration. Even though pongamia oil soap 0.6

per cent and neem oil soap 0.6 per cent were statistically on par, better efficacy was showed by neem oil soap 0.6 per cent in reducing leaf hopper population (% reduction). Similar results were observed by Anitha (2007) who reported that among the botanicals and myco pathogens, neem oil 2 per cent recorded the least leafhopper population (2.90 leafhoppers / 3 leaves) followed by pongamia oil 2 per cent (3.44 leafhoppers / 3 leaves) on okra. Superiority of neem based insecticides have been reported by Mandal *et al.* (2006) and Sinha and Sharma (2007). Higher efficacy of pongamia oil soap 2 per cent against leaf hopper as observed in this study is in line with Sardana and Krishnakumar (1989), who stated that maximum reduction in hopper population to the extent of 17.51 leafhoppers per plant was recorded in case of pongamia oil (2 %) as compared to neem oil (0.5 %) and garlic oil (0.5 to 1%).

Reduction in leaf hopper population was observed maximum at seventh day after the spray. On the fourteenth day, a gradual increase in hopper population was observed in all the treatments with pongamia oil soap 2 per cent showing the lowest population among the botanicals. Reduction in hopper population by pogamia oil soap may be due to the antifeedent and repellent properties in addition to its mortal effect on leaf hoppers. Pongamia oil contains secondary metabolites which serve as natural pest repellents (Pavela, 2009). Efficacy of pongamia oil soap against the overall jassid population is in accordance with Dehariya *et al.* (2018), who reported that pongamia oil 1% (14.25 per 15 leaves) was at par with neem oil 1% (13.25/15 leaves) which proved to be the superior treatment to rest of the botanical treatments in controlling leaf hopper population.

Soap solution 0.5 per cent always showed results similar to control indicating that the reduction in hopper population was solely due to the insecticidal properties of the oil rather than the soap solution which is a component of pongamia oil soap.

Incidence of leaf hopper was low during the summer season. It can be supported by the findings of Srinivasen *et al.* (1988), where he reported that the

seasonal pattern of leaf hopper has a significant positive correlation with minimum temperature.

5.2.2 Efficacy of pongamia oil soap against leaf roller during rabi season (October to January 2018-19)

From the results it is clear that the per cent infestation of okra leaf roller *Sylepta derrogata* was lowest in the plot treated with quinalphos 25 EC (0.05%) during rabi season. Incidence of leaf roller was negligible during the summer season which can be explained by the findings of Badiyala (2011) where he stated that maximum temperature and bright sunshine hours negatively influence the larval population and leaf infestation of *Sylepta derogata* infesting okra.

However, among the botanicals pongamia oil soap 2 per cent showed lowest leaf infestation by leaf roller which was followed by pongamia oil soap 1 per cent. Neem oil soap and pongamia oil soap 0.6 per cent showed results which were statistically similar to each other. Per cent of damaged leaves was highly reduced by the seventh day after the spray among all the treatments except soap solution 0.5 per cent and control while a slight increase was observed by the fourteenth day after the spray. However, by the end of the season pongamia oil 2 per cent showed significant reduction in damaged leaves as compared to other botanicals whereas, the damage per cent was significantly increased in control and soap solution.

Bandyopadhyay *et al.* (2013) reported that pongamia oil (1%) was very effective in reducing the population density of leaf webber, *Glyphodes pyloalis* Walker infesting mulberry even upto fifteen days after spray, followed by neem oil and agro spray. Gopalakrishnan *et al.* (2011) revealed that, pongamia leaf extract induced a larval mortality of 76 and 74 per cent and a weight reduction of 58 and 56 per cent when treated on healthy larvae of *H. armigera* and *S. litura,* respectively. According to Kulat *et al.* 2010, pongamia oil could interfere with the enzyme metabolism of *Spodoptera litura* and proved to be lethal to the pest. Adhikary (1984) reported that leaf rolls caused by okra leaf roller, *Sylepta derogata* was highly reduced by all concentrations of methanolic neem extracts as compared to that of control.

Hence it can be stated that, lower per cent of damaged leaves was observed in pongamia oil soap 2 per cent due to the antifeedent and larvicidal activity of pongamia oil and high concentration of pongamia oil in 2 per cent soap as compared to other botanicals. However soap solution which forms a component of pongamia oil soap did not show any effect in lowering the leaf damage.

5.2.3 Efficacy of pongamia oil soap against shoot and fruit borer, *Earias vitella* during rabi (October to January 2018-19) and summer (February to May) season

The data on mean percentage of shoots infested by okra shoot and fruit borer *Earias vitella* during rabi and summer season revealed that quinalphos 25 EC (0.05 %) treated plot showed minimum per cent of infestation and was the superior among other treatments. Similar findings were made by Rahman *et al.* (2013) in which application of quinalphos 25 EC provided maximum reduction in shoot damage as compared to that of control and neem leaf extract (16 ml/l) and also quinalphos 25 EC was statistically similar to carbofuran 5G.

While among the botanicals, pongamia oil soap 2 per cent showed significant reduction in shoot damage followed by pongamia oil soap 1 per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent. Mathur *et al.* (2012) have also reported that pongamia oil 2 per cent was quite effective in reducing both shoot and fruit infestation. Mean per cent of shoot infestation was reduced on seventh day after treatment and later on a gradual increase was observed in all the treatments by the fourteenth day. However shoot damage was reduced in all the treatments prior to second and third spray which were applied during the reproductive stage of the crop on both the seasons. It may be due to the lower survival and feeding activity of larvae or due to the lower ovipositional activity by adults. Sharma and Bhatnagar (1993) stated that the application of neem and pongamiaj oils reduced the survival and feeding activity of larvae and the ovipositional activity by adults of *Chilo partellus.* Pongamia oil, methanolic seed extract, petroleum ether and chloroform extract of seeds and aqueous seed

extract at different concentrations showed antifeedant activity (Prabhakar *et al.* 1994; Chandel *et al.* 1995; Deka *et al.* 1998) oviposition deterrence (Sojitra & Patel, 1992; Murthy *et al.* 1994; Bhatnagar & Sharma, 1995), larval mortality and morphogenetic defects (Behera & Satapathy, 1996; Jeyakumar & Uthamasamy, 1997; Murugan & Babu, 1998).

During both the seasons pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent almost showed similar effects in the reduction of shoot damage which indicates that pongamia oil soap have similar effects as that of neem oil soap at same concentrations and as the concentration increased, a significant reduction was observed in shoot infestation. Soap solution 0.5 per cent did not exhibit any effect against shoot and fruit borer and showed results similar to the control indicating that soap solution used to make pongamia oil soap does not have any role in pest control. Eswarareddy and Shrinivasa (2004) also reported that neem oil 2 per cent and pongamia oil 2 per cent was highly effective in reducing the borer damage caused by brinjal shoot and fruit, *Leucinodes orbonalis* after three applications during summer season.

Shoot damage infestation was observed high during summer season (Fig. 2). Maximum infestation was observed during vegetative stage initial reproductive stage of the crop while infestation was decreased towards the end of the season. This study can be supported by the findings of Sreedevi (2011) where she stated that the incidence of *Earias vitella* started from vegetative stage and continued till fruit formation stage. Pongamia oil soap 2 per cent was effective in reducing the shoot infestation caused by *Earias vitella* during both the season. Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent showed similar effects in controlling shoot infestation. The findings were supported by Bhatnagar and Sharma (1995), where he observed that the application of neem and pongamia oils reduced the survival and feeding activity of larvae and the ovipositional activity by adults of *Chilo partellus.* Soap solution 0.5 per cent did not show any effect in controlling shoot damage and was similar to control.

5.2.4 Efficacy of pongamia oil soap against fruit borers *Earias vitella* and *Helicoverpa armigera* during rabi (October to January 2018-19) and summer (February to May) seasons

From the results it is clear that quinalphos 25 EC showed the lowest percentage of fruit damage during both rabi and summer season indicating that chemical treatments are better in action as compared to that of botanicals. Rahman *et al.* (2013) also stated that application of quinalphos 25 EC reduced the fruit damage to a greater extend as compared to that of the botanical product neem leaf extract (16ml/l) and gave statistically similar results with that of carbofuran 5G. Pathan *et al.* (2010) reported that dimethoate 0.03 per cent treated plot recorded lowest infested okra fruit both in number and weight basis which was followed by carbaryl 0.2 per cent and quinalphos 0.05 per cent. The results obtained in this study can also be correlated with the findings of Kumar (2013), who stated that imidacloprid followed by triazophos, quinalphos and neem based insecticide treated plots recorded lowest fruit infestation on number basis.

In the present study among the botanicals, the highest concentration of pongamia oil soap (2 %) gave maximum control of fruit damage followed by pongamia oil soap 1 per cent. Neem oil soap and pongamia oil soap at 0.6 per cent gave statistically similar results indicating similar insecticidal properties of pongamia oil with that of neem oil. Soap solution 0.5 per cent showed results which was statistically similar to control stating that the reduction in fruit damage is completely due to the insecticidal properties of pongamia oil.

Reduction in fruit damage by pongamia oil soap treatment may be due to its insecticidal properties on larval stages, feeding deterrency and ovipositional deterrency. Morale *et al.* (2000) explained that neem oil (1 %) and pongamia oil (1 %), showed significant effects on fecundity, larval period and larval mortality of *H. armigera* infesting cotton. Khaire *et al.* (1993) also stated that pongamia oil 1 per cent shows strong oviposition repellent activity against many pests.

Fruit damage during the early reproductive stages were due to okra shoot and fruit borer, *Earias vitella* while towards the end of the season fruits were infested by fruit borer *Helicoverpa armigera* also. A significant reduction in fruit

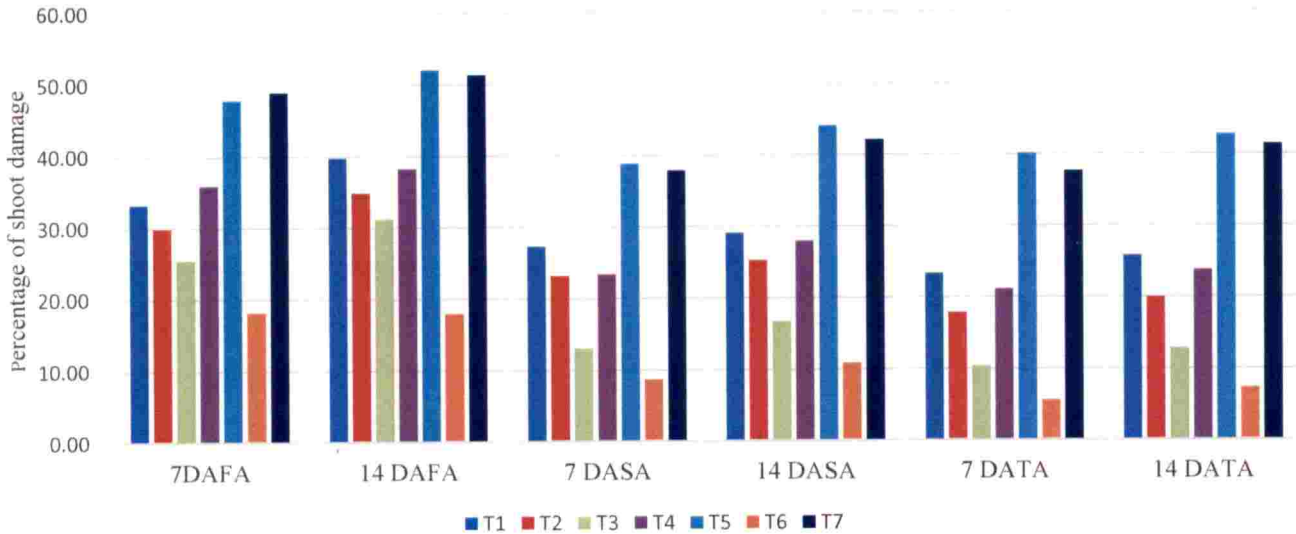
damage was observed on seventh day after second and third spray during both the season in all the treatments except the soap solution 0.5 per cent and control while it gradually increased by the fourteenth day. However the lowest fruit damage was recorded in pongamia oil soap 2 per cent among the botanicals. According to Kushwaha and Painkra (2016) fruit damage caused by brinjal shoot and fruit borer, *Leucinodes orbonalis* was lower in cypermethrin 25 EC which was on par with neem oil 4 per cent water emulsion and was followed by NSKE 5 per cent and pongamia oil 5 per cent water emulsion.

Fruit damage caused by *Earias vitella* and *Helicoverpa armigera* was recorded maximum during summer season (Fig. 3). By the end of the season, fruits were infested mainly by *H. armigera.* Infestation of fruit borers was observed to be high by the end of the season. Pongamia oil soap 2 per cent was effective in controlling the fruit infestation during both the season. Findings of Morale *et al.* (2000) is in accordance with present findings, where he stated that neem oil (1 %) and pongamia oil (1 %), showed significant effects on fecundity, larval period and larval mortality of *H. armigera* infesting cotton. Pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent gave similar results. Due to the higher incidence of fruit damage during summer season, total yield and marketable yield was also low during summer season as compared to that of rabi season.

5.3 BIOMETRIC OBSERVATIONS

Length of the fruits were taken to study the influence of treatments on the biometric parameter of fruit. From the mean length of the fruit taken during each harvest it was noted that the maximum fruit length was observed from the plot treated with quinalphos 25 EC. Among the botanicals, plot treated with pongamia oil soap 2 per cent gave maximum fruit length during both the season, while control treated plot gave the lowest fruit length. All the treatments showed their superiority over the control while soap solution 0.5 per cent was statistically on

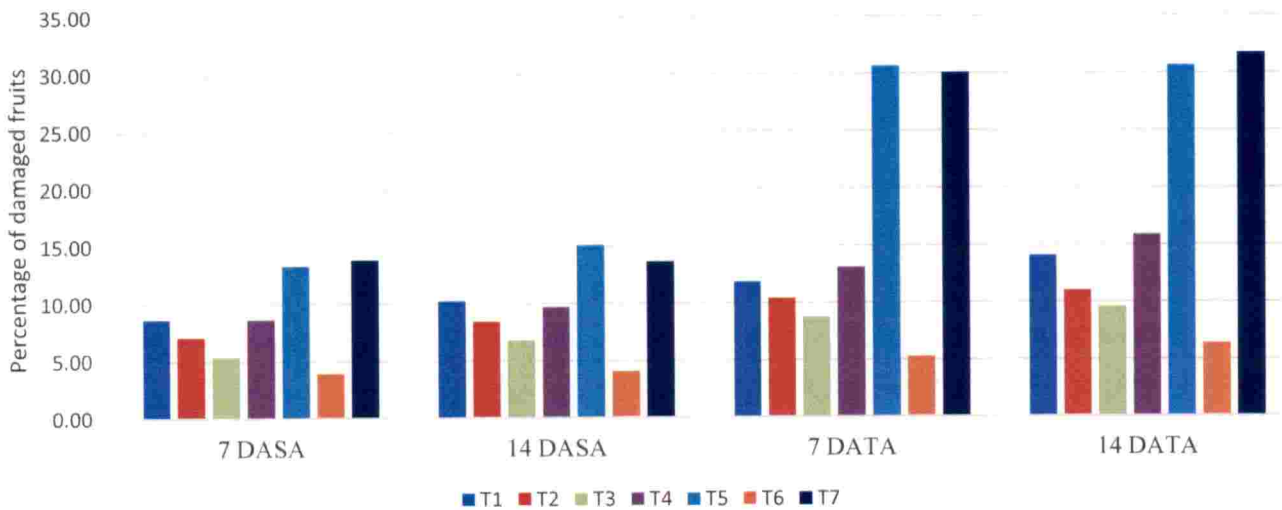
Fig. 2 Pooled analysis of the per cent shoot damage caused by shoot and fruit borer, *Earias vitella* during rabi and summer season.



DAFS – days after first spray, DASS – days after second spray, DATS – days after third spray

T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Quinalphos 0.05% - Standard check; T_7: Control

Fig. 3 Pooled analysis of the per cent fruit damage caused by *Helicoverpa armigera* and *Earias vitella* during rabi and summer season.



DASS – days after second spray, DATS – days after third spray

T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Quinalphos 0.05% - Standard check; T_7: Control

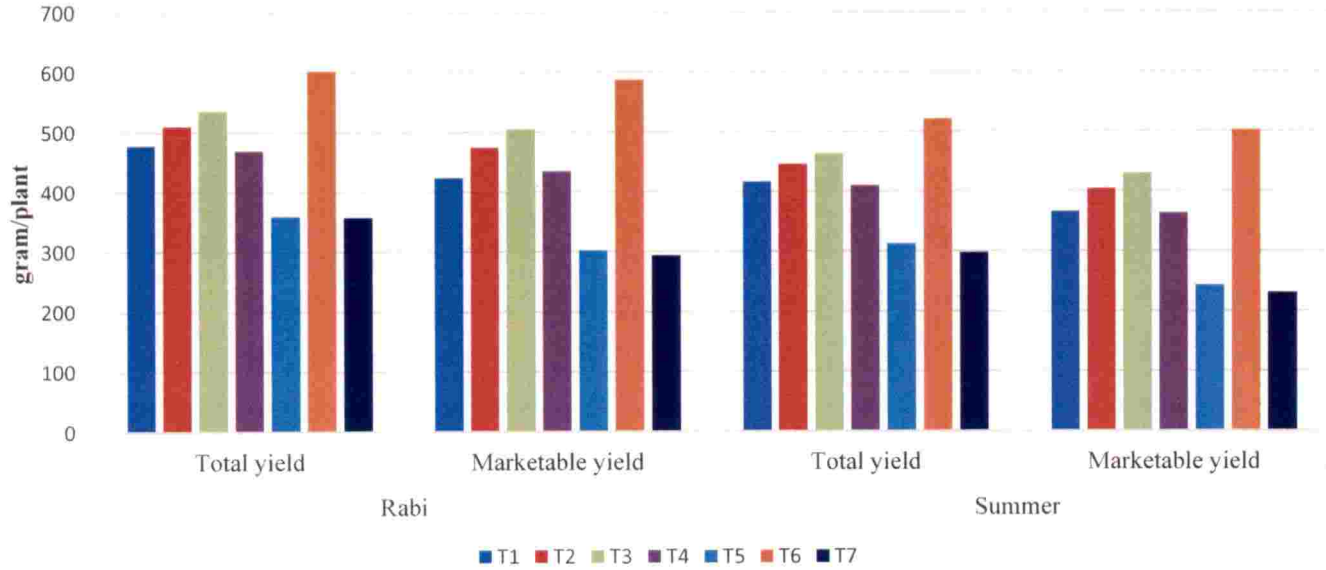
par with control. Variation in fruit length from the control may be due to lower incidence of fruit borer infestation. Infestation of fruit borers may result in deformed fruits and finally reflects in the fruit length and quality. But no significant difference was observed among the treatments except control and soap solution 0.5 per cent which indicates that the treatments have no much effect on fruit length since this character may be influenced by genetic and nutrient factors.

5.4 YIELD ATTRIBUTES

During both the season the maximum total yield was obtained from the plot treated with quinalphos 25 EC @ 0.05 per cent which proved to be the best among all the treatment (Fig. 4). It was followed by pongamia oil soap 2 per cent which was considered as the best treatment among the botanicals. However all the treatments gave significantly superior results from control except soap solution 0.5 per cent. Marketable yield of okra varied from 231.3 g/plant to 502.2 g/plant during rabi season and from 294.2 g/plant to 587.8 g/plant during summer season. However marketable yield obtained was in the order of quinalphos 25 EC > pongamia oil soap 2 per cent > pongamia oil soap 1 per cent > neem oil soap 0.6 per cent > pongamia oil soap 0.6 per cent > soap solution 0.5 per cent > control. Higher yield was recorded in standard check which indicate its higher efficacy in controlling the shoot and fruit borer, *Earias vitella* and fruit borer, *Helicoverpa armigera* which reduces the marketable yield of the crop due to its heavy infestation. Rahman *et al.* (2013) stated that okra variety Arka Anamika under quinalphos 25 EC and carbofuran 5G were the most desirable associations in controlling okra shoot and fruit borer which resulted in higher marketable fruit yield.

Among the botanicals pongamia oil soap 2 per cent proved its efficacy against *E. vitella* and *H. armigera* resulting in highest marketable fruit yield. So from the present finding it can be concluded that application of pongamia oil soap 2 per cent may help in procuring higher marketable yield by reducing the pest infestation and it would be an ideal biorational insecticide in organic agriculture.

Fig. 4 Yield attributes of okra taken during rabi and summer season



T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Quinalphos 0.05% - Standard check; T_7: Control

5.5 ECONOMIC ATTRIBUTES

Quinalphos 25 EC @ 0.05 per cent proved to be the best treatment in turns of cost benefit ratio followed by of pongamia oil soap 2 per cent, pongamia oil soap 1per cent, neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent. Similar findings were reported by Kumar (2013) where application of quinalphos 25 EC @ 1.5 ml/L and 1 ml/L proved to be the best treatment in turns of cost benefit ratio followed by triazophos imidacloprid and neem based insecticides.

In other words for every one rupee invested pongamia oil soap 2 per cent gave a return of 2.67 and 2.27 during rabi and summer season respectively. Neem oil soap 0.6 per cent when compared with pongamia oil soap 0.6 per cent the former gave an additional amount of 2.35 and 1.97 rupees while pongamia oil soap 0.6 gave 2.30 and 1.99 rupees during rabi and summer season respectively which indicate that the treatments gave a net return almost similar to each other and can be alternatively used during pest management.

Summary

6. SUMMARY

The proposed study entitled, Evaluation of Pongamia Oil Soap against major pests of okra, *Abelmoschus esculentus* (L). Moench was aimed at evaluating the efficacy of a new product made of pongamia oil - pongamia oil soap at different concentrations in combating the major pests of okra *viz.*, shoot and fruit borer, leaf roller and leaf hopper.

Laboratory bioassay of pongamia oil soap was carried out in the Department of Agricultural Entomology, College of Agriculture, Padannakkad, during 2019 to evaluate the feeding deterrency and growth retardation properties of pongamia oil soap against fourth instar and first instar larvae of bhindi leaf roller, *S. derogata* respectively and mortality study against bhindi leaf hopper, *Amrasca biguttula biguttula*. The test organisms were exposed to six treatments including T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Control under completely randomised design (CRD) with three replications.

Field study was carried out in Randomised block design with seven treatments and four replications on okra variety 'Arka Anamika' during rabi and summer seasons at Instructional farm of College of Agriculture in Padannakkad. The treatments applied were: T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Quinalphos 0.05% - Standard check; T_7: Control. All treatments were applied once at vegetative stage and twice during reproductive stage. Observations were taken one day prior to treatment and 1, 3, 5, 7 and 14 days after treatment (DAT) for sucking pests. Damage symptoms caused by lepidopteran pests were observed one day prior to and 7 and 14 DAT.

The following are the salient findings of present investigation.

1. Pongamia oil soap 2 per cent showed the maximum feeding deterrency against fourth instar larvae of okra leaf roller due to its antifeedent and repellent properties.

2. Growth retardation of first instar larvae of okra leaf roller was exhibited maximum by pongamia oil soap 2 per cent due to its antifeedent activity.

3. Complete mortality of leaf hoppers was observed within 16 hours after treatment in pongamia oil soap 2 per cent due to its repellent and insecticidal activities.

4. Soap solution 0.5 per cent did not exhibit any of the properties like antifeedent, growth retardation and insecticidal activity.

5. During the rabi season, pongamia oil soap 2 per cent was effective in controlling the leaf hopper population from further builup due to its insecticidal, repellent, ovicidal and anti-ovipositional properties.

6. The effectiveness of pongamia oil soap against leaf hopper lasted up to seven days after treatment and a further decline was observed by the fourteenth day after application.

7. Damage caused by leaf roller *Sylepta derogata* during rabi season was cut down by the treatment of pongamia oil soap 2 per cent among the botanicals for seven days due to its antifeedent, repellent and growth retardation activity.

8. Pongamia oil 2 per cent was effective in reducing the damage caused by borer pests *viz., Earias vitella* and *Helicoverpa armigera* during both the seasons. Reduction in damage per cent is due to its repellent properties which remained effective for seven days and further reduced.

9. Effectiveness of pongamia oil soap declined with time and concentration.

10. Maximum fruit length was observed in standard check which was followed by pongamia oil soap 2 per cent treated plot for both the season

due to the reduced incidence of fruit borers, *Earias vitella* and *Helicoverpa armigera*.

11. Pongamia oil soap 2 per cent exhibited increased fruit yield and marketable yield as compared to that of control due to lower incidence of pests during both the seasons.

12. Economics of pongamia oil soap 2 per cent in turns of cost benefit ratio was also high as compared to control in both the rabi and summer seasons, making it an effective component in IPM programmes.

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Abstract

EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF OKRA, *Abelmoschus esculentus* (L). Moench

by

ANU THOMAS

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ABSTRACT

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ABSTRACT

The proposed study entitled, Evaluation of pongamia oil soap against major pests of okra, *Abelmoschus esculentus* (L). Moench was aimed at evaluating the efficacy of a new product made of pongamia oil - pongamia oil soap at different concentrations in combating the major pests of okra *viz.*, shoot and fruit borer, leaf roller and leaf hopper.

Laboratory bioassay of pongamia oil soap was carried out in the Department of Agricultural Entomology, College of Agriculture, Padannakkad, during 2018-19 to evaluate the feeding deterrency and growth retardation properties of pongamia oil soap against fourth instar and first instar larvae of bhindi leaf roller, *Sylepta derogata* respectively and its insecticidal property or repellent property on bhendi leaf hopper, *Amrasca biguttula biguttula*. The test organisms were exposed to six treatments *viz.*, T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: control with three replications under completely randomised design (CRD).

Among the different treatments, pongamia oil 2 per cent showed the maximum antifeedent activity on fourth instar larvae and maximum growth retardation activity on first instar larvae of *S. derogata*. Spraying of pongamia oil soap 2 per cent showed 100 per cent mortality of leaf hoppers by 16 h after the treatment. But neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent took 24 h to attain 100 per cent mortality.

Field efficacy of pongamia oil soap was evaluated by randomised block design (RBD) with seven treatments and four replications on okra variety 'Arka Anamika' during rabi and summer seasons at the Instructional farm in College of Agriculture, Padannakkad. The treatments applied were: T_1: Pongamia oil soap 0.6%; T_2: Pongamia oil soap 1%; T_3: Pongamia oil soap 2%; T_4: Neem oil soap 0.6%; T_5: Soap solution 0.5%; T_6: Quinalphos 0.05% - (Standard check); T_7:

Control. All treatments were applied once at vegetative stage and twice during reproductive stage. Observations were taken one day prior to treatment and 1, 3, 5, 7 and 14 days after treatment (DAT) for sucking pests. Damage symptoms caused by lepidopteran pests were observed one day prior to and 7 and 14 DAT.

After three sprays during the rabi season pongamia oil soap 2 per cent was superior among botanicals in reducing the leaf hopper population significantly as compared to that of control. The effectiveness against leaf hopper lasted up to seven days after treatment. By the end of the rabi season pongamia oil 2 per cent showed significant reduction in damaged leaves as compared to other botanicals whereas the damage per cent was significantly increased in control and soap solution 0.5 per cent. Damage caused by leaf roller was cut down by the treatment of pongamia oil soap 2 per cent for seven days due to its antifeedent, repellent and growth retardation activity. Mean percentage of shoots and fruits infested by okra shoot and fruit borer *Earias vitella* and fruit borer *Helicoverpa armigera* during rabi and summer season was observed lowest in pongamia oil 2 per cent among botanicals. Reduction in mean per cent of fruit and shoot damage by pongamia oil soap may be due to the feeding deterrency of pongamia oil which remained effective for seven days. However all the treatments were effective in reducing the pest infestation except soap solution 0.5 per cent. Effectiveness of pongamia oil soap was observed to decline after seven days after spray application. Higher concentration of the soap gave better results as compared to that of lower concentrations.

Pongamia oil soap 2 per cent exhibited increased fruit yield and marketable yield as compared to that of control due to lower incidence of pests during both the seasons. Economics of pongamia oil soap 2 per cent in turns of cost benefit ratio was also high as compared to control in both rabi and summer seasons, making it an effective component in IPM programmes and organic farming.