EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGTABLE COWPEA, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGTABLE COWPEA, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt"** 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.

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Sajay S.

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Introduction

1. INTRODUCTION

Vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt is an annual herbaceous legume. It is a multipurpose leguminous vegetable crop and also known as Yardlong bean which serves as a proteinaceous food. The development of pests is easier on its leaves and shoots due to this prolific amount of protein (Breukel and Post, 1959). It also serves as a source of fodder and provides soil nitrogen.

Among the insect pests, the major ones are the aphids, *Aphis craccivora* Koch (Hemiptera: Aphididae); serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae); pod borers such as gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae); spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae); blue butterflies, *Lampides boeticus* (L.) (Lepidoptera:Lycaenidae); pod bugs such as *Riptortus pedestris* (F.) (Hemiptera: Coreidae); *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae); *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae) and *Nezara viridula* (L.) (Hemiptera: Pentatomidae).

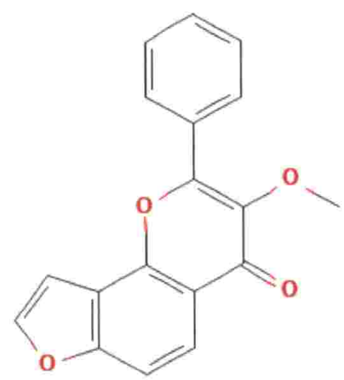
The aphids cause considerable damage due to the infestation on tender parts. They attack the tender parts like leaves, tender shoots, flowers and pods and suck the sap from those parts. This results in the malformation, wilting and drying up of plants. Due to higher fecundity and resistance against synthetic pesticides aphids are difficult to control. (Jagadish *et al.,* 2011). Among the pod borers, the spotted pod borer, *Maruca vitrata* engenders considerable yield loss due its attack on flowers and pods. The reduction in grain yield was estimated as 51.75 per cent when 8 larvae per plant occurs and it was 66.67 per cent when 16 larvae per plant. (Sharma *et al.,* 1999). Pod bugs are another threat for the cowpea crop. *Riptortus pedestris, Clavigralla gibbosa, Clavigralla tomentosicollis* and *Nezara viridula* are the important ones among them which cause considerable damage. More than 80 per cent yield reduction occurs due to the attack of pod sucking bug *Clavigralla tomentosicollis* when severe infestation occurs (Singh *et al.,* 1990).

Chemical pesticides are widely used for controlling the pests of leguminous crops. But the improper use of pesticides for intensive cultivation has caused resistance in target species, residues in the farm produce, resurgence of minor pests, destruction of natural enemies, death of non-target organism and disruption of the ecosystem. For reducing such risks, alternative environmentally safe methods like bio pesticides, biorational insecticides and botanicals (Khade *et al.*, 2014). Pongamia oil is such an insecticide which shows pesticidal properties and is obtained from a small evergreen tree, *Pongamia pinnata*.

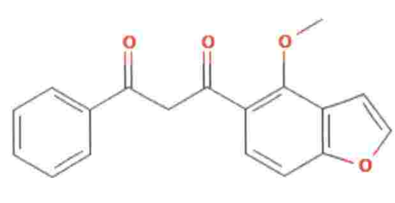
Pongamia pinnata (L.) belonging to the family Fabaceae is also known as Indian beech tree, which is widely distributed in India, China, Bangladesh and Australia. A thick brownish oil can be extracted from the large seeds of pongamia with a saponification value in the range of 186-196 mg KOH/g of oil, and is used industrially and in medicine, notably for the treatment of rheumatism. This brownish oil extracted from the seeds of pongamia is called as karanj oil or pongamia oil. It contains several phytoconstituents belonging to the category of flavonoids. The secondary metabolites (flavonoids, chalcones, steroids and terpenoids) in pongam oil serve as defense against insect pests (Pavela, 2007). The presence of karanjin and pongamol (Fig. 1 (a) and Fig. 1 (b)) make pongamia oil effective against several insect pests (Mathur *et al.,* 1990). Dried leaves are used as insect repellent in stored grains and also as a pesticide (Warrier and Nambiar 1995). Researchers report that pongam oil is safe to humans and other mammals (Tripathi *et al.,* 2002).

Vegetable cowpea has to be harvested very frequently. But for most of the pesticides, a waiting period of 4-5 days is to be observed which is not possible in cowpea once yielding starts. So development of effective alternative to the chemical pesticides is very important in vegetable cowpea pest management. With this background, the proposed study was conducted to evaluate the efficacy of pongamia oil soap in managing major pests of vegetable cowpea.

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 available literature pertaining to various aspects on the study of evaluation of pongamia oil soap against major pests of vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt. has been reviewed and presented here.

2.1. EFFECT OF PONGAMIA PRODUCTS IN CONTROLLING MAJOR HEMIPTERAN PESTS

Sridhar *et al.* (2017) observed that when neem/pongamia/fish oils were used together @ 3ml/l each, it resulted in 75 per cent mortality of *Bemisia tabaci*. Oils alone resulted in 48.75 per cent mortality of *B. tabaci*. All the oils showed synergism with different insecticides tried against whitefly and highest synergism was recorded with neem oil followed by fish oil and pongamia oil.

Bhat *et al.* (2016) reported that spraying neem seed powder extract (4 per cent) mixed with neem soap (0.5 per cent) could suppress aphids on brinjal, bitter gourd and chilli crop. Its effect on okra leaf hopper was moderate.

Tran *et al.* (2015) reported that pongam leaf extract 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 h, respectively under 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.

Ghosh and Chakraborty (2015) discovered that extracts of polygonum and pongamia leaves at a concentration of 7 per cent and Spinosad (1ml/3L) gave higher Jassid control, recording more than 50 per cent mortality.

Madhuri *et al.* (2014) observed that the seed kernel and leaf extracts of *Azadirachta indica*, *Pongamia pinnata, Madhuca longifolia* and only leaf extracts

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of *Lantana camara, Adathoda vasica* were directly used as a foliar spray on M-5 mulberry saplings. After fifth spray (25 days after release of crawlers) seed kernel extracts of neem, pongamia and mahua exhibited their high sensitivity and reported highest mortality of bugs from neem seed kernel extract @ 4 per cent (78.67 per cent) to mahua seed kernel extract @ 2 per cent (37.33 per cent), followed by neem seed kernel extract @ 2 per cent (68.00 per cent), pongamia seed kernel extract @ 4 per cent (56.0 per cent), mahua seed kernel extract @ 4 per cent (46.67 per cent) and pongamia seed kernel extract @ 2 per cent (44.0 per cent).

According to Akashe *et al.* (2013), 83.6 per cent decline in aphid population was recorded with 1 per cent karanj oil treatment which was statistically at par with 1 per cent neem oil (81.03) and 1 per cent castor oil (74.59) after second spray. Karanj 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).

Among the different botanicals treated against jassids, sole application of neem oil (3 per cent), fish oil resin soap (FORS) (2 per cent) and pongamia oil (3 per cent) recorded 48.73, 46.88 and 42.49 per cent reduction in population.The synergistic effect of neem oil and FORS recorded the best, 72.64 per cent reduction followed by pongamia oil + FORS (62.81 per cent) and neem oil + pongamia oil (60.16 per cent). (Sakthivel *et al.*, 2012)

Neem seed kernel extract (5 per cent) was found to be effective followed by *Pongamia glabra* seed kernel extract (5 per cent), neem oil (3 per cent) and *Pongamia glabra* oil (3 per cent) against the leaf hopper and aphids of cotton. Maximum population reduction was noticed on the 3rd day after treatment. (Vinodhini and Malaikozhundan, 2011).

Extracts of *Pongamia glabra, Azadirachta indica* and *Chrysanthemum cinerariifoliun* were treated against *Spodoptera littoralis, Myzus persicae* and *Tetranychus urticae* on green house plants. In all treated extracts, the highest concentration (3 per cent) caused 100 per cent mortality. On day 12 after application, pongamia oil showed higher efficiency against *Myzus persicae* compared to other treatments. (PaVela, 2009).

Smitha (2005) found that the treatment combinations mango + karanj oil, mango + hydnocarpus oil, mango + cow's urine + asafoetida, and snake wood + hydnocarpus oil exhibited effective control over the population of rice bug.

Singh (2002) observed that *Clavigrella gibbosa* eggs showed 22.5 to 58.6 per cent inhibition in hatching when treated with different concentrations ranging from 0.5 to 5 per cent.

Among different treatments comprised 5 per cent neem seed kernel extract, 5 per cent neem seed cake extract, 1 per cent neem oil, 0.5 per cent commercial neem formulation, 5 per cent *Pongamia pinnata* extract, 5 per cent *Lantana camara* extract, 0.05% dimethoate and an untreated control, 5 percent *Pongmia pinnata* extract showed comparable efficiency with the insecticide when treated against safflower aphid, *Uroleucon compositae* and these products were environmentally and ecologically safe and possess high cost benefit ratio.(Mallapur *et al.*, 2001)

According to Saminathan and Jayaraj (2001), when Dimethoate 0.05 per cent was compared with pongam oil 3 per cent against *Ferrisia virgata* using leaf dip method, 50 per cent mortality was recorded for pongam oil after 72 hrs of treatment as against 66.67 per cent for Dimethoate.

Rajappan *et al.* (1999) observed the effect of pongamia oil on the survival of *Nephotettix virescens*. The combination of pongam oil and neem oil was as effective as Monocrotophos and considerably reduced RYD transmission by *N. virescens.*

Kulat *et al.* (1997) observed that aqueous leaf extract of *P. pinnata* (at 5 per cent) gave a similar level of control compared to Monocrotophos (0.05 per cent) for the control of *Aphis gossypii* and *Empoasca devastans* on okra.

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Bindu (1996) found that emulsions of neem and pongamia oil at 2 per cent and 5 per cent spray caused mortality of adult tea mosqito bug after 12h exposure. Neem and pongamia oil when sprayed on the grafts at 2 per cent concentration was found to be very effective in preventing the feeding by the TMB.

According to Jothi *et al.* (1990), pongamia oil at 1 per cent and pongamia seed extract at 2 per cent was found to possess insecticidal property against citrus aphid *Toxoptera citricidus.*

Ramraju and Sundrababu (1989) observed that there is a reduction in the emergence of rice brown plant hopper, *Nilaparvatha lugens* when it was treated with seed extract of karanj oil emulsion two per cent.

2.2. EFFECT OF PONGAMIA PRODUCTS IN CONTROLLING MAJOR LEPIDOPTERAN PESTS

According to Reena *et al.* (2012), mature seed extract of *Pongamia pinnata* deterred the adult females of *Helicoverpa armigera* from egg laying when applied on to the oviposition substrate (no choice, choice and without actual contact condition) at concentrations as low as 2.5 per cent. Hatching inhibition of one-day old eggs was also recorded.

Kumar *et al.* (2006) observed that methanolic extracts of crude seed oil of *Pongamia pinnata* (karanj) showed the maximum growth reduction and antifeedancy against the larvae of *Spodoptera litura* and crude seed oil of karanj showed the maximum repellency against *Trogoderma granarium.*

Sureshgowda *et al.* (2005) reported that the biology and food consumption utilization indices of first instar larvae of *Plutella xylostella* under laboratory condition was adversely affected when the larvae were allowed to feed on cabbage leaves treated with 1 per cent karanj oil for 48 h.

According to Reena (2004), 5.0 per cent methanolic extract of mature as well as immature seeds of *Pongamia pinnata* caused more than 50 per cent larval mortality in *Helicoverpa armigera.* It also exhibited feeding deterrence to third instar larvae at a rate of 42.08 - 73.77 per cent and 31.69 - 67.76 per cent respectively.

Moorthy and Kumar (2004) observed that sprays of 1 per cent neem and 1 per cent pongamia soaps were found to be highly effective in controlling insecticide resistant diamond back moth(DBM) in cabbage (2.33 and 4.67 DBM incidence per plant respectively). The studies conducted at IIHR have shown that 1 per cent neem and 1 per cent pongamia soaps were also effective in reducing *Helicoverpa armigera* in tomato (6.64 per cent and 6.96 per cent mean fruits bored respectively) and to a limited extent shoot and fruit borer in brinjal.

In order to evaluate the antifeedant and insecticidal activities on third instar larvae of the *Dalbegia sissoo* defoliator, *Plecoptera reflexa*, crude extracts of the fresh leaves of 14 different plant species were tested. It was found that the extracts of *Melia azadirach*, followed by extracts of Eucalyptus hybrid and *Pongamia pinnata* were the most effective insecticidal agents and antifeedants (Meshram, 2000).

Bajpai and Sehgal (1999) observed that among different botanical insecticides like Neem Guard (0.4 per cent), neem oil (2.0 per cent), neem seed kernel extract (5.0 per cent) and karanj oil (2.0 per cent), karanj oil resulted in the highest grain yield (1.29 t ha^{-1}) with 44 per cent pod damage when they were tested against *Helicoverpa armigera* infesting chickpea in a field experiment.

Monocrotophos, fish oil rosin soap, Phosphamidon and pongamia oil were the most effective treatments against infestations of *Phyllocnistis citrella* on mandarin followed by Dimethoate, mahua (*Madhuca longifolia*) oil and neem oil. Indiara (of unstated composition), castor oil and Neemark (an extract of *Azadirachta indica*) were ineffective. (Katole *et al.,* 1993).

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Satpathi and Ghatak (1990) reported that karanj seed methanolic extract 1 per cent when applied topically to fourth instar *Cydia critica* and *Plutella xylostella* larvae exerted 100 per cent mortality within 12-14 hrs of treatment.

In a laboratory study using fifth instar larvae of *Euproctis fraterna* with castor leaves soaked in 250, 500, 750 and 1000 ppm of acetone extract of *Pongamia pinnata,* the rate of food consumption, production and assimilation showed a negative correlation with the concentration of the extract. The activity of digestive enzymes, invertase, amylase and protease reduced with the increasing concentration of pongamia extract and the larval pupal intermidate were produced at 1000 ppm. (Sridhar and Chetty, 1989)

The last instar larvae of groundnut pest *Spodoptera litura* showed the poisoning symptoms when it was treated with water extract of *Pongamia pinnata* at various concentrations (0.5, 1, 2, 4 and 6 per cent) in a laboratory study. (Sahayaraj and Paulraj, 1998)

Verma and Singh (1985) observed that 0.1 per cent water emulsion of pongamia oil showed antifeedant activity against *Amsacta moorei* Butler.

2.3. EFFECT OF PONGAMIA PRODUCTS IN CONTROLLING MAJOR STORAGE PESTS

The efficacy of edible and non-edible plants oil on the infestation of *Rhizopertha dominica* studied 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 (Srilakshmi and Virant, 2018).

Kuldipake *et al.* (2016) found that application of 5 g karanj leaf powder (*Pongamia pinnata*) per kg of seeds of wheat was found most effective and recorded

13.33 per cent mortality of rice weevil at 21 days after inoculation. It was also found that *Pongamia pinnata* leaf powder water extract was most effective and significantly superior treatment as repellent for the rice weevil *Sitophilus oryzae* and recorded 76.00 – 84.33 per cent repellency against *Sitophilus oryzae* L. damage in wheat.

A laboratory study showed that pigeon pea seeds can be protected from *Callosobruchus maculatus* by treating it with karanj oil at 2.5, 5.0 and 10.0 ml kg^{-1} and 5 ml kg^{-1} which gave protection up to four months of storage. (Raghavani and Kapadia, 2003)

Singh (2003) recorded that the pigeon pea seeds could be protected from *Callosobruchus chinensis* up to nine months by treating it with 8 ml kg^{-1} karanj oil and it prevented the egg laying and controlled the population build-up of beetle.

Tripathy *et al.* (2001) recorded that the attack of storage pest *Callosobruchus chinensis* in black gram seeds could be reduced when treated with pongamia oil at two different doses (2 ml kg^{-1} and 4 ml kg^{-1}). When compared to malathion treatment (6 ppm) both of these concentrations were superior in protecting the seed from pulse beetle.

Lohra *et al.* (2001) found that *Tribolium castaneum* showed oviposition deterrency when sorghum seeds were treated with 1.0, 2.5 and 5.0 ml 100 g^{-1} of plant extract of karanj. Seeds treated with 5.0 ml 100 g^{-1} resulted in zero egg laying.

Khaire *et al.* (1993) observed that there was a strong repellent activity of pongamia against the pulse beetle, *Callosobruchus chinensis* on *Cajanus cajan.*

Dakshinamurthy (1993) observed larval mortality of stored grain pest of rice, *Corcyra cephalonica* when treated with two percent water and methanol extract of karanja leaves.

According to Babu *et al.* (1989), seeds of *Vigna radiata* when treated with pongamia oil at 5 and 10 ml kg^{-1}resulted in reduced oviposition of *Callosobruchus* *chinensis* under conditions of artificial infestation, while maintaining a high level of germination for over 18 months of storage under ambient conditions.

Prakash and Rao (1986) reported the repellent action of pungam oil (10.38 mg cm^{-3}) and plant extract on stored grain pest of rice, *Tribolium castaneum.*

2.4. EFFECT OF PONGAMIA PRODUCTS IN CONTROLLING MITES

Roy *et al.* (2018) found that among different plant oils treated against red spider mite *Oligonychus coffeae*, karanj oil was the most toxic adulticide followed by mustard oil and olive oil. The egg hatchability was significantly affected in all treatments with rose oil being toxic ovicide among the plant oils followed by karanja oil and olive oil.

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 per cent) 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 per cent) and treated bioassay (28.00 to 63.33 per cent).

Rahman *et al.* (2016) evaluated the efficacy of three botanical oils *viz.* neem, mahogany and karanja oil and a 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. The effectiveness was shown highest in the plants treated with acaricide Ambush 1.8 EC (80.25 per cent) while among the botanicals, neem oil, mahogany oil and karanj oil caused 60.55 per cent, 55.89 per cent and 35.0 per cent reduction in 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 lowest mite population was recorded in NSKE (9.82 mites/ 3 leaves) followed by neem oil (10.29 mites/3 leaves) and pongamia oil (10.83 mites/ 3 leaves).

Increased 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). The study revealed that the lowest mite population was observed in Dicofol +castor oil treatment followed by Dicofol + pongamia oil treatment. 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 PRODUCTS IN CONTROLLING OTHER PESTS

Vasanthlal (2012) observed that among the oils and plant extract/botanicals, neem oil 0.5 per cent, mahuda oil 1 per cent, mineral oil 0.2 per cent, pongamia oil 1 per cent, eucalyptus oil 1 per cent as well as custard apple leaf extract 10 per cent, commercial neem product Gronim 0.5 per cent, neem seed kernel extract 10 per cent and neem leaf extract 10 per cent found more effective in suppressing the chilli mite *Scirtothrips dorsalis* population in chilli.

Malini (2007) observed that pongamia oil two percent, azadirachtin 0.004 per cent and neem cake soil application @ 250 kg ha^{-1} + NSKE five per cent were the effective phytochemicals against the pest of tulsi based on the result of field experiment.

100 per cent mortality of *Boophilus microplus* ticks was found after 48 hours when neem oil, karanj oil and eucalyptus oil were used. The emulsification of karanj oil in 1 per cent teepol solution was more as compared to neem oil and a uniform emulsification was found. (Thakur *et al.*, 2007).

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

Pongamia glabra commonly known as karanj is reported to be effective against insect pest of stored grains, field and plantation crops and household commodities. Oil, methanolic seed extract, acetone leaf extract, aqueous seed extract, chloroform seed extract and petroleum ether seed extract of karanj have been evaluated and found to act as oviposition deterrents, antifeedants and larvicides against a wide range of insect pests. (Kumar and Singh, 2002).

Karanj gave the high mortality compared to neem and mahua oil cakes when they were applied to pots containing two year old arecanut (*Areca catechu*) seedlings grown in sterile soil with third instar grubs of *Leucopholis burmeisteri* in it. (Padmanabhan *et al.*, 1997)

The larval population of epilachna beetle, *Henosepilachna viginctioctopunctata* showed reduction by the use of one percent petroleum ether extract of karanja. (Reddy *et al.,* 1990)

2.6. EFFECT OF PONGAMIA PRODUCTS 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 spiders (0.46 to 0.63/plant) indicating their safety to the natural enemies.

Bopche (2015) stated that biopesticides tested against safflower aphids including hingan bet fruit extract (*Balanites aegyptiaca*) @ 5 per cent, neem seed extract (*Azadirachta indica* A. Juss) @ 5 per cent, Karanj 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 and Visalakshi (2007) to determine the compatibility of ten pesticides *viz.* Endosulfan, Dinocap, Acephate, Chlorothalonil, Abamectin, Ethion, Carbendazim, pongamia oil, 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 per cent) and maximum sporulation of 47.2×10^6 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 biopesticides 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.

Babu *et al.* (1989) reported that karanj is used for its medicinal properties over thousand years and showed insecticidal properties similar to neem which includes antifeedant, larvicidal, ovipositional deterrent, antibacterial and cleansing properties.

Chopra *et al.* (1965) stated that karanj (*Pongamia glabra*), neem (*Azadirachta indica*), tobacco (*Nicotiana* spp.), garadi (*Cleistanthus collinus*), bankan (*Melia aradirach*), besharam (*Ipomea carnea*) and mahua (*Madhuca indica*) are some of the common plants used for different medicinal purposes and show insecticidal properties against various insects but are comparatively harmless to man.

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Material and methods

3. MATERIAL AND METHODS

This chapter is providing information regarding different materials used and methods carried out for evaluating the efficacy of pongamia oil soap against major pests of cowpea, *viz.*, pod borers, pod bugs and aphids.

3.1. PREPARATION OF PONGAMIA OIL SOAP

Pongamia oil required for the preparation of soap was obtained from Tamil Nadu Agricultural University, the cost of which was Rs. 85/L. The saponification value was determined to check the purity of the oil in Soil Science and Agricultural Chemistry Lab, College of Agriculture, Padannakkad which was 194 mg KOH/g (Horowitz, 1975). It 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). The pH value of the soap solution (10.5) was determined using a pH meter.

3.2 LABORATORY BIOASSAY OF PONGAMIA OIL SOAP

Laboratory bioassay was carried out on the insects *viz.,* leaf eating caterpillar *Spodoptera litura* and aphids *Aphis craccivora* in laboratory, Department of Entomology, College of Agriculture, Padannakkad, during 2019. The design was CRD with 6 treatments and 3 replications.

3.2.1. Details of the treatments

Table 1. Treatments imposed at laboratory level

Sl. No.	Treatments	Concentration
1	T_1 - Pongamia oil soap 0.6 %	6 g/L
2	T_2 - Pongamia oil soap 1 %	10 g/L
3	T_3 - Pongamia oil soap 2 %	20 g/L
4	T_4 - Neem oil soap 0.6 %	6 g/L
5	T_5 - Soap solution 0.5 %	5 ml/L
6	T_6 – Control	

Plate 1. Pongamia oil soap

(a) Pongamia oil soap

(b) Pongamia oil soap solution

3.2.2. Collection of egg mass and nymphs

Egg mass of leaf eating caterpillar *Spodoptera litura* and nymphs and adults of aphids *Aphis craccivora* were collected from the farmer's fields. Different instars of *Spodoptera litura* larvae were identified based on Ramaiah and Maheswari, 2018.

3.2.3. Feeding deterrency index

Pongamia oil soap of varying concentrations and 0.6 % neem soap were applied on the upper surface of the leaf discs of suitable size of vegetable cowpea that were randomly arranged at equal interval along the periphery of petri dishes (140 mm ID × 20 mm H) lined with moistened filter paper. After 10 min, final instar larvae of *Spodoptera litura* starved for 4 h were introduced individually at the centre of each petri dish. The dishes were transferred into a climatic chamber at a temperature of 25˚C ± 2˚C, relative humidity (60% - 70%) and 16L: 8D. After 10 h of feeding, the insects were removed and feeding amounts measured using transparent millimeter-square graph paper. The feeding deterrency index (FDI) was calculated by the formula (Li *et al.,* 2014).

Feeding deterrency Index = (C-T) x100/(C+T)

Where,

C = average consumed area of controlled disc.

T = average consumed area of treated disc.

3.2.4. Growth index and Relative growth index

Newly hatched larvae of *Spodoptera litura* were introduced into petri dishes containing leaves treated with various concentrations of pongamia oil soap and 0.6% neem soap. Larvae in control were provided with same leaves without any treatment. When 95% of control larvae get pupated, all larvae of treated leaves were classified into defined stages and counted, based on which Growth Index (GI) and Relative Growth Index (RGI) were calculated using the formula (Zhang *et al.,* 1993) given below:

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$$GI = \sum_{i=1}^{i_{max}} [n_{(i)} \times i] + \sum_{i=1}^{i_{max}} [n'_i \times (i-1)] \div N \times i_{max}$$

Where,

i = stage number

n_i = no. of live larvae at i

n'_i= no. of dead larvae at i

i_{max} = 6 (i.e. pupal stage)

N = total no. of larvae in the group

When GI for each treatment and control are obtained, RGI of each tested group was obtained by

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

3.2.5. Mortality of aphids

Two to three leaved stage cowpea plants maintained in paper cups. Aphids were kept in petri dishes and different treatments applied topically using a hand sprayer. After the application, treated aphids were transferred to cowpea plants. Observation were taken at definite intervals up to 12 hours (Paramasivam and Selvi, 2017).

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

3.3. FIELD EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGETABLE COWPEA FOR TWO SEASONS

A field study was carried out at the instructional farm of College of Agriculture, Padannakkad for two seasons during 2018 – 2019.

3.3.1. Details of the experiment

Crop	: Vegetable Cowpea
Variety	: Vellayani Jyothika
Design	: RBD

Treatments : 7
Replications : 4
Sowing method : Dibbling
First season : October - January
Second season : February - May
Plot size : 2 x 2 m^2 with 4 plants per plot

Crop was trailed on trellis. Each trellis was treated as one replication unit.

Table 2. Treatments imposed at field level

Sl.no	Treatment details	Application rate
1	T_1 - Pongamia oil soap 0.6%	6g/L
2	T_2 - Pongamia oil soap 1%	10g/L
3	T_3 - Pongamia oil soap 2%	20g/L
4	T_4 - Neem oil soap 0.6%	6g/L
5	T_5 - Spinosad 45 SC– Standard check	0.5 ml/L
6	T_6 - Soap solution 0.5%	5ml/L
7	T_7 - Control	

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

3.3.2. Preparation of main field

Land preparations were carried out one week prior to planting. Farm yard manure (FYM) and lime were applied immediately after land preparation and the basal dose of NPK fertilizers, recommended in the KAU, Package of Practices: Crops 2016 (POP, KAU) were applied prior to sowing of seeds. Seeds were sowed by dibbling method at a spacing of 1.5m x 0.45m during rabi and summer seasons with four plants per treatment and the treatments were replicated four times. When the vines started trailing, trellis were fixed around the plants. Irrigation was given at 2-3 days interval during rabi and daily during summer. Other cultural practices

Plate 2. Experimental plot

a) Experimental plot

Plate 3. Field view

(a) Seedling stage

(b) After one and half months

including fertilizer application, weeding and earthing up were carried out as per the recommendation of the KAU, Package of Practices: Crops 2016 (POP, KAU). Treatments were applied after 30 DAS during vegetative phase and 55 and 70 DAS during the rabi season and after 30 DAS during vegetative phase and 55 and 85 DAS during the summer season.

3.3.3. Method of recording observation

Observations on population density were made a day prior to spraying and post treatment population density at 1,3,5,7 and 14 DAT while damage symptoms were observed at 7 and 14 DAT.

3.3.3.1.Aphids: Aphis craccivora

The damage due to aphids, *Aphis craccivora* was assessed with total number of shoots, number of aphid infested shoots, total number of pods, number of pods infested with aphids, scoring of aphid colonies as low/medium/high based on standard scale (Egho, 2011).

The standard scale for scoring the aphid population was shown in Table 3. The scoring was done by observing the aphid colonies on each cowpea stands per treatment. Size of the colony was then observed visually and scored based on the scale.

Table 3. Scale for assessing the population of aphids

Sl. No.	Rating	Number of aphids	Appearance
1	0	0	no infestation
2	1	1-4	a few individual colonies
3	3	5-20	a few isolated colonies
4	5	21-100	several small colonies
5	7	101-500	large isolated colonies
6	9	>500	Large continuous colonies

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

3.3.3.2.Pod borer: Maruca vitrata

The damage of flower and pod borer *Maruca vitrata* was observed by counting the number of pod borer larvae per plant, total number of flowers and pods, number of damaged flowers and pods there by expressing the percentage of damage.

% of Flower damage = (No. of damaged flowers ÷ Total no. of flowers) X100

% of Pod damage = (No. of damaged pods ÷ Total no. of pods) X100

3.3.3.3.Pod bugs

The damage caused by pod bug *Riptortus pedestris, Clavigrella gibbosa, Clavigrella tomentosicollis and Nezara viridula* were recorded by counting the number of nymphs/adults of pod bugs, total number of pods and number of infested pods.

% of Pod damage = (No. of damaged pods ÷ Total no. of pods) X100

3.3.3.4.Leaf miner, Liriomyza trifolii

Negligible leaf miner incidence was noticed during both the seasons. So it was not recorded.

3.3.4. 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. When treatments applied, three days maintained as waiting period. Length of five randomly selected pods 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.

3.3.5. Statistical analysis

Data on the population density of pests were analysed after square root transformation and data on per cent damage were analysed after arc sin transformation. While yield parameters and cost – benefit ratio were analysed without any transformation. Pooled analysis was worked out to compare the efficacy of the soap during both seasons. The data were analysed using analysis of variance (ANOVA). The data obtained after two seasons were pooled to see the treatment performance. Web Agri Stat Package WASP 2.0 was used to compare the significance of each treatment.

Results

4. RESULTS

4.1 LABORATORY BIOASSAY OF PONGAMIA OIL SOAP

Laboratory bioassay studies to find the efficacy of pongamia oil soap was carried out in the laboratory, Department of Entomology, College of Agriculture, Padannakkad, during 2019 and the results obtained from the study is presented below.

4.1.1 Feeding deterrency index of pongamia oil soap against *Spodoptera litura*

Based on the results from the leaf area consumed by the fifth instar larvae of *Spodoptera litura* antifeedent property of different concentrations of pongamia oil soap and 0.6% neem soap was evaluated. Feeding deterrency of various treatments were computed from the observed data and presented in table 4.

From the table values, it can be concluded that pongamia oil soap treatment at 2 per cent had higher feeding deterrency index (93.96) which was on par with pongamia oil soap 1 per cent (83.91). Pongamia oil soap 0.6 per cent (55.70) was on par with neem oil soap 0.6 per cent (50.75) compared to control with zero feeding deterrency index. Soap solution (4.92) was statistically on par with control.

4.1.2 Growth index and Relative growth index

Growth retardation property of pongamia oil soap was evaluated against first instar larvae of *Spodoptera litura* and growth Index (GI) was calculated and presented in table 5. The relative growth index (RGI) of each treatment was calculated from GI and presented in the table 6.

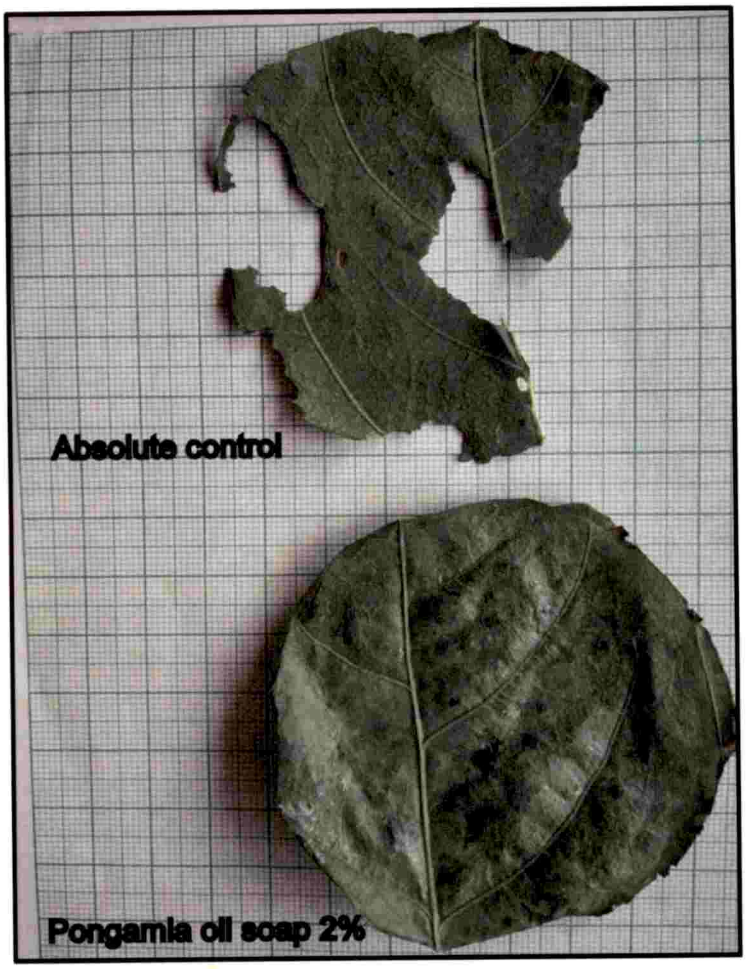
Five first instar larvae were used in each treatment. All the first instar larvae died in pongamia oil soap 2 per cent and four larvae in pongamia oil soap 1 per cent. Four larvae died in pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent and one in pongamia oil soap 1 per cent at second instar stage. One third instar larvae died in pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent.

Table 4. Feeding deterrency index in the fifth instar larvae of *Spodoptera litura* under different treatments

Treatments	Feeding deterrency index
Pongamia oil soap 0.6%	55.70 [b]
Pongamia oil soap 1%	83.91 [a]
Pongamia oil soap 2%	93.96 [a]
Neem oil soap 0.6%	50.75 [b]
Soap solution 0.5%	4.92 [c]
Control	0.00 [c]
C.D (0.05)	21.91

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

Plate 4. Laboratory bioassay on fifth instar larvae of *Spodoptera litura*



(a) Leaf are consumed by fifth instar larvae of *Spodoptera litura*

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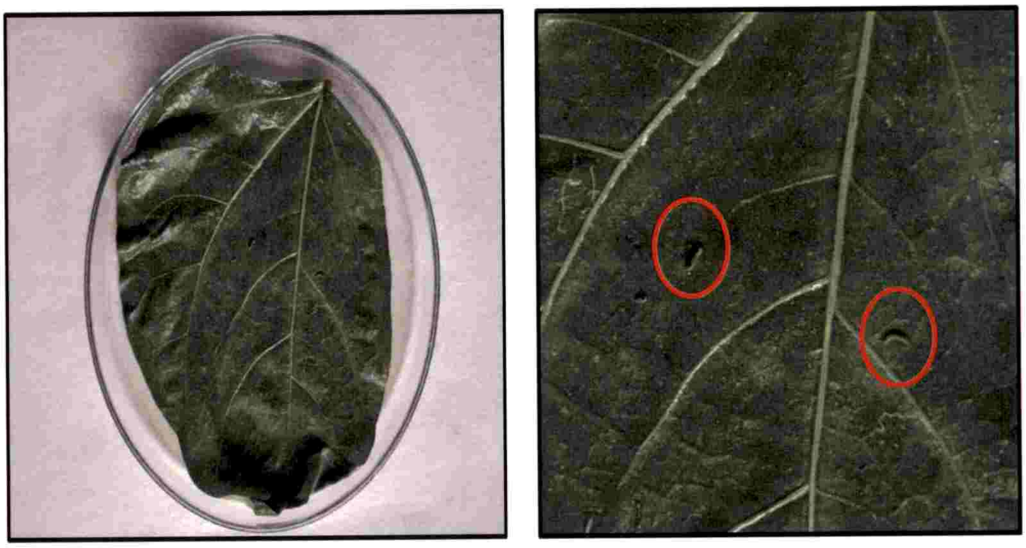
Table 5. Growth index of *Spodoptera litura* larvae under different treatments

Treatments	No. of Ist instar larvae at the begin ing of the experiment	No. of live larvae present in different stages						No. of dead larvae present in different stages						Growth index
		Ist instar	IInd instar	IIIrd instar	IVth instar	Vth instar	Pupa	Ist instar	IInd instar	IIIrd instar	IVth instar	Vth instar	Pupa	
Pongamia oil soap 0.6%	5	-	-	-	-	-	-		4	1	-	-	-	**0.20**
Pongamia oil soap 1%	5	-	-	-	-	-	-	4	1	-	-	-	-	**0.03**
Pongamia oil soap 2%	5	-	-	-	-	-	-	5		-	-	-	-	**0.00**
Neem oil soap 0.6%	5	-	-	-	-	-	-	-	4	1		-	-	**0.20**
Soap solution 0.5%	5	-	-	-	-		5	-	-	-	-	-	-	**1.00**
Control	5	-	-	-	-	-	5	-	-	-	-	-	-	**1.00**

Plate 5. Laboratory bioassay on first instar larvae of *Spodoptera litura*



(a) Dead 1st instar larvae in Pongamia oil soap 2 per cent

(b) Puaption in Control

The ratio of rate of increase in size of larvae in treatment to that of the larvae in control was noted lowest in pongamia oil soap 2 per cent with (0.00) RGI which was on par with pongamia oil soap 1 per cent (0.17) when compared to control (1.00) and soap solution (1.00) was on par with each other. Growth retardation was observed in pongamia oil soap 0.6 per cent (0.14) was on par with neem oil soap 0.6 per cent (0.14).

4.1.3 Mortality of aphids

The mortality percentage of aphids at 2, 4, 6, 8, 10 and 12 hours intervals was computed and presented in table 7.

Two hours after the treatment, T_3 (100 per cent) showed high percentage of mortality which was followed by T_2 (95.55 per cent), T4 (88.88 per cent) and T_1 (81.1 per cent) when compared to control (T_6) having zero percentage of mortality. Treatment T_5 (1.11 per cent) was statistically on par with T_6.

Four hours after the treatment, T_3 (100 per cent) showed high percentage of mortality which was on par with T_2 (100 per cent) followed by T_4 (88.88 per cent) and T_1 (81.1 per cent) when compared to control (T_6) having zero percentage of mortality. Treatment T_5 (1.11 per cent) was statistically on par with T_6.

Six hours after the treatment, T_3 (100 per cent) showed high percentage of mortality which was on par with T_2 (100 per cent) followed by T_4 (88.88 per cent) and T_1 (81.1 per cent) when compared to control (T_6) having zero percentage of mortality. Treatment T_5 (1.11 per cent) was statistically on par with T_6.

T_3 (100 per cent) showed high percentage of mortality which was on par with T_2 (100 per cent) followed by T_1 (92.22 per cent) on par with T_4 (91.11 per cent) when compared to control (T_6) having zero percentage of mortality eight hours after the treatment. Treatment T_5 (1.11 per cent) was statistically on par with T_6.

Table 6. Relative growth index of *Spodoptera litura* larvae under different treatments

Treatments	Relative growth index
Pongamia oil soap 0.6%	0.14 [b]
Pongamia oil soap 1%	0.17 [bc]
Pongamia oil soap 2%	0.00 [c]
Neem oil soap 0.6%	0.14 [b]
Soap solution 0.5%	1.00 [a]
Control	1.00 [a]
C.D (0.05)	0.12

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

Ten hours after the treatment, T_3 (100 per cent) showed high percentage of mortality which was on par with T_2 (100 per cent) followed by T_4 (95.55 per cent) on par with T_1 (94.44 per cent) when compared to control (T_6) having zero percentage of mortality. Treatment T_5 (1.11 per cent) was statistically on par with T6.

Twelve hours after the treatment, T_1, T_2, T_3 and T_4 showed 100 per cent percentage of mortality when compared to control (T_6) having zero percentage of mortality. Treatment T_5 (1.11 per cent) was statistically on par with T_6.

4.2 FIELD EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGETABLE COWPEA PERFORMED FOR TWO SEASONS

The field experiment was carried out to study the efficacy of pongamia oil soap at different concentrations for the management of pests of vegetable cowpea in field conditions during two consecutive seasons: rabi and summer, 2018 - 2019 at College of Agriculture, Kerala Agricultural University, Padannakkad. The interpreted results obtained from the study is presented below.

4.2.1 Scoring of aphid colonies on shoots based on standard scale during rabi season from October 2018 to January 2019

The effect of different concentrations of pongamia oil soap on aphid population on shoots were tested to find out their efficacy during rabi season from October 2018 to January 2019.

Aphid colonies were scored based on standard scale on 1, 3, 5, 7 and 14 days and the data obtained were statistically analysed and presented in table 8. Aphid population were negligible after second and third spray.

Pre count of aphid population showed no significant difference between the treatments, indicating that the population density of aphids was uniform in all the treatments prior to the first spraying.

Table 7. Percentage mortality of aphids under different treatments

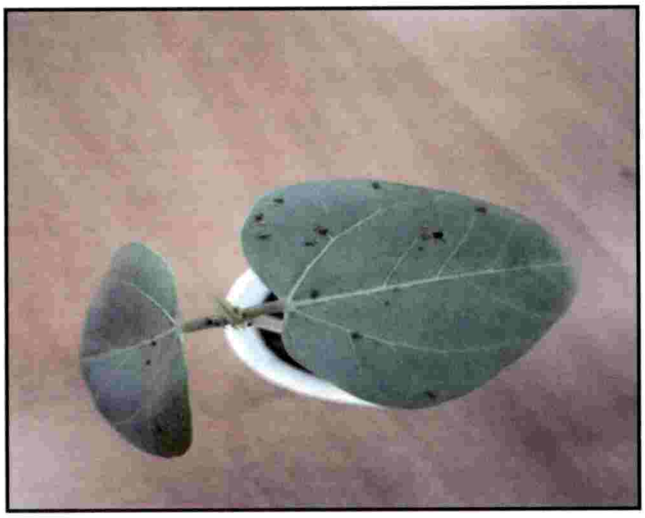
Treatments	Percentage of mortality of aphids					
	2 hr	4 hr	6 hr	8 hr	10 hr	12 hr
T_1	81.11 (64.37)^{d}	81.11 (64.37)^{c}	81.11 (64.37)^{c}	92.22 (73.87)^{b}	94.44 (76.51)^{b}	100 (89.45)^{a}
T_2	95.55 (77.99)^{b}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}
T_3	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}	100 (89.45)^{a}
T_4	88.88 (70.83)	88.88 (70.83)^{b}	88.88 (70.83)^{b}	91.11 (73.20)^{b}	95.55 (77.99)^{b}	100 (89.45)^{a}
T_5	1.11 (3.86)^{e}	1.11 (3.86)^{d}	1.11 (3.86)^{d}	1.11 (3.86)^{c}	1.11 (3.86)^{c}	1.11 (3.86)^{b}
T_6	0.00 (0.54)^{e}	0.00 (0.54)^{d}	0.00 (0.54)^{d}	0.00 (0.54)^{c}	0.00 (0.54)^{c}	0.00 (0.54)^{b}
CD (0.05)	6.31	6.03	6.03	6.02	4.94	4.18

Figures in parenthesis denotes arc sin transformed values.

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

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

Plate 6. Laboratory bioassay on nymphs and adults of aphids



(a) Dead aphids on plant treated with Pongamia oil soap 2%

(b) Live aphids on Control plant

One day after first spray of application, minimum count of aphid population was seen in T_3 (0.12) followed by T_2 (0.75) and T_1 (1.37). Maximum aphid population score was recorded in T_7 (2.50) followed by T_6 (2.25) and T_5 (2.00). Treatment T_4 (1.43) was statistically on par with T_1 (1.37) and treatments T_7 and T_5 were on par with T_6. All the treatments except T_6 were significantly superior over the control (T_7).

Minimum count of aphid population was seen in T_3 (0.12) followed by T_2 (0.75) and T_1 (1.37) on third day after first spray. Maximum aphid population score was recorded in T_7 (2.62) followed by T_6 (2.37) and T_5 (2.00). Treatments T_7 (2.62) and T_6 (2.37) were statistically on par Treatment T_4 (1.43) was statistically on par with T_1 (1.37). All the treatments except T_6 were significantly superior over the control (T_7).

A gradual increase in the aphid population was seen on five days after spray. Minimum count of aphid population was seen in T_3 (0.31) followed by T_2 (0.87) and T_1 (1.75). Maximum aphid population score was recorded in T_7 (3.62) followed by T6 (2.62) and T_5 (2.25). Treatment T4 (1.68) was statistically on par with T_1 (1.75). All the treatments except T_6 were significantly superior over the control (T_7).

Observations on seventh day after first spray revealed that minimum count of aphid population was seen in T_3 (0.31) followed by T_2 (1.00) and T_4 (1.68). Maximum aphid population score was recorded in T_7 (3.75) followed by T_6 (3.37) and T_5 (2.25). Treatment T_1 (2.00) was statistically on par with T_4 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on fourteenth day after first spray found that minimum count of aphid population was seen in T_3 (0.43) followed by T_2 (1.06) and T_4 (1.75). Maximum aphid population score was recorded in T_7 (5.06) followed by T_6 (5.00) and T_5 (2.31). Treatment T_1 (2.06) was statistically on par with T_4 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

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Table 8. Scoring of aphid colonies on shoots based on standard scale during rabi season from October 2018 to January 2019

Treatments	Aphids scoring on shoots *					
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	7 DAFS	14 DAFS
T_1	1.62 (1.26)	1.37 (1.36) [c]	1.37 (1.36) [c]	1.75 (1.49) [c]	2.00 (1.57) [b]	2.06 (1.59) [b]
T_2	1.68 (1.28)	0.75 (1.11) [d]	0.75 (1.11) [d]	0.87 (1.16) [d]	1.00 (1.22) [c]	1.06 (1.24) [c]
T_3	1.62 (1.26)	0.12 (0.78) [e]	0.12 (0.78) [e]	0.31 (0.88) [e]	0.31 (0.88) [d]	0.43 (0.95) [d]
T_4	1.75 (1.32)	1.43 (1.39) [c]	1.43 (1.39) [c]	1.68 (1.47) [c]	1.68 (1.47) [b]	1.75 (1.49) [b]
T_5	1.87 (1.36)	2.00 (1.57) [b]	2.00 (1.57) [b]	2.25 (1.64) [bc]	2.25 (1.64) [b]	2.31 (1.66) [b]
T_6	1.87 (1.36)	2.25 (1.65) [ab]	2.37 (1.69) [a]	2.62 (1.76) [b]	3.37 (1.96) [a]	5.00 (2.34) [a]
T_7	2.37 (1.53)	2.50 (1.73)[a]	2.62 (1.76) [a]	3.62 (2.03) [a]	3.75 (2.06) [a]	5.06 (2.35) [a]
C.D. (0.05)	NS	0.08	0.09	0.19	0.20	0.20

* Mean of observations of sixteen plants.

Figures in parenthesis denotes square root transformed values.

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

DBFS- Day before first spray; DAFS- Days after first spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

4.2.2 Scoring of aphid colonies on shoots based on standard scale during summer season from February 2019 to May 2019

The effect of different concentrations of pongamia oil soap on aphid population on shoots were tested to find out their efficacy during summer season from February 2018 to May 2019. Aphid colonies were scored based on a standard scale on 1, 3, 5, 7 and 14 days and the data obtained were statistically analysed and presented in table 9. Here also aphid population were negligible after second and third spray.

Pre count of aphid population showed no significant difference between the treatments, indicating that the population density of aphids was uniform in all the treatments prior to the first spraying.

One day after first spray application, minimum count of aphid population was seen in T_3 (0.00) followed by T_2 (0.75) and T_1 (2.56). Maximum aphid population score was recorded in T_7 (9.00) and T_6 (9.00) and T_5 (6.00). Treatment T_4 (3.12) was statistically on par with T1 and treatment T_7 was on par with T_6. All the treatments except T_6 were significantly superior over the control (T_7).

Minimum count of aphid population was seen in T_3 (0.00) followed by T_2 (0.62) and T_1 (2.31) on 3rd day after first spray. Maximum aphid population score was recorded in T_7 (9.00) and T_6 (9.00) followed by T_5 (6.00). Treatment T_4 (2.43) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T7).

All the treatments except T_6 were significantly superior over the control (T_7) on five days after spray. Minimum count of aphid population was seen in T3 (0.00) followed by T_2 (0.62) and T_1 (2.25). Maximum aphid population score was recorded in T_7 (9.00) followed by T_6 (8.00) and T_5 (5.50).Treatment T4 (2.31) was statistically on par with T1.

Observations at seventh day after first spray found that minimum count of aphid population was seen in T_3 (0.06) followed by T_2 (0.75) and T_1 (2.56). Maximum aphid population score was recorded in T_7 (9.00) and T_6 (9.00) and followed by T_5 (6.00). Treatment T_4 (3.12) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after first spray revealed that minimum count of aphid population was seen in T_3 (0.12) followed by T_2 (1.00) and T_4 (2.56). Maximum aphid population score was recorded in T_7 (9.00) followed by T_6 (8.00) and T_5 (5.50). Treatment T_1 (2.75) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

4.2.3 Mean per cent of aphid infestation on shoots during rabi season from from October 2018 to January 2019

The effect of different concentrations of pongamia oil soap on aphid population on shoots were tested to find out their efficacy during rabi season from October 2018 to January 2019. The infestation on shoots due to aphids, *Aphis craccivora* after first spray application of treatments was expressed as percentage of shoots infested and was presented in table 10. The observation on infestation on shoots due to aphids after second and third spray was avoided, as no infestation found.

No significant per cent of aphid infestation on shoots was recorded between all the treatments prior to the first spray.

A significant reduction in aphid infestation on shoots was observed in the plot treated with treatment T_3 (1.57 per cent) after seven days of first spray followed by T_2 (6.59 per cent) and T_4 (11.34 per cent). Maximum per cent of aphid infestation on shoots was recorded in T_7 (44.57 per cent) which was at par with T_6 (38.93 per cent) followed by T_5 (21.23 per cent). Treatment T4 was statistically on par with T_1 (11.86 per cent). All the treatments except T_6 were significantly superior over the control (T_7).

Table 9. Scoring of aphid colonies on shoots based on standard scale during summer season from February 2019 to May 2019

Treatments	Aphids scoring on shoots *					
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	7 DAFS	14 DAFS
T_1	4.37 (2.09)	2.56 (1.74) ^{c}	2.31 (1.67) ^{c}	2.25 (1.65) ^{c}	2.56 (1.74) ^{c}	2.75 (1.79) ^{c}
T_2	4.43 (2.10)	0.75 (1.06) ^{d}	0.62 (1.01) ^{d}	0.62 (1.01) ^{d}	0.75 (1.07) ^{d}	1.00 (1.22) ^{d}
T_3	4.37 (2.08)	0.00 (0.70) ^{e}	0.00 (0.70) ^{e}	0.00 (0.70) ^{e}	0.06 (0.74) ^{e}	0.12 (0.78) ^{e}
T_4	4.5 (2.12)	3.12 (1.90) ^{c}	2.43 (1.71) ^{c}	2.31 (1.67) ^{c}	3.12 (1.90) ^{c}	2.56 (1.74) ^{c}
T_5	4.62 (2.14)	6.00 (2.54) ^{b}	6.00 (2.54) ^{b}	5.50 (2.44) ^{b}	6.00 (2.54) ^{b}	5.50 (2.44) ^{b}
T_6	4.62 (2.14)	9.00 (3.08) ^{a}	9.00 (3.08) ^{a}	8.00 (2.91) ^{a}	9.00 (3.08) ^{a}	8.00 (2.91) ^{a}
T_7	5.12 (2.26)	9.00 (3.08) ^{a}	9.00 (3.08) ^{a}	9.00 (3.08) ^{a}	9.00 (3.08) ^{a}	9.00 (3.08) ^{a}
C.D. (0.05)	NS	0.28	0.23	0.25	0.26	0.19

* Mean of observations of sixteen plants.

Figures in parenthesis denotes square root transformed values.

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

DBFS- Day before first spray; DAFS- Days after first spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

The observation on aphid infestation on shoots after fourteen days of first spray showed that treatment T_3 (5.32 per cent) found with minimum per cent of aphid infestation on shoots which was on par with T_2 (8.48 per cent) and T_4 (13.87 per cent). Maximum per cent of aphid infestation on shoots was recorded in T7 (56.83 per cent) which was at par with T_6 (40.21 per cent) followed by T_5 (24.59 per cent).Treatment T_4 was statistically on par with T_1 (15.87 per cent) and T_2. All the treatments except T_6 were significantly superior over the control (T_7).

4.2.4 Mean per cent of aphid infestation on shoots during summer season from February 2019 to May 2019

The effect of different concentrations of pongamia oil soap on aphid population on shoots were tested to find out their efficacy during summer season from February 2018 to May 2019. The infestation on shoots due to aphids, *Aphis craccivora* after first spray application of treatments was expressed as percentage of shoots infested and was presented in table 11. The observation on infestation on shoots due to aphids after second and third spray avoided, as no infestation found.

No significant per cent of aphid infestation on shoots was recorded between all the treatments prior to the first spray.

A significant reduction in aphid infestation on shoots was observed in the plot treated with treatment T_3 (0.20 per cent) after seven days of first spray followed by T_2 (3.22 per cent) and T_1 (14.69 per cent). Maximum per cent of aphid infestation on shoots was recorded in T_7 (89.00 per cent) which was at par with T_6 (88.08 per cent) followed by T_5 (44.42 per cent). Treatment T_1 was statistically on par with T_4 (16.13 per cent). All the treatments except T_6 were significantly superior over the control (T_7).

Table 10.Mean per cent of aphid infestation on shoots during rabi season from October 2018 to January 2019

Treatments	Aphid infestation on shoots *		
	1 DBFS	7 DAFS	14 DAFS
T_1	18.33 (25.08)	11.86 (20.14) [c]	15.87 (23.37) [cd]
T_2	18.28 (24.60)	6.59 (14.84) [d]	8.48 (16.83) [de]
T_3	20.51 (26.91)	1.57 (1.57) [e]	5.32 (11.53) [e]
T_4	21.10 (27.23)	11.34 (19.68) [c]	13.87 (21.83) [d]
T_5	18.36 (25.30)	21.23 (27.43) [b]	24.59 (29.68) [c]
T_6	17.17 (24.41)	38.93 (38.56) [a]	40.21 (39.27) [b]
T_7	20.68 (26.86)	44.57 (41.88) [a]	56.83 (48.95) [a]
C.D. (0.05)	NS	3.48	7.01

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBFS- Day before first spray; DAFS- Days after first spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Plate 7. Incidence of aphids on vegetable cowpea

(a) Aphids *Aphis craccivora*

(b) Infestation on shoots

Observation on aphid infestation on shoots after fourteen days indicated that there was gradual increase in the per cent of aphid infestation on shoots in all treatments except control (T_7). Minimum per cent of aphid infestation on shoots was recorded in T_3 (0.54 per cent) which was at par with T_2 (5.62 per cent) followed by T_1 (18.94 per cent). Maximum per cent of aphid infestation on shoots was recorded in T_6 (87.75 per cent) which was at par with T_7 (85.58 per cent) followed by T_5 (49.27 per cent). Treatment T_4 (32.45 per cent) was statistically on par with T_1 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

4.2.5 Mean number of nymphs and adults of pod bugs during rabi season from October 2018 to January 2019

The effect of different concentrations of pongamia oil soap on nymphs and adults of pod bug were tested to find out their efficacy during rabi season from October 2018 to January 2019. Observations were taken on 1, 3, 5, 7 and 14 days and the data obtained from second and third spray were statistically analysed and presented in table 12.

Pre count of nymphs and adults of pod bug showed no significant difference between the treatments, indicating that the population density of pod bugs was uniform in all the treatments prior to the second spray.

One day after second spray of application, less number of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.12) and T_1 (0.62) whereas the population of nymphs and adults of pod bug were high in T_7 (2.00) and T_6 (2.00) followed by T_5 (0.87). Treatment T_4 (0.68) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on third day after second spray recorded that less number of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.18) and T_1 (0.68) whereas the population of nymphs and adults of pod bug were high in T_7 (2.00) and (2.00) followed by T_5 (0.87). Treatment T_4 (0.75) was statistically on par

Table 11.Mean per cent of aphid infestation on shoots during summer season from February 2019 to May 2019

Treatments	Aphid infestation on shoots *		
	1 DBFS	7 DAFS	14 DAFS
T_1	64.97 (53.93)	14.69 (22.52) ^{c}	18.94 (25.79) ^{d}
T_2	60.87 (51.47)	3.22 (9.05) ^{d}	5.62 (13.51) ^{d}
T_3	66.98 (55.35)	0.20 (1.69) ^{e}	0.54 (3.25) ^{e}
T_4	69.29 (56.58)	16.13 (23.66) ^{c}	32.45 (33.90) ^{bc}
T_5	57.50 (49.34)	44.42 (41.78) ^{b}	49.27 (44.57) ^{b}
T_6	67.38 (55.68)	88.08 (69.81) ^{a}	87.75 (69.53) ^{a}
T_7	67.85 (55.57)	89.00 (70.64) ^{a}	85.58 (67.70) ^{a}
C.D. (0.05)	NS	3.88	11.50

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBFS- Day before first spray; DAFS- Days after first spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

with T_1 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.12) followed by T_2 (0.25) and T_1 (0.75) on five days after spray whereas the population of nymphs and adults of pod bug were high in T_7 (2.00) and T_6 (2.00) and followed by T_5 (1.00). Treatment T_4 (0.75) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at seventh day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.75) followed by T_2 (0.87) and T_1 (0.87) whereas the population of nymphs and adults of pod bug were high in T_7 (2.12) and T_6 (1.75) and followed by T_5 (1.25). Treatment T_7 was statistically on par with T6 and treatment T6 was on par with T_5. Treatments T_1, T_2, T_3 and T_4 were on par and T_5 on par with T_1, T_2 and T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (1.00) followed by T_2 (1.18) and T_1 (1.18) whereas the population of nymphs and adults of pod bug were high in T_7 (2.25) followed by T_6 (2.00) which were statistically on par and followed by T_5 (1.31). Treatments T_1, T_2, T_3, T_4 and T_5 were on par. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after second spray taken as pre count of the third spray.

One day after third spray of application, less number of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.25) and T_4 (0.62) whereas the population of nymphs and adults of pod bug were high in T_7 (2.00) which was at par with T_6 (1.75) followed by T_5 (1.00). Treatment T_1 (0.68) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on third day after third spray recorded that less number of nymphs and adults of pod bug were observed in T_3 (0.06) followed by T_2 (0.25) and T_1 (0.68) whereas the population of nymphs and adults of pod bug were high in T_7 (2.06) which was at par with T_6 (2.00) followed by T_5 (1.12). Treatment T_4 (0.75) was statistically on par with T_1 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.12) followed by T_2 (0.37) and T_4 (0.81) on five days after spray whereas the population of nymphs and adults of pod bug were high in T_7 (2.06) and T_6 (2.06) and followed by T_5 (1.18). Treatment T_1 (0.93) was statistically on par with T_4. All the treatments except T6 were significantly superior over the control (T_7).

Observations at seventh day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.68) followed by T_2 (0.93) and T_1 (0.93) whereas the population of nymphs and adults of pod bug were high in T_7 (1.87) and T_6 (1.81) and followed by T_5 (1.31). Treatment T_7 was statistically on par with T_6 and treatment T_6 was on par with T_5. Treatments T_1, T_2, T_3 and T_4 were on par and T_5 on par with T_1, T_2 and T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.75) followed by T_2 (1.06) and T_1 (1.43) whereas the population of nymphs and adults of pod bug were high in T_7 (2.75) and T_6 (2.56) and followed by T_5 (1.68). Treatment T_7 was statistically on par with T_6. Treatments T_1, T_2, T_4 and T_5 were on par and T_2 on par with T_3. All the treatments except T_6 were significantly superior over the control (T_7).

4.2.6 Mean number of nymphs and adults of pod bugs during summer season from February 2019 to May 2019

The effect of different concentrations of pongamia oil soap on nymphs and adults of pod bug were tested to find out their efficacy during summer season from

Table 12. Mean number of nymphs and adults of pod bugs during rabi season from October 2018 to January 2019

Treatments	Number of nymphs and adults of pod bugs *										
	1 DBSS	1 DASS	3 DASS	5 DASS	7 DASS	14 DASS	1 DATS	3 DATS	5 DATS	7 DATS	14 DATS
T_1	1.12 (1.02)	0.62 (1.05) ^{c}	0.68 (1.08) ^{c}	0.75 (1.11) ^{c}	0.87 (0.93) ^{cd}	1.18 (1.07) ^{b}	0.68 (1.08) ^{c}	0.68 (1.08) ^{c}	0.93 (1.19) ^{c}	0.93 (0.96) ^{cd}	1.43 (1.17) ^{b}
T_2	1.18 (1.08)	0.12 (0.78) ^{d}	0.18 (0.82) ^{d}	0.25 (0.86) ^{d}	0.87 (0.92) ^{cd}	1.18 (1.07) ^{b}	0.25 (0.86) ^{d}	0.25 (0.86) ^{d}	0.37 (0.93) ^{d}	0.93 (0.96) ^{cd}	1.06 (1.02) ^{bc}
T_3	1.62 (1.25)	0.00 (0.70) ^{e}	0.00 (0.70) ^{e}	0.12 (0.78) ^{e}	0.75 (0.86) ^{d}	1.00 (0.98) ^{b}	0.00 (0.70) ^{e}	0.06 (0.74) ^{e}	0.12 (0.78) ^{e}	0.68 (0.82) ^{d}	0.75 (0.85) ^{c}
T_4	1.12 (1.05)	0.68 (1.08) ^{c}	0.75 (1.11) ^{bc}	0.75 (1.11) ^{c}	0.93 (0.96) ^{cd}	1.18 (1.08) ^{b}	0.62 (1.05) ^{c}	0.75 (1.11) ^{c}	0.81 (1.14) ^{c}	1.00 (0.99) ^{cd}	1.50 (1.20) ^{b}
T_5	1.00 (1.00)	0.87 (1.17) ^{b}	0.87 (1.17) ^{b}	1.00 (1.22) ^{b}	1.25 (1.10) ^{bc}	1.31 (1.13) ^{b}	1.00 (1.22) ^{b}	1.12 (1.27) ^{b}	1.18 (1.29) ^{b}	1.31 (1.13) ^{bc}	1.68 (1.25) ^{b}
T_6	1.62 (1.26)	2.00 (1.58) ^{a}	2.00 (1.58) ^{a}	2.00 (1.58) ^{a}	1.75 (1.31) ^{ab}	2.00 (1.41) ^{a}	1.75 (1.49) ^{a}	2.00 (1.58) ^{a}	2.06 (1.60) ^{a}	1.81 (1.33) ^{ab}	2.56 (1.59) ^{a}
T_7	1.43 (1.18)	2.00 (1.58) ^{a}	2.00 (1.58) ^{a}	2.00 (1.58) ^{a}	2.12 (1.44) ^{a}	2.25 (1.49) ^{a}	2.00 (1.58) ^{a}	2.06 (1.60) ^{a}	2.06 (1.60) ^{a}	1.87 (1.36) ^{a}	2.75 (1.65) ^{a}
C.D. (0.05)	NS	0.06	0.06	0.05	0.21	0.26	0.11	0.06	0.09	0.21	0.30

* Mean of observations of sixteen plants.

Figures in parenthesis denotes square root transformed values. Means superscripted by similar letters are not significantly different at 5% level of DMRT

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

February 2019 to May 2019. Observations were taken on 1, 3, 5, 7 and 14 days and the data obtained from second and third spray which done at reproductive stage were statistically analysed and presented in table 13.

Pre count of nymphs and adults of pod bug showed no significant difference between the treatments, indicating that the population density of pod bugs was uniform in all the treatments prior to the second spray.

One day after second spray, less number of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.31) and T_4 (0.68) whereas the population of nymphs and adults of pod bug were high in T_7 (2.06) which was at par with T_6 (1.81) followed by T_5 (1.06). Treatment T_1 (0.75) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on third day after the second spray recorded that less number of nymphs and adults of pod bug were observed in T_3 (0.18) followed by T_2 (0.37) and T_1 (0.81) whereas the population of nymphs and adults of pod bug were high in T_7 (2.18) which was at par with T_6 (2.12) followed by T_5 (1.62). Treatment T4 (0.81) was statistically on par with T_1 and T_6 on par with T_7 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.25) followed by T_2 (0.50) and T_4 (0.87) on five days after spray whereas the population of nymphs and adults of pod bug were high in T_7 (2.31) and T_6 (2.18) and followed by T_5 (1.62) Treatment T_4 was statistically on par with T_1 (1.06) and T_2 and treatment T_2 was statistically on par with T3. Treatment T_6 statistically on par with T_7 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at seventh day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.31) followed by T_2 (0.56) and T_4 (0.93) whereas the population of nymphs and adults of pod bug were high in T_7 (2.43) and T_6 (2.31) and followed by T_5 (1.68). Treatment T_7 was statistically on par with T_6 and treatment T_6 was on par with T_5. Treatments T_2 was on par with T_3 and T_4 and T_1 was on par with T_5 and T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.50) followed by T_2 (0.68) and T_4 (1.18) whereas the population of nymphs and adults of pod bug were high in T_7 (2.93) and T_6 (2.68) and followed by T_5 (1.81). Treatment T_7 was statistically on par with T_6 and treatment T_6 was on par with T_5. Treatments T_3 was on par with T_2 and T_1 was on par with T_5 and T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Prior to the third spray also, pre count of nymphs and adults of pod bug showed no significant difference between the treatments, indicating that the population density of pod bugs was uniform in all the treatments.

One day after third spray application, less number of count of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.18) and T_4 (0.56) whereas the population of nymphs and adults of pod bug were high in T_7 (1.81) which was at par with T_6 (1.56) followed by T_5 (0.93) which was at par with T6. Treatment T_1 (0.68) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on third day after the third spray recorded that less number of nymphs and adults of pod bug were observed in T_3 (0.12) followed by T_2 (0.25) and T_4 (0.62) whereas the population of nymphs and adults of pod bug were high in in T_7 (1.87) and T_6 (1.87) followed by T_5 (1.31) which was at par with T_6. Treatment T_1 (0.68) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.18) which was at on par with T_2 (0.37) and followed by T_4 (0.75) on five days after spray whereas the population of nymphs and adults of pod bug were high in T_7

(2.12) and T_6 (2.00) and followed by T_5 (1.37). Treatment T_1 (0.75) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at seventh day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.31) followed by T_2 (0.50) and T_1 (0.81) whereas the population of nymphs and adults of pod bug were high in T_7 (2.00) and T_6 (2.00) which were at par with T_5 (1.50). Treatment T_7 was statistically on par with T_6 and treatment T_6 was on par with T_5. Treatments T_2, T_1 and T_4 were on par and T_3 on par with T_2. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.56) followed by T_2 (0.68) and T_1 (0.81) whereas the population of nymphs and adults of pod bug were high in T_7 (2.12) which was at par with T_6 (2.00) and followed by T_5 (1.25). Treatments T_1, T_2 and T_3 were on par. All the treatments except T_6 were significantly superior over the control (T_7).

4.2.7 Pooled analysis of mean number of nymphs and adults of pod bugs during both rabi and summer seasons

Mean number of nymphs and adults of pod bugs during both seasons presented in table 14. One day after second spray of application, less number of nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.22) and T_1 (0.69) whereas the population of nymphs and adults of pod bug were high in T_7 (2.03) which was on par with T_6 (1.91) followed by T_5 (0.97). Treatment T_4 (0.69) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Observations on third day after the second spray recorded that less number of nymphs and adults of pod bug were observed in T_3 (0.09) followed by T_2 (0.28) and T_1 (0.75) whereas the population of nymphs and adults of pod bug were high

Table 13.Mean number of nymphs and adults of pod bugs during summer season from February 2019 to May 2019

Treatments	Number of nymphs and adults of pod bugs *											
	1 DBSS	1 DASS	3 DASS	5 DASS	7 DASS	14 DASS	1 DBTS	1 DATS	3 DATS	5 DATS	7 DATS	14 DATS
T_1	1.18 (1.07)	0.75 (1.11) [c]	0.81 (1.14) [c]	1.06 (1.24) [c]	1.12 (1.26) [cd]	1.43 (1.38) [c]	1.12 (1.05)	0.68 (1.08) [c]	0.68 (1.08) [d]	0.75 (1.11) [d]	0.81 (1.14) [b]	0.81 (1.14) [bcd]
T_2	1.31 (1.14)	0.31 (0.89) [d]	0.37 (0.92) [d]	0.50 (0.99) [de]	0.56 (1.02) [ef]	0.68 (1.07) [de]	1.18 (1.08)	0.18 (0.82) [d]	0.25 (0.84) [d]	0.37 (0.92) [d]	0.50 (0.97) [bc]	0.68 (1.07) [cd]
T_3	1.62 (1.26)	0.00 (0.70) [e]	0.18 (0.80) [d]	0.25 (0.84) [e]	0.31 (0.87) [f]	0.50 (0.96) [e]	1.62 (1.25)	0.00 (0.70) [d]	0.12 (0.78) [d]	0.18 (0.82) [c]	0.31 (0.87) [c]	0.56 (1.00) [d]
T_4	1.18 (1.08)	0.68 (1.08) [c]	0.81 (1.14) [c]	0.87 (1.17) [cd]	0.93 (1.19) [de]	1.18 (1.28) [cd]	1.12 (1.05)	0.56 (1.02) [c]	0.62 (1.05) [c]	0.75 (1.10) [c]	0.81 (1.13) [b]	1.00 (1.22) [bc]
T_5	0.87 (0.93)	1.06 (1.24) [b]	1.62 (1.45) [b]	1.62 (1.45) [b]	1.68 (1.47) [bc]	1.81 (1.51) [bc]	1.00 (1.00)	0.93 (1.29) [b]	1.31 (1.34) [b]	1.37 (1.36) [b]	1.50 (1.40) [a]	1.25 (1.31) [b]
T_6	1.56 (1.24)	1.81 (1.51) [a]	2.12 (1.61) [ab]	2.18 (1.63) [ab]	2.31 (1.67) [ab]	2.68 (1.78) [ab]	1.62 (1.26)	1.56 (1.42) [ab]	1.87 (1.53) [ab]	2.00 (1.58) [a]	2.00 (1.58) [a]	2.00 (1.58) [a]
T_7	1.31 (1.13)	2.06 (1.60) [a]	2.18 (1.63) [a]	2.31 (1.67) [a]	2.43 (1.71) [a]	2.93 (1.85) [a]	1.43 (1.18)	1.81 (1.51) [a]	1.87 (1.52) [a]	2.12 (1.61) [a]	2.00 (1.58) [a]	2.12 (1.61) [a]
C.D. (0.05)	NS	0.08	0.17	0.18	0.21	0.26	NS	0.18	0.19	0.16	0.21	0.20

* Mean of observations of sixteen plants.

Figures in parenthesis denotes square root transformed values. Means superscripted by similar letters are not significantly different at 5% level of DMRT.

DBSS- Day before second spray; DASS- Days after second spray; DBTS- Day before third spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

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in T_7 (2.09) which was on par with T_6 (2.06) followed by T_5 (1.25). Treatment T_4 (0.78) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.19) which was on par with T_2 (0.38) and T_4 (0.81) on five days after spray whereas population of nymphs and adults of pod bug were high in T_7 (2.16) which was on par with T_6 (2.09) and followed by T_5 (1.31). Treatment T_1 (0.91) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at seventh day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.53) which was on par with T_2 (0.72) and T_4 (0.94) whereas population of nymphs and adults of pod bug were high in T_7 (2.28) which was on par with T_6 (2.03) and followed by T_5 (1.47). Treatment T_7 was statistically on par with T_6. Treatments T_3, T_2, T_1 and T_4 were on par and T_5 on par with T_1 and T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after second spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.75) which was on par with T_2 (0.94) and T_4 (1.19) whereas population of nymphs and adults of pod bug were high in T_7 (2.59) followed by T_6 (2.34) which were statistically on par and followed by T_5 (1.56). Treatments T_1, T_2, T_3 and T_4 were on par. All the treatments except T_6 were significantly superior over the control (T_7).

One day after third spray of application, less number of count nymphs and adults of pod bug were observed in T_3 (0.00) followed by T_2 (0.22) and T_4 (0.59) whereas population of nymphs and adults of pod bug were high in in T_7 (1.91) which was at par with T_6 (1.86) followed by T_5 (0.97). Treatment T_1 (0.69) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Plate 8. Incidence of pod bugs on vegetable cowpea

(a) Pod bug *Riptortus pedestris*

(b) Infestation on pods

Observations on third day after third spray recorded that less number of count of nymphs and adults of pod bug were observed in T_3 (0.09) followed by T_2 (0.28) and T_1 (0.69) whereas population of nymphs and adults of pod bug were high in T_7 (1.97) which was on par with T_6 (1.94) followed by T_5 (1.22). Treatment T_4 (0.69) was statistically on par with T_1. All the treatments except T_6 were significantly superior over the control (T_7).

Less number of nymphs and adults of pod bug were observed in T_3 (0.16) followed by T_2 (0.38) and T_4 (0.78) on five days after spray whereas population of nymphs and adults of pod bug were high in T_7 (2.09) which was on par with T6 (2.03) and followed by T_5 (1.28). Treatment T_1 (0.84) was statistically on par with T_4. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at seventh day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.50) which was on par with T_2 (0.72) and followed by T_1 (0.88) whereas population of nymphs and adults of pod bug were high in T_7 (1.94) and T_6 (1.91) and followed by T_5 (1.41). Treatment T_7 was statistically on par with T_6. Treatment T_4 (0.91) was statistically on par with T_1 and T_2. All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after third spray found that less number of nymphs and adults of pod bug were observed in T_3 (0.66) which was on par with T_2 (0.88) followed by T_1 (1.13) whereas population of nymphs and adults of pod bug were high in T_7 (2.44) which was on par with T_6 (2.28) and followed by T_5 (1.47). Treatment T_4 (1.25) was statistically on par with T_1 and T_5. All the treatments except T_6 were significantly superior over the control (T_7).

Table 14.Pooled analysis of mean number of nymphs and adults of pod bugs during both rabi and summer seasons

Treatments	Number of nymphs and adults of pod bugs *									
	1 DASS	3 DASS	5 DASS	7 DASS	14 DASS	1 DATS	3 DATS	5 DATS	7 DATS	14 DATS
T_1	0.69^{c}	0.75^{c}	0.91^{c}	1.00^{bc}	1.31^{bc}	0.69^{c}	0.69^{c}	0.84^{c}	0.88^{c}	1.13^{c}
T_2	0.22^{d}	0.28^{d}	0.38^{d}	0.72^{c}	0.94^{bc}	0.22^{d}	0.28^{d}	0.38^{d}	0.72^{cd}	0.88^{d}
T_3	0.00^{e}	0.09^{d}	0.19^{d}	0.53^{c}	0.75^{c}	0.00^{e}	0.09^{e}	0.16^{e}	0.50^{d}	0.66^{d}
T_4	0.69^{c}	0.78^{c}	0.81^{c}	0.94^{bc}	1.19^{bc}	0.59^{c}	0.69^{c}	0.78^{c}	0.91^{c}	1.25^{bc}
T_5	0.97^{b}	1.25^{b}	1.31^{b}	1.47^{b}	1.56^{b}	0.97^{b}	1.22^{b}	1.28^{b}	1.41^{b}	1.47^{b}
T_6	1.91^{a}	2.06^{a}	2.09^{a}	2.03^{a}	2.34^{a}	1.86^{a}	1.94^{a}	2.03^{a}	1.91^{a}	2.28^{a}
T_7	2.03^{a}	2.09^{a}	2.16^{a}	2.28^{a}	2.59^{a}	1.91^{a}	1.97^{a}	2.09^{a}	1.94^{a}	2.44^{a}
C.D. Treatment	0.19	0.33	0.24	0.54	0.73	0.11	0.18	0.17	0.37	0.22

* Mean of observations of sixteen plants.

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

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

4.2.8 Mean per cent of pods infested by nymphs and adults of pod bugs during rabi season from October 2018 to January 2019

The data on percentage of damage caused by nymphs and adults of pod bugs on the pods of vegetable cowpea during rabi season from October 2018 to January 2019 were statistically analysed and presented in the table 15.

No significant per cent of damaged pods was recorded between all the treatments prior to the second spray.

All the treatments were significantly superior over the Control (T_7) except T_6 after seven days of second spray. Minimum per cent of damaged pods was recorded in T_3 (26.45 per cent) which was at par with T_2 (43.37 per cent) followed by T_4 (57.50 per cent). Maximum per cent of damaged pods was recorded in T_7 (92.50 per cent) which was at par with T_6 (86.59 per cent) followed by T_5 (57.88 per cent). Treatment T_1 (59.43 per cent) was statistically on par with T_2, T_4 and T_5.

After fourteenth days of second spray minimum per cent of damaged pods was recorded in T_3 (48.33 per cent) which was at par with T_2 (49.99 per cent), T_5 (58.33 per cent), T_1 (60.00 per cent) and T_4 (63.75 per cent). Maximum per cent of damaged pods was recorded in T_7 (92.85 per cent) which was at par with T_6 (91.00 per cent) .All the treatments except T_6 were significantly superior over the control (T_7).

Observations at fourteenth day after second spray taken as pre count of the third spray.

Minimum per cent of damaged pods was recorded in T_3 (30.57 per cent) after seven days of third spray followed by T_2 (39.79 per cent) which was at par with T_1 (59.52 per cent). Maximum per cent of damaged pods was recorded in T7 (89.01 per cent) which was at par with T_6 (87.26 per cent) followed by T_4 (63.33 per cent). Treatment T_5 (60.00 per cent) was statistically on par with T_1, T_2 and T_4.

Table 15.Mean per cent of pods infested by nymphs and adults of pod bugs during rabi season from October 2018 to January 2019

Treatments	Percentage of infested pods *				
	1 DBSS	7 DASS	14 DASS	7 DATS	14 DATS
T_1	76.73 (64.57)	59.43 (50.68) ^{b}	60.00 (51.05) ^{b}	59.52 (50.60) ^{b}	60.35 (51.33) ^{b}
T_2	74.80 (59.89)	43.37 (40.50) ^{bc}	49.99 (45.35) ^{b}	39.79 (38.41) ^{bc}	48.12 (43.25) ^{b}
T_3	80.35 (66.94)	26.45 (30.18) ^{c}	48.33 (43.86) ^{b}	30.57 (32.78) ^{c}	32.58 (34.14) ^{b}
T_4	71.87 (62.18)	57.50 (49.61) ^{b}	63.75 (53.35) ^{b}	63.33 (52.81) ^{b}	60.21 (51.07) ^{b}
T_5	83.26 (66.15)	57.88 (50.36) ^{b}	58.33 (50.22) ^{b}	60.00 (51.05) ^{b}	57.84 (49.91) ^{b}
T_6	83.93 (67.11)	86.59 (68.70) ^{a}	91.00 (74.92) ^{a}	87.26 (71.64) ^{a}	88.75 (75.58) ^{a}
T_7	87.31 (72.11)	92.50 (78.47) ^{a}	92.85 (78.62) ^{a}	89.01 (75.83) ^{a}	89.58 (76.20) ^{a}
C.D. (0.05)	NS	17.89	14.75	15.08	24.02

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Minimum per cent of damaged pods was recorded in T_3 (32.58 per cent) after fourteen days of third spray which was at par with T_2 (48.12 per cent), T5 (57.84 per cent), T_4 (60.21 per cent) and T_1 (60.35 per cent). Maximum per cent of damaged pods was recorded in T_7 (89.58 per cent) which was at par with T_6 (88.75 per cent). All the treatments except T_6. were significantly superior over the control (T_7)

4.2.9 Mean per cent of pods infested by nymphs and adults of pod bugs during summer season from February 2019 to May 2019

The data on percentage of damage caused by nymphs and adults of pod bugs on the pods of vegetable cowpea during summer season from February 2019 to May 2019 were statistically analysed and presented in the table 16.

No significant per cent of damaged pods was recorded between all the treatments prior to the second spray.

All the treatments except T_6 were significantly superior over the control (T_7). Minimum per cent of damaged pods was recorded in T_3 (14.37 per cent) after seven days of second spray which was at par with T_2 (32.41 per cent). Treatments T_1 (47.85 per cent), T_4 (44.44 per cent) and T_5 (44.30 per cent) were at par with T2. Maximum per cent of damaged pods was recorded in T_7 (87.70 per cent) which was at par with T_6 (83.30 per cent).

Observations after fourteenth day after second spray found that minimum per cent of damaged pods was recorded in T_3 (36.25 per cent) which was at par with T_2 (45.26 per cent), T1 (48.21 per cent), T_4 (48.88 per cent) and T_5 (50.62 per cent). Maximum per cent of damaged pods was recorded in T_7 (86.66 per cent) which was at par with T_6 (84.16 per cent). All the treatments except T_6 were significantly superior over the control (T_7).

No significant per cent of damaged pods was recorded between all the treatments prior to the second spray.

Minimum per cent of damaged pods was recorded in T_3 (14.02 per cent) after seven days of third spray followed by T_2 (21.11 per cent). Treatments T_1 (41.19 per cent), T_4 (40.32 per cent) and T_5 (42.32 per cent) were at par. Maximum per cent of damaged pods was recorded in T_7 (86.80 per cent) which was at par with T_6 (82.05 per cent). All the treatments except T_6 were significantly superior over the control (T_7).

Observations after fourteenth day after third spray found that minimum per cent of damaged pods was recorded in T_3 (41.25 per cent) which was at par with T_2 (43.39 per cent), T1 (56.69 per cent), T_5 (58.75 per cent) and T_4 (64.44 per cent). Maximum per cent of damaged pods was recorded in T_7 (95.00 per cent) which was at par with T_6 (83.54 per cent). All the treatments except T_6 were significantly superior over the control (T_7).

4.2.10 Pooled analysis of mean per cent of pods infested by nymphs and adults of pod bugs during both rabi and summer seasons

Mean per cent of pods infested by nymphs and adults of pod bugs during both seasons were presented in table 17. All the treatments were significantly superior over the Control (T_7) except T_6 after seven days of second spray. Minimum per cent of damaged pods was recorded in T_3 (20.42 per cent) followed by T_2 (37.89 per cent) followed by T_4 (50.97 per cent). Maximum per cent of damaged pods was recorded in T_7 (90.10 per cent) which was at par with T_6 (84.95 per cent) followed by T_5 (51.10 per cent). Treatment T_1 (53.64 per cent) was statistically on par with T_4 and T_5.

After fourteenth days of second spray minimum per cent of damaged pods was recorded in T_3 (42.29 per cent) which was on par with T_2 (47.63 per cent) followed by T_1 (54.11 per cent). Maximum per cent of damaged pods was recorded in T_7 (89.76 per cent) which was at par with T_6 (87.60 per cent) which was followed by T_4 (56.32 per cent). Treatment T_5 (54.48 per cent) was statistically on par with T_1 and T_4.All the treatments were significantly superior over the Control (T_7) except T_6.

Table 16.Mean per cent of pods infested by nymphs and adults of pod bugs during summer season from February 2019 to May 2019

Treatments	Percentage of infested pods *					
	1 DBSS	7 DASS	14 DASS	1 DBTS	7 DATS	14 DATS
T_1	77.50 (61.71)	47.85 (43.49) ^{b}	48.21 (43.97) ^{b}	65.17 (41.25)	41.19 (39.68) ^{b}	56.69 (49.12) ^{bc}
T_2	76.25 (61.01)	32.41 (33.64) ^{bc}	45.26 (41.80) ^{b}	55 (53.86)	21.11 (26.72) ^{b}	43.39 (41.24) ^{c}
T_3	81.11 (64.8)	14.37 (22.16) ^{c}	36.25 (36.01) ^{b}	68.75 (61.30)	14.02 (21.86) ^{c}	41.25 (38.90) ^{c}
T_4	82.50 (68.38)	44.44 (41.41) ^{b}	48.88 (44.39) ^{b}	48.61 (43.55)	40.32 (38.63) ^{b}	64.44 (53.67) ^{bc}
T_5	74.30 (60)	44.30 (41.64) ^{b}	50.62 (45.49) ^{b}	52.84 (43.85)	42.32 (40.16) ^{b}	58.75 (53.80) ^{bc}
T_6	80.13 (64.20)	83.30 (65.98) ^{a}	84.16 (72.61) ^{a}	50.41 (44.50)	82.05 (65.13) ^{a}	83.54 (69.23) ^{ab}
T_7	79.72 (63.65)	87.70 (72.02) ^{a}	86.66 (74.27) ^{a}	65.17 (53.13)	86.80 (68.75) ^{a}	95.00 (82.95) ^{a}
C.D. (0.05)	NS	17.20	21.03	NS	16.61	25.24

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second spray; DBTS- Day before third spray; DATS- Days after third spray; NS – Not Significant.

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Minimum per cent of damaged pods was recorded in T_3 (22.30 per cent) after seven days of third spray which was on par with T_2 (30.45 per cent) followed by T_1 (50.36 per cent). Maximum per cent of damaged pods was recorded in T_7 (87.91 per cent) which was at par with T_6 (84.66 per cent) followed by T_4 (51.83 per cent). Treatment T_5 (51.16 per cent) was statistically on par with T_1 and T_4.

Minimum per cent of damaged pods was recorded in T_3 (36.92 per cent) after fourteen days of third spray which was at par with T_2 (45.76 per cent) followed by T_5 (58.30 per cent). Maximum per cent of damaged pods was recorded in T_7 (92.29 per cent) which was at par with T_6 (86.15 per cent) followed by T_4 (62.33 per cent). Treatment T_1 (60.61 per cent) was statistically on par with T_4 and T_5. All the treatments were significantly superior over the Control (T_7) except T_6.

4.2.11 Mean per cent of flowers infested by larvae of *Maruca vitrata* during rabi season from October 2018 to January 2019

In the field experiment conducted, the data on percentage of flowers infested by larvae of *Maruca vitrata* on the flowers of vegetable cowpea during rabi season from October 2018 to January 2019 were statistically analysed and presented in the Table 18.

No significant per cent of damaged flowers was recorded between all the treatments prior to the second spray.

Minimum per cent of damaged flowers was recorded in T_5 (13.98 per cent) after seven days of second spray followed by T_4 (84.53 per cent) which was at par with T_1 (85.82 per cent) after seven days of second spray. Maximum per cent of damaged flowers was recorded in T_7 (88.15 per cent) which was at par with T_3 (87.45 per cent) and T_6 (87.05 per cent). Treatment T5 was significantly superior over all other treatments. Treatments T_1, T_2, T_3, T_4, T_6 and T_7 were at par.

Table 17.Pooled analysis of mean per cent of pods infested by nymphs and adults of pod bugs during both rabi and summer seasons

	Percentage of infested pods *			
Treatments	7 DASS	14 DASS	7 DATS	14 DATS
T_1	53.64[b]	54.11[b]	50.36[b]	60.61[b]
T_2	37.89[c]	47.63[c]	30.45[c]	45.76[c]
T_3	20.42[d]	42.29[c]	22.30[c]	36.92[c]
T_4	50.97[b]	56.32[b]	51.83[b]	62.33[b]
T_5	51.10[b]	54.48[b]	51.16[b]	58.30[b]
T_6	84.95[a]	87.60[a]	84.66[a]	86.15[a]
T_7	90.10[a]	89.76[a]	87.91[a]	92.29[a]
C.D. Treatment	5.91	5.35	11.04	8.94

* Mean of observations of sixteen plants.

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

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged flowers was recorded in T_5 (15.86 per cent) followed by T_3 (82.18 per cent) which was at par with T_2 (85.13 per cent). Maximum per cent of damaged flowers was recorded in T_7 (89.61 per cent) which was at par with T_6 (85.97 per cent) and T_1 (86.15 per cent). Treatments T_7, T_4, T_1, T_6 and T_2 were at par. Treatment T_5 were significantly superior over all other treatments.

Observations at fourteenth day after second spray taken as pre count of the third spray.

Minimum per cent of damaged flowers was recorded in T_5 (15.30 per cent) after seven days of third spray followed by T_2 (85.17 per cent) which was at par with T_4 (86.09 per cent). Maximum per cent of damaged flowers was recorded in T_7 (87.98 per cent) which was at par with T_1 (87.89 per cent) and T_6 (86.74 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

Damaged flowers were negligible at fourteenth day after third spray.

4.2.12 Mean per cent of flowers infested by larvae of *Maruca vitrata* during summer season from February 2019 to May 2019

In the field experiment conducted, the data on percentage of flowers infested by larvae of *Maruca vitrata* on the flowers of vegetable cowpea during rabi season from February 2019 to May 2019 were statistically analysed and presented in the table 19.

No significant per cent of damaged flowers was recorded between all the treatments prior to the second spray.

Minimum per cent of damaged flowers was recorded in T_5 (27.13 per cent) after seven days of second spray followed by T_3 (61.19 per cent) which was at par with T_2 (63.48 per cent). Maximum per cent of damaged flowers was recorded in T_7 (92.77 per cent) which was at par with T_6 (89.65 per cent) and followed by T_4

Table 18.Mean per cent of pod borer infestation on flowers during rabi season from October 2018 to January 2019

Treatments	Percentage of infested flowers *			
	1 DBSS	7 DASS	14 DASS	7 DATS
T_1	83.33 (72.09)	85.82 (67.90)[a]	86.15 (68.26)[a]	87.89 (69.73)[a]
T_2	53.75 (47.30)	86.84 (68.87)[a]	85.13 (67.34)[a]	85.17 (67.41)[a]
T_3	86.60 (74.15)	87.45 (69.32)[a]	82.18 (65.24)[a]	86.39 (68.36)[a]
T_4	76.25 (60.85)	84.53 (67.27)[a]	87.17 (69.28 [a])	86.09 (68.35)[a]
T_5	76.60 (61.13)	13.98 (21.92)[b]	15.86 (23.396)[b]	15.30 (22.99)[b]
T_6	77.50 (61.71)	87.05 (68.96)[a]	85.97 (68.23)[a]	86.74 (68.72 [a]
T_7	60.00 (54.67)	88.15 (69.97)[a]	89.61 (71.25)[a]	87.98 (69.72)[a]
C.D. (0.05)	NS	4.61	5.15	3.35

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

(70.12 per cent). Treatments T_1, T_2, T_3 and T_4 were at par. Treatment T_5 was significantly superior over all other treatments.

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged flowers was recorded in T_5 (15.79 per cent) followed by T_3 (65.45 per cent) which was at par with T_2 (68.02 per cent). Maximum per cent of damaged flowers was recorded in T_7 (92.31 per cent) which was at par with T_6 (91.91 per cent) and followed by T_4 (76.25 per cent). Treatments T_1, T_2, T_3 and T_4 were at par. Treatment T_5 were significantly superior over all other treatments.

There was only negligible numbers of damaged flowers found on seven and fourteen days after third spray. So it was not recorded.

4.2.13 Pooled analysis of mean per cent of flowers infested by larvae of *Maruca vitrata* during both rabi and summer seasons

Mean per cent of flowers infested by larvae of *Maruca vitrata* during both seasons presented in table 20. Minimum per cent of damaged flowers was recorded in T_5 (20.56 per cent) after seven days of second spray followed by T_3 (74.33 per cent) which was at par with T_2 (75.16 per cent) after seven days of second spray. Maximum per cent of damaged flowers was recorded in T_7 (90.47 per cent) which was at par with T_6 (88.35 per cent) and T_1 (77.80 per cent). Treatment T_5 was significantly superior over all other treatments.

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged flowers was recorded in T_5 (15.83 per cent) followed by T_3 (73.82 per cent) which was at par with T_2 (76.58 per cent). Maximum per cent of damaged flowers was recorded in T_7 (90.96 per cent) which was at par with T_6 (88.94 per cent) and T_4 (81.71 per cent). Treatments T_1, T_2, T_4, T_6 and T_7 were at par. Treatment T_5 were significantly superior over all other treatments.

Table 19.Mean per cent of pod borer infestation on flowers during summer season from February 2019 to May 2019

Treatments	Percentage of infested flowers *		
	1 DBSS	7 DASS	14 DASS
T_1	77.67 (61.94)	69.77 (56.87) [b]	75.83 (60.74) [b]
T_2	76.74 (61.93)	63.48 (53.10) [b]	68.02 (56.03) [b]
T_3	70.98 (57.98)	61.19 (51.79) [b]	65.45 (54.57) [b]
T_4	75.00 (60.54)	70.12 (57.17) [b]	76.25 (61.24) [b]
T_5	81.26 (65.11)	27.13 (31.28) [c]	15.79 (23.35) [c]
T_6	76.52 (61.33)	89.65 (71.46) [a]	91.91 (73.80) [a]
T_7	82.82 (68.60)	92.77 (78.95) [a]	92.31 (75.92) [a]
C.D. (0.05)	NS	8.84	12.35

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second 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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Table 20.Pooled analysis of mean per cent of pod borer infestation on flowers during both rabi and summer seasons

	Percentage of infested flowers *	
Treatments	7 DASS	14 DASS
T_1	77.8[a]	80.99[ab]
T_2	75.16[a]	76.58[ab]
T_3	74.33[a]	73.82[b]
T_4	77.33[a]	81.71[a]
T_5	20.56[b]	15.83[c]
T_6	88.35[a]	88.94[a]
T_7	90.47[a]	90.96[a]
C.D. Treatment	21.84	13.50

* Mean of observations of sixteen plants.

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

DASS- Days after second 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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Plate 9. Incidence of pod borers on vegetable cowpea

(a) Spotted pod borer *Maruca vitrata*

(b) Feeding on pods

4.2.14 Mean per cent of pods infested by larvae of *Maruca vitrata* during rabi season from October 2018 to January 2019

In the field experiment conducted, the data on percentage of pods infested by larvae of *Maruca vitrata* on the flowers of vegetable cowpea during rabi season from October 2018 to January 2019 were statistically analysed and presented in the table 21.No significant per cent of damaged flowers was recorded between all the treatments prior to the second spray.

Minimum per cent of damaged pods was recorded in T_5 (11.90 per cent) after seven days of second spray followed by T_1 (81.93 per cent) which was at par with T_4 (82.70 per cent). Maximum per cent of damaged pods was recorded in T_7 (92.08 per cent) which was at par with T_6 (89.92 per cent) and T_2 (86.33 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged pods was recorded in T_5 (14.79 per cent) followed by T_3 (83.75 per cent) which was at par with T_2 (84.37 per cent). Maximum per cent of damaged pods was recorded in T_7 (89.73 per cent) which was at par with T_1 (87.70 per cent) and T_6 (87.63 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

Observations at fourteenth day after second spray taken as pre count of the third spray.

Minimum per cent of damaged pods was recorded in T_5 (15.41 per cent) after seven days of third spray followed by T_4 (81.80 per cent) which was at par with T_2 (82.70 per cent). Maximum per cent of damaged pods was recorded in T_7 (91.28 per cent) which was at par with T_6 (86.63 per cent) and T_1 (86.01 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

Table 21.Mean per cent of pod borer infestation on pods during rabi season from October 2018 to January 2019

Treatments	Percentage of infested pods *				
	I DBSS	7 DASS	14 DASS	7 DATS	14 DATS
T_1	82.29 (71.47)	81.93 $(65.13)^{b}$	87.70 $(69.58)^{ab}$	86.01 $(68.07)^{b}$	86.42 $(71.02)^{ab}$
T_2	69.34 (56.88)	86.33 $(68.32)^{b}$	84.37 $(66.75)^{ab}$	82.70 $(65.51)^{b}$	81.87 $(64.90)^{b}$
T_3	77.67 (62.10)	86.04 $(68.22)^{b}$	83.75 $(66.36)^{b}$	85.52 $(67.75)^{b}$	87.05 $(68.91)^{ab}$
T_4	82.22 (68.54)	82.70 $(65.51)^{b}$	87.08 $(69.01)^{ab}$	81.80 $(64.96)^{b}$	86.35 $(68.37)^{ab}$
T_5	79.68 (63.63)	11.90 $(20.09)^{c}$	14.79 $(22.44)^{c}$	15.41 $(23.01)^{c}$	17.15 $(24.18)^{c}$
T_6	88.47 (70.59)	89.92 $(71.60)^{ab}$	87.63 $(69.42)^{ab}$	86.63 $(68.63)^{b}$	79.58 $(63.19)^{b}$
T_7	89.07 (70.86)	92.08 $(75.70)^{a}$	89.73 $(73.58)^{a}$	91.28 $(77.39)^{a}$	91.66 $(77.68)^{a}$
C.D. (0.05)	NS	4.66	3.76	8.69	11.04

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second spray; DATS- Days after third spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Observations recorded after fourteenth days of third spray indicated that minimum per cent of damaged pods was recorded in T_5 (17.15 per cent) followed by T_6 (79.58 per cent) which was at par with T_2 (81.87 per cent). Maximum per cent of damaged pods was recorded in T_7 (91.66 per cent) which was at par with T_1 (86.42 per cent) and T_3 (87.05 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

4.2.15 Mean per cent of pods infested by larvae of *Maruca vitrata* during summer season from February 2019 to May 2019

In the field experiment conducted, the data on percentage of pods infested by larvae of *Maruca vitrata* on the pods of vegetable cowpea during summer season from February 2019 to May 2019 were statistically analysed and presented in the table 22.

No significant per cent of damaged pods was recorded between all the treatments prior to the second spray.

Minimum per cent of damaged pods was recorded in T_5 (14.02 per cent) after seven days of second spray followed by T_3 (51.25 per cent) which was at par with T_2 (55.08 per cent). Maximum per cent of damaged pods was recorded in T_7 (90.17 per cent) which was at par with T_6 (86.60 per cent). Treatments T_1, T_2, T_3, T_4 and T_6 were at par. Treatment T_5 was significantly superior over all other treatments.

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged pods was recorded in T_5 (11.87 per cent) followed by T_3 (58.12 per cent) which was at par with T_2 (60.35 per cent). Maximum per cent of damaged pods was recorded in T_7 (88.75 per cent) which was at par with T_6 (85.83 per cent) .Treatments T_1, T_2, T_3 and T_4 were at par. Treatment T_5 was significantly superior over all other treatments.

Table 22.Mean per cent of pod borer infestation on pods during summer season from February 2019 to May 2019

Treatments	Percentage of infested pods *		
	1 DBSS	7 DASS	14 DASS
T_1	61.25 (51.91)	56.42 (48.90) [b]	66.96 (55.22) [b]
T_2	70.00 (54.67)	55.08 (48.09) [b]	60.35 (51.33) [b]
T_3	68.33 (59.54)	51.25 (45.85) [b]	58.12 (50.10) [b]
T_4	70.00 (60.72)	62.15 (52.27) [b]	67.22 (55.46) [b]
T_5	66.66 (55.09)	14.02 (21.86) [c]	11.87 (20.13) [c]
T_6	68.33 (59.54)	86.60 (74.15) [a]	85.83 (70.55) [a]
T_7	68.33 (59.54)	90.17 (76.67) [a]	88.75 (73.00) [a]
C.D. (0.05)	NS	10.84	10.70

* Mean of observations of sixteen plants.

Figures in parenthesis denotes arc sin transformed values.

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

DBSS- Day before second spray; DASS- Days after second spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

There was only negligible numbers of damaged pods found on seven and fourteen days after third spray. So it was not recorded.

4.2.16 Pooled analysis of mean per cent of pods infested by larvae of *Maruca vitrata* during both rabi and summer seasons

Mean per cent of pods infested by larvae of *Maruca vitrata* during both seasons presented in table 23. Minimum per cent of damaged pods was recorded inT_5 (12.97 per cent) after seven days of second spray followed by T_3 (68.65 per cent) which was at par with T_2 (69.18 per cent). Maximum per cent of damaged pods was recorded in T_7 (91.13 per cent) which was at par with T_6 (88.27 per cent) and T_4 (72.43 per cent). Treatments T_1, T_2, T_4, T_6 and T_7 were at par. Treatment T_5 was significantly superior over all other treatments.

Observations recorded after fourteenth days of second spray indicated that minimum per cent of damaged pods was recorded in T_5 (13.33 per cent) followed by T_3 (70.94 per cent) which was at par with T_2 (72.36 per cent). Maximum per cent of damaged pods was recorded in T_7 (89.24 per cent) which was at par with T_6 (86.73 per cent) and T_1 (77.34 per cent). Treatments T_1, T_4, T_6 and T_7 were at par. Treatment T_5 was significantly superior over all other treatments.

4.3 BIOMETRIC OBSERVATIONS

4.3.1 Length of pods measured from the yield obtained during rabi season from October 2018 to January 2019

The length of pods was taken from 12 pods per treatment and their average was calculated during rabi season from October 2018 to January 2019. The data obtained were analysed statistically and presented in the table 24.

During rabi season maximum pod length was observed in T_5 with an average value of 47.09 cm. Minimum length of 39.90 cm was observed in Control (T_7). While among the botanicals T_3 showed the maximum pod length of 45.12 cm.

Table 23.Pooled analysis of Mean per cent of pod borer infestation on pods during both rabi and summer seasons

	Percentage of infested pods *	
Treatments	7 DASS	14 DASS
T_1	70.71^{ab}	77.34^{ab}
T_2	69.18^{ab}	72.36^{b}
T_3	68.65^{b}	70.94^{b}
T_4	72.43^{ab}	77.15^{ab}
T_5	12.97^{c}	13.33^{c}
T_6	88.27^{ab}	86.73^{ab}
T_7	91.13^{a}	89.24^{a}
C.D. Treatment	21.77	16.09

* Mean of observations of sixteen plants.

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

DASS- Days after second spray; NS – Not Significant

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

T_1 and T_4 with pod length of 42.98 cm and 43.37 cm respectively was found on par with each other.

4.3.2 Length of pods measured from the yield obtained during summer season from February 2019 to May 2019

The length of pods was taken from 12 pods per treatment and their average was calculated during summer season from February 2019 to May 2019. The data obtained were analysed statistically and presented in the table 24.

Maximum pod length was observed in T_5 with an average value of 43.85 cm during summer season. Minimum length of 34.13 cm was observed in control (T_7). While among the botanicals T_3 showed the maximum pod length of 41.25 cm. T_1 and T_4 with pod length of 38.5 cm and 38.76 cm respectively was found on par with each other.

4.4 YIELD ATTRIBUTES OF VEGETABLE COWPEA 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

The fresh weight of pods were taken after each harvest and recorded. Seven harvests were made during rabi season from October 2018 to January 2019. Total yield was calculated by addition of the yield obtained from each harvest. Out of the total yield obtained, marketable yield was calculated. The data obtained was subjected to statistical analysis and presented in table 25.

From the fresh weight obtained during first harvest, T_5 recorded the highest yield (24.37 g per plant) followed by T_3 (21.18 g per plant). Minimum yield was recorded in T_7 (10.29 g per plant) which was on par with T_6 (11.37 g per plant). Among botanicals, maximum yield was obtained in T_3 (21.18 g per plant) followed by T_2 (18.49 g per plant), T_1 (16.81 g per plant) and T_4 (12.81 g per plant). During

Table 24. Mean length of twelve 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
T1	42.98	38.50
T2	44.56	40.12
T3	45.12	41.25
T4	43.37	38.76
T5	47.09	43.85
T6	40.96	35.56
T7	39.90	34.13
C.D. (0.05)	4.23	6.79

* Average of twelve observations

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

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the time of second harvest, T_5 recorded the highest yield (43.00 g per plant) followed by T_3 (39.31 g per plant). Minimum yield was recorded in T_7 (25.85 g per plant) which was on par with T_6 (26.75 g per plant). Among botanicals, maximum yield was obtained in T_3 (39.31 g per plant) followed by T_2 (34.98 g per plant). Treatment T_1 (30.32 g per plant) was statistically on par with T_4 (30.52 g per plant).

During the time of third harvest, T_5 recorded the highest yield (143.56 g per plant) followed by T_3 (104.85 g per plant). Minimum yield was recorded in T_7 (41.50 g per plant) followed by T_6 (54.33 g per plant).Among the botanicals, maximum yield was obtained in T_3 (104.85 g per plant) followed by T_2 (87.50 g per plan), T_4 (72.51 g per plant) and T_1 (63.47 g per plant).The fresh weight obtained during fourth harvest revealed that the maximum yield was recorded in T_5 (78.45 g per plant) followed by T_3 (73.88 g per plant). Minimum yield was recorded in T7 (55.07 g per plant) followed by T_6 (56.97 g per plant). Among the botanicals, maximum yield was obtained in T_3 (73.88 g per plant) followed by T_2 (70.00 g per plant). Treatment T_1 (58.75 g per plant) was statistically on par with T_4 (59.41 g per plant) and T_6.

From the fresh weight obtained during fifth harvest T_5, recorded the highest yield (115.98 g per plant) followed by T_3 (102.87 g per plant). Minimum yield was recorded in T_7 (39.68 g per plant) followed by T_6 (43.76 g per plant).Among botanicals, maximum yield was obtained in T_3 (102.87 g per plant) followed by T_2 (85.37 g per plant), T_4 (75.46 g per plant) and T_1 (73.02 g per plant). During the time of sixth harvest, T_5 recorded the highest yield (186.87 g per plant) followed by T_3 (166.18 g per plant). Minimum yield was recorded in T_7 74.68 g per plant) followed by T_6 (84.12 g per plant). Among the botanicals, maximum yield obtained in T_3 (166.18 g per plant) which was on par with T_2 (163.00 g per plant) followed by T_1 (151.48 g per plant) and T_4 (143.60 g per plant). The fresh weight obtained during seventh harvest revealed that the maximum yield recorded in T_5 (61.75 g per plant) followed by T_6 (63.28 g per plant). Minimum yield was recorded in T_7 (61.75 g per plant) which was on par with T_6 (63.28 g per plant).

Table 25. Effect of treatments on the yield attributes of vegetable cowpea during rabi season from October 2018 to January 2019

Treatments	Fresh weight of pods (g/plant) *							Total yield (g/plant)	Marketable yield (g/plant)	Reduction in yield (g/plant)
	First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest	Sixth harvest	Seventh harvest			
T1	16.81	30.32	63.47	58.75	73.02	151.48	106.57	500.45	453.33	47.12
T2	18.49	34.98	87.50	70.00	85.37	163.00	129.37	588.73	557.65	31.08
T3	21.18	39.31	104.85	73.88	102.87	166.18	143.75	652.04	630.45	21.59
T4	12.81	30.52	72.51	59.41	75.46	143.60	109.87	504.21	468.25	35.96
T5	24.37	43.00	143.56	78.45	115.98	186.87	166.12	758.38	737.74	20.64
T6	11.37	26.75	54.33	56.97	43.76	84.12	63.28	340.60	268.55	72.05
T7	10.29	25.85	41.50	55.07	39.68	74.68	61.75	308.84	234.50	74.34
C.D. (0.05)	1.07	1.58	5.05	1.82	2.11	4.63	1.92	13.65	10.70	

*Mean of observations of sixteen plants

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Absolute control

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From the total yield calculated, T_5 (758.38 g per plant) recorded the highest yield which followed by T_3 (652.04 g per plant). The lowest yield was obtained in T_7 (308.84 g per plant) which followed by T_6 (343.1 g per plant).

Maximum marketable yield was obtained in T_5 (737.74 g per plant) recorded the highest yield which followed by T_3 (630.45 g per plant). The lowest yield was obtained in T_7 (234.50 g per plant) which was followed by T_6 (268.55 g per plant). While T_1 and T_4 was on par with each other with 453.33 and 468.25 g per plant of marketable yield.

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

The fresh weight of pods were taken after each harvest and recorded. Four harvests were made during summer season from February 2019 to May 2019. Total yield was calculated by addition of the yield obtained from each harvest. Out of the total yield obtained, marketable yield was also calculated. The data obtained was subjected to statistical analysis and presented in table 26.

From the fresh weight obtained during first harvest, T_5 recorded the highest yield (86.90 g per plant) which was on par with T_3 (84.48 g per plant). Minimum yield was recorded in T_7 (55.93 g per plant) followed by T_4 (64.75 g per plant). Among the botanicals, maximum yield was obtained in T_3 (84.48 g per plant) followed by T_2 (77.78 g per plant) and T_1 (69.84 g per plant). During the time of second harvest, T_5 recorded the highest yield (146.56 g per plant) followed by T_3 (108.65 g per plant). Minimum yield was recorded in T_7 (69.40 g per plant) which was on par with T_6 (70.00 g per plant). Among the botanicals, maximum yield was obtained in T_3 (108.65 g per plant) followed by T_2 (101.15 g per plant).Treatment T_1 (96.84 g per plant) was statistically on par with T_4 (93.00 g per plant) and T_2.

During the time of third harvest, T_5 recorded the highest yield (123.12 g per plant) followed by T_3 (108.81 g per plant). Minimum yield was recorded in T_7 (82.96 g per plant) which was on par with T_6 (84.40 g per plant). Among the botanicals, maximum yield was obtained in T_3 (108.81 g per plant) which was on par with T_2 (108.00 g per plan), T_1 (101.93 g per plant) and T_4 (94.96 g per plant).The fresh weight obtained during fourth harvest revealed that the maximum yield was recorded in T_5 (132.43 g per plant) followed by T_3 (120.68 g per plant). Minimum yield was recorded in T_7 (84.81 g per plant) which was followed by T_6 (93.65 g per plant). Among the botanicals, maximum yield was obtained in T_3 (120.68 g per plant) followed by T_2 (114.15 g per plant) and T_4 (107.06 g per plant). Treatment T_1 (94.18 g per plant) was statistically on par with T_6.

From the total yield calculated, T_5 (466.84 g per plant) recorded the highest yield which followed by T_3 (394.45 g per plant). The lowest yield was obtained in T_7 (326.80 g per plant) which was followed by T_6 (333.67 g per plant).

Maximum marketable yield was obtained in T_5 (444.76 g per plant) which was followed by T_3 (371.57 g per plant). The lowest yield was obtained in T_7 (256.89 g per plant) which was on par with T_6 (263.78 g per plant). While T_1 and T_4 were on par with each other with 335.35 and 301.98 g per plant of marketable yield.

4.5 ECONOMIC ANALYSIS

The economics of different treatments on production of vegetable cowpea 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 treatment.

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

Economics of production of vegetable cowpea during rabi season was calculated and presented in Table 27.

The maximum net income was obtained in T_5 (Rs. 194164.60/ha) followed by T_3 (Rs.147691.40/ha) and T_2 (Rs.122626.60/ha). For every one rupee invested an amount of Rs.2.49 was obtained in standard check while only Rs.0.18 was

Table 26. Effect of treatments on the yield attributes of vegetable cowpea during summer season from February to May 2019

Treatments	Fresh weight of pods (g/plant) *				Total yield (g/plant)	Marketable yield (g/plant)	Reduction in yield (g/plant)
	First harvest	Second harvest	Third harvest	Fourth harvest			
T1	69.84	96.84	101.93	94.18	366.87	335.35	51.52
T2	77.78	101.15	108.00	114.15	382.18	357.44	34.74
T3	84.48	108.65	108.81	120.68	394.45	371.57	22.88
T4	64.75	93.00	94.96	107.06	343.46	301.98	41.48
T5	86.90	146.56	123.12	132.43	466.84	444.76	22.08
T6	65.15	70.00	84.40	93.65	333.67	263.78	69.89
T7	55.93	69.40	82.96	84.81	326.80	256.89	69.91
C.D. (0.05)	5.81	6.01	5.53	5.02	7.94	10.94	

*Mean of observations of sixteen plants

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Absolute control obtained in control. T_3 earned a return of Rs.2.14 giving the highest cost benefit ratio among the botanicals.

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

Economics of production of vegetable cowpea during summer season was calculated and presented in Table 28.During summer season also the net returns was recorded maximum in T_5 (Rs.65566.86/ha) with a B: C ratio of 1.50 followed by T_3 with a net return of Rs.34061.00/ha and B: C ratio of 1.26. Lowest B: C was observed in control with only 0.90 rupees for every one rupee expenditure.

Table 27. Economics of cultivation of vegetable cowpea during rabi season from October 2018 to January 2019

Treatments	Economics of vegetable cowpea					
	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
T1	124032.00	1500.00	125532.00	207758.70	82226.74	1.65
T2	124032.00	2500.00	126532.00	249158.60	122626.60	1.96
T3	124032.00	5000.00	129032.00	276723.40	147691.40	2.14
T4	124032.00	1800.00	125832.00	209918.30	84086.27	1.66
T5	124032.00	5619.65	129651.65	323816.20	194164.55	2.49
T6	124032.00	100.00	124132.00	117874.70	-6257.35	0.94
T7	124032.00	0.00	124032.00	102929.10	-21102.90	0.82

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check, T_6: Soap solution 0.5%; T_7: Control.

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Table 28. Economics of cultivation of vegetable cowpea during summer season from February to May 2019

Treatments	Economics of vegetable cowpea					
	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
T1	124032.00	1500.00	125532.00	184939.50	22979.97	1.18
T2	124032.00	2500.00	126532.00	221792.20	30359.14	1.23
T3	124032.00	5000.00	129032.00	246329.40	34061.22	1.26
T4	124032.00	1800.00	125832.00	186861.80	12861.10	1.10
T5	124032.00	5619.50	129651.50	288249.80	65566.86	1.50
T6	124032.00	100.00	124132.00	104927.90	-8351.04	0.93
T7	124032.00	0.00	124032.00	91623.84	-11275.30	0.90

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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check, T_6: Soap solution 0.5%; T_7: Control

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Discussion

5. DISCUSSION

The results obtained from the laboratory bioassay and field level experiment conducted on the topic "Evaluation of pongamia oil soap against major pests of vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" are discussed in this chapter. There is a scarcity of research on evaluation of pongamia oil soap on major pests of vegetable cowpea in literature for comparison. Hence the results obtained is compared with studies carried out with pongamia products on other pests.

5.1 LABORATORY BIOASSAY OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGETABLE COWPEA

Laboratory bioassay was carried out to study the efficacy of pongamia oil soap against aphids *Aphis craccivora* and leaf eating caterpillar *Spodoptera litura*.

5.1.1 Feeding deterrency of pongamia oil soap against leaf eating caterpillar *Spodoptera litura*

Among the different treatments pongamia oil 2 per cent showed the maximum antifeedent activity against final instar larvae of *Spodoptera litura* followed by pongamia oil 1 per cent, pongamia oil 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 Karanj oil followed by crude karanj 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 present in the oil. Mathur *et al.,* (1990) also stated that karanjin and pongamol were effective against several insect pests. Pramod (2014) reported that leaf area consumed by fourth instar larvae of *Spodoptera litura* recorded minimum in NSKE (46.12 per cent), followed by *Acacia arabica* (48.12 per cent), *Nicotiana tobacum* (56 per cent)and PSKE (Pongamia seed kernel extract) (57.20 per cent).

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Soap solution 0.5 per cent showed results similar to absolute control indicating that soap solution which is a 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 evaluation of growth retardation properties of pongamia oil soap against first instar larvae of *Spodoptera litura* showed that pongamia oil soap 2 per cent recorded the maximum growth retardation properties followed by pongamia oil soap 1 per cent, pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent. Growth retardation properties of pongamia oil soap 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 Karanj oil followed by crude karanj oil showed maximum antifeedant and growth reduction activity against *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 caused due to the pongamia oil only.

5.1.3 Mortality of aphids

Among the different concentrations of pongamia oil soap and 0.6 per cent neem oil soap applied, pongamia oil soap 2 per cent showed 100 per cent mortality of aphids after 2 hours followed by pongamia oil 1 per cent which took 4 hours. While pongamia oil soap 0.6 per cent and neem oil soap 0.6 per cent attained 100 per cent mortality of aphids after 12 hours. The results showed that the time required for the mortality of aphids can directly related to concentration of the pongamia oil in the treatments. Mortality of aphids might be due acute toxicity property of pongamia. The effectiveness of same was reported by Tran *et al.,* (2015) that pongam leaf extract showed acute toxicity to the turnip aphid with the LC50 value 0.585 per cent, 0.151 per cent and 0.113 per cent at 24, 48 and 72 h, respectively under laboratory conditions. He also noted that laboratory studies indicated with low concentrations of pongam leaf extract caused significant reduction in 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.

5.2 FIELD EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGETABLE COWPEA

The field experiment conducted with an aim to find the efficacy of pongamia oil soap against major pests of vegetable cowpea *viz.*, aphids, pod bugs and pod borers during rabi (October to January) and summer (February to May), during 2018-2019 in the instructional farm of College of Agriculture, Padannakkad.

5.2.1 Efficacy of pongamia oil soap against aphid *Aphis craccivora* during rabi season (October to January 2018-19) and summer season (February to May 2019)

From the results obtained, it is noticeable that all the treatments except soap solution 0.5 per cent was effective in reducing aphid population during both rabi and summer seasons from October 2018 to January 2019 and February 2019 to May 2019 respectively. 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. Similar findings were reported by Ranawat (2018) where he stated that karanj oil 1 per cent and neem oil 1 per cent showed significant reduction in cowpea aphid *Aphis craccivora* population over the control. Balikai (2001) also reported some findings related to this that *Pongamia pinnata* kernel 2 per cent and *Pongamia pinnata* leaves 5 per cent showed significant reduction in sorghum aphid *Melanaphis sacchari* over the control. This reduction might be due to insecticidal property of pongamia oil in the pongamia oil soap. Pongamia oil contains secondary metabolites which shows insecticidal activity (Pavela, 2007).

It was also seen that efficacy of pongamia oil soap increased with the increase in concentration of the oil and pongamia oil soap 2 per cent showed highest efficacy. The neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent showed statistically similar reduction in aphid population. Similar findings were reported by Akashe *et al.,* (2013), they stated that 83.6 per cent decline in aphid population was recorded with 1 per cent karanj oil treatment which was statistically at par with 1 per cent neem oil (81.03).

There was an increase in the population of aphids which was seen from 7 days to 14 days after application of treatment. Singh (2013) found similar results when pongamia oil 1 per cent was treated against the peach leaf curl aphid *Brachycaudus helichrysi*.

Aphid infestation on shoots also showed significant efficacy of treatments over the control after seven and fourteen days of first spray. There was only negligible infestation of aphids during reproductive stage of the crop during both seasons. So second and third sprays were avoided.

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

5.2.2 Efficacy of pongamia oil soap against pod bugs during rabi (October to January 2018-19) and summer (February to May 2019) season

The data obtained indicated that all the treatments except soap solution 0.5 per cent was effective against pod bugs compared to control during both rabi and summer seasons from October 2018 to January 2019 and February 2019 to May 2019 respectively. 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. Pooled analysis also gave similar results. Almost identical conclusions were reported by Sreenivasulu (2010) who stated that pongamia leaf extract 5 per cent, pongamia seed extract 5 per cent and neem oil 0.5 per cent exhibited significant efficacy against pod bug population over the control. This efficacy might be due to antifeedent and repellent properties. Pongamia oil contains secondary metabolites which serve as natural pest repellents (Pavela, 2007).

It was also observed the mean percentage of damaged pods after seven and fourteen days in all the treatments was significantly lower than the control during both seasons. But there was an increase in the mean percentage of damaged pods from seven to fourteen days after the application. This might be due to the increase in nymphs and adults population of pod bugs from seven to fourteen days. This statement is supported by the findings of Sreenivasulu (2010) who reported as increase of pod bug population from seven to fourteen days after the application.

From the data on population of nymphs and adults of pod bugs and mean percentage of damaged pods it also found that treatment having neem oil soap 0.6 per cent exhibited a significant effect over the control. The study of Meena (2007) is in line with this findings in which she reported that there was significant effect over the control shown by botanical insecticides like Amrutneem 5ml/l, Nimbecidine 2ml/l and Neem Azal 2ml/l.

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

5.2.3 Efficacy of pongamia oil soap against spotted pod borer *Maruca vitrata* during rabi (October to January 2018-19) and summer (February to May) season

From the mean percentage of damaged flowers and damaged pods recorded, it was clear that Spinosad 45 SC impart significant control on pod borer among all treatments. Pooled analysis of both seasons also exhibited similar results. During rabi season, all treatments having botanicals were not effective in controlling pod borers including pongamia oil soap 2 per cent with higher concentration of pongamia oil. This might be due to higher incidence of pod borer which was above ETL value (3 larvae/plant) and it caused very high damage. So comparing to other treatments, Spinosad 45 SC gave a better result.

The mean percentage of damaged flowers was low in treatment having Spinosad 45 SC compared to control after seven and fourteen days after second spray and seven days after third spray during rabi season. The effectiveness of the same was reported by Sreekanth *et al.* (2015) that the application of Spinosad resulted in minimum inflorescence damage (6.21 per cent) in pigeon pea compared to control (31.18 per cent). Damaged flowers were negligible after fourteen days after third spray.

The mean percentage of damaged pods was also low in treatment Spinosad 45 SC compared to control after seven and fourteen days of second spray and seven and fourteen days after third spray during rabi season. This observation was in conformity with Mishra *et al.* (2014) who mentioned that Spinosad 45SC resulted in 6.66 per cent of pod infestation compared to control having 27.02 per cent of pod damage when sprayed 40 days after sowing.

During summer season, the spotted pod borer *Maruca vitrata* infestation was low compared to rabi season. This was supported by Choragudi (2013) who reported that the number of larvae of pod borer *Maruca vitrata* per plant as 70.52 and 53.48 and percentage of pod damage as 89.60 and 55.05 during rabi and summer respectively. Summer season had a low population and after third spray there was only negligible population. So it was not recorded. This is in line with study of Choragudi (2013) who reported that by the end of April there was disappearance of pod borer *Maruca vitrata.*

The Spinosad 45 SC was significantly effective than all other treatments in summer season also. The mean percentage of damaged flowers was low in treatment having Spinosad 45 SC compared to control after seven and fourteen days after second spray. This statement in line with the observation made by Sreekanth and Seshamahalakshmi (2012) that Spinosad 45 SC effectively reduce the inflorescence damage in pigeon pea. The mean percentage of damaged pods was also low in treatment having Spinosad 45 SC compared to control after seven and fourteen days of second spray. Similar results were reported by Anitha and Parimala (2014) where the Spinosad treatment recorded the lowest pod damage with 5.1 per cent.

During summer season, the botanicals gave significant effect compared to control which might be due to low pod borer damage. Still Spinosad 45 SC remained as the best treatment and all botanicals were at par including pongamia oil soap 0.6 per cent, pongamia oil soap 1 per cent, pongamia oil soap 2 per cent and neem oil soap 0.6 per cent. Similar findings made by Vineetha (2018) who observed that Spinosad 45 SC exhibited higher efficiency over Azadirachtin 1 per cent and neem oil emulsion 5 per cent when treated against the spotted pod borer *Maruca vitarta* in cowpea.

Here also soap solution 0.5 per cent always showed results similar to control.

5.3 BIOMETRIC OBSERVATIONS

5.3.1 Length of pods during during rabi (October to January 2018-19) and summer (February to May) season

Maximum pod length was observed in Spinosad 45SC and minimum in control. Among the botanicals, maximum pod length was exhibited by pongamia oil soap 2 per cent during both the seasons. Both Spinosad 45SC and pongamia oil soap 2 per cent were significantly superior over the control. Pod length is a genetically determined character. Veyres *et al.* (2008) is in conformity with this who identified a gene named sweetie that encodes glycosyl transferase enzyme which helps in regulation of sugar flux thereby pod length.

5.4 YIELD ATTRIBUTES

5.4.1 Yield of vegetable cowpea during rabi (October to January 2018-19) and summer (February to May) season

During both the seasons, Spinosad 45SC exhibited highest yield among the different treatments. It might be due its efficiency in controlling the destructive pest pod borer. From the results, it could be discerned that Spinosad 45SC exhibited significant control of pod borers and superior to other treatments. Thus the treatment having Spinosad 45SC yielded better. Similar study reported by Anitha and Parimala (2014) that the Spinosad 45SC resulted the pigeon pea with least pod damage and higher yield of 1237 kg/ha.

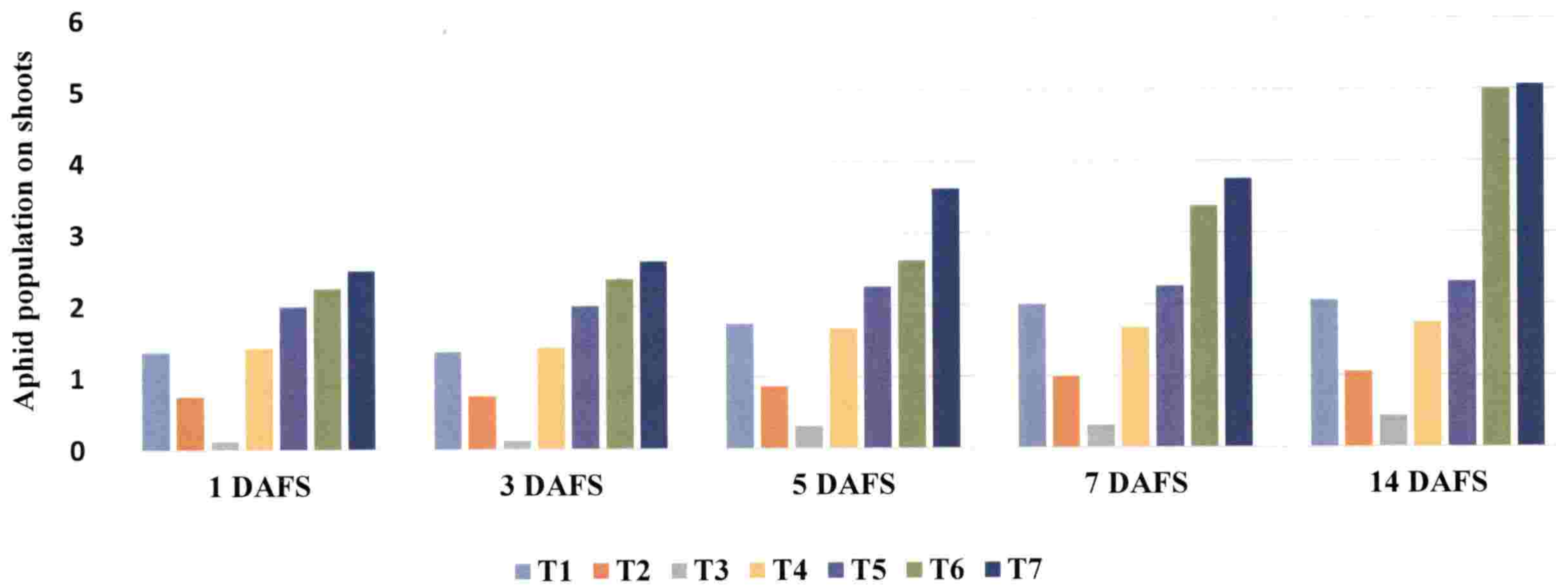
The lowest yield was found in control which had severe pest infestation. Among botanicals, pongamia oil soap 2 per cent recorded higher yield with lower pest infestation when compared to other treatments having botanicals.

5.5 ECONOMIC ATTRIBUTES

5.5.1 Economics of production of vegetable cowpea during rabi (October to January 2018-19) and summer (February to May 2019) season

The highest cost benefit ratio recorded in Spinosad 45SC followed by pongamia oil soap 2 per cent. For every one rupee invested, Spinosad 45SC had given return of 2.49 and 1.50 during rabi and summer season respectively while pongamia oil soap 2 per cent gave a return of 2.14 and 1.26. It was followed by pongamia oil soap 1 per cent which had given a return of 1.96 and 1.23 for every one rupee invested during rabi and summer season respectively. Even though Spinosad 45SC is costlier insecticide compared to other treatments, this had given a higher net income through its highest yield.

Fig. 2 Scoring of aphid colonies on shoots based on standard scale during rabi season from October 2018 to January 2019



DAFS- Days after first 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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

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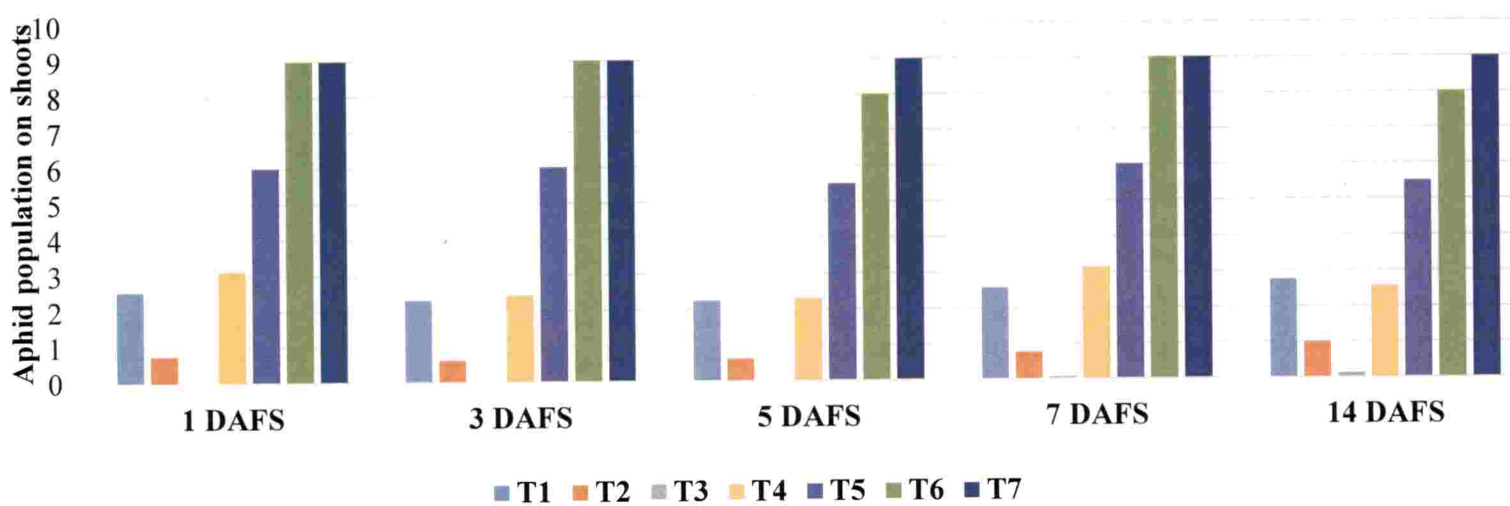
Fig. 3 Scoring of aphid colonies on shoots based on standard scale during rabi season from October 2018 to January 2019



DAFS- Days after first 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: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Control

Summary

6. SUMMARY

The research programme entitled "Evaluation of pongamia oil soap against major pests of vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt" was aimed at evaluating the efficacy of a new product made of pongamia oil - pongamia oil soap at different concentrations in managing the major pests of vegetable cowpea *viz.,* pod borers, pod bugs, leaf miner and aphids.

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 fifth instar and first instar larvae of leaf eating caterpillar *Spodoptera litura* respectively and mortality study against aphids *Aphis craccivora.* 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 using Randomised block design with seven treatments and four replications on vegetable cowpea variety 'Vellayani Jyothika' during rabi and summer seasons at the Instructional farm of 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: Spinosad 45 SC– Standard check; T_6: Soap solution 0.5%; 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). Damage symptoms caused 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 which was on par with pongamia oil soap 1 per cent against fifth instar

larvae of leaf eating caterpillar *Spodoptera litura* due to its antifeedent properties.

2. Growth retardation of first instar larvae of leaf eating caterpillar *Spodoptera litura* was exhibited maximum in pongamia oil soap 2 per cent which was on par with pongamia oil soap 1 per cent due to its antifeedent activity.

3. Complete mortality of aphids was observed within 2 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 both rabi and summer seasons, pongamia oil soap 2 per cent was effective in controlling the aphid *Aphis craccivora* population due to its insecticidal properties.

6. Pongamia oil soap 2 per cent exhibited highest efficacy in controlling pod bug population during both rabi and summer seasons till seven days followed by Pongamia oil soap 1 per cent due its repellent and antifeedent properties. Reduction in damage per cent is due to its repellent properties which remained effective for seven days.

7. Pongamia oil soap 2 per cent was not much effective in reducing the damage caused by spotted pod borer *Maruca vitrata* when compared to the standard check Spinosad 45SC.

8. There was no significant difference between the mean length of pods during both rabi and summer seasons since pod length is a genetically determined character.

9. 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.

10. Economics of pongamia oil soap 2 per cent in terms of cost benefit ratio was also high as compared to control in both the rabi and summer seasons.

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Abstract

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EVALUATION OF PONGAMIA OIL SOAP AGAINST MAJOR PESTS OF VEGTABLE COWPEA, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.

by

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ABSTRACT

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ABSTRACT

The study entitled 'Evaluation of pongamia oil soap against major pests of vegtable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt' 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 vegetable cowpea, *viz.,* pod borers, pod bugs, leaf miner and aphids.

Laboratory bioassay of pongamia oil soap was carried out in the Department of Agricultural Entomology, College of Agriculture, Padannakkad, during 2018-2019 to evaluate the feeding deterrency and growth retardation properties of pongamia oil soap against fifth instar and first instar larvae of leaf eating caterpillar, *Spodoptera litura* respectively. 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 soap 2 per cent showed the maximum antifeedent activity which was statistically on par with pongamia oil soap 1 per cent against fifth instar larva of *Spodoptera litura*. Pongamia oil soap 2 per cent exhibited maximum growth retardation activity which was statistically on par with pongamia oil soap 1 per cent against first instar larvae of *S. litura*. Spraying of pongamia oil soap 2 per cent showed 100 per cent mortality of aphids *Aphis craccivora* two hours after the treatment. Pongamia oil soap 1 per cent caused 100 per cent mortality four hours after treatment while neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent resulted in 100 per cent mortality only twelve hours after treatment.

Field study was carried out using randomised block design (RBD) with seven treatments and four replications on vegetable cowpea variety 'Vellayani Jyothika' during rabi and summer seasons at the Instructional farm, 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

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0.6%; T_5: Spinosad 45 SC @ 0.5 ml/L of water –Standard check; T_6: Soap solution 0.5%; T_7: Absolute 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 were observed one day prior to and 7 and 14 DAT.

After first spray during rabi and summer seasons, pongamia oil soap 2 per cent was significantly superior among all the treatments in reducing the aphid *Aphis craccivora* population. The same trend was observed in the case of mean percentage of shoots infested by aphid population. Against pod bugs, pongamia oil soap 2 per cent showed maximum efficacy compared to other treatments after second and third spray during rabi and summer seasons up to seven days and was significantly superior over the control. Damaged pods recorded on seven days after the spray also exhibited similar results. The mean percentage of damaged flowers and pods due to spotted pod borer *Maruca vitrata* were significantly low in Spinosad 45SC as compared to other treatments including pongamia oil soap 2 per cent. However all the treatments were effective in reducing the sucking pests except soap solution 0.5 per cent. The soap solution 0.5 per cent always was on par with control indicating that soap has no role in the effect of pongamia oil soap. Since the leaf miner attack was negligible in the field during both rabi and summer seasons, it was not recorded.

Pongamia oil soap 2 per cent exhibited increased total 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 terms 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.