BOTANICALS FOR THE MANAGEMENT OF PESTS OF BRINJAL, *Solanum melongena* L.

by

DEEKSHITH D

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"BOTANICALS FOR THE MANAGEMENT OF PESTS OF BRINJAL, *Solanum melongena* L."** 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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CERTIFICATE

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ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
ANOVA	Analysis of Variance
CNSL	Cashew nut shell liquid
cm	Centi meter
CD	Critical Difference
ºC	Degree Celsius
DAP	Days after planting
DAT	Days after treatment
EC	Emulsifiable Concentrate
FYM	Farm yard manure
g	Gram
ha	hectare
IPM	Integrated pest management
kg	Kilogram
mg	Milligram
mL	Millilitre
viz.,	Namely
ha^{-1}	Per hectare
L^{-1}	Per Litre
SC	Soluble Concentrate
WG	Wettable granules

INTRODUCTION

1. INTRODUCTION

Brinjal, *Solanum melongena* L. (order Polemoniales ; family Solanaceae), is one of the important vegetable crops in many parts of the world including India. It is an important commercial vegetable crop grown throughout the year for its fruits, commonly known as garden egg. Brinjal is considered as the King of vegetables and common man's vegetable in India due to its versatile use, high productivity (25 metric tonnes ha^{-1}) and consumer preference (Choudhary and Gaur, 2009). Brinjal occupies an area of 1.72 million ha with 43.17 million tonnes production in the world and in India it covers an area of 6.12 lakh ha with an annual production of 12.78 million tonnes (FAOSTAT, 2018).

The major constraint in brinjal production is the high incidence of insect and the mite pests. Brinjal is infested by more than 36 insect pests from the nursery stage to harvest (Reghupathy *et al*., 1997).

Among these brinjal pests, brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen.; epilachna beetle, *Henosepilachna vigintioctopunctata* (F.); aphid, *Aphis gossypii* Glover; whitefly, *Bemisia tabaci* (Genn.); leafhopper, *Amarasca devastans* (Dist.); lace wing bug, *Urentius hystricellus* (Richt.); mealy bugs, *Coccidohystrix insolita* (Green) cause severe damage affecting quality and yield of the crop necessitating control measures at frequent intervals (Vevai, 1970).

Epilachna beetle is the most important leaf feeding pest infesting brinjal. It mainly feeds on the chlorophyll content scraped from the epidermal tissue of the leaves and cause considerable leaf damage of up to 80 per cent (Rajagopal and Trivedi, 1989) leading to economic damage amounting up to 60 per cent (Mall *et al.*, 1992). *C. insolita* and various other mealybugs seen clustering in leaves and shoots of brinjal like a thick mat with waxy secretions. They suck the sap mainly from the leaves and tender shoots resulting in reduced plant vigour. They also attack flower blooms and fruits resulting in fruit drop.

Farmers often resort to application of chemical pesticides in large quantity to mitigate the heavy crop loss by these pests. Farmers take four to six sprays of synthetic insecticides in managing the pests. In spite of giving repeated insecticide sprays in a crop the pests are not effectively managed due to build-up of pesticide resistance and resurgence (Kabir *et al*., 1994). Though chemical insecticides at a time manage the pests efficiently, indiscriminate use results in many insecticide related complications such as toxicity to non-target organisms like beneficial insects, fishes, human health hazards, pest resurgence, secondary pest outbreak and environmental pollution (Mamun *et al.,* 2009).

To overcome these problems, it has now become imperative to reduce the application of chemical insecticides. Among alternative management strategies, use of botanicals is very promising. Plants being stationary employ chemical warfare to counter herbivory. Plants have evolutionarily gained ability to ward off pests by producing certain metabolites that are of no primary use. Many plant derived materials such as neem seed kernel extract, neem oil and pongam oil containing insect toxic secondary metabolites are widely used for combating pest infestations (Gahukar, 2000; Mote and Bhavikatti, 2003; Singh and Kumar, 2003). Some of these plant products such as pyrethrum, azadirachtin, nicotine, ryania and rotenone are developed as commercial botanical pesticides (Martina and Kristina, 2013; Iqbal *et al*., 2015).

Cashew plant (*Anacardium occidentale* L.) produce a phenolic secondary metabolite anacardic acid to counter herbivory which it stores in large quantities in the honeycomb structure in the pericarp of its nuts. During processing of cashew nuts this viscous liquid is expelled out and is available in plenty as technical cashew nut shell liquid (CNSL) at cheaper rate. CNSL contains cardol (8 - 11 %), 2 methyl cardol (2 %) (Ikeda *et al.*, 2002) and cardanol (83 - 84 %), which is a thermal decarboxylated product of anacardic acid (Rodrigues *et al.,* 2006).

CNSL is reported to have multivariate uses in automotive industries for friction powder formulations, waterproofing, electrical insulations etc. It also exhibits molluscicidal, anti-tumourous, anti-microbial activities as well as inhibitory activity towards prostaglandin synthase and lipoxy-genase (Shobha and Ravindranath, 1991). It is reported to have insecticidal potential against chewing pests, *Leucopholis coneophora* Burm. (John, 2008), *Helicoverpa armigera* (Hübner) and *Spilarctia obliqua* (Walker) (Mahapatro, 2011).

CNSL is also found toxic to sucking pests like *Aphis craccivora* Koch (Olotuah and Ofuya, 2010) and *A. gossypii* (Sundaran and Faizal, 2018).

A formulation of CNSL in an emulsifiable concentrate formulation (CNSL 20 % EC) has been developed in the Department of Entomology, College of Agriculture, Vellayani and found effective to manage sucking pests of cowpea @ 0.3 %, without any adverse effect on the plant (Lekha, 2020). The present project was undertaken to check its efficacy against pests of brinjal with the following objectives.

- Laboratory evaluation of CNSL 20 % EC against *H. vigintioctopunctata.*
- Laboratory evaluation of CNSL 20 % EC against mealybugs.
- Phytotoxicity evaluation of CNSL 20 % EC on brinjal.
- Laboratory evaluation of botanicals against test insect *H. vigintioctopunctata.*
- Pot culture experiment to find out the effective botanical against brinjal pests.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Brinjal, commonly known as the eggplant is a small bushy plant popular in many parts of the world. It is cultivated in India for the last 40 centuries mainly for its fruits which are used for the culinary purposes (Sundareswari and Sudarmani, 2019).

Despite being a potentially high yielding crop, there are several production constraints that reduce the yield. The damage by insect pests which cause 70 to 92 per cent yield loss (Rosaiah, 2001) is one of the major threats for its production (Kaur *et al*., 2014).

Reghupathy *et al*. (1997) reported that more than 36 insect pests infesting brinjal crop from the nursery stage to harvest stage. The eggplant production is affected severely by these insect pests and mites (Srinivasan, 2009). Brinjal shoot and fruit borer and sucking pests like leafhopper and whitefly are major pests in north India and cause yield loss up to 50 per cent (Naik *et al.*, 2009).

2.1 CHEWING PESTS OF BRINJAL

The brinjal is infested by variety of chewing insects *viz.*, brinjal fruit and shoot borer (*Leucinodes orbonalis* Guen.), epilachna beetle (*Henosepilachna vigintioctopunctata* (F.)), stem borer (*Euzophera perticella* Rag.), brinjal leaf folder (*Antoba olevaceae* (Wlk.)) (Vevai, 1970), flea beetle (*Monolepta signata* Olivier.), hairy caterpillar (*Selepa docilis* Butter) (Borkakati *et al.,* 2019) and some of the minor pests including golden twin spot tomato looper (*Chrysodeixis chalcites* (Esper)), brinjal leaf webber (*Herpetogramma bipunctalis* (F.)), ash weevil (*Myllocerus subfasciatus* Guerin -Meneville), tussock caterpillar (*Olene mendosa* Hübner), darth maul moth (*Olepa ricini* F.), flower chafer beetle (*Oxycetonia versicolor* (F.)), Tobacco splitworm (*Phthorimaea operculella* (Zeller)) and transverse moth (*Xanthodes transversa* Guenée) (NBAIR, 2020).

Other than these pests, plume moth (Ramakrishna, 1940), grasshopper (Vevai, 1970) and termite (Peswani and Katiyar, 1972) are also reported to infest the brinjal plants. Among these pests epilachna beetle is the second most important pest causing 60 per cent yield loss (Mall *et al.,* 1992) next to fruit and shoot borer which cause 70 to 92 per cent yield loss (Rosaiah, 2001).

2.1.1 Epilachna beetles in brinjal

The genus *Epilachna* has nearly 500 species and it attacks mainly the vegetable crops belongs to the family Solanaceae, Cucurbitaceae and also some medicinal crops (Mathur and Srivastava, 1964; Azam *et al*., 1974). Brinjal being a solanaceous plant is attacked by epilachna beetles *viz.*, *Epilachna dodecastigma*, *E. vigintioctopunctata*, *E. ocellate* and *Henosepilachna sparsa* (Rajagopal and Trivedi, 1989).

H. vigintioctopunctata is the one which is widely distributed in South East Asia, Sri Lanka, Australia, East Indies, Malaya, China and India (Kapur, 1950) also Siberia and America (Mandal, 1971) among different species. It is one of the most important one that attacks brinjal (Butani and Verma, 1976; Kalra, 1997; Shankar *et al.*, 2010). The population of the beetle reaches maximum in the months of March to May when the temperature is high and relative humidity and rainfall are low (Ashwathy, 2015).

Both adults and grubs act as damaging stages. Adult insects cause damage by scraping the tissues in the epidermal layer in semi-circular fashion leaving the veins and nervures intact. Grubs cause damage to the leaf surface by scraping the softer tissues that is easy to ingest. The skeletonized leaves show a lace like appearance which later dry and drop down from the plants affecting photosynthetic efficiency and thereby the yield in brinjal (Ghosh and Senapati, 2001). The infestation can be seen even in the calyx of the fruit in severe cases. There is also reduction in biochemical constituents such as the chlorophyll content, proteins, carbohydrates, phenols, carotenoids, anthocyanins of the infected brinjal leaves (Sundareswari and Sudarmani, 2019).

2.2 SUCKING PESTS IN BRINJAL

Various sucking pests like mealy bug, *Coccidohysteryx insolitus* (Guen.); whitefly, *Bemisia tabaci* (Genn.); leafhopper, *Amarasca devastans* (Distant); aphid, *Aphis gossypii* (Glover.); lace wing bug, *Urentius hystricellus* (Richt.) attacks brinjal (Vevai, 1970). Apart from these, *Aleurodicus dispersus* (Rus.), *Lipaphis erysimi* Kalt., *Aspidoitus destructor* Sign., *Aonidiella auranti* (Maskell), *Thrips palmi* Karny and Ants are also reported in brinjal crop (Mishra and Tripathi, 2017).

Sucking pests cause 10 to 15 per cent loss to the crop depending on their infestation levels (Munde *et al*., 2011). Indirectly, they also involved in the transmission of vector borne viruses resulting in diseases development. Sucking nature of these insects interferes with the normal growth of the plant and fruit quality. Honeydew production by these homopteran insect groups favours the sooty mould growth and reduces the active photosynthetic area of the leaves resulting in poor fruit quality in terms of weight, size and number **(**Jones, 2005; Konar *et al.,* 2011**)**.

2.2.1 Mealybugs

Mealybugs are one of the important sucking pests that affects the brinjal crop. Different species of mealybugs *viz., C. insolita*, *Pseudococcus* sp. and *Ferrisia virgata* (Cockerell) are reported from brinjal (Lit *et al.,* 1998). The number of mealybugs species infesting the crops increased due to the changing environment in recent days (Janaki *et al*., 2012).

Phenacoccus solenopsis Tinsley one of the highly polyphagous mealybug that infests more than 52 plant families (Arif *et al.*, 2009) now reported to be a pest of brinjal and cause damage to the leaves, fruits, branches and roots (Nabil *et al.*, 2015).

Planococcus citri (Risso) (citrus mealybug) which affects 54 host plants belonging to different families including Solanaceae (Strickland, 1951) also reported from brinjal (Ben-Dov, 1994). Ahmed and Hasan (2009) reported the attack of this mealybug on the mature and immature fruits of eggplant. Sakthivel *et al.* (2012) reported the high infestation level of *Paracoccus marginatus* (Williams and Granara de Willink) commonly known as papaya mealybug on brinjal.

Along with these mealybugs *Maconellicoccus hirsutus* (Green), *Paracoccus solani* Ezzat and McConnel, *Peliococcus trsipinosus* (James), *Phenococcus madeirrensis* Green, *Phenococcus parvus* Morrision, *Phenococcus solani* Ferris, *Planococcus lilacinus* (Cockrell), *Planococcus minor* (Maskell), *Pseudococcus longsipinus* (Targioni Tozzetti) were also reported in brinjal (Mani and Shivaraju 2016).

The occurrence of brinjal mealybugs *C. insolita* reaches its peak during March and May absent for the rest of the time (Suresh and Kavitha, 2008). The population tends to decrease as the morning RH and the rainfall increases. It is polyphagous pest and attacks more than twenty-one families (Moore *et al.,* 2014).

C. insolita infests the lower surface of the leaves resulting in yellowing of the leaves and it also results in the malformation of the apical plant portion (Vijay and Suresh, 2013). It attacks the flowers and fruits resulting in the shrivelling and dropping of the fruit. It is also an emerging pest in case of pegion pea (Sharma *et al.,* 2016). It is known to produce deterrent chemical cues through dorsal rim ducts and ventral oral collar ducts to avoid predation by natural enemies (Kitherian *et al.,* 2018).

2.3 MANAGEMENT OF BRINJAL PESTS

There are ongoing efforts to combine the IPM components such as cultural, mechanical, pheromone and chemical to manage the major pests of brinjal (Maleque *et al*., 1998; Sasikala *et al*., 1999; Islam *et al*., 1999).

Increase in the fruit yield and improvement is reported by utilizing IPM components such as balanced fertilizer use (Patnaik *et al*., 1998), field sanitation by removing the crop debris and refuges (Sasikala *et al*., 1999), mechanical methods such as collection and destruction of damaged parts (Rahman *et al*., 2002; Alam *et al*., 2003; FAO, 2003) by reducing the fruit and shoot borer incidence.

The following two treatments found effective in controlling the pests of brinjal *viz*., *A. biguttula biguttula*, *L. orbonalis*, *E. dodecastigma*, *H. vigintioctopunctata* and *U. hystricellus* in terms of treatment cost, effectiveness and also subsequent residue levels; **(a)** Applicaton of eight insecticide sprays such that 1^{st}, 2^{nd}, 4^{th}, 6^{th} and 8^{th} spray with carbaryl 0.15 % and 3^{rd}, 5^{th} and 7^{th} spray with malathion 0.05 % at fortnightly intervals from 15 days after transplanting and **(b)** Phorate granules application at 1 kg toxicant ha^{-1} and 6 insecticide sprays such that sprays 1, 3 and 5 being 0.05 % malathion and 2, 4 and 6 being 0.15 % carbaryl at fortnightly intervals starting from 6 weeks after transplanting (Sohi *et al.,* 1974). Various test doses of thiamethoxam (Actara 25 % WG) was evaluated against the pests of brinjal in field condition and found that foliar spray was effective against jassids, *A.*

bigutulla bigutulla and epilachna beetle, *H. vigintioctopunctata* at 50 g a.i ha^{-1} and soil drenching was effective at 50 and 100 g a.i ha^{-1} against jassids and epilachna beetle respectively (Patnaik *et al.*, 2004). Two foliar sprays of either bifenthrin (50g a.i ha^{-1}) or chlorpyriphos + cypermethrin (1000 mL ha^{-1}) for leafhopper and whitefly management in brinjal and two sprays of either cartap hydrochloride (500 g a.i. ha^{-1}) or endosulfan (700 g a.i. ha^{-1}) or carbosulfan (750 mL ha^{-1}) in minimizing borer infestation and thereby reported the possibility of these chemicals in IPM of brinjal by Sinha and Sharma (2010).

Baskaran and Kumar (1980) tested the sublethal doses of insecticides *viz.*, carbaryl 0.04 %, dichlorovos 0.05 %, endosulfan 0.01 % and quinalphos 0.2 % in combination with microbial pesticide dipel (*Bacillus thuringiensis* var *alesti*) against the pests of brinjal and concluded that carbaryl and dipel combination is better against a large number of brinjal pests. The results also revealed that the amount of insecticide combined with the bacterium is sufficient to effectively manage the pests compared to recommended dosages. Cow urine and vermiwash at 50 % concentration found effective against the sucking pests and also the shoot and fruit borer in brinjal among different concentrations of vermiwash 10, 20, 30, 40 and 50 % along with cow urine which gives higher yield and benefit cost ratio (Karkar *et al.*, 2014).

2.3.1 Management of Chewing pests

Zadda (2007) reported that the organic source of nutrients such as FYM + biofertilizers + neem cake and its integration with the 3 % neem oil spray effective in reducing the hadda beetle and ash weevil damage in brinjal. IPM strategy for managing *H. vigintioctopunctata* includes intercropping (crop association), soil application of granular insecticides and need based spray of chlorpyriphos 20 EC at 1000 mL ha^{-1} was documented by Prasad *et al*. (2008). Mean mortality of 63.33 per cent of epilachna beetle due to *Beauveria bassiana* infection was observed by Jiji *et al.* (2008). The Bt formulation @ 1 ml L^{-1}was found to be highly effective for early instar larvae of *A. olivacea* (Gowrish, 2014). Flubendiamide 24 WG @ 0.012 % found effective against brinjal fruit and shoot borer as it exhibited the highest toxicity both in laboratory as well as field conditions among different insecticides tested (Latif *et al.*, 2010).

Spinosad 45 SC @ 162.5 mL ha^{-1} was found effective against the brinjal fruit and shoot borer and also safe to the natural enemies when evaluated along with six chemical insecticides *viz.*, emamectin benzoate 5 WSG, cypermethrin 10 EC, quinalphos 25 EC, endosulfan 35 EC, Lambda cyhalothrin 5 EC, Chlorpyrifos 20 EC and found ineffective against sucking pests and hadda beetle (Khan *et al.,* 2014). Mulching and entomopathogenic nematode application @ 2.5kg ha^{-1} before planting and at every 30 days interval upto 150 DAP which recorded zero incidence of *M. subfasciatus* up to 30 DAP and 2.50 to 7.50 per cent damage up to 150 DAP can be adopted in management of this pest (Shanmugam *et al.,* 2018).

Gowrish (2014) reported that azadirachtin 1 % was found to be most effective in controlling *H. vigintioctopunctata* adults and grubs. Reduction in the mean per cent of leaf infestation was also found during both summer and kharif season. It was also found effective to manage *S. docilis*. *Serratia marcescens* caused 93.27 per cent mortality of epilachna grubs at 5 DAT which was found to be on par with Chlorantraniliprole 18.5 SC @ 0.006 % (Ashwathy, 2015).

2.3.2 Management of Sucking pests

Arya (2015) found that the new generation insecticides *viz.,* spiromesifen 96 g ai ha^{-1} and thiamethoxam 50 g ai ha^{-1} can be used for the management of leaf hopper and whitefly in brinjal as alternative to conventional insecticides which are more toxic. Lekha *et al.* (2018) found that dinotefuran (20 % SG) @ 30 g a.i ha^{-1} was most effective in controlling the sucking pests of brinjal. Sticky traps of different colours such as green, yellow, white, red, orange and blue were tried against the sucking pests *viz.*, aphid (*A. gossypii*), jassid (*A. biguttula biguttula*), thrips (*T. tabaci*) and whitefly (*B. tabaci*) in cotton, maize, cabbage, cauliflower and brinjal and concluded that green sticky traps attracted highest number of aphid, jassids, thrips and whitefly adults in brinjal crop (Murtaza *et al.*,2019).

Beauveria bassiana (10 gL^{-1}), *Pseudomonas fluorescens* (10 gL^{-1}), Spinosad (45 SC @ 1 mL L^{-1}) and Fish Oil Rosin Soap (FORS) (@ 25 mL L^{-1}) tested in field for its bio-efficacy against the papaya mealybug *P. marginatus* in brinjal and found that *P. fluorescens* resulted in higher yield and lowest mean population of mealybug (Janaki *et al.*, 2012). Biopesticide formulation (BPF) prepared by mixing nine botanicals (*Phyllanthus emblica* L., *Curcuma zedooria* Rosc., *Lycopersicon esculentum* Mill., *Azadirechta indica* A. Juss., *Calotropis procera* (Aiton.), *Allium sativum* L., *Allium cepa* L., *Occimum canum* Sims. and *Ferula narthexboiss* Boiss.), natural mineral salts (Potassium aluminum sulphate dodecahydrate) and one animal product (fresh cow dung in cow urine) give successful results when used against the mealybugs in brinjal at 5 % without phytotoxicity (Patel *et al.*, 2014).

2.3.3 Ill-effects of Chemical control

Vegetables and fruits consume 13 per cent of the pesticides in the country (Nigam and Murthy, 2000). The farmers rely upon chemicals for pest management that they apply insecticides more than 23 times in a season. They use various formulations of chemicals belonging to different groups for managing the pests (Rashid *et al*., 2008).

Anwar *et al*. (2015) opinioned that the insecticide application is the most common method to control the pests. Though the chemical control is suggested by many of the researchers against the brinjal pests it could not become the universal remedy due to many reasons.

Synthetic insecticides were used effectively to ward off the insect pests. The basic elements of life *viz.*, food, water and air are contaminated by these synthetic chemicals. Aphid, mite and whitefly resurgence is reported in brinjal due to excessive application of synthetic pyrethroids for the management of shoot and fruit borer (Reddy and Srinivas, 2005).

The use of synthetic insecticides results in the depletion of the soil microbial diversity, deposition of toxic residues and resistance among the pests and diseases (Gupta *et al*., 1997). Almost 98 per cent of the sprayed chemicals do not reach the target and they contribute to the environmental pollution and ecological imbalance by affecting the natural enemy population (Sarwar and Sattar, 2012; Hina *et al*., 2015). Pesticide residue deposition on fruits became common in case of brinjal as the fruits are harvested in short time interval. Thus, there is an intense scope for research on development of botanical insecticides.

2.3.4 Botanicals for pest management

Using of botanicals in its crude form or after processing into different formulations will serve the purpose of controlling the pests in a biological way (Isaacs *et al*., 2004).

More than 2000 plant species have known to produce the metabolites and chemical factors that are useful in pest management. They were cheaper and hazard free in comparison to chemical insecticide (Saxena *et al*., 1992). Salvatore *et al*. (2004) and Shrivastava *et al*. (2010) reported the insecticidal activity of these secondary metabolites against Coleoptera and Diptera. The compounds such as alkaloids, steroids, non-proteic amino acids, phenols, flavonoids, glycosides, glucosinolates, tannins, terpenoids, quinones, salanine, piretrolone, meliantrol, azadiractin, cinerolone and jasmolone present are responsible for the insecticidal properties. They act as contact poisons, stomach poisons, feeding deterrents.

Lipophilic monoterpenoids present in the eucalyptus can penetrate into insect's cuticle, interfere with the physiological function resulting in death of the insect (Isman, 2000). Certain pesticides from neem act as hormone disruptors. Products of neem and lantana control aphids as effectively as chemical insecticides (Shreth *et al*., 2009).

2.3.4.1 Neem

The extracts of neem are effective against 400 species of insect pests including the resistant pests like *B. tabaci*, *Plutella xylostella* (L.), and *Amblyomma cajennense* F. that are resistant to conventional insecticides. It acts both as a contact and systemic poison and also exhibits antifeedant, repellent, oviposition deterrent, growth inhibiting and chemo-sterilant effects. It is environmentally safe and low cost pest management is possible by integrating it with IPM programmes (Hillocks l995, Gahukar, 2000). Two sprays of 1 % neem oil is effective against aphids, leafhoppers and whiteflies in brinjal (Sarangdevot *et al*. 2006). Naik *et al*. (2009) showed that azadirachtin in combination with other chemicals give better control of sucking pests and shoot and fruit borer in brinjal.

2.3.4.2 Pongamia

Pongam oil also possess insecticidal, repellent and ovipositional properties (Parmar and Gulati 1969). Plenty of furano-flavonoid compounds such as karanjin, pongamol, pongapin, glabrin, karanjachromene, karanjone and pongaglabrone present in the seed oil contributes to the pesticidal properties of pongamia. Seed extracts of pongamia is reported to have antifeedant effect on *Tribolium castaneum* Herbstand, *Spodoptera litura* F., *Diacrisia obliqua* Walker., *Scelodonata strigicollis* Mots. and *Trialeurodes vaporariorum* (Westwood)

(Pavela, 2009). Gahukar (2015) reported its effectiveness against the *Zeuzera indica* Helf. (Cossidae) on Som and Saolu and *Myzus persicae* (Sulzer) in green houses.

Pongam oil can be used against *P. xylostella* in combination with garden thyme *Thymus vulgaris* L. and its synergistic effect can be utilized by mixing it with other botanicals such as neem or with lower dosages of other synthetic insecticides (Vastrad *et al*., 2002). It is also effective in reducing the number of whiteflies on chrysanthemum plants (Pavela and Herda, 2007). Its effects are reported in adults of *Oligonychus indicus* (Hirst.) and *Tetranychus macfarlanei* Baker & Pritchard (Dodia *et al.,* 2010). Pongam oil based commercial insecticide PONNEEM also shows insecticidal activity against *H. armigera* and *S. litura* (Packiam and Ignacimuthu, 2012; Packiam *et al*., 2014).

2.3.4.3 Cashew nut shell liquid

Cashew nut shell liquid is a greenish yellow viscous liquid present in the soft honeycomb structure in the pericarp of cashew nut. It is made up of mixture of phenolic compounds such as cardol, cardanol, anacardic acid and other polymeric materials in various proportions. The proportion of these constituents varies depending on the method of extraction of CNSL and can be categorized into natural CNSL and technical CNSL based on the method of extraction. This by-product of cashew industry represents approximately 25 per cent of the weight of the nut (Mazzetto *et al*., 2009).

Natural CNSL is the one which is obtained from the cold extraction method using the solvents or by mechanical extraction and it contains anacardic acid (60 - 65 %), cardol (10 - 15 %), Cardanol (10 %) and other polymeric materials in trace amounts. The anacardic acid undergoes decarboxylation and forms cardol and cardanol in technical CNSL, which is a hot extracted one and hence contains 83 to 84 % of cardanol, 8 to11 % cardol, 10 % polymeric materials and 2 % methyl alcohol (Ikeda *et al*, 2002).

CNSL is having the insecticidal, fungicidal, anti-termite, and medicinal uses (Lubi and Thachil, 2000). It also affects the growth and development of insects and can be utilized as an antifeedant, repellent and attractants in pest management (Isman, 2006; Ozkan *et al*., 2014; Martínez *et al*., 2015).

CNSL is reported to have other uses such as brake and clutch linings, floor coverings, manufacture of different types of paints, weather resistant surface coatings, anti-corrosive paint formulations for ship bottoms, electropainting compositions, varnish manufacture, preparation of lacquers for decorative purposes, lubricant production and also used as a hypergolic rocket fuel (Lubi and Thachil, 2000).

Natural CNSL controls the termites feeding on wood and tunneling into the soil as it is toxic to the termites (Lepage and De Lelis, 1980). Asogwa *et al.* (2007) reported that 1 % CNSL can bring about 53 per cent mortality in termites. At 6, 8 and 10 % it gives 100 per cent mortality of both soldier (at 90th min.) and worker castes of termites (at 60th min.). Oladejo *et al*. (2016) found that the number of termites and the mean number of furrows on the CNSL treated billets were significantly different from that of the control. They concluded that CNSL has pesticidal effects against termite attack and treatment containing CNSL 40 % is having the highest effect on *Triplochiton scleroxylon* Obeche. wood.

Olotuah and Ofuya (2010) suggested the use of 1 % CNSL as substitute for the synthetic insecticides in control of field insect pests of cowpea. Mahapatro (2011) reported that hydrogenated CNSL @ 1 % was more active and exhibited 75 per cent mortality of *H. armigera* till pupation. The insecticidal activity is mild but exhibited more cumulative toxicity. Twenty per cent larval mortality of *Spilarctia obliqua* (Walker) was recorded till pupation upon treating with 1 % hydrogenated CNSL.

The potential of CNSL in coconut root grub *Leucopholis coneophora* Burm. control is reported by John (2008). Raja (2008) reported the reduction in the egg laying of bruchids on black gram seeds treated with 4 mL kg^{-1}. Raja *et al*. (2015) concluded from his work that seed treatment of green gram and red gram seeds with CNSL at 4 mL kg^{-1} reduced the pulse beetle infestation in seeds by reducing the number of eggs $seed^{-1}$, number of insects kg^{-1} and also the percent damage without affecting the germination and vigour of the seeds.

Sundaran and Faizal (2018) reported the toxicity of CNSL against *A. gossypii* at much lower concentrations of 0.075 to 0.2 % and the increase in mortality with the increasing CNSL concentrations. They concluded that CNSL 0.2 % is effective as that of the chemical check thiamethoxam 0.03 %. CNSL 0.2 %, CNSL 0.075 % and the combination treatment of CNSL 0.2 % + *Lecanicilium lecanii* @ 10^7 spores mL^{-1} can be used for sucking pest management in chilli (Sundaran, 2018). Andayanie *et al.* (2019) reported that phenolic compound present in CNSL especially anacardic acid exhibits antifeedant activity and these compounds acts as a feeding barrier against the whiteflies, *B. tabaci* and brings death due to starvation. They proved that CNSL at lower concentration of 0.75 % inhibits the landing and staying of whiteflies more strongly than the chemical imidacloprid at 0.50%. Percentage of oviposition activities were also found less in all the CNSL treatments compared to imidacloprid which shows that it can be developed as an effective botanical against whiteflies.

Lekha (2020) concluded that the LC_{50} and LC_{90} values of CNSL against sucking pests of cowpea was 0.1 and 0.3 respectively and that against *S. litura* was 0.36 and 2.97 respectively. Two formulations in an emulsifiable concentrate form EC-1 (CNSL 20 % EC) and EC-2 (Combination of CNSL and pongam oil in the ratio 20: 20) was also developed.

CNSL at higher concentrations of 200 mg mL^{-1} and 100mg mL^{-1} affect the germination of lettuce and tomato seeds respectively and it also had effect on vigour of coffee senna. Both aerial and root parts of lettuce and tomato were affected by CNSL (Matias *et al.*, 2017). Growth retardation of chilly plants at higher concentrations of CNSL (0.2 %) was reported by Sundaran (2018). Lekha *et al*. (2019) reported the safety of CNSL formulation upto 0.6 % in cowpea.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Botanicals for the management of pests of brinjal *Solanum melongena* L." was carried out at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2018-2020. An emulsifiable concentrate formulation of cashew nut shell liquid (CNSL 20 % EC), developed in the Department of Agricultural Entomology, College of Agriculture, Vellayani was tested for its efficacy against major pests of brinjal under laboratory conditions. The effective doses of CNSL, fixed based on the bioassay were evaluated both under laboratory and field conditions for their efficacy in managing pests of brinjal, along with commonly used botanicals and their combinations.

3.1 SCREENING OF CNSL 20 % EC AGAINST TEST INSECTS

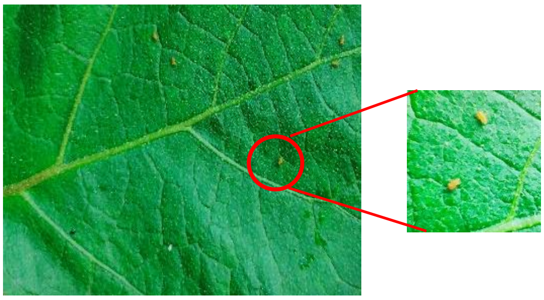
Emulsions of CNSL derived out of the formulation (CNSL 20 % EC) at various concentrations were evaluated against test insects epilachna beetle and mealybugs under laboratory conditions.

3.1.1 Maintenance of test insects

3.1.1.1 Henosepilachna vigintioctopunctata

The field collected epilachna beetles were reared on detached fresh brinjal leaves in a plastic container covered with muslin cloth. Adults obtained from the maintained culture were released @ 10 per jar and regularly observed for egg laying. The eggs laid on the leaves or on the walls of the containers were carefully collected daily and kept separately on petri plates moistened with wet tissue paper. The grubs upon hatching, were transferred carefully using fine camel hair brush to tender leaves kept in polypet jars and reared by providing fresh leaves. The third instar grubs obtained from eggs of the same age were utilized for the experiment. Different life stages of *H. vigintioctopunctata* is shown in plate 1.

(a) Eggs



(b) Newly hatched grubs

(c) Developing grubs

(d) Late instar grubs

(e) Pupal stage

(f) Adult stage

Plate 1. Life stages of *Henosepilachna vigintioctopunctata* (F.)

3.1.1.2 Planococcus citri

The mealybugs were collected from the field and mass multiplied on a pumpkin in laboratory conditions. Healthy, medium sized, well ripened pumpkin having prominent ridges was selected for the mealybug multiplication. The pumpkins as well as the plastic tubs and trays used for the mass multiplication were sterilized using 70 % ethanol. The sterilized pumpkins inoculated with gravid mealybugs were placed on the plastic tubs kept inside plastic trays containing water to protect it from ants (Plate 2). The whole set up was kept in dark as the multiplication rate is high under dark conditions.

3.1.2 Preparation of cashew nut shell liquid 20 % EC

Table 1. Composition of cashew nut shell liquid 20 % EC

Ingredients		Percent
Active ingredient	Cashew nut shell liquid	20
Emulsifier	Sodium oleate : Span-20 (91:9)	12
Solvent	Isopropyl alcohol	53
Water	Sterile distilled water	10
Co-solvent	Cyclohexanone	5

The CNSL derived out of drum roasting method of processing was purchased from the Mahatma Cashew Exports, Kollam, Kerala. 200 mL of CNSL was dissolved in 580 mL of solvent comprising of iso-propyl alcohol and cyclohexanol in the ratio of 94.83 : 5.17 under constant stirring for 30 minutes in a mechanical shaker (Plate 3).

109.2 g of sodium oleate was dissolved separately in 100 mL of sterile distilled water in a water bath at 50 ºC. To this 10.8 mL of span-20 was added and the mixture was thoroughly stirred in a mechanical shaker for about 30 minutes. The emulsifier blend thus

(a) Pumpkin fruits tied with ropes through ridges for easy handling

(b) Inocculation with leaves containing mealybugs

(c) Fruit with mealybug population build up

(d) Mealybugs collected for the experiment

Plate 2. Laboratory rearing of mealybug *Planococcus citri* (Risso) in pumpkin fruits

(a) Emulsifiers
(Sodium oleate + Span-20)

(b) Emulsifiers blending

(c) Final blending
(Solvents + active ingredient + emulsifiers)

(d) CNSL 20 % EC formulation

Plate 3. Preparation of Cashew Nut Shell Liquid 20% EC formulation

prepared was added to the CNSL solvent mixture under constant stirring in a mechanical shaker for 30 minutes to yield 1 litre of the formulation.

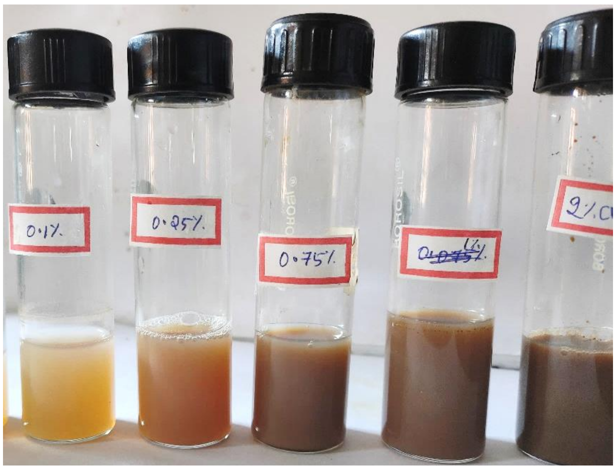
3.1.3 Evaluation of CNSL against test insects

3.1.3.1 H. vigintioctopunctata

The different concentration of CNSL *viz.*, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % were prepared by mixing 0.5, 1.25, 2.5, 3.75, 5, 10, 15, 20 and 25 mL of CNSL 20 % EC with 100 mL of water respectively (Plate 4). The bio-efficacy evaluation was conducted using third instar grubs derived from the stock culture (5 numbers per replication) in completely randomized block design with 11 treatments and 3 replications as detailed below.

T_1: CNSL 0.1 %
T_2: CNSL 0.25 %
T_3: CNSL 0.50 %
T_4: CNSL 0.75 %
T_5: CNSL 1 %
T_6: CNSL 2 %
T_7: CNSL 3 %
T_8: CNSL 4 %
T_9: CNSL 5 %
T_{10}: Emamectin benzoate 5 % SG 10g a.i ha^{-1}
T_{11}: Untreated

The treatments were applied uniformly to brinjal leaf harbouring five number of grubs taken in petri plates using the potter's precision spray tower @ 2 mL per replication and were subsequently transferred to kept in polyvinyl containers covered with muslin cloth. Leaves harbouring grubs treated with water served as untreated check. Fresh leaves were provided every alternate day. Mortality of the insects were observed at 1, 2, 3 ,5 and 7 days after treatment. The data was subjected to probit analysis (using **SPSS 16.0** version).



(a) Emulsions of CNSL 20 % EC

(b) Epilachna grubs treated with CNSL 20 % EC

(c) Dead grub exhibiting dark brown discolouration

Plate 4. Bioassay of CNSL 20 % EC on *Henosepilachna vigintioctopunctata* (F.)

3.1.3.2 P. citri

The different concentrations of CNSL *viz.*, 0.05, 0.075, 0.1, 0.25, 0.75, 1 and 2 % were prepared by mixing 0.25, 0.375, 0.5, 1.25, 3.75, 5 and 10 mL of CNSL 20 % EC with 100 mL of water respectively. The bio-efficacy evaluation was conducted using later instar nymphs (Plate 5) derived from the stock culture (5 numbers per replication) in completely randomized block design with 9 treatments and 3 replications as detailed below.

T_1: CNSL 0.05 %
T_2: CNSL 0.075 %
T_3: CNSL 0.1 %
T_4: CNSL 0.25 %
T_5: CNSL 0.75 %
T_6: CNSL 1 %
T_7: CNSL 2 %
T_8: Thiamethoxam 25 % WG 50 g a.i ha^{-1}
T_9: Untreated

The treatments were applied and the data was recorded similar to ***3.1.3.1.***

3.2 PHYTOTOXICITY EVALUATION OF CNSL TO BRINJAL

The phytotoxicity effects of CNSL on brinjal at various doses *viz.*, 0.05, 0.075, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % were tested.

Brinjal plants were raised at College of Agriculture, Vellayani in 1 x 0.5 m^2 plots. Two plants were transplanted in the plot with 60 cm spacing. The crop was maintained according to package of practices recommendations of KAU (KAU, 2016). CNSL at respective concentrations were applied on the plants at 60 DAP using a hand sprayer up to the point of run off. Control plants were sprayed with water. The treated plants were observed visually for symptoms of toxicity such as yellowing, necrosis, scorching, epinasty and hyponasty and rated according to the protocol of Central Insecticides Board and Registration committee (CIBRC) as detailed below.

(a) Emulsions of CNSL 20 % EC (Lower concentrations)

(b) Mealybugs treated with CNSL 20 % EC

Plate 5. Bioassay of CNSL 20 % EC on *Planococcus citri* (Risso)

Rating	Phytotoxic symptoms (%)
0	No symptom
1	01 - 10
2	11 - 20
3	21 - 30
4	31 - 40
5	41 - 50
6	51 - 60
7	61 - 70
8	71 - 80
9	81 - 90
10	91 - 100

3.3 SCREENING OF BOTANICALS AGAINST *H. VIGINTIOCTOPUNCTATA*

3.3.1 Preparation of botanicals

3.3.1.1 Soap solution

Six grams of ordinary bar soap was sliced into small pieces and dissolved in 100 mL of luke warm water and was used for the preparation of one litre of neem and pongam oil emulsions

3.3.1.2 Neem oil emulsion (2 %)

One litre of neem oil emulsion was prepared by adding 20 mL of neem oil to 100 mL soap solution prepared as in *3.3.1.1* and made upto 1000 mL under constant agitation (Sundaran, 2018).

3.3.1.3 Pongam oil emulsion (1 %)

One litre of pongam oil emulsion was prepared by adding 10 mL of pongam oil to 100 mL soap solution prepared as in *3.3.1.1* and made upto 1000 mL under constant agitation (Sundaran, 2018).

3.3.2 Evaluation of botanicals

Botanicals were evaluated using *H. vigintioctopunctata* as test insect in completely randomized block design with 8 treatments and 3 replications (10 number of grubs per replication) as detailed below.

T_1: CNSL 0.25 % (LC_{50})
T_2: CNSL 0.5 % ($2LC_{50}$)
T_3: CNSL 1 %
T_4: CNSL 2 %
T_5: Neem oil emulsion 2 %
T_6: Pongam oil emulsion 1 %
T_7: Emamectin benzoate 0.04 %
T_8: Untreated

The treatments were applied as detailed in **3.1.3** and mortality of the insects were recorded at 1, 2, 3, 5 and 7 DAT.

3.4 MANAGEMENT OF MAJOR PESTS OF BRINJAL USING BOTANICALS

A pot culture experiment was conducted to evaluate the efficacy of the selected botanicals from **3.3.2** against the pests of brinjal. The experiment was laid out in completely randomized design (CRD) with 9 treatments and 3 replications. Three plants constitute a replication (Plate 7).

Brinjal seedlings (Vellayani local) were purchased from the Kerala Agricultural University, instructional Farm, Vellayani and raised in growbags (35 x 20 x 20 cm) filled with potting mixture prepared with sand : soil : farm yard manure in the ratio of 1 : 2 : 1. The crop was raised according to the KAU package of practices (KAU, 2016). Black polythene mulch was spread on the ground upon which the growbags were placed. The plants were not sprayed with any of the chemical pesticides. The treatments selected for the pot culture experiment included

T_1: CNSL 0.25 % (LC_{50})
T_2: CNSL 0.5 % ($2LC_{50}$)
T_3: CNSL 1 %
T_4: CNSL 0.25 % + neem oil 1 %
T_5: CNSL 0.5 % + neem oil 1 %
T_6: CNSL 1 % + neem oil 1 %
T_7: Emamectin benzoate 5 % SG 10 g a.i. ha^{-1}
T_8: Thiomethoxam 25 % WG 50 g a.i. ha^{-1}
T_9: Untreated

The first round of treatments was applied 30 days after planting (DAP) in the vegetative stage of the crop. Pre-treatment population of pests were recorded before treatment application. Each treatment was applied to three plants using a hand sprayer ensuring both abaxial and adaxial surface coverage and replicated thrice. Water sprayed plants served as control. The post treatment population of pests was observed on 1, 2, 3, 5 and 7 days after treatment.

One leaf each was selected from top, middle and bottom randomly to assess the pest population. The count of pests was taken from both surface of the leaves using a hand lens and expressed as numbers per leaf. Second round of treatment was applied in the reproductive stage of the crop at 60 DAP and the observations were recorded. Phytotoxicity effect of different treatments were also evaluated as detailed in 3.2.

3.4.1 Growth parameters of brinjal treated with different botanicals

The following biometric observations were also recorded in a pot culture experiment at 1, 7 and 14 DAT to understand the possible effects of treatments on plant growth.

3.4.1.1 Plant height

The plant height was measured using the measuring scale and the mean was expressed in centimeters. Observations were recorded.

3.4.1.2 Internode length

The mean length of the internode was recorded in centimeters.

3.4.1.3 Number of leaves

The total number of leaves were counted and expressed as number of leaves plant^{-1}.

3.4.1.4 Number of fruits

The number of fruits in a plant were recorded.

3.4.1.5 Yeild

The weight of the fruits was also recorded.

3.5 STATISTICAL ANALYSIS

Data of each experiment were analysed with the help of suitable analytical methods. Data on per cent mortality and mean population of pests in field were analysed by one-way analysis of variance (ANOVA) (Panse and Sukhatme, 1967) after arc sine and square root transformations, respectively using WASP 2.0 software (Web Assisted Statistical Package). Probit analysis was performed using the SPSS 16.0 version (Statistical Package for the Social Sciences).

RESULTS

4. RESULTS

4.1 SCREENING OF CNSL AGAINST TEST INSECT

The different concentration of CNSL 20 % EC were evaluated against *Henosepilachna vigintioctopunctata* (F.) and *Planococcus citri* (Risso) under laboratory conditions and the percentage mortality of the treated insects at 1, 2, 3 ,5 and 7 days after treatment (DAT) were recorded.

4.1.1 *H. vigintioctopunctata*

The grubs of *H. vigintioctopunctata* which were pale green in colour before treatment changed to dark brown colour and dried up after death upon treatment with different concentrations of CNSL (plate 4c). Cumulative percentage mortality of *H. vigintioctopunctata* treated with different concentration of CNSL *viz.*, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % at 1, 2, 3 ,5 and 7 DAT are presented in table 2.

At 1 DAT, the treatments did not differ statistically and produced mortality ranging from 0 to 6.67 per cent.

At 2 DAT, CNSL 5 %, CNSL 4 %, CNSL 3 %, CNSL 2 %, CNSL 1 %, and CNSL 0.75 % recorded 80, 73.33, 53.33, 60, 66.67 and 53.33 per cent mortality respectively of *H. vigintioctopunctata* and were superior to all other treatments and found to be on par with each other. CNSL 0.5 % with 40 per cent mortality was found to be the next best treatment and which was on par with CNSL 0.75 %, CNSL 1 %, CNSL 2 % and CNSL 3 % with mortality percentage 53.33, 66.67, 60 and 53.33 respectively. CNSL 0.25 % caused 26.67 per cent mortality and found to be par with chemical check emamectin benzoate 5 % SG @ 0.04 % (33.33 % mortality). CNSL 0.1 % caused the least mortality of 20 per cent and was inferior to all other treatments except untreated check. There was no mortality observed in the untreated check.

Treatments with CNSL 5 %, CNSL 4 %, CNSL 3 %, CNSL 2 % and CNSL 1 % caused mortality ranging from 66.67 to 80 per cent and were found to be superior to rest of

Table 2. Percentage mortality of *Henosepilachna vigintioctopunctata* (F.) treated with different CNSL concentrations

Treatments	Percentage Mortality*				
	1DAT**	2DAT	3DAT	5DAT	7DAT
CNSL 0.1 %	6.67 (9.05)	20.00 (26.57) d	26.67 (30.79) e	26.67 (30.79) e	26.67 (30.79) e
CNSL 0.25 %	6.67 (9.05)	26.67 (30.79) cd	33.33 (35.01) de	46.67 (43.08) de	53.33 (46.92) de
CNSL 0.5 %	6.67 (9.05)	40.00 (38.86) bcd	46.67 (43.08) cd	53.33 (46.92) de	60.00 (51.15) d
CNSL 0.75 %	6.67 (9.05)	53.33 (46.92) abc	60.00 (51.15) bc	66.67 (55.37) cd	73.33 (59.21) cd
CNSL 1 %	6.67 (9.05)	66.67 (54.99) ab	73.33 (59.21) ab	73.33 (59.21) bcd	80.00 (63.44) bcd
CNSL 2 %	0 (0.29)	60.00 (50.77) ab	73.33 (59.21) ab	73.33 (59.21) bcd	73.33 (59.21) cd
CNSL 3 %	6.67 (9.05)	53.33 (46.92) abc	66.67 (54.99) ab	73.33 (59.21) bcd	86.67 (72.19)abc
CNSL 4 %	6.67 (9.05)	73.33 (59.21) a	80.00 (63.44) a	86.67 (72.19) abc	86.67 (72.19) abc
CNSL 5 %	20.00 (26.57)	80.00 (63.44) a	80.00 (63.44) a	86.67 (76.73) ab	93.33 (80.95) ab
Emamectin benzoate 5 % SG @ 0.04 %	26.67 (25.87)	33.33 (30.1) cd	66.67 (54.99) ab	100.00 (89.71) a	100.00 (89.71) a
Control	0 (0.29)	0 (0.29) e	0 (0.29) f	6.67 (9.05) f	6.67 (9.05) f
CD (0.05)	NS	(16.899)	(11.551)	(19.535)	(18.211)

***Mean of three replications comprising 5 grubs each**

(Values in the parentheses are angular transformed values)

****Days After Treatment**

the treatments and on par with that of chemical check emamectin benzoate 5 % SG @ 0.04 % (66.67 % mortality) at 3 DAT. CNSL 0.75 % with 60 per cent mortality was found to be the next best treatment which was on par with CNSL concentrations 1, 2, 3 as well as chemical emamectin benzoate 5 % SG @ 0.04 %. CNSL 0.5 % and CNSL 0.25 % caused the mortality of 46.67 per cent and 33.33 per cent respectively. The lowest mortality (26.67 %) was observed in treatment with CNSL 0.1 %. There was no mortality in the control at 3 DAT also.

At 5 DAT, 100 per cent mortality was recorded in treatment with emamectin benzoate 5 % SG @ 0.04 % which was on par with CNSL 4 % and 5 % with 86.67 per cent mortality. CNSL 1 %, 2 % and 3 % treatments with 73.33 per cent mortality was the next best treatments and were on par with CNSL 4 % and CNSL 5 %. CNSL 0.75 %, CNSL 0.5 % and CNSL 0.25 % were on par with each other with mortality of 66.67, 53.33 and 46.67 per cent respectively. CNSL 0.1 % recorded the least mortality of 26.67 per cent at 5 DAT next to control (6.67 %).

Chemical check, emamectin benzoate 5 % SG @ 0.04 % with 100 per cent mortality found superior to other treatments at 7 DAT and was on par with CNSL 5 % (93.33 %), CNSL 4 % (86.67 %) and CNSL 3 % (86.67 %). CNSL 1 % with 80 per cent mortality found to be the next best treatment and was on par with CNSL 3 %, 4 % and 5 %. CNSL 0.75 % (73.33) was on par with CNSL 1 %, 2 %, 3 % and 4 %. CNSL 0.1 %, 0.25 % and 0.5 % with mortality ranging from 26.67 per cent to 60 per cent were found superior to control though inferior to other treatments.

4.1.2 Mealybugs

Cumulative percentage mortality of *P. citri* treated with different concentration of CNSL *viz.*, 0.05, 0.075, 0.1, 0.25, 0.75, 1 and 2 % at 1, 2, 3 ,5 and 7 DAT are presented in the table 3.

Table 3. Percentage mortality of *Planococcus citri* (Risso) treated with different CNSL concentrations

Treatments	**Percentage Mortality***				
	1DAT**	2DAT	3DAT	5DAT	7DAT
CNSL 0.05 %	0 (0.29)	0 (0.29) ^{b}	0 (0.29) ^{c}	13.33 (17.81) ^{c}	20 (26.57) ^{bc}
CNSL 0.075 %	0 (0.29)	0 (0.29) ^{b}	6.67 (9.05) ^{bc}	26.67 (30.79) ^{c}	40.00 (38.86) ^{b}
CNSL 0.1 %	0 (0.29)	0 (0.29) ^{b}	6.67 (9.05) ^{bc}	13.33 (17.81) ^{c}	20.00 (22.03) ^{bc}
CNSL 0.25 %	6.67 (9.05)	6.67 (9.05) ^{b}	6.67 (9.05) ^{bc}	20.00 (26.57) ^{c}	40.00 (38.86) ^{b}
CNSL 0.75 %	6.67 (9.05)	13.33 (13.27) ^{b}	20.00 (22.03) ^{bc}	26.67 (30.79) ^{c}	33.33 (35.01) ^{b}
CNSL 1 %	0 (0.29)	0 (0.29) ^{b}	20.00 (22.03) ^{bc}	60.00 (51.15) ^{b}	80.00 (67.97) ^{a}
CNSL 2 %	6.67 (9.05)	0 (0.29) ^{b}	26.67 (30.79) ^{b}	66.67 (54.99) ^{b}	86.67 (72.19) ^{a}
Thiomethoxam 25% WG @ 0.015 %	0 (0.29)	40.00 (38.86) ^{a}	66.67 (54.99) ^{a}	100.00 (89.71) ^{a}	100.00 (89.71) ^{a}
Control	0 (0.29)	0 (0.29) ^{b}	0 (0.29) ^{c}	0 (0.29) ^{d}	6.67 (9.05) ^{c}
CD (0.05)	NS	(16.985)	(22.778)	(15.840)	(22.846)

***Mean of three replications comprising 5 mealybugs each**

(Values in the parentheses are angular transformed values)

****Days After Treatment**

The different treatments did not differ significantly at 1 DAT causing mortality ranging from 0 to 6.67 per cent.

Chemical check thiamethoxam 25 % WG (@ 0.015 %) with 40 per cent mortality was found statistically superior to all other treatments at 2 DAT. Various CNSL treatments and the control did not differ statistically in causing mortality.

At 3 DAT also thiamethoxam 25 % WG @ 0.015 % recorded the highest per cent mortality (66.67) and was found to be the best treatment. All CNSL treatments except CNSL 0.05 % with mortality ranging from 6.67 per cent to 26.67 per cent produced the effect superior to control though inferior to chemical check thiamethoxam. CNSL 0.05 % recorded no mortality as that of the control and found not effective after 3days.

Cent per cent mortality was recorded in the treatment with thiamethoxam 25 % WG @ 0.015 % and was found superior to other treatments at 5 DAT. This was followed by CNSL 2 % and CNSL 1 % with 66.67 and 60 per cent mortality respectively and were the next best treatments. CNSL 0.75 % (26.67 %), CNSL 0.075 % (26.67 %), CNSL 0.25 % (20 %), CNSL 0.1 % (13.33 %) and CNSL 0.05 % (13.33 %) were found on par with one another and found superior to control. No mortality was observed in control at 5 DAT also.

Thiamethoxam 25 % WG, CNSL 2 % and CNSL 1 % with mortality percent of 100, 86.67 and 80 respectively found to be superior at 7 DAT. All the remaining CNSL treatments with mortality per cent ranging from 20 to 40 were found to be on par with each other and superior to control. Least mortality of 6.67 per cent was noticed in control which was on par with CNSL 0.05 % and CNSL 0.1 % at 7 DAT.

4.1.3 Probit analysis

Probit analysis was performed to obtain dose mortality response for *H. viginitioctopuntata* and *P. citri* to CNSL and the results of which are presented in table 4 and 5.

4.1.3.1 H. vigintioctopunctata

Lethal concentrations (LC_{50} and LC_{90}) were calculated for 2, 3, 5 and 7day intervals. Since the mortality percentage was low (0 - 26.67 %) at 1 DAT, no upper and lower bound values were obtained.

At 2 DAT, LC_{50} value was 0.85 % with 0.58 and 1.21 % lower and upper bound respectively and the LC_{90} value was 24.54 % with lower and upper bound values 11.35 and 93.93 % respectively.

At 3 DAT, LC_{50} value estimated was 0.49 % with lower and upper bound values of 0.31 and 0.70 % respectively. The LC_{90} value was 13.56 % with lower and upper bound values 7.14 and 39.35 respectively.

LC_{50} value at 5 DAT was 0.352 % with 0.174 and 0.553 upper and lower bound values respectively and LC_{90} value was found to be 8.09 % with 4.09 and 29.37 lower and upper bound values.

At 7 DAT, LC_{50} value was 0.268 % (0.146 and 0.402 upper and lower bound values respectively) and LC_{90} was 4.35 % (2.65 and 9.78 % upper and lower bound respectively).

4.1.3.2 P. citri

Lethal concentrations (LC_{50} and LC_{90}) were calculated for 2, 3, 5 and 7day intervals. Since the mortality percentage was low (0 - 40 %) at 1 and 2 DAT, no upper and lower bound values were obtained.

At 3 DAT, LC_{50} value estimated was 10.33 % with lower and upper bound values of 2.48 and 18070 % respectively. The LC_{90} value was 376.7 % with lower and upper bound values 22.41 and 3.5×10^9 respectively.

LC_{50} value at 5 DAT was 1.08 % with 0.59 and 3.42 upper and lower bound values respectively and LC_{90} value was found to be 32.54 % with 7.58 and 1169 lower and upper bound values.

Table 4. Dose mortality response of *Henosepilachna vigintioctopunctata* (F.) to CNSL through probit analysis

Days	**LC_{50}**			**LC_{90}**			**Chi square value**
	Estimate	Lower bound	Upper bound	Estimate	Lower bound	Upper bound	
1	2.59×10^{7}	-	-	8.76×10^{12}	-	-	396.175
2	0.856	0.58	1.21	24.54	11.35	93.93	161.135
3	0.49	0.32	0.70	13.56	7.14	39.35	149.437
5	0.352	0.174	0.553	8.09	4.09	29.37	258.693
7	0.268	0.146	0.402	4.35	2.65	9.78	210.182

Table 5. Dose mortality response of *Planococcus citri* (Risso) to CNSL through probit analysis

Days	**LC_{50}**			**LC_{90}**			**Chi square value**
	Estimate	Lower bound	Upper bound	Estimate	Lower bound	Upper bound	
1	4.6×10^{6}	-	-	5.15×10^{8}	-	-	309.861
2	1.7×10^{8}	-	-	2.34×10^{11}	-	-	550.587
3	10.33	2.48	18070	376.7	22.41	3.5×10^{9}	297.723
5	1.08	0.59	3.42	32.54	7.58	1169	222.004
7	0.370	0.190	0.849	7.64	2.29	211.46	371.212

At 7 DAT, LC_{50} value was 0.370 % (0.190 and 0.849 upper and lower bound values respectively) and LC_{90} was 7.64 % (2.29 and 211.46 upper and lower bound respectively).

4.2 PHYTOTOXICITY EVALUATION OF CNSL TO BRINJAL

Various concentration of CNSL *viz.,* 0.05, 0.075, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % were applied to brinjal plants and the phytotoxicity symptoms *viz.,* yellowing, scorching, necrosis, epinasty and hyponasty were observed (Table 6). The symptoms of phytotoxicity are shown in plate 6.

. The lower concentrations of CNSL *viz.,* 0.05 %, 0.075 %, 0.1 %, 0.25 %, 0.5 %, 0.75 % did not show any yellowing, necrosis, scorching, epinasty or hyponasty (score 0).

Plants treated with CNSL 1 % exhibited necrosis of score 1 (0 - 10 %). There was no yellowing, scorching, epinasty and hyponasty as their rating was 0.

Yellowing up to 10 % (score 1) and necrosis up to 20 % (score 2) was seen in plants treated with CNSL @ 2 % (Plate 6d).

Yellowing (score 1) and necrosis (score 4) were noticed in plants treated with CNSL 3 % which exhibited 0 - 10 % yellowing and 31 - 40 % necrosis (Plate 6c) respectively. There was no scorching, epinasty or hyponasty with rate 0.

Yellowing and necrosis were rated as 1 and 7 respectively in treatment with CNSL 4 % exhibiting 0 - 10 % yellowing and 61 - 70 % necrosis.

The maximum ratings for yellowing (2), necrosis (8) and scorching (1) among the different CNSL concentrations were noticed in CNSL 5 % revealing 11 - 20 % yellowing, 71 - 80 % of necrosis (Plate 6a) and up to 10 % scorching in the treated plants. There was a subsequent leaf fall in CNSL 5 % treated plants (Plate 6b).

The scores for epinasty and hyponasty in all the cases remains 0 showing no epinasty and hyponasty in all the cases.

Table 6. Phytotoxicity scoring of different CNSL concentrations on brinjal

CNSL Concentration	Yellowing	Necrosis	Scorching	Epinasty	Hyponasty
CNSL 0.05 %	0	0	0	0	0
CNSL 0.075 %	0	0	0	0	0
CNSL 0.1 %	0	0	0	0	0
CNSL 0.25 %	0	0	0	0	0
CNSL 0.5 %	0	0	0	0	0
CNSL 0.75 %	0	0	0	0	0
CNSL 1 %	0	**1**	0	0	0
CNSL 2 %	**1**	**2**	0	0	0
CNSL 3 %	**1**	**4**	0	0	0
CNSL 4 %	**1**	**7**	0	0	0
CNSL 5 %	**2**	**8**	**1**	0	0

CNSL – cashew nut shell liquid

Table 7. Phytotoxicity effect of different CNSL treatments on brinjal

CNSL Concentration	Phytotoxicity effect
0.05 % - 1 %	No Phytotoxicity
2 %	Slight phytotoxicity (necrosis)
3 %	Moderate phytotoxicity (31-40 % necrosis)
4 % and 5 %	Severe phytotoxicity (Yellowing of older leaves, severe necrosis and subsequent leaf fall)

(a) Severe necrosis in leaves exposed to CNSL @ 5 %

(b) Plant exhibiting leaf fall after treatment with CNSL @ 5 %

(c) Modearate necrosis in leaves exposed to CNSL @ 3 %

(d) Slight necrosis in leaves exposed to to CNSL @ 2 %

Plate 6. Phytotoxicity symptoms of CNSL 20 % EC on brinjal

4.3 SCREENING OF BOTANICALS AGAINST *H. VIGINTIOCTOPUNCTATA*.

The different concentrations of CNSL, 0.25 % (LC_{50}), 0.5 % ($2LC_{50}$) and 1 % (higher concentration without phytotoxicity) were evaluated along with commonly used botanicals neem oil 2 %, pongam oil 1 %. Emamectin benzoate 5 % SG @ 0.04 % served as chemical check. Percentage mortality of treated grubs at 1, 2, 3 ,5 and 7 days after treatment are presented in Table 8.

At 1 DAT, the treatments did not differ statistically. Treatments with botanicals caused mortality ranging from 0 to 6.67 per cent. A higher mortality of 26.67 per cent was observed in emamectin benzoate 5 % SG @ 0.04 %.

At 2 DAT, CNSL 1 %, CNSL 2 % and CNSL 0.5 % found superior to other treatments with percentage mortality of 66.67, 60 and 40 respectively. This was followed by emamectin benzoate 5 % SG and CNSL 0.25 % with mortality percentage 3.33 and 26.67 which were on par with each other. Neem oil 2 % recorded 13.33 per cent mortality and was on par with CNSL 0.25 % and chemical check emamectin benzoate @ 0.04 %. Pongam oil 1 % was least effective with no mortality as that in the case of untreated control.

CNSL 1 % and CNSL 2 % both with 73.33 per cent mortality were found superior to all other treatments at 3 DAT and were on par with chemical emamectin benzoate 5 % SG @ 0.04 % (66.67 %). CNSL 0.5 % with mortality percentage of 46.67 was on par with emamectin benzoate @ 0.04 %. CNSL 0.25 % and neem oil 2 % were found to be the next best treatments which were superior over control though inferior to other treatments. Pongam oil 1 % was least effective and it did not vary significantly from the untreated.

At 5 and 7 DAT, emamectin benzoate 5 % SG @ 0.04 % was superior to all other treatments with 100 per cent mortality. All other treatments except pongam oil 1 % were on par with each other. Pongam oil 1 % and control remained as least effective.

Table 8. Percentage mortality of *Henosepilachna vigintioctopunctata* (F.) treated with different botanicals

Treatments	**Percentage Mortality***				
	1 DAT**	2 DAT	3 DAT	5 DAT	7 DAT
CNSL 0.25 %	6.67 (9.05)	26.67 (30.79) [bc]	33.33 (35.01) [c]	46.67 (43.08) [b]	53.33 (46.923) [b]
CNSL 0.5 %	6.67 (9.05)	40.00 (38.85) [ab]	46.67 (43.08) [bc]	53.33 (49.92) [b]	60.00 (51.14) [b]
CNSL 1 %	6.67 (9.05)	66.67 (54.99) [a]	73.33 (59.21) [a]	73.33 (59.21) [b]	80.00 (63.43) [b]
CNSL 2 %	0 (0.29)	60.00 (50.77) [ab]	73.33 (59.21) [a]	73.33 (59.21) [b]	73.33 (59.21) [b]
Neem oil 2 %	0 (0.29)	13.33 (13.27) [cd]	33.33 (34.63) [c]	53.33 (46.92) [b]	53.33 (46.92) [b]
Pongam oil 1 %	0 (0.29)	0 (0.29) [d]	0 (0.29) [d]	6.66 (9.04) [c]	13.33 (17.81) [c]
Emamectin benzoate 5 % SG @ 0.04 %	26.67 (25.87)	33.33 (30.09) [bc]	66.67 (54.91) [ab]	100.00 (89.71) [a]	100.00 (89.71) [a]
Control	0 (0.29)	0 (0.29) [d]	0 (0.29) [d]	6.667 (9.046) [c]	6.67 (9.05) [c]
CD (0.05)	NS	(23.370)	(13.033)	(19.421)	(19.885)

***Mean of three replications comprising 5 grubs each**

(Values in the parentheses are angular transformed values)

****Days After Treatment**

4.4 MANAGEMENT OF MAJOR PESTS OF BRINJAL USING BOTANICALS

Pot culture experiment was carried out at the Department of Agricultural Entomology, College of Agriculture, Vellayani to find out the effective botanical for the management of brinjal pests in field conditions.

The different concentrations of CNSL *viz.*, 0.25 % (LC_{50}), 0.5 % ($2LC_{50}$), 1 % (higher concentration without phytotoxicity) and combination treatments with neem oil 1 % were evaluated by spraying these treatments two times one at the vegetative stage and another at the reproductive stage of the crop. The results of the study are presented below.

Vegetative stage

In vegetative stage, epilachna beetle was absent due to the unfavourable environment conditions. Incidence of some of the sucking pests *viz.,* whiteflies, aphids and mealybugs were seen. The mean population of these sucking pests in plants treated with different botanicals did not differ significantly which are evident from the tables 9, 10 and 11. The low and unequal number of these pests in different treatments and the environmental condition which did not favour the build up of these pests may be the reasons for this unusual results.

Reproductive stage

In the reproductive stage also, there was no natural incidence of epilachna beetle. The experiment was continued with artificially released epilachna beetle and mealybugs to all the plants in equal numbers. The results of the experiment are presented below.

The mean population of *H. vigintioctopunctata* in plants treated with different botanicals is presented in the table 12. The mean population of *H. vigintioctopunctata* was low in emamectin benzoate 5 % SG @ 0.04 % and CNSL 1 % treated plants at 2 DAT. All other treatments containing CNSL except CNSL 0.5 % + neem oil 1 % and thiamethoxam 25 % WG @ 0.015 % were on par with CNSL 1 % and superior over control at 2 DAT.

Table 9. Mean population of whiteflies (leaf^{-1}) in plants treated with different CNSL concentrations (Vegetative stage)

Treatments	1 DAT*	2 DAT	3 DAT	5 DAT
CNSL 0.25 %	28.00 (4.57)	28.00 (4.57)	7.33 (2.05)	2.67 (1.44)
CNSL 0.5 %	3.33 (1.55)	4.67 (1.74)	4.33 (1.7)	3.67 (1.6)
CNSL 1 %	10.00 (2.31)	9.00 (2.22)	0 (0.71)	0 (0.71)
CNSL 0.25 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
CNSL 0.5 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	4 (1.65)
CNSL 1 % + neem oil 1 %	44.00 (5.67)	36.67 (5.2)	30.33 (4.73)	4.56 (1.73)
Emamectin benzoate 5 % SG @ 0.04 %	44.44 (5.67)	38.33 (5.3)	0 (0.71)	0 (0.71)
Thiamethoxam 25 % WG @ 0.015 %	14.50 (2.68)	0 (0.71)	0 (0.71)	0 (0.71)
Control	46.33 (4.41)	38.33 (4.05)	26.00 (3.43)	3.33 (1.55)
CD (0.05)	**NS**	**NS**	**NS**	**NS**

***Days after treatment**

Table 10. Mean population of aphids ($leaf^{-1}$) in plants treated different CNSL concentrations (Vegetative stage)

Treatments	1 DAT*	2 DAT	3 DAT	5 DAT
CNSL 0.25 %	100.00 (6.25)	104.00 (6.36)	41.00 (4.18)	17.50 (2.9)
CNSL 0.5 %	10.00 (2.31)	8.67 (2.19)	4.33 (1.7)	0 (0.71)
CNSL 1 %	0 (0.71)	0 (0.71)	32.00 (3.75)	40.00 (4.13)
CNSL 0.25 % + neem oil 1 %	152.00 (7.59)	141.33 (7.34)	0 (0.71)	0 (0.71)
CNSL 0.5 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
CNSL 1 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
Emamectin benzoate 5 % SG @ 0.04 %	0 (0.71)	0 (0.71)	0 (0.71)	24.00 (3.31)
Thiamethoxam 25 % WG @ 0.015 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
Control	0 (0.71)	0 (0.71)	0 (0.71)	49.67 (5.25)
CD (0.05)	**NS**	**NS**	**NS**	**NS**

***Days After Treatment**

Table 11. Mean population of mealybugs (leaf^{-1}) in plants treated different CNSL concentrations (Vegetative stage)

Treatments	**1 DAT***	**2 DAT**	**3 DAT**	**5 DAT**
CNSL 0.25 %	4.00 (1.65)	4.00 (1.65)	4.33 (1.7)	10.00 (2.86)
CNSL 0.5 %	0 (0.71)	0 (0.71)	0 (0.71)	6.67 (1.98)
CNSL 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
CNSL 0.25 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
CNSL 0.5 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
CNSL 1 % + neem oil 1 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
Emamectin benzoate 5 % SG @ 0.04 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
Thiamethoxam 25 % WG @ 0.015 %	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
Control	0 (0.71)	0 (0.71)	0 (0.71)	1.00 (1.1)
CD (0.05)	**NS**	**NS**	**NS**	**NS**

***Days After Treatment**

At 5 DAT, CNSL 1 % found to be the best treatment with mean population of 1 $leaf^{-1}$ followed by the CNSL 0.5 % (2.33 $leaf^{-1}$) which was on par with chemicals (emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 %) and higher concentration of combination treatment (CNSL 1 % + neem oil 1 %). The other two combination treatments (CNSL 0.25 % + neem oil 1 %, CNSL 0.5 % + neem oil 1 %) and the CNSL 0.25 % found superior over control though inferior to chemical check.

All the treatments remain statistically on par at 7 DAT as the effect of treatments lasted only up to 7days. There was increase in the pest population after 7 days but the mean population in different treatments did not differ statistically.

The mean population of mealybug*s* in plants treated with different botanicals is presented in the table 13. The mealybugs inoculated externally failed to survive after 3 days and hence the observation (mean population of mealybugs) were recorded in the initial two days wherein the mean population did not differ significantly between the plants treated with different treatments.

The phytotoxicity evaluation of different treatments in pot culture experiment was done by scoring the various visual symptoms like yellowing, scorching, necrosis, epinasty and hyponasty and the results were presented in the table 14. There was no phytotoxicity symptoms in any of the treatment since we have selected only those CNSL concentrations with no phytotoxicity symptoms based on the results of previous phytotoxicity evaluation.

Table 12. Mean population of *Henosepilachna vigintioctopunctata* (F.) (leaf^{-1}) in plants treated different CNSL concentrations

Treatments	1 DAT*	2 DAT	3 DAT	5 DAT	7 DAT	14 DAT
CNSL 0.25 %	5	4.67 (2.16)^{ab}	4.00 (2.00)^{ab}	4.33 (2.2)^{ab}	2.33 (1.64)	1.00 (1.17)
CNSL 0.5 %	5	4.67 (2.16)^{ab}	3.00 (1.73)^{c}	2.33 (1.68)^{c}	1.00 (1.1)	0.67 (1.05)
CNSL 1 %	5	4.00 (2)^{bc}	3.00 (1.73)^{c}	1.00 (1.17)^{d}	0.67 (1.05)	5.33 (1.96)
CNSL 0.25 % + neem oil 1 %	5	4.67 (2.16)^{ab}	4.33 (2.08)^{ab}	4.33 (2.2)^{ab}	2.00 (1.56)	0 (0.71)
CNSL 0.5 % + neem oil 1 %	5	5.00 (2.24)^{a}	4.00 (2.00)^{ab}	4.33 (2.2)^{ab}	3.33 (1.95)	3.67 (1.79)
CNSL 1 % + neem oil 1 %	5	4.33 (2.08)^{ab}	3.67 (1.9)^{bc}	3.33 (1.93)^{bc}	0.67 (1.05)	1.67 (1.35)
Emamectin benzoate 5 % SG @ 0.04 %	5	3.33 (1.82)^{c}	3.67 (1.91)^{bc}	3.67 (2.04)^{bc}	1.00 (1.1)	4.33 (1.7)
Thiamethoxam 25 % WG @ 0.015 %	5	4.67 (2.16)^{ab}	3.00 (1.73)^{c}	3.67 (2.04)^{bc}	2.00 (1.47)	1.67 (1.25)
Control	5	5.00 (2.24)^{a}	4.67 (2.16)^{a}	5.67 (2.48)^{a}	2.67 (1.65)	6.67 (2.2)
CD (0.05)	**NS**	(0.195)	(0.218)	(0.394)	**NS**	**NS**

***Days After Treatment**

Table 13. Mean population of mealybugs (leaf^{-1}) in plants treated different CNSL concentrations

Treatments	1 DAT*	2 DAT
CNSL 0.25 %	2.3 (1.82)	2.33 (1.52)^{a}
CNSL 0.5 %	2.33 (1.82)	3.00 (1.52)^{a}
CNSL 1 %	2.66 (1.82)	3.33 (1.62)^{a}
CNSL 0.25 % + neem oil 1 %	2.33 (1.82)	3.33 (1.52)^{a}
CNSL 0.5 % + neem oil 1 %	2.66 (1.73)	3.33 (1.62)^{a}
CNSL 1 % + neem oil 1 %	3.00 (1.98)	3.00 (1.71)^{a}
Emamectin benzoate 5 % SG @ 0.04 %	1.33 (1.71)	4.00 (1.13)^{b}
Thiamethoxam 25 % WG @ 0.015 %	3.33 (2.06)	3.00 (1.82)^{a}
Control	2.66 (2.06)	4.33 (1.62)^{a}
CD (0.05)	**NS**	**(0.347)**

***Days After Treatment**

Table 14. Phytotoxicity evaluation of different CNSL concentrations in brinjal (pot culture experiment)

Treatments	Yellowing	Necrosis	Scorching	Epinasty	Hyponasty
CNSL 0.25 %	0	0	0	0	0
CNSL 0.5 %	0	0	0	0	0
CNSL 1 %	0	0	0	0	0
CNSL 0.25 % + neem oil 1 %	0	0	0	0	0
CNSL 0.5 % + neem oil 1 %	0	0	0	0	0
CNSL 1 % + neem oil 1 %	0	0	0	0	0

4.4.1 Growth parameters of brinjal treated with different botanicals

The growth parameters such as the plant height, internode length, number of leaves in different treatments were recorded at 2, 7 and 14 days after treatment at both vegetative and reproductive stage which did not vary significantly between the plants treated with different treatments.

In vegetative stage, CNSL 0.25 % and CNSL 0.5 % recorded superior plant height of 33.67 and 33.44, respectively at 7 DAT. All the combination treatments and CNSL 1 % recorded the plant heights ranging from 27.78 to 29.56. The plants in the chemical check treatments, emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 % recorded least plant heights of 25.33 and 24.89, respectively.

However, both at 2 DAT and 14 DAT there was no statistically significant difference between the plant heights among the different treatments.

Table 15. Effect of different CNSL concentrations on plant height (pot culture experiment)

Treatments	Vegetative stage			Reproductive stage		
	2 DAT*	7 DAT	14 DAT	2 DAT	7 DAT	14 DAT
CNSL 0.25 %	28.40	36.67[a]	28.28	53.11	57.223	58
CNSL 0.5 %	26.22	33.44[ab]	25.49	51.33	54.667	54.667
CNSL 1 %	20.63	28.00[bc]	19.95	52.777	53.113	54.78
CNSL 0.25 % + neem oil 1 %	22.02	27.78[bc]	21.22	46.667	50.22	51.333
CNSL 0.5 % + neem oil 1 %	24.97	29.56[bc]	21.28	48.447	50.113	52.943
CNSL 1 % + neem oil 1 %	22.82	29.44[bc]	20.72	53.00	53.447	53.723
Emamectin benzoate 5 % SG @ 0.04 %	18.68	25.33[c]	19.72	47.78	51.553	53
Thiamethoxam 25 % WG @ 0.015 %	22.30	24.89[c]	22.11	44.553	49.443	50.667
Control	29.87	33.33[ab]	29.55	57.667	57.667	55.167
CD (0.05)	NS	(6.784)	NS	NS	NS	NS

***Days After Treatment**

Table 16. Effect of different CNSL concentrations on internode length (pot culture experiment)

Treatments	**Vegetative stage**			**Reproductive stage**		
	2 DAT*	7 DAT	14 DAT	2 DAT	7 DAT	14 DAT
CNSL 0.25 %	4.16	3.98[a]	4.17	2.91	2.97	2.95
CNSL 0.5 %	3.20	3.45[bc]	3.15	2.853	2.85	2.95
CNSL 1 %	3.85	3.18[cd]	3.89	2.643	2.687	2.65
CNSL 0.25 % + neem oil 1 %	3.53	2.70[d]	3.58	2.523	2.467	2.42
CNSL 0.5 % + neem oil 1 %	3.60	3.01[cd]	3.65	2.267	2.26	2.28
CNSL 1 % + neem oil 1 %	3.48	2.70[d]	3.55	2.11	2.39	2.28
Emamectin benzoate 5 % SG @ 0.04 %	3.76	3.10[cd]	3.85	2.29	2.21	2.27
Thiamethoxam 25 % WG @ 0.015 %	3.41	2.87[d]	3.46	2.347	2.31	2.29
Control	3.34	3.73[ab]	3.29	2.947	2.68	2.88
CD (0.05)	NS	(0.522)	NS	NS	NS	NS

***Days After Treatment**

Table 17. Effect of different CNSL concentrations on number of leaves (pot culture experiment)

Treatments	**Vegetative stage**			**Reproductive stage**		
	2 DAT*	7 DAT	14 DAT	2 DAT	7 DAT	14 DAT
CNSL 0.25 %	35.00	48.33	35.00	29.78	30.33	31.11
CNSL 0.5 %	45.67	41.67	45.00	39.11	39.55	40.00
CNSL 1 %	29.33	32.00	29.33	25.22	24.33	24.22
CNSL 0.25 % + neem oil 1 %	34.67	39.00	33.33	26.44	29.44	31.22
CNSL 0.5 % + neem oil 1 %	24.33	32.67	23.00	28.89	31.55	33.78
CNSL 1 % + neem oil 1 %	30.67	39.00	25.67	30.45	32.00	35.33
Emamectin benzoate 5 % SG @ 0.04 %	29.67	33.33	26.33	27.22	29.67	31.33
Thiamethoxam 25 % WG @ 0.015 %	28.67	31.67	27.67	30.67	30.55	32.33
Control	36.33	32.00	34.33	39.56	38.89	40.45
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

***Days After Treatment**

Table 18. Effect of different CNSL concentrations on number and yield of fruits (pot culture experiment)

Treatments	Fruit number	Fruit yield
CNSL 0.25 %	4.8	186.957
CNSL 0.5 %	5.22	163.317
CNSL 1 %	4.67	120.983
CNSL 0.25 % + neem oil 1 %	3.95	130.293
CNSL 0.5 % + neem oil 1 %	4.39	138.957
CNSL 1 % + neem oil 1 %	5.33	133.063
Emamectin benzoate 5 % SG @ 0.04 %	4.78	125.89
Thiamethoxam 25 % WG @ 0.015 %	6.67	139.307
Control	5.81	158.47
CD (0.05)	**NS**	**NS**

Plants treated with treatment CNSL 0.25 % recorded the internode length of 3.98 which was superior to all other treatments at 7 DAT. This was followed by CNSL 0.5 % with internode length of 3.45cm. All other treatments found to be on par with internode lengths ranging from 2.7 to 3.18cm. However, both at 2 DAT and 14 DAT there was no statistically significant difference between the internode lengths among the different treatments. The leaf number ranging from 25.67 to 48.33 did not differ statistically among the treatments at any of the intervals in vegetative stage.

In reproductive stage, the plant heights (ranging from 44.55 to 58cm), internode length (ranging from 2.11 to 2.97cm) and the leaf number (ranging from 24.22 to 40.45) did not show significant difference among the treatments at any intervals.

There was also no statistical difference in fruit number and the fruit yield in different treatments.

DISCUSSION

5. DISCUSSION

Brinjal, *Solanum melongena* L. (order Polemoniales ; family Solanaceae) is the second major vegetable crop cultivated in India after tomato (Chadha, 2002). It is called as vegetable of social masses because of its popularity among all the social strata (Patel and Sarnaik, 2003). It is cultivated in an area of 7.36 lakh ha in India with the production of 12.7 tonnes (Indiastat, 2018). But its cultivation is hindered by serious pest problems resulting in yield reduction up to 70 to 92 per cent (Rosaiah, 2001).

The crop is damaged by an array of chewing as well as sucking pests. The leaf eating epilachna beetles are among one of the chewing pests causing extensive damage contributing yield loss up to 65 per cent (Bhalla and Pawar, 1977). The adults and grubs of *Henosepilachna vigintioctopunctata* (F.) cause extensive damage by feeding on epidermis of the leaf, skeletonizing the leaves affecting the photosynthetic efficiency of the crop thereby substantially reducing the yield. They also attack the calyx of flower when the infestation is severe.

Mealybugs are the major sucking pests that infest brinjal. In addition to desapping they also transmit various diseases. Reduced plant vigour combined with reduced photosynthetic efficiency due to sooty mould development on the honeydew secretions of mealybugs drastically affect the yield.

Various chemical pesticides are used by the farmers along with other control practices to minimize crop losses. Farmers apply pesticides blindly without considering types of pesticides to be used against the specific pests, their quantities and the method of application, economic injury level and waiting period. About 57 per cent of farmers take 12 to 19 sprayings with average of 15 sprayings and the remaining give 16 to 19 sprayings in brinjal frequently to manage the high incidence of these pests (Jeyanthi and Kombairaju, 2005).

Only 0.1 per cent of the pesticides reach the target and rest of which contaminate the surrounding environment (Carriger *et al*., 2006). These persistent and non-biodegradable chemicals pollute nook and corner of the environment including soil, water, air including animals. These toxic chemicals enter into the food chain and accumulate to the higher tropic levels causing health hazards. Indiscriminate use leads to many of the problems *viz.*, adverse effect on non-target organisms (Ware, 1980) including natural enemies such as predators and parasitoids (Aveling, 1977; Vickerman, 1988), secondary pest outbreak (Dhaliwal *et al*., 2006) and resistance development by target pest species (Tabashnik *et al*., 2009). Recently, human acute and chronic illness were also reported due to these contaminants (Mostafalou and Abdollahi, 2012) necessitating exploration of alternate management strategies.

Employment of botanicals for pest management is one solution that can take care of these problems. Over 2000 plant species are known to possess compound having insecticidal properties (Ojo,1996; Isman 2008). Plants produce and store secondary metabolites for insect resistance as they are stationary.

These secondary metabolites produced to defend against the insects have the property of suppression of calling behaviour (Khan and Saxena, 1986), growth retardation (Breuer and Schimdt, 1995), toxicity (Hiremath *et al.,* 1997), oviposition deterrence (Zhao *et al.,* 1998), feeding inhibition (Klepzig and Schlyter, 1999; Wheeler and Isman, 2001) and reduction of fecundity and fertility (El- Ibrashy, 1974; Muthukrishnan and Pushpalatha, 2001). These secondary metabolites come under three classes *viz.*, Terpenoids, Alkaloids and phenols (Kabera *et al*., 2014).

Glandular trichomes of *Artemisia* contains terpenes which were developed as insecticide and herbicide (Duke *et al.*,1988). Pine oil, act as a feeding deterrent to a pine weevil (Alfaro *et al.,* 1984). A monoterpene, alpha terpinol, major constituent of pine oil is reported to repel three bark beetle species (Nijholt *et al*.,1981).

Plant derived terpenoids like azadirachtin and pyrethrum have been developed as commercial botanical pesticides (Isman, 2005). Alkaloids like nicotine and ryanodine were also exploited as botanical pesticides.

Phenolic compounds though reported to have strong insecticidal activity (Cruz-Estrada *et al*., 2013) are less exploited as commercial botanical pesticides.

Cashew plants produce and store mixture of phenolic compounds (Ancardic acid, cardol and cardanol) in the honeycomb structure of the pericarp of its nut to protect it from herbivory (Lubic and Thachil, 2003). This viscous liquid exudes out of the shell during cashew processing and is available as technical cashew nut shell liquid (CNSL), as a by-product of cashew industry at cheap rate. An emulsifiable concentrate formulation of CNSL (CNSL 20 % EC) was developed in the Department of Agricultural Entomology, College of agriculture, Vellayani and was proved to be effective against pests of cowpea (Lekha, 2020). The present study was undertaken to evaluate the efficacy of this formulation as a botanical pesticide against the pests of brinjal.

The different concentrations of CNSL *viz.*, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 %, prepared from the CNSL 20 % EC formulation were evaluated against *H. vigintioctopunctata* under laboratory conditions. CNSL did not produce quick effect on *H. vigintioctopunctata* as evidenced by low mortality (0 – 20 %) at 1 DAT. There was no statistically significant difference between the treatments at this interval.

At 2 and 3 DAT, Higher concentrations of CNSL from 1 to 5 % were found superior to rest of the treatments. CNSL 4 % and 5 % recorded per cent mortality ranging from 86.67 to 93.33 per cent at 5 and 7 DAT which was on par with chemical emamectin benzoate 5 % SG 0.04 % (100 % mortality). CNSL 1 %, 2 % and 3 % were on par with 4 and 5 % though inferior to the chemical check. CNSL at higher concentrations caused high mortality of epilachna beetle under laboratory conditions.

CNSL at higher concentration of 5 to 25 % was reported to cause 100 per cent mortality of the coconut rootgrub, *Leucopholis coneophora* Burm (John, 2008). CNSL was found to be toxic to *Helicoverpa armigera* (Hübner), and *Spilarctia obliqua* (Walker) (Mahapatro, 2011).

Though the higher concentration is required for effective kill of chewing pests as evidenced by above reports much lower concentrations were proved to be effective earlier against the sucking pests (Sundaran and Faizal, 2018; Andayanie *et al.*, 2019). Thus, lower concentrations ranging from 0.025 % to 2 % were tested against mealybug, (*P. citr*i) under laboratory conditions.

The different concentrations of CNSL *viz.*, 0.05, 0.1, 0.25, 0.5, 0.75, 1 and 2 % were evaluated against the mealybugs. Not much mortality was reported against mealybugs till 2 DAT. Thiamethoxam 25 % WG @ 0.015 % was found superior at different intervals of seven days' time. Though less effective initially CNSL treatments caused significant mortality from 5 DAT onwards. Higher concentrations of 1 % and 2 % produce 60 and 66.67 per cent respectively at 5 DAT though inferior to chemical check. Thiamethoxam 25 % WG @ 0.015 % was proved effective against the citrus mealybug, *P. citri* (Willmott, 2012). At 7 DAT, CNSL 1 % and 2 % produced mortality of 80 per cent and 86.67 per cent respectively and was on par with the chemical thiamethoxam 25 %WG @ 0.015 %.

The dose mortality response was obtained after probit analysis. The LC_{50} and LC_{90} values of CNSL against *H. vigintioctopunctata* were 0.26 and 4.35 % respectively. These values were comparable with the LC_{50} and LC_{90} values of *S. litura* (0.275 and 2.979 respectively) reported in previous works (Lekha, 2020). But the LC_{50} and LC_{90} values of CNSL against mealybugs was found to be 0.37 % and 7.64 % respectively in the present study which was found to be very high when compared with that of the sucking pests reported earlier. The LC_{50} and LC_{90} values of CNSL against *Riptortus pedestris* (F.) was 0.095 and 0.275 % respectively and against *Aphis craccivora* Koch was 0.079 and 0.250 % respectively (Lekha, 2020).

CNSL being rich in phenolic compound is likely to cause phytotoxicity to crop plants at higher doses as evidenced by work on coffee senna and tomato wherein aerial as well as the root phytotoxicity was reported (Matias *et al*., 2017). Hence in the present study a phytotoxicity evaluation of CNSL on brinjal was carried out to select doses effective against pests and safe to the crop for further studies.

Different concentrations of CNSL ranging from 0.05 % to 5 % were applied to brinjal plants and evaluated for phytotoxicity. No phytotoxicity symptoms were observed in the plants treated with lower concentrations ranging from 0.05 to 1 %. CNSL 2 % exhibited slight phytotoxicity (yellowing less than 10 %) whereas 3 % exhibited moderate phytotoxicity with yellowing up to 10 % and necrosis up to 40 %. The higher concentrations of 4 and 5 % resulted in yellowing up to 20 % and severe necrosis of 61 to 80 % and subsequent leaf fall (only in CNSL 5 %), proving to be highly phytotoxic to brinjal. Thus, CNSL at higher concentrations was phytotoxic to brinjal plants. Though CNSL at 0.2 % was found to have growth retarding effect on chilly (Sundaran, 2018), no phytotoxicity was reported when tested at doses 0.05 to 1 % in cowpea (Lekha *et al.,* 2019).

Matias *et al*. (2017) reported that CNSL affects the germination of lettuce and tomato seeds at concentrations 200 mg mL^{-1} and 100 mg mL^{-1} respectively and it also had effect on coffee senna. They also noted that the tomato (family Solanaceaea) seeds were more affected than lettuce.

Response of various crop differed upon treatment with CNSL which can be related to physiology of the species as the response of species from different families towards the secondary metabolites varies (Rizzi *et al*. 2016). Present study indicated the safety of CNSL to brinjal upto a dose of 1 %.

Due to phytotoxicity to brinjal, the LC_{90} doses obtained for *H. vigintioctopunctata* (4.35 %) and *P. citri* (7.64 %) could not be selected for further evaluation. So, the lower concentrations (LC_{50}, $2LC_{50}$) and maximum possible higher concentrations (1 and 2 %) were selected for further evaluation. Hence the following treatments of CNSL 0.25 % (LC_{50}), 0.5 %($2LC_{50}$), 1 %, and 2 % (possible higher concentrations) were evaluated along with botanicals (neem oil 2 % and pongam oil 1 %) and insecticide emamectin benzoate @ 0.04 % against *H. vigintioctopunctata* under laboratory conditions.

Quick mortality was not observed in any of the botanical treatments. All the CNSL treatments except 0.25 % was found superior over other botanicals and control at 2 DAT with mortality ranging from 26.67 to 66.67 per cent. Mortality of 73.33 per cent was shown by CNSL 1 % and 2 % at 3 DAT, an effect on par with chemical check emamectin benzoate 5 % SG @ 0.04 %. But at 5 and 7 DAT emamectin benozoate 5 % SG @ 0.04 % produced 100 per cent mortality superior than other botanicals tried. Emamectin benzoate 5 % SG at 0.1 % was found effective against *H. vigintioctopunctata* and *H. dodecastigma* (Sharma and Kaushik, 2010). Biswal (2016) in her laboratory study found that emamectin benzoate gives quick mortality.

At 5 and 7 DAT all CNSL concentrations and neem oil 2 % produced mortality superior over control. Mahapatro (2011) reported that the CNSL @ 1% was toxic to *H. armigera* and *S. obliqua.* John (2008) reported the toxicity of CNSL against coconut root grub at concentrations above 5 %. In the present study CNSL @ 0.25 % to 2 % produced almost similar effect when tested against *H. vigintioctopunctata.* This effect was on par with the conventionally used botanical insecticide, neem oil emulsion. Since the present study was undertaken with 20 % EC formulation which was proved stable and yielding ready emulsions (Lekha, 2020), the stakeholders can use this formulation to yield quick emulsion rather than attempting emulsification of neem oil using soap which is laborious. The pesticidal property of natural cashew nut shell is attributed to high anacardic acid content (80 %) (Lubic and Thachil, 2003). During the processing of cashew nuts this anacardic acid is decarboxylated to cardanol. The technical CNSL contains higher cardanol content (83 - 84 %), less cardol (8 - 11 %) and polymeric material (10 %) and 2-methyl cardol (2 %) and was proved effective against chewing pests (Ikeda *et al*., 2002; Kumar *et al*., 2002).

The toxicity of neem is primarily due to the presence of tetranortriterpenoid azadirachtin (Isman *et al*, 1990). Maredia *et al*. (1992) reported the toxicity of neem oil against the corn earworm, *H. zeae*, fall armyworm, *S. frugiperda,* sugarcane borer, *Diatrea saccharalis (*F.) and Southwest corn borer *Diatrea grandiosella* Dyar.

Pongam oil was found ineffective against *H. vigintioctopunctata* producing mortality of only 13 per cent and did not differ statistically from control. Karanjin which is the active ingredient of pongam though reported to have insecticidal activity against mustard aphid, *Lipaphis erymsimi* (Kaltenbach) (Parmar and Gulati, 1969), *S. litura* (Meera *et al*., 2003) and was found ineffective in the present study.

Karanji oil at higher doses (1 and 2 %) produced good results when compared to lower concentrations (Kumar and Singh, 2002).

Pongam oil is not effective as that of the neem and hence less scope to use at farmers level (Deshmukh and Borle, 1975). Botanicals has a synergists role in ecological pest management (Morales-Rodriguez and Peck, 2009). Neem oil formulation can be used as synergist with endosulfan and reduce the quantity of chemical in insect pest control (War *et al.*, 2011).

Feeding reduction of *S. litura* in the combined treatment of neem oil and synthetic pyrethroids was reported by Rao and Dhingra (2000). Number of jassids and their damage in okra can be reduced by combination of neem cake + neem oil + endosulfan. (Mandal *et al.,* 2007).

Based on these results three CNSL treatments (CNSL 0.25 %, 0.5 % and 1 %) and 3 combination treatments of CNSL with neem oil 1 % (CNSL 0.25 % + neem oil 1 %, CNSL 0.5 % + neem oil 1 % and CNSL 1 % + neem oil 1 %) were evaluated under field conditions (pot culture) for pest management in brinjal. The treatments were applied twice one at vegetative and one more at reproductive stage of the crop. In the vegetative stage, no infestation of epilachna beetles and other chewing insects was noticed. Though there was incidence of few sucking pests *viz.*, whiteflies, aphids and mealybugs, their population statistically did not differ between the treatments.

The per cent reduction of population of whiteflies over control is shown in Fig. 1. CNSL 0.5 % resulted in 92.81, 87.82 and 83.35 per cent reduction of whiteflies over control at 1, 2 and 3 DAT, respectively. CNSL 1 % recorded 78.42 and 76.52 per cent reduction over control at 1 and 2 DAT, respectively and 100 per cent reduction at 3 DAT. Combination treatments CNSL 0.25 % + neem oil 1 % and CNSL 0.5 % + Neem oil 1 % shown 100 per cent reduction over control at all time intervals. CNSL 0.25 % recorded 64.77 per cent reduction of aphids over control at 5 DAT. CNSL 0.5 % and all the combination treatments shown 100 per cent reduction of aphids over control (Fig. 2).

In reproductive stage, CNSL 1 % and chemical check emamectic benzoate 5 % SG @ 0.04 % recorded lowest population of 4 and 3.33 epilachna beetle leaf $^{-1}$ and found superior over other treatments at 2 DAT. CNSL 2 % reported to cause 80 per cent mortality of *L. coneophora* (Jeevan and Sreekumar, 2015). All other CNSL treatments and the combination treatments were also found effective. CNSL 0.5 %, CNSL 1 % and CNSL 1 % + neem oil 1 % with mean population of 3, 3 and 3.67 beetles leaf $^{-1}$ was effective as that of the chemicals at 3 DAT. At 5 DAT, CNSL 1 % was found superior than chemical check with lowest mean population of 1 insect leaf^{-1}. CNSL 1 % + neem oil 1 % recorded mean pest population of 3.33 leaf^{-1} was the next best treatment which was on par with the chemicals. The effects of various treatments did not differ after 7 days indicating that the effect of CNSL remains only up to 7 days.

CNSL 1 % recorded 20 per cent reduction of *H. vigintioctopunctata* over control at 2 DAT. AT 3 DAT, both CNSL 0.5 %, 1 % shown 35.76 per cent reduction and the combination treatment CNSL 1 % + neem oil 1 % reduced the population comparable to

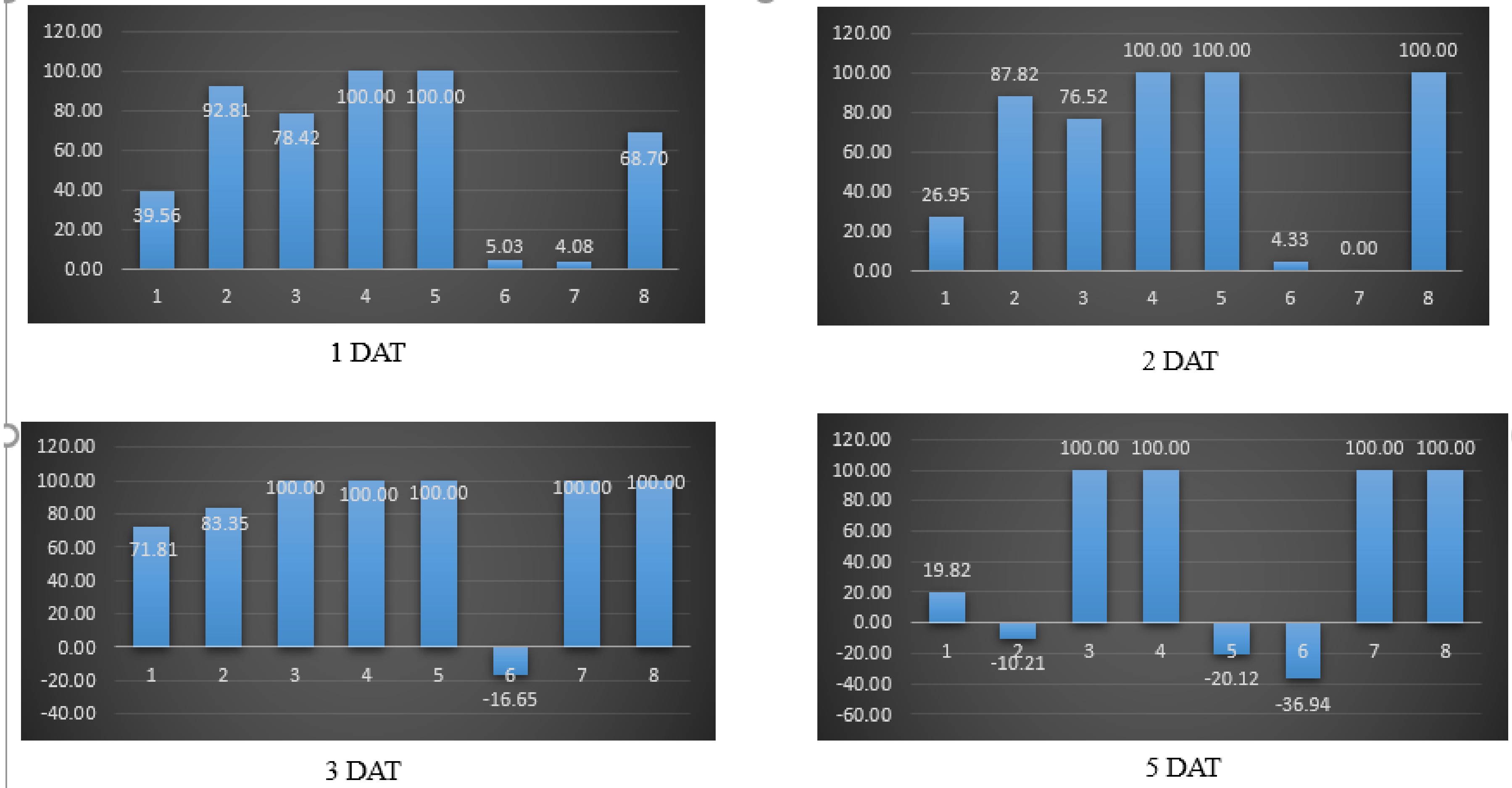


Fig. 1. Percent reduction in the population of whiteflies over control after spraying at vegetative stage

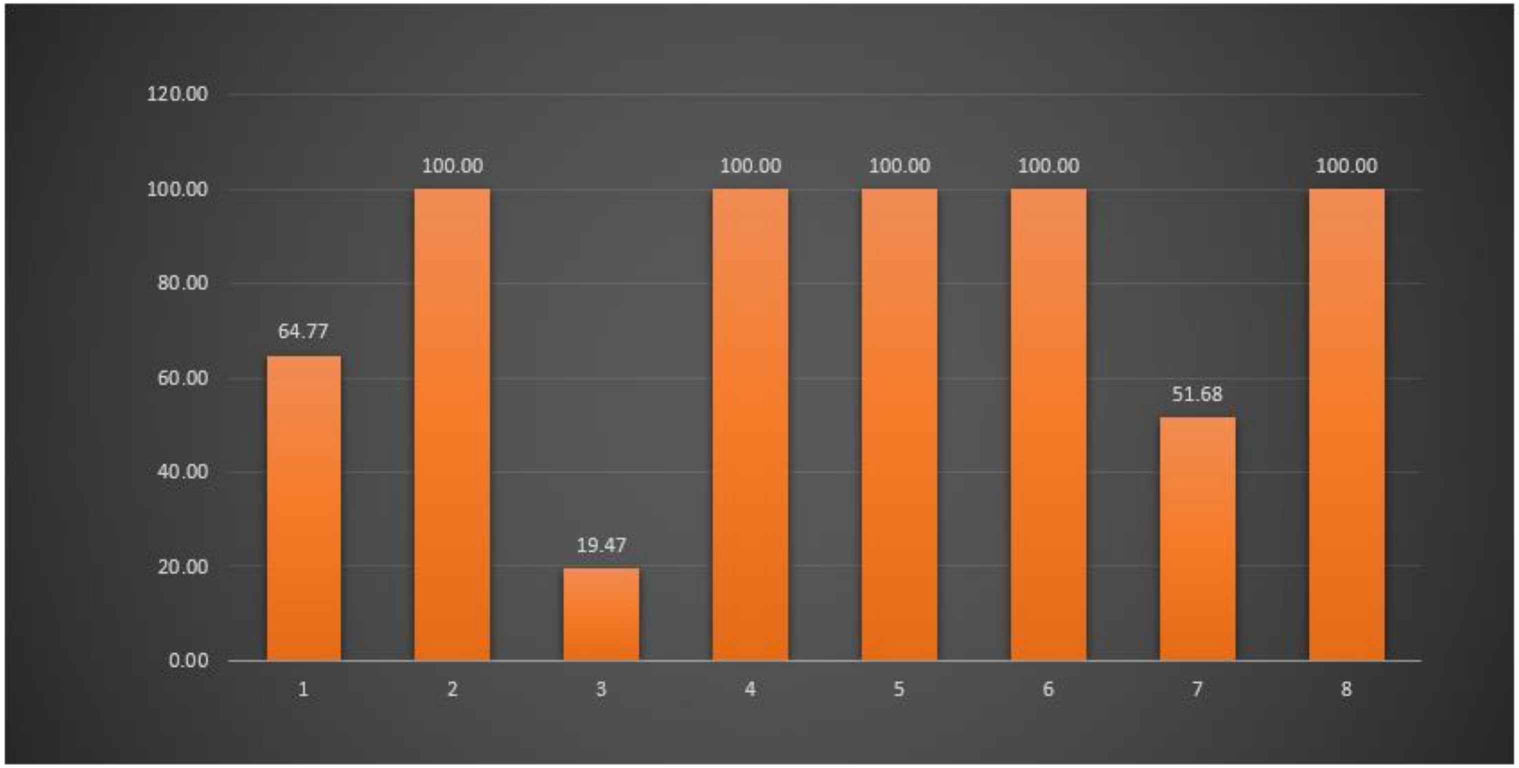


Fig. 2. Percent reduction in the population of aphids over control after spraying at vegetative stage at 5DAT

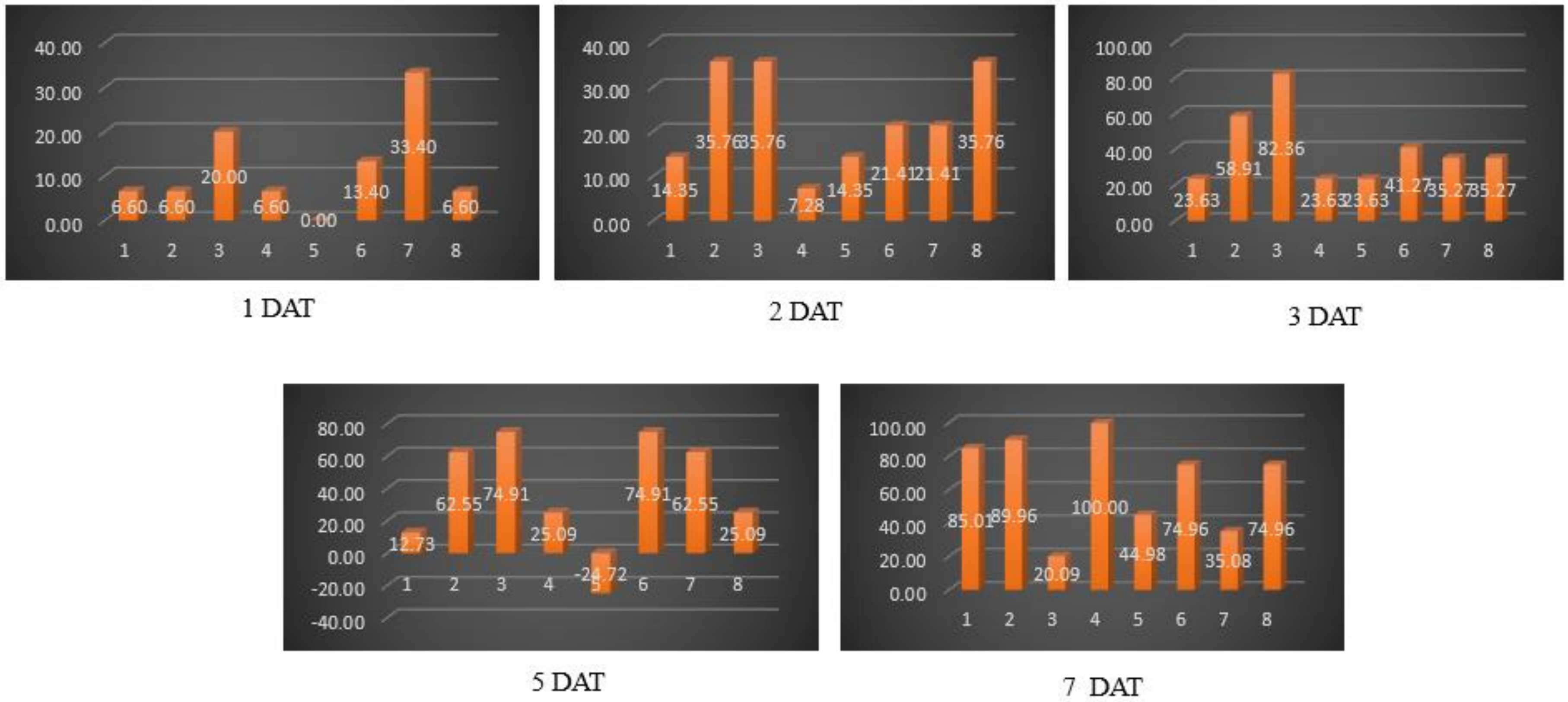
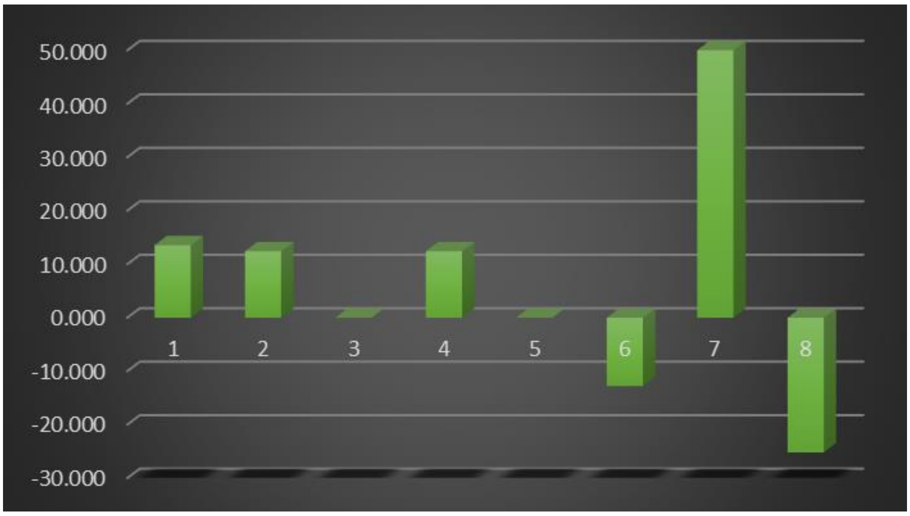
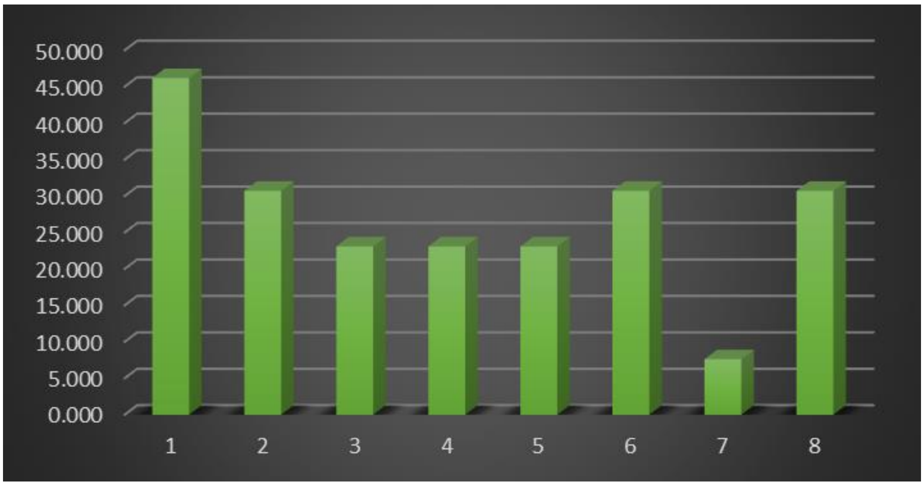


Fig. 3. Percent reduction in the population of *Henosepilachna vigintioctopunctata* (F.) over control after spraying (at reproductive stage)



1 DAT



2 DAT

Fig. 4. Percent reduction in the population of mealybugs over control after spraying (at reproductive stage)

chemical emamectin benzoate 5 % SG @ 0.04 %. 82.36 and 74.9 per cent reduction was recorded in CNSL 1 % at 5 and 7 days respectively (Fig.3). CNSL 2.5 % and its combination with other botanicals found to reduce the cocoa pod borer and the percentage seed damage of cocoa (La Ode Santiaji *et al.*,2019).

The mean population of mealybugs in various treatments did not differ significantly. The CNSL treatments recorded only 23.09 to 46.18 per cent reduction of mealybugs over control (Fig. 4). In the previous reports CNSL was found to be very effective against various sucking pests. The toxicity of CNSL against *A. gossypii* at 0.075 to 0.2 % was reported by Sundaran and Faizal (2018). Andayanie *et al.* (2019) proved that CNSL at lower concentration of 0.75 % inhibits the landing and staying of whiteflies more strongly than the chemical imidacloprid at 0.50%. However, in the present study the CNSL was not found to be effective against mealybugs at lower concentrations. This may be due to the surface waxy coating of mealybugs which prevents the penetration of the toxicant to the body.

Suitable surfactants are added to the insecticidal formulations of *Datura stramonium* L., *Azadirachta indica* A. Juss. and *Nicotiana tobaccum* L. to use against the mealybugs which helps in removing the waxy covering (Araujo *et al*., 2009). The mortality of mealybug is lower in field conditions when compared to laboratory conditions (Prishanthini and Vinobaba, 2014; Tacoli *et al*., 2018). Peschiutta *et al*. (2018) concluded that addition of sodium lauryl sulphate and anhydrous citric acid to the organic products is more effective in managing the mealybugs as it removes the waxy coating of mealybug.

Phytotoxicity evaluation in pot culture studies had recorded no phytotoxicity. Highest yield of 186.95 g plant^{-1} was obtained in CNSL 0.25 % treated plants and was not significantly different from other treatments. Other growth parameters *viz.,* plant height, number of leaves and internode length did not show any difference between the treatments. This indicates that the CNSL is safer at lower concentrations. The lower concentration of CNSL from 0.2 to 0.6 % did not show any adverse effects on physiological as well as biometric characters of cowpea and found to be not phytotoxic (Lekha *et al.,* 2019).

Thus, results of the study proved CNSL treatments at 1 % is effective against the pests of brinjal. Even though CNSL is effective at much lower concentrations against the sucking insects earlier comparatively higher concentrations was required against mealybugs. So, further works has to be conducted to study its efficacy upon addition of suitable surfactants against mealybugs.

SUMMARY

6. SUMMARY

Brinjal, *Solanum melongena* L. is the most popular vegetable crop which is grown commercially for its fruits in different parts of the country. It is considered as the King of vegetables and common man's vegetable due to its high productivity. But the productivity of this crop is severely affected by heavy infestation of major insect and non-insect pests. In the process of managing these pests, farmers are forced to apply the dangerous synthetic pesticides frequently at different stage of the crop. Frequent application of these chemicals resulted in residue problems along with resistance development, pest resurgence, adverse effects on natural enemies, secondary pest outbreak and contamination of different components of environment. Use of botanicals in pest management served as the best alternative to minimize these problems.

Plant synthesize, store and exude a variety of compounds (secondary metabolites) against the herbivores. This natural gift can be utilized in the plant protection against the insect pests and many such compounds *viz.*, azadirachtin, pyrethrum, ryanodine, nicotine are developed and commercialized as a botanical pesticide. Cashew nut shell liquid is a by-product of cashew industry and available plenty at cheap rate. Since this plant derived material contains phenolic secondary metabolite having pesticidal effect, it was formulated as an emulsifiable concentrate (CNSL 20 % EC) at the Department of Agricultural Entomology, College of Agriculture, Vellayani which gives good results in controlling the chewing as well as sucking pests. The present study entitled "Botanicals for the management of pests of brinjal, *Solanum melongena* L. was undertaken during the period 2018-2020 to check efficacy of this formulation against the brinjal pests with the objective to manage the major pests of brinjal *viz.*, *Henosepilachna vigintioctopunctata* and mealy bugs using botanicals including the formulation of Cashew nut Shell Liquid.

CNSL 20 % EC, a potential botanical insecticide was evaluated at different concentrations *viz.*, CNSL 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % against test insect *H. vigintioctopunctata* and CNSL 0.05, 0.075, 0.1, 0.25, 0.75, 1 and 2 % against test insect mealybugs. Emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 % served as the chemical check for epilachna beetle and mealybugs respectively.

When tested against *H. vigintioctopunctata* higher concentrations of CNSL *viz.,* 5 %, 4 %, 3 %, 2 % and 1 % with percentage mortality of 80, 73.33, 53.33, 66.67 and 60 respectively was found to be superior at 2 DAT. At 3 DAT also the higher concentrations of CNSL (1 % to 5 %) with mortality ranging from 53.33 to 80 per cent was found superior to rest of the treatments and on par with that of chemical check emamectin benzoate 5 % SG @ 0.04 % (66.67 % mortality). At 5 and 7 DAT, 100 per cent mortality is recorded in chemical check, emamectin benzoate 5 % SG @ 0.04 % which was on par with CNSL 4 % and 5 %. CNSL 1 %, 2 % and 3 % also was on par, though inferior to the chemical check. CNSL at higher concentrations (1 to 5 %) produced high mortality ranging from 66.67 to 93.33 per cent.

When tested against mealybugs all the CNSL treatments were on par with each other with mortality percentage ranging from 0 to 26.67 at 2 and 3 DAT though inferior to chemical check. Thiamethoxam 25 % WG @ 0.015 % produced superior mortality at different intervals after treatments. At 5 and 7 DAT, CNSL treatments found superior over control with mortality percentage ranging from 6.67 to 66.67. At 7 DAT, higher concentrations of CNSL (1 % and 2 %) produced mortality comparable to chemical check.

Probit analysis was performed to find the dose mortality response. The LC_{50} and LC_{90} values of CNSL against *H. vigintioctopunctata* were 0.26 % (with 0.146 and 0.402 % upper and lower bound values) and 4.35 % (with 2.65 and 9.78 % upper and lower bound values) respectively and that against mealybugs were 0.37 % (with 0.190 and 0.849 % upper and lower bound values) and 7.64 % (with 2.29 and 211.46 % upper and lower bound values) respectively.

CNSL at different concentrations *viz.,* 0.05, 0.075, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % was applied on to brinjal plants and the phytotoxicity symptoms observed *viz.,* yellowing, scorching, necrosis, epinasty and hyponasty which were scored as per CIB RC protocol where in no phytotoxicity was noticed at lower concentration ranging from 0.05 to 1 % which scored 0 for all symptoms. Slight (negligible) phytotoxicity with yellowing up to 10 % and necrosis up to 20 % was noticed in plants treated with CNSL 2 %. CNSL 3 % was found moderately phytotoxic with yellowing and necrosis scores 1 and 4 respectively. Plants treated with 4 and 5 % exhibited severe phytotoxic symptoms with yellowing (score 1-2), severe necrosis (score 7-8) and subsequent leaf fall.

Based on laboratory evaluation efficacy and phytotoxicity evaluation on crop CNSL concentrations 0.25 % (LC_{50} value), 0.5 %, 1 % and 2 % were selected for further evaluation using *H. vigintioctopunctata* as test insect. Commonly used botanicals *viz.,* neem oil 2 % and pongam oil 1 % and chemical emamectin benzoate 5 % SG @ 0.04 % were also tested. All the CNSL treatments except 0.25 % produced superior mortality (ranging from 13.33 to 66.67 %) over control at 2 DAT. CNSL 1 % and 2 % recorded significantly superior mortality of 66.67 and 60 per cent which was on par with chemical check. At 5 and 7 DAT, all the CNSL treatments and neem oil 2 % produced mortality superior over control though inferior to chemical check. Pongam oil 1 % was found to be ineffective at all intervals.

A pot culture experiment was carried out in brinjal (Vellayani local) with effective CNSL concentrations (0.25 %, 0.5 % and 1 %) selected based on the laboratory experiments along with the combination treatments of CNSL and neem oil (CNSL 0.25 % + neem oil 1 %, CNSL 0.5 % + neem oil 1 % and CNSL 1 % + neem oil 1 %) were tested to assess the field efficacy against the pests of brinjal. Emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 % served as the chemical checks. Two rounds of application one each at vegetative and reproductive phase were administered.

In vegetative stage, there was no epilachna beetle incidence. The mean population of sucking pests *viz.,* whiteflies, aphids and mealybugs did not differ statistically in plants treated with different treatments. In reproductive stage CNSL 1 % and chemical check emamectin benzoate 5 % SG @ 0.04 % found superior with lowest population of epilachna beetle at 2 DAT. All other CNSL treatments and the combination treatments found superior over control though inferior to chemical check. At 3 and 5 DAT, CNSL 0.5 % and 1 % with population ranging from 1 to 3 $leaf^{-1}$ was found to be superior and equally effective as that of chemical check. All combination treatments of CNSL with neem oil 1 % were also found to be effective. There was no significant difference between the treatments in managing the population of mealybugs and the crop yield was also not significant among treatments.

Phytotoxicity evaluation in pot culture studies had recorded no phytotoxicity. Analysis of biometric parameters (plant height, internode length, number of leaves and yield,) did not exhibit any adverse effect on plant growth upon treatment with CNSL. CNSL treatments @1 % or below neither produced phytotoxic effect nor affected the growth characteristics of brinjal. Thus CNSL @ 1 %, can be used as a botanical pesticide against pests of brinjal.

REFERENCES

7. REFERENCES

Ahmed, K. N. and Hasan, M. R. 2009. Sudden outbreak of mealybug and armoured scale causing severe damage to economic crops in Bangladesh. *J. Plant Prot. Sci*. 2(2): 45-48.

Alam, S. N., Rashid, M. A., Rouf, F. M. A., Jhala, R. C., Patel, J. R., Satpathy, S., Shivalingaswamy, T. M., Rai, S., Wahundeniya, I., Cork, A., and Ammaranan, C. 2003. *Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia*. Technical bulletin No. 28, Shanhua, Taiwan: AVRDC-World Vegetable Center, 56p.

Alfaro, R. I., Borden, J. H., Harris, L. J., Nijholt, W.W., and McMullen, L. H. 1984. Pine oil, a feeding deterrent for the white pine weevil, *Pissodes strobi* (Coleoptera: Curculionidae). *Canadian Entomologist* 116(1): 41-44.

Andayanie, W. R., Nuriana, W., and Ermawaty, N. 2019. Bioactive compounds and their their antifeedant activity in the cashew nut (*Anacardium occidentale* L.) shell extract against *Bemisia tabaci* (Gennadius, 1889)(Hemiptera: Aleyrodidae). *Acta Agriculturae* 113(2): 281-288.

Anwar, S., Mari, J. M., Khanzada, M. A., and Ullah, F. 2015. Efficacy of insecticides against infestation of brinjal fruit borer, *Leucinodes orbonalis* Guenee (Pyralidae: Lepidoptera) under field conditions. *J. Entomol. Zool. Stud.* 3(3): 292-295.

Araujo, J. M. D., Marques, E. J., and Oliveira, J. V. D. 2009. Potential of *Metarhizium anisopliae* and *Beauveria bassiana* isolates and Neem oil to control the aphid *Lipaphis erysimi* (Kalt.) (Hemiptera: Aphididae). *Neotrop. Entomol.* 38(4): 520-525.

Arif, M. I., Rafiq, M., and Ghaffar, A. 2009. Host plants of cotton mealybug (*Phenacoccus solenopsis*): a new menace to cotton agroecosystem of Punjab, Pakistan. *Int. J. Agric. Biol.* 11(2): 163-167.

Arya, V. C. 2015. Management of sucking pests of brinjal (*Solanum melongena* L.) M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 112p.

Ashwathy. 2015. Management of epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.) with phylloplane and pathogenic microorganisms. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 117p.

Asogwa, E. U., Mokwunye, I. U., Yahaya, L. E., and Ajao, A. A. 2007. Evaluation of cashew nut shell liquid (CNSL) as a potential natural insecticide against termites (soldiers and workers castes). *Res. J. Appl. Sci.* 2(9): 939-942.

Aveling, C. 1977. The biology of Anthocorids (Heterophera: Anthocoridae) and their role in the integrated control of the damson-hop aphid (*Phorodon humili* Schrank). PhD Thesis, University of London, 328p.

Azam, K. M., Aziz, S. A., and Ali, M. H. 1974. A new record of *Uga menoni* as parasite of *Epilachna vigintioctopunctata* in India. *Curr. Res*. 3: 88.

Baskaran, P. and Kumar, A. 1980. Further studies on Dipel-insecticide combinations against the insect pests of brinjal. *Pesticides* 14(1): 9-11.

Ben-Dov, Y**.** 1994. *A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance*. Intercept Limited, Andover, UK, 686p.

Bhalla, O. P. and Pawar. A. D. 1977. *A survey study of insect and non-insect pests of economic importance in Himachal Pradesh*. Tiku KitabMahal, Bombay, 80p.

Biswal, L. 2016. Bioefficacy of certain insecticides and mixed formulations against some economically important insect pests. Ph.D. Thesis, G. B. Pant University of Agriculture and Technology, Pantnagar, 260p.

Borkakati, R. N., Venkatesh, M. R., and Saikia, D. K. 2019. Insect pests of brinjal and their natural enemies. *J. Entomol. Zool. Stud.* 7(1): 932-937.

Breuer, M. and Schmidt, G. H. 1995. Influence of short-term treatment with Melia azedarach-Ex tract via leaf material on food intake and growth of the larvae of *Spodoptera frugiperda* (JE Smith) (Lep., Noctuidae). *J. Plant Dis. Prot*. 633-654.

Butani, D. K. and Verma, S. 1976. Pests of vegetables and their control in brinjal. *Pesticides* 11(1): 33-35.

Carriger, J. F., Rand, G. M., Gardinali, P. R., Perry, W. B., Tompkins, M. S., and Fernandez, A. M. 2006. Pesticides of potential ecological concern in sediment from South Florida canals: an ecological risk prioritization for aquatic arthropods. *Soil Sediment Contamination* 15(1): 21-45.

Chadha, K. L. 2002. *Handbook of Horticulture*. Indian Council of Agricultural Research, New Delhi, India,1-64p.

Choudhary, B. and Gaur, K. 2009. The development and regulation of *Bt* brinjal in India (Eggplant/Aubergine). International Service for the Acquisition of Agri-biotech Applications (ISAAA), New Delhi, 102p.

Cruz-Estrada, A., Gamboa-Angulo, M., Borges-Argáez, R., and Ruiz-Sánchez, E. 2013. Insecticidal effects of plant extracts on immature whitefly *Bemisia tabaci* Genn.(Hemiptera: Aleyroideae). *Electr. J. Biotechnol*. 16(1): 6-6.

Deshmukh, S. D. and Borle, M. N. 1975. Studies on the insecticidal properties of indigenous plant products. *Ind. J. Entomol*. 37:11–18

Dhaliwal, G.S., Singh, R. and Chhillar, B.S. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, Ludhiana, India. 451 pp.

Dodia, D. A., Patel, I. S., and Patel, G. M. 2010. *Botanical pesticides for pest management*. Scientific Publishers, Jodhpur, India, 340p.

Duke, S. O., Paul, R. N., and Lee, S. M. 1988. Terpenoids from the genus Artemisia as potential pesticides. *Am. Chem. Soc. Symp. Ser*. 829: 52–66.

El-Ibrashy, M. T. 1974. Sterilization of the Egyptian Cotton Leafworm *Spodoptera littoralis* Boisd. with a foliage extract of *Podocarpus gracilior* P. *Zeitschrift fur Angew. Entomol*. 75(1&4): 107-109.

FAO (Food and Agricultural organization). 2003. *Inter Country Programme for Integrated Pest Management in Vegetables in South and South-East Asia*. *Eggplant Integrated Pest Management: An Ecological Guide.* Food and Agricultural Organization, Rome, Italy, 177p.

FAOSTAT, 2018. Area, yield and production quantity of crops [on-line]. Available: https://www.fao.org/faostat/en/#data/QC [05 July 2020]

Gahukar, R. T. 2015. Management of pests and diseases of tropical sericultural plants by using plant-derived products: a review. *J. For. Res*. 26(3): 533-544.

Gahukar, R.T. 2000. Use of neem products/pesticides in cotton pest management. *Int. J. Pest Manag.* 46(2): 149-160.

Ghosh, S. K. and Senapati. 2001. Biology and seasonal fluctuation of *Henosepilachna vigintioctopunctata*. Fab. on brinjal under terai region of West Bengal. *Indian J. Agric. Res.* 35(3): 149-154.

Gowrish, K. R. 2014. Biorational management of major pests in Brinjal (*Solanum melongena* L.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 177p.

Gupta, A. K., Suthar, J., Muralikrishnan., Srinivas., Patel, K., Chauhan, V., Koradia, D., Rawal, A., Pastakia, A., Shukla, S., and Chand, V.S. 1997. Farmers Innovations for Sustainable Resource Management and Conservation of Biological Diversity. In: Heidhues, F. / Fadani, A. (eds), *Proceedings of the International Symposium on Food Security & Innovations: Successes and Lessons Learned*, University of Hohenheim Frankfurt, Berlin Peter Lang, pp.97-112.

Hillocks, R. J. 1995. Integrated management of insect pests, diseases and weeds of cotton in Africa. *Integrated Pest Manag. Rev.* 1(1): 31-47.

Hina, H. K., Sarwar, M., and Lohar, M. K. 2015. Repellence activity of plant oils against red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in wheat. *Int. J. Anim. Biol.* 1 (3): 86-92.

Hiremath, G. I., Ahn, Y. J., and Kim, S. I. 1997. Insecticidal activity of Indian plant extracts against *Nilaparvata lugens* (Homoptera: Delphacidae). *Appl. Entomol. Zool.* 32(1): 159-166.

Ikeda, R., Tanaka, H., Uyama, H., and Kobayashi, S. 2002. Synthesis and curing behaviors of a crosslinkable polymer from cashew nut shell liquid. *Polym*. 43(12): 3475-3481.

Indiastat, 2018. Area, production and productivity of brinjal in India [on-line]. Available: https://www.indiastat.com/agriculture-data/2/brinjal/17453/brinjal production/1343596/stats.aspx [05 July 2020].

Iqbal, J., Ali, H., Hassan, M.W., and Jamil, M. 2015. Evaluation of indigenous plant extracts against sucking insect pests of okra crop. *Pakist. Entomol.* 37(1): 39-44.

Isaacs, R., Mercader, R. J., and Wise, J. C. 2004. Activity of conventional and reduced risk insecticides for protection of grapevines against the rose chafer, *Macrodactylus subspinosus* (Coleoptera: Scarabaeidae). *J. Appl. Entomol.* 128(5): 371-376.

Islam, M. N., Karim, M. A., Mannan, M. A., Chowdhury, J. C. S., and Islam, M. 1999. Integrated management of the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen.(Lepidoptera: Pyralidae), based on insecticide. *Bangladesh J. Entomol.* 9(1/2): 75-85.

Isman, M. B. 2000. Plant essential oils for pest and disease management. *Crop Prot*. 19(8-10): 603-608.

Isman, M. B. 2005. Problems and opportunities for the commercialization of botanical insecticides. *Biopesticides Plant Origin* 64(1): 283-91.

Isman, M. B. 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu. Rev. Entomol*. 51(1): 45-66.

Isman, M. B. 2008. Botanical insecticides: for richer, for poorer. *Pest Manag. Sci*. 64(1): 8-11.

Isman, M. B., Koul, O., Luczynski, A., and Kaminski, J. 1990. Insecticidal and antifeedant bioactivities of neem oils and their relationship to azadirachtin content. *J. Agric. Food Chem.* 38(6): 1406-1411.

Janaki, I., Suresh, S., and Karuppuchamy, P. 2012. Efficacy and economics of biopesticides for the management of papaya mealybug, *Paracoccus marginatus* (Williams and Granara de Willink) in brinjal (*Solanum melongena* L.). *J. Biopest.* 5(1): 87-90.

Jeevan, C. H. and Sreekumar, K. M. 2015. Ecofriendly management of coconut root grub *Leucopholis coneophora* Burm. *J. Trop. Agric.* 53(2): 222-226.

Jeyanthi, H. and Kombairaju, S. 2005. Pesticide use in vegetable crops: frequency, intensity and determinant factors. *Agric. Econ. Res. Rev.* 18(2): 209-221.

Jiji, T., Praveena, R., Naseema, A., Anitha, N., and Simna, T. 2008. Entamopathogenic fungus, *Beauveria bassiana* (B.) V. for the management of key pests of vegetables. *Green Farming* 1(10-11): 54-56.

John, J. 2008. Pesticidal effect of leaf, root and bark extracts of multipurpose trees and cashew nut shell liquid on coconut root grub (*Leucopholis coneophora* Bur.). *J. Plant Crops* 36(3): 447-450.

Jones, D. R. 2005. Plant viruses transmitted by thrips. *Eur. J. Plant Pathol.* 113(2): 119-157.

Kabera, J. N., Semana, E., Mussa, A. R., and He, X. 2014. Plant secondary metabolites: biosynthesis, classification, function and pharmacological properties. *J. Pharm. Pharmacol.* 2: 377-392.

Kabir, K. H., Rouf, F. M. A., Islam, M. N., and Malakar, P. K. 1994. Efficacy of different insecticides in controlling brinjal shoot and fruit borer, *Leucinodes* orbonalis Guen. *J. Zool. Rajshahi Univ.*13: 1-8.

Kalra, V. K. 1997. Insect pest management in brinjal and cabbage/ cauliflower. In: *Advanced Training Course on Insect Pest Management*, Indian Council of Agricultural Research, Centre for Advanced Studies, CCS. H.A.U, Hissar, pp.110-117.

Kapur, A. P. 1950. The biology and external morphology of the larvae of Epilachninae (Coleoptera, Coccinellidae). *Bull. Entomol. Res*. 41(1): 161-208.

Karkar, D. B., Korat, D. M., and Dabhi, M. R., 2014. Bioefficacy of microbial insecticides against insect pests of brinjal. *Karnataka J. Agric. Sci*. 27(2): 236-238.

KAU [Kerala Agricultural University]. 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 393p.

Kaur, P., Yadav, G. S., Wargantiwar, R. K., and Burange, P. S. 2014. Population dynamics of brinjal shoot and fruit borer, *L. orbonalis* Guenee (Lepidoptera: Crambidae) under agroclimatic condition of Hisar, Haryana, India. *Ecoscan* 8 (2): 1-5.

Khan, F., Mazid, M., Khan, T. A., Patel, H. K., and Roychowdhury, R. 2014. Plant derived pesticides in control of lepidopteran insects: dictum and directions. *Res. J. Biol.* 2(1): 1-10.

Khan, Z. R. and Saxena, R. C. 1986. Effect of steam distillate extracts of resistant and susceptible rice cultivars on behavior of *Sogatella furcifera* (Homoptera: Delphacidae). *J. Econ. Entomol.* 79(4): 928-935.

Kitherian, S., Kumar, V., Banu, N., Avery, P. B., Radhika, A., McKenzie, C. L., and Osborne, L. S. 2018. Predation potential of *Rhynocoris marginatus* (Hemiptera: Reduviidae) against three mealybug species of agricultural importance. *Appl. Entomol. Zool.* 53(4): 475-482.

Klepzig, K. D. and Schlyter, F. 1999. Laboratory evaluation of plant-derived antifeedants against the pine weevil *Hylobius abietis* (Coleoptera: Curculionidae). *J. Econ. Entomol.* 92(3): 644-650.

Konar, A., Paul, S., and More, K. A. 2011. Efficacy of different insecticidal treatment schedules against aphid and whitefly on brinjal. *Plant Prot. Sci*. 3: 43-52.

Mani, M. and Shivaraju. 2016. *Mealybugs and their management in agricultural and horticultural crops* (1st Ed.). Berlin, Germany. 458p.

Kumar, M. and Singh, R. 2002. Potential of *Pongamia glabra* vent as an insecticide of plant origin. *Biol. Agric. Hortic.* 20(1): 29-50.

Kumar, P. P., Paramashivappa, R., Vithayathil, P. J., Subba Rao, P.V., and Rao, S. A. 2002. Process for isolation of cardanol from technical cashew (*Anacardium occidentale* L.) nut shell liquid. *J. Agric. Food Chem.* 50(16): 4705-4708.

La Ode Santiaji., Gusnawaty, H. S., Mariadi, M., and Nuriadi, N. 2019. Effectiveness of botanical insecticide formulations against cocoa pod borer *Conopomorpha cramerella* (Snell.) Bande. *J. HPT. Tropica* 19(1): 1-7.

Latif, M. A., Rahman, M. M., and Alam, M. Z. 2010. Efficacy of nine insecticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in eggplant. *J. Pest. Sci.* 83(4): 391-397.

Lekha, H. S., Jat, S. K., and Jeengar, K. L. 2018. Bio efficacy of Dinotefuran (20% SG) against major sucking pests of Brinjal. *J. Entomol. Zool. Stud.* 6(3): 1832-1837.

Lekha, M., Faizal, M. H., and Anitha, N. 2019. Effect of cashew nut shell liquid on the growth of cowpea and its biosafety evaluation. *Ann. Biosci.* 12(11): 788-793.

Lekha, M. 2020. Cashew nut shell liquid based botanical insecticide for pest management in yard long bean, (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.), Kerala Agricultural University, Thrissur, 222p.

Lepage, E. S. and De Lelis, A. T. 1980. Protecting wood against dry-wood termites with cashewnut shell oil. *For. Product J.* 30(6): 35-36.

Lit, I. L., Lit, M. C., and Venus, C. J. 1998. The mealybugs (Pseudococcidae, Coccoidea, Hemiptera) of egglant (*Solanum melongena* Linn.) in the Philippines. *Philipp. Entomologist* 12 (1): 29-41.

Lubi, M.C. and Thachil, E.T., 2000. Cashew nut shell liquid (CNSL)-a versatile monomer for polymer synthesis. *Des. Monomers polym*. 3(2), pp.123-153.

Lubic, M. and Thachil, E.T. 2003. Copolymerization of cashew nut shell liquid (CNSL) and phenol by condensation with hexamine. *Int. J. Polymeric Mater*. 52(9): 793-807.

Mahapatro, G. K. 2011. Insecticidal activity of cashew nut shell liquid against two lepidopteran pests. *Indian J. Entomol*. 73: 121-124.

Maleque, M. A., Islam, M. N., Kundu, R., and Islam, M. S. 1998. Judicious use of insecticides for the management of the brinjal shoot and fruit borer. *Bangladesh J. Entomol*. 8(1/2): 97-107.

Mall, N. P., Pandey, R. S., Singh, S. V., and Singh, S. K. 1992. Seasonal incidence of insect-pests and estimation of the losses caused by shoot and fruit borer on brinjal. *Indian J. Entomol.* 54(3): 241-247.

Mamun, M. S. A., Shahjahan, M., and Ahmad, M. 2009. Laboratory evaluation of some indigenous plant extracts as toxicants against red flour beetle, *Tribolium castaneum* Herbst. *J. Bangladesh Agric. Univ.* 7(1): 1-5.

Mandal, S. C. 1971. A note on the host range of Epilachna beetle *E. vigintioctopuntata* in Bihar. *Allahabad Farmer* 45: 187-188.

Mandal, S. K., Sah, S. B., and Gupta, S. C. 2007. Management of insect pests on okra with biopesticides and chemicals. *Ann. Plant Prot. Sci.* 15(1): 87-91.

Maredia, K. M., Segura, O. L., and Mihm, J. A. 1992. Effects of neem, *Azadirachta indica* on six species of maize insect pests. *Int. J. Pest Manag.* 38(2): 190-195.

Martina, G. and Kristina, G. 2013. Botanical insecticides in plant protection. *Agriculturae Conspectus Scientificus* 78(2): 85-93.

Martínez, L. C., Plata-Rueda, A., Zanuncio, J. C., and Serrao, J. E. 2015. Bioactivity of six plant extracts on adults of *Demotispa neivai* (Coleoptera: Chrysomelidae). *J. Insect Sci.* 15(1): 1-5.

Mathur, A. C. and Srivastava, J. B. 1964. *Epilachna vigintioctopunctata* as a defoliator of some solanaceous medicinal plants. *Indian J. Entomol*. 26: 246.

Matias, R., Rosa, A. C., Oliveira, A. K. M., Pereira, K. C. L., Rizzi, E. S., and Machado, A. A. 2017. Cashew nut shell liquid and formulation: toxicity during the germination of lettuce, tomato seeds and coffee senna and seedling formation. *Acta Scientiarum Agron*. 39(4): 487-495.

Mazzetto, S. E., Lomonaco, D., and Mele, G. 2009. Cashew nut oil: opportunities and challenges in the context of sustainable industrial development. *Química Nova* 32(3): 732-741.

Meera, B., Kumar, S., and Kalidhar, S. B. 2003. A review of the chemistry and biological activity of Pongamia pinnata. *J. Med. Arom. Plant Sci*. 25: 441- 65.

Mishra, V. K. and Tripathi, N. P. 2017. Ecological and control of brinjal insect pests from Rewa region. *Int. J. Adv. Sci. Res*. 2(3): 37-39.

Moore, A., Watson, G., and Bamba, J. 2014. First record of eggplant mealy- bug, *Coccidohystrix insolita* (Hemiptera: Pseudococcidae), on Guam: potentially a major pest. *Biodivers. Data J.* 2: 1042.

Morales-Rodriguez, A. and Peck, D. C. 2009. Synergies between biological and neonicotinoid insecticides for the curative control of the white grubs *Amphimallon majale* and *Popillia japonica*. *Biol. Control* 51(1): 169-180.

Mostafalou, S. and Abdollahi, M. 2012. Concerns of Environmental Persistence of Pesticides and Human Chronic Diseases. *Clin. Exp. Pharmacol.* 2(3): 1000-1108.

Mote, U. N. and Bhavikatti, S. 2003. Efficacy of chemical and non-chemical insecticides against major pests of brinjal in kharif season. *J. Appl. Zool. Res.* 14(1): 54-56.

Munde, A. D., Latpate, C. B., Shinde, S. T., and Badgujar, A. G. 2011. Integrated management of aphids and jassids infesting brinjal. *J. Entomol. Res*. 35(1): 43- 49.

Murtaza, G., Ramzan, M., Ghani, M.U., Munawar, N., Majeed, M., Perveen, A., and Umar, K. 2019. Effectiveness of different traps for monitoring sucking and chewing insect pests of crops. *Egyptian Acad. J. Biol. Sci.* 12(6): 15-21.

Muthukrishnan, J. and Pushpalatha, E. 2001. Effects of plant extracts on fecundity and fertility of mosquitoes. *J. Appl. Entomol.* 125(1&2): 31-35.

Nabil, H. A., Hassan, A. S., and Ismail, S. A. A. 2015. Registration of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: sternorrhyncha: coccoidea: pseudococcidae) for the first time on four economical crops in Egypt. *Zagazig J. Agric. Res.* 42(6): 32-36.

Naik, V., Rao, P., Krishnayya, P. V., and Chalam, M. S. V. 2009. Seasonal incidence and management of *Bemisia tabaci* Gennadius and *Amrasca biguttula biguttula* Ishida of brinjal. *An. Plant Prot. Sci*. 17(1): 9-13.

NBAIR, 2020. Pests of brinjal [on-line]. Available: https://www.nbair.res.in/Databases/insectpests/pestsearch.php?cropname=Brinjal [05 July 2020].

Nigam, G. L. and Murthy, K. S. 2000. An optimum use of pesticides in integrated pest management technology. *Pesticides Inf.* 25(1): 6-9.

Nijholt, W.W., McMullen, L. H., and Safranyik, L. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera: Scolytidae). *Canadian Entomologist* 113(4): 337-340.

Ojo, I. O. 1996. On the effectiveness of insecticides of biological origin. In: *Proceeding of 25th Annual Conference*. Entomological Society of Nigeria. 30: 25-31.

Oladejo, A. O., Adeleke, A., Musa, F., and John, W. C. 2016. Efficacy of cashew nutshell extract against termite attack on *Triplochiton scleroxylon* Wood. *Annu. Res. Rev. Biol*. 10(4): 1-7.

Olotuah, O. F. and Ofuya, T. I. 2010. Comparative protection of cowpea, *Vigna unguiculata* (L.) Walker against field insect pests using cashew nut shell liquid and cypermethrin (Cymbush). *Pakist. J. Nutr*. 9(2): 158-161.

Ozkan, C., Tunca, H., and Kilincer, N. 2014. Toxicity and repellent effects of some botanical insecticides on the egg-larval parasitoid *Chelonus oculator* Panzer (Hymenoptera: Braconidae). *Sci. Res. Essays* 9(5): 106-113.

Packiam, S. M., Baskar, K., and Ignacimuthu, S. 2014. Feeding deterrent and growth inhibitory activities of PONNEEM, a newly developed phytopesticidal formulation against *Helicoverpa armigera* (Hubner). *Asian Pac. J. Trop. Biomedicine* 4: S323-S328.

Packiam, S.M. and Ignacimuthu, S. 2012. Effect of ponneem on *Spodoptera litura* (Fab.) and its compatibility with *Trichogramma chilonis* Ishii. *Braz. Arch. Biol. Technol.* 55(2): 291-298.

Panse V. G. and Sukhatme, P. V. 1967. *Statistical method for Agricultural workers.* Second edition. Indian Council of Agricultural Research. New Delhi, 381p.

Parmar, B. S. and Gulati, K. C. 1969. Synergists for pyrethrins (II)-karanjin. *Indian J. Entomol.* 31(3): 239-243.

Patel, K. K. and Sarnaik, D. A. 2003. Performance study of long fruited genotypes of brinjal under Raipur conditions. *Orissa J. Hort.* 31(1): 74-77.

Patel, K., Ishnava, K., and Soni, H. 2014. Bio Pesticide formulation for plant growth regulation and anti mealy bug–borer activity in brinjal *(Solanum Melongena L.)* or egg plant. *Int. J. Recent Res. Rev*. 7(4): 7-15.

Patnaik, H. P., Mohapatra, L. N., and Maity, B. K. 2004. Effectiveness of thiamethoxam 25 WG against the insect pests of brinjal under field conditions. *J. Plant. Prot. Environ*. 1(1/2): 39-46.

Patnaik, H. P., Singh, D. N., and Mohapatra, S. 1998. Effect of NPK fertilizers on the incidence of shoot and fruit borer, (*Leucinodes orbonalis* Gueen.) in brinjal under insecticidal protection. *Orissa J. Hortic*. 26: 56-60.

Pavela, R. 2009. Effectiveness of some botanical insecticides against *Spodoptera littoralis* Boisduvala (Lepidoptera: Noctudiae), *Myzus persicae* Sulzer (Hemiptera: Aphididae) and *Tetranychus urticae* Koch (Acari: Tetranychidae). *Plant Prot. Sci*. 45(4): 161-167.

Pavela, R. and Herda, G. 2007. Repellent effects of pongam oil on settlement and oviposition of the common greenhouse whitefly *Trialeurodes vaporariorum* on chrysanthemum. *Insect Sci.* 14(3): 219-224.

Peschiutta, M. L., Brito, V. D., Achimón, F., Dambolena, J. S., Zygadlo, J. A., and Ordano, M. A. 2018. Botanical compounds to combat vineyards mealybugs: An ideal alternative for organic vitiviniculture. *Res. Rev. J. Botanic. Sci*. 7(3): 9-16.

Peswani, K. M. and Katiyar, R. N. 1972. *Termite problems in India*. Council of Scientific and Indian Research, New Delhi, 81p.

Prasad, U. K., Rabindra, P., and Devendra, P. 2008. Integrated management of epilachna beetle (*Henosepilachna vigintioctopuncta* Fabricious) infesting brinjal. *J. Res. BAU*. 20 (1): 77 - 82.

Prishanthini, M. and Vinobaba, M. 2014. Efficacy of some selected botanical extracts against the Cotton mealybug *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). *Int. J. Sci. Res. Publ.* 4(3): 1-6.

Rahman, M. S., Alam, M. Z., Huq, M., Sultana, N., and Islam, K. S. 2002. Effect of some integrated pest management (IPM) packages against brinjal shoot and fruit borer and its consequence on yield. *J. Biol. Sci*. 2: 489-491.

Raja, K. 2008. Toxicity and oviposition deterrency of cashew nut shell liquid (CNSL) on pulse beetle in blackgram seeds. *Seed Sci*. *Technol*. 36(1): 210p.

Raja, K., Sivasubramaniam, K., Geetha, R., and Sujatha, K. 2015. Toxicity of cashew nut shell liquid (CNSL) on bruchids in greengram and redgram seeds. *Acta Hortic*. 1080: 429-436.

Rajagopal, D. and Trivedi, T. P. 1989. Status, bioecology and management of Epilachna beetle, *Epilachna vigintioctopunctata* (Fab.)(Coleoptera: Coccinellidae) on potato in India: A review. *Int. J. Pest Manag.* 35(4): 410-413.

Ramakrishna, A. 1940. *Handbook of economic Entomology for South India*. M*adras Government Press,* 320p.

Rao, G. R. and Dhingra, S. 2000. Variations in the efficacy of mixed formulations comprising vegetable oils and synthetic pyrethroids against susceptible (Delhi) and resistant (Guntur) larval populations of *Spodoptera litura* (Fabricius). *J. Entomol. Res.* 24(2): 115-120.

Rashid, M. H., Mohiuddin, M., and Mannan, M. A. 2008. Survey and identification of major insect pest and pest management practices of brinjal during winter at Chittagong district*. Int. J. Sustain. Crop Prod*. 3(2): 27-32.

Reddy, S. G. and Srinivas, N. 2005. Efficacy of insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.). *Pestology* 29(1): 31-33.

Reghupathy, A., Palanisamy, S., Chandramohan, N., and Gunathilagaraj. K. 1997. *A Guide on Crop Pests*. Sooriya Desktop Publishers, Coimbatore, 264p.

Rizzi, E. S., Pereira, K. C. L., de Araujo Abreu, C. A., de Lima Silva, B. C. F., Fernandes, R. M., de Oliveira, A. K. M., and Matias, R. 2016. Allelopathic potential and phytochemistry of cambarazinho (*Vochysia haenkeana* (Spreng.) Mart.) leaves in the germination and development of lettuce and tomato. *Biosci. J.* 32(1): 234-240.

Rodrigues, F. H. A., Feitosa, J., Ricardo, N. M., França, F. C. F. D., and Carioca, J. O. B. 2006. Antioxidant activity of cashew nut shell liquid (CNSL) derivatives on the thermal oxidation of synthetic cis-1,4-polyisoprene. *J. Braz. Chem. Soc.* 17(2): 265-271.

Rosaiah, B. 2001. Evaluation of different botanicals against the pest complex of brinjal. *Pestology* 25(4): 14-16.

Sakthivel, P., Karuppuchamy, P., Kalyanasundaram, M., and Srinivasan, T. 2012. Host Plants of Invasive Papaya Mealybug, *Paracoccus marginatus* (Williams and Granara de Willink) in Tamil Nadu. *Madras Agric. J*. 99 (7-9): 615-619.

Salvatore, A., Borkosky, S., Willink, E., and Bardon, A. 2004. Toxic effects of lemon peel constituents on *Ceratitis capitata*. *J. Chem. Ecol.* 30(2): 323-333.

Sarangdevot, S. S., Sharma, U. S., and Ameta, O. P. 2006. Efficacy of insecticides and neem oil against sucking insect pests of brinjal (*Solanum melongena* Linn). *Pestology* 30(2): 31-34.

Sarwar, M. and Sattar, M. 2012. Appraisal of different plant products against *Trogoderma granarium* Everts to protect stored wheat–a laboratory comparison. *The Nucleus* 49(1): 65-69.

Sasikala, K., Rao, P., and Krishnayya, P.V. 1999. Comparative efficacy of eco-friendly methods involving egg parasitoid, *Trichogramma japonicum*, mechanical control and safe chemicals against *Leucinodes orbonalis* Guenee infesting brinjal. *J Entomol. Res*. 23(4): 369-372.

Saxena, R. C., Dixit, O. P., and Harshan, V. 1992. Insecticidal action of *Lantana camara* against *Callosobruchus chinensis* (Coleoptera: Bruchidae). *J. Stored Products Res*. 28(4): 279-281.

Shankar, U., Kumar, D., and Gupta, S. 2010. *Integrated pest management in brinjal*. Technical Bulletin No. 4, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, 16p.

Shanmugam, P. S., Indhumathi, K., and Sangeetha, M. 2018. Management of ash weevil *Myllocerus subfasciatus* Guerin-Meneville (Coleoptera; Curculionidae) in Brinjal. *J. Entomol. Zool. Stud.* 6(6): 1230-1234.

Sharma, H. C., Manuele, T., Bouhssini, M. E., and Rao, R. G.V. 2016. Pest Management in Grain Legumes: Potential and Limitations. *Integrated Pest Manag. Trop*. 4: 275-292.

Sharma, S. S. and Kaushik, H. D. 2010. Effect of Spinosad (a bioinsecticide) and other insecticides against pest complex and natural enemies on eggplant (*Solanum melongena* L.). *J. Entomol. Res.* 34(1): 39-44.

Shobha, S.V. and Ravindranath, B. 1991. Supercritical carbon dioxide and solvent extraction of the phenolic lipids of cashew nut (*Anacardium occidentale*) shells. *J. Agric. Food Chem.* 39(12): 2214-2217.

Shreth, C. N., Singh, K. I., and William, S. J. 2009. Laboratory evaluation of certain cow urine extract of indigenous plants against mustard aphid, *Lipaphis erysimi* (Kaltenbach) infesting cabbage. *Hexapoda* 16(1): 11-13.

Shrivastava, G., Rogers, M., Wszelaki, A., Panthee, D. R., and Chen, F. 2010. Plant volatiles-based insect pest management in organic farming. *Crit. Rev. Plant Sci.* 29(2): 123-133.

Singh, A. K. and Kumar, M. 2003. Efficacy and economics of neem-based products against cotton jassid, Amrasca biguttulla biguttulla Ishida in okra. *Crop Res.* 26(2): 271-274.

Sinha, S. R. and Sharma, R. K. 2010. Effect of insecticides on insect pests of brinjal. *An. Plant Prot. Sci*. 18(1): 82-85.

Sohi, A. S., Bindra, O. S., and Deol, G. S. 1974. Studies on the control of the brinjal little-leaf disease and insect pests of brinjal. *Indian J. Entomol*. 36(4): 362-364.

Srinivasan, R. 2009. *Insect and mite pests on eggplant: a field guide for identification and arrangement*. AVRDC publication No. 09-729, AVRDC–The World Vegetable Center, Shanhua, Taiwan, 64p.

Strickland, A. H. 1951. The entomology of swollen shoot of cacao. II-The bionomics and ecology of the species involved. *Bull. Entomol. Res*. 42(1): 65-103.

Sundaran, C. P. 2018. Management of sucking pest complex in chilly using botanical and microbial pesticides. Kerala Agricultural University, Thrissur, 90p.

Sundaran, C. P. and Faizal, M. H. 2018. Laboratory evaluation of cashew nut shell liquid against chilli aphid *Aphis gossypii* Glover (Homoptera: Aphididae). *Entomon* 43(3): 219-222.

Sundareswari, C. and Sudarmani, D. N. P. 2019. Biochemical changes in the leaves of brinjal (*Solanum melongena* L) infected with ladybird beetle, *Epilachna vigintioctopunctata*. *J. Entomol. Zool. Stud.* 7(4): 598-601.

Suresh, S. and Kavitha, P. C. 2008. Seasonal incidence of economically important coccid pests in Tamil Nadu. In: Branco, M., Franco, J. C., and Hodgson, C. J. (eds), *Proceedings of the XI International Symposium on Scale Insect Studies*, 24–27 September 2007, Oeiras, Portugal,pp. 285–291.

Tabashnik, B. E., Van Rensburg, J. B. J., and Carrière, Y. 2009. Field-evolved insect resistance to Bt crops: definition, theory, and data. *J. Econ. Entomol.* 102(6): 2011-2025.

Tacoli, F., Bell, V. A., Cargnus, E., and Pavan, F. 2018. Insecticidal activity of natural products against vineyard mealybugs (Hemiptera: Pseudococcidae). *Crop Prot.* 111: 50-57.

Vastrad, A. S., Lingappa, S., and Basavanagoud, K. 2002. Vegetable oils as synergists of synthetic pyrethroids against diamondback moth, *Plutella xylostella* L. (Yponomeutidae Lepidoptera). *J. Entomol. Res.* 26(4): 285-290.

Vevai, E. J. 1970. Know your crop, its pest problems and control: Brinjal. *Pesticides*. 4: 26-33.

Vickerman, G. P.1988. Farm scale evaluation of the long-term effects of different pesticide regimes on the arthropod fauna of winter wheat. In: Greeves, M. P., Grieg-Smith, P. W., and Smith, B. D. (eds.). *Fields methods for the study of environmental effects of pesticides*. BCPC Monograph No. 40 British Crop Protection Council, Farnham, UK, pp. 127-135.

Vijay, A. and Suresh, S. 2013. Coccid pests of flower and medicinal crops in Tamil Nadu. *Karnataka. J. Agric. Sci.* 26: 46–53.

War, A. R., Paulraj, M. G., and Ignacimuthu, S. 2011. Synergistic activity of endosulfan with neem oil formulation against tobacco caterpillar *Spodoptera litura* (Fab.)(Lepidoptera: Noctuidae). *J. Entomol*. 8(6): 530-538.

Ware, G. W. 1980. *Effects of pesticides on nontarget organisms. In Residue reviews.* Springer, New York, 173-201p.

Wheeler, D. A. and Isman, M. B. 2001. Antifeedant and toxic activity of *Trichilia americana* extract against the larvae of *Spodoptera litura*. *Entomol. Exp. Appl.* 98(1): 9-16.

Willmott, A. L. 2012. *Efficacy of Systemic Insecticides Against The Citrus Mealybug, Planococcus citri, and Pesticide Mixtures Against the Western Flower Thrips, Frankliniella occidentalis, in Protected Environments*. PhD Thesis, Kansas State University, 345p.

Zadda, K., Rajendran, R., and Vijayaraghavan, C. 2007. Influence of organic fertilizers in inducing resistance to Epilachna beetle, *Henosepilachna vigintioctopunctata* (Wied.) and ash weevil, *Myllocerus maculosus* (Desb.) in brinjal. *J. Appl. Zool. Res.* 18(1): 24-28.

Zhao, B., Grant, G. G., Langevin, D., and MacDonald, L. 1998. Deterring and inhibiting effects of quinolizidine alkaloids on spruce budworm (Lepidoptera: Tortricidae) oviposition. *Environ. Entomol*. 27(4): 984-992.

ABSTRACT

BOTANICALS FOR THE MANAGEMENT OF PESTS OF BRINJAL, *Solanum melongena* L.

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ABSTRACT

The study entitled "Botanicals for the management of pests of brinjal, *Solanum melongena* L. was undertaken in the Department of Agricultural Entomology at College of Agriculture, Vellayani during the period 2018-2020 with an objective to manage the pests of brinjal using botanicals including formulation of cashew nut shell liquid (CNSL).

Laboratory evaluation of CNSL was done taking epilachna beetle (*Henosepilachna vigintioctopunctata* (F.)) and mealybugs as test insects of chewing and sucking type respectively. Cashew nut shell liquid (CNSL), a potential insecticide and a cheap by-product of cashew industry containing a mixture of phenolic compounds which was formulated into an emulsifiable concentrate formulation in Department of Agricultural Entomology, College of Agriculture, Vellayani was evaluated at different concentrations *viz.*, CNSL @ 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % against *H. vigintioctopunctata* and CNSL @ 0.05, 0.075, 0.1, 0.25, 0.75, 1 and 2 % against mealybugs. Emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 % served as the chemical check for epilachna beetle and mealybugs respectively.

Higher concentrations of CNSL (5 %, 4 %, 3 %, 2 % and 1 %) was found to be superior with mortality ranging from 53.33 to 80 per cent at 2 and 3 DAT when tested against *H. vigintioctopunctata.* At 5 and 7 DAT, 100 per cent mortality was recorded in chemical check, emamectin benzoate 5 % SG @ 0.04 % which was on par with CNSL 4 % and 5 %. CNSL 1 %, 2 % and 3 % also was on par, though inferior to the chemical check. CNSL at higher concentrations (1 - 5 %) produced high mortality ranging from 66.67 to 93.33 per cent of epilachna beetles under laboratory conditions.

Against mealybugs, at 2 and 3 DAT all the CNSL treatments were on par with each other with mortality percentage ranging from 0 to 26.67. At 5 and 7 DAT, CNSL treatments produced superior mortality over control. However, when tested against mealybugs, the chemical check thiamethoxam 25 % WG @ 0.015 % produced superior mortality at different intervals after treatments. At 7 DAT, higher concentrations of CNSL (1 % and 2 %) produced mortality comparable to chemical check.

Probit analysis was performed to find the dose mortality response. The LC_{50} and LC_{90} values of CNSL against *H. vigintioctopunctata* were 0.26 and 4.35 % respectively and that against mealybugs were 0.37 and 7.64 % respectively.

CNSL at different concentrations *viz.,* 0.05, 0.075, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4 and 5 % was applied on to brinjal plants and the phytotoxicity symptoms were scored as per CIB RC protocol where in no phytotoxicity was noticed at lower concentration ranging from 0.05 to 1 %. Slight (negligible) and moderate phytotoxicity were noticed in plants exposed to CNSL @ 2 and 3 % respectively. Plants treated with 5 % exhibited severe phytotoxic symptoms with severe necrosis and subsequent leaf fall.

Based on the results of laboratory and phytotoxicity evaluation, CNSL concentrations 0.25 % (LC_{50} value), 0.5 %, 1 % and 2 % were selected for further laboratory evaluation using *H. vigintioctopunctata* as test insect. Commonly used botanicals *viz.*, neem oil 2 % and pongam oil 1 % and chemical emamectin benzoate 5 % SG @ 0.04 % were also tested. All the CNSL treatments except 0.25 % produced superior mortality over control at 2 DAT. At 3 DAT, CNSL 1 % and 2 % recorded significantly superior mortality than rest of the treatments and was on par with chemical check. At 5 and 7 DAT, all the CNSL treatments and neem oil 2 % produced mortality superior over control though inferior to chemical check. Pongam oil 1 % was found to be ineffective at all intervals.

A pot culture experiment was carried out in brinjal (Vellayani local) with effective CNSL concentrations selected based on the laboratory experiments. Combination treatment with neem oil (CNSL 0.25 % + neem oil 1 %, CNSL 0.5 % + neem oil 1 % and CNSL 1 % + neem oil 1 %) were also tested. Emamectin benzoate 5 % SG @ 0.04 % and thiamethoxam 25 % WG @ 0.015 % served as the chemical checks. Two rounds of application one each at vegetative and reproductive phase were administered.

In vegetative stage, there was no major pest incidence. In reproductive stage CNSL 1 % and chemical check emamectin benzoate 5 % SG @ 0.04 % found superior with lowest pest (*H. vigintioctopunctata*) population at 2 DAT. All other CNSL treatments and the combination treatments found superior over control though inferior to chemical check. At 3 and 5 DAT, CNSL alone (0.5 % and 1 %) was found to be superior and equally effective as that of chemical check. All combination treatments of CNSL with neem oil 1 % were also found to be effective. There was no significant difference between the treatments in managing mealybugs and the crop yield was also not significant among treatments. Phytotoxicity evaluation in pot culture studies had recorded no phytotoxicity. Analysis of biometric parameters (plant height, internode length, number of leaves and yield) did not exhibit any adverse effect on plant growth upon treatment with CNSL. CNSL treatments @ 1 % or below neither produced phytotoxic effect nor affected the growth characteristics of brinjal. Thus CNSL @ 1 %, can be used as a botanical pesticide against pests of brinjal.

സംഗ്രഹം

വഴുതനയിലെ കീടങ്ങളെ സസ്യജന്യമായ കീടനാശിനികൾ ഉപയോഗിച്ചു നിയന്ത്രിയ്ക്കുന്നതിനായി 2018-20 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിലെ കീടശാസ്ത്ര വിഭാഗത്തിൽ നടത്തിയ ഗവേഷണമായിരുന്നു "ബൊട്ടാണിക്കൽസ് ഫോർ ദ മാനേജ്മെൻറ്റ് ഓഫ് പെസ്റ്റ് ഓഫ് ബ്രിഞ്ജാൾ."

കശുവണ്ടി തോടിൽ നിന്നും ലഭിക്കുന്ന കശുവണ്ടി തോട് ദ്രവം അഥവാ ക്യാഷൂ നട്ട് ഷെൽ ലികിഡ് (CNSL) എമൽസിഫയബിൾ കോൺസെൻട്രേറ്റ് ഫോർമുലേഷനായി രൂപപ്പെടുത്തി (CNSL 20 % EC) വിവിധ സാന്ദ്രതകളിൽ വഴുതനയിലെ ആമ വണ്ടിനും (ഹീനോസെപിലാക്ന വിജിന്ടിയോക്ടോപന്ക്ടേറ്റ) മീലി മുട്ടയ്കുമെതിരെ പരീക്ഷിച്ചു.

ആമ വണ്ടിനെതിരെ പരീക്ഷിച്ചപ്പോൾ CNSL ഉയർന്ന സാന്ദ്രതകളിൽ (5 %, 4 %, 3 %, 2 %, 1 %) രണ്ടും മൂന്നും ദിവസങ്ങൾക്ക് ശേഷം 53.33 മുതൽ 80 % വരെ മരണനിരക്ക് ഉണ്ടാക്കുന്നതായി കണ്ടു. അഞ്ചും ഏഴും ദിവസങ്ങൾക്ക് ശേഷം രാസ കീടനാശിനി ആയ എമമെക്റ്റിൻ ബെൻസോയേറ്റ് 5 % SG 0.04 %, 100 % വരെ മരണനിരക്ക് ഉണ്ടാക്കുന്നതായി കണ്ടു. CNSL 4 %, 5 % എന്നിവ രേഖപ്പെടുത്തിയ മരണനിരക്ക് എമമെക്റ്റിൻ ബെൻസോയേറ്റിനു തുല്യമായി കണ്ടു. രാസ കീടനാശിനിയേക്കാൾ താഴ്ന്നതാണെങ്കിലും CNSL 1 %, 2 %, 3 % എന്നിവയും ഗണികമായി തുല്യ മരണനിരക്ക് രേഖപ്പെടുത്തി. ആമ വണ്ടുകളിൽ, ഉയർന്ന

സാന്ദ്രതയിലുള്ള CNSL (1 - 5 %) ലബോറട്ടറി സാഹചര്യങ്ങളിൽ 66.67 മുതൽ 93.33 % വരെ മരണനിരക്ക് ഉണ്ടാക്കി.

മീലി മുട്ടക്കെതിരെ പരീക്ഷിച്ചപ്പോൾ രണ്ടും മൂന്നും ദിവസങ്ങൾക്ക് ശേഷം എല്ലാ CNSL സാന്ദ്രതകളും (0.05 %, 0.075 %, 0.1 %, 0.25 %, 0.75 %, 1 % and 2 %) തുല്യ മരണനിരക്ക് ഉണ്ടാക്കുന്നതായി കണ്ടു (0 മുതൽ 26.67 % വരെ). ഏഴാം ദിവസത്തിൽ CNSLന്റെ ഉയർന്ന സാന്ദ്രത (1 %, 2 %) സൃഷ്ടിച്ച മരണനിരക്ക് രാസകീടനാശിനിയായ തയോമെത്തോക്സാം 25 % WG 0.015 % നോട് താരതമ്യപ്പെടുത്താവുന്നതായിരുന്നു.

പ്രോബിറ്റ് വിശകലനം നടത്തിയപ്പോൾ CNSLന്റെ LC_{50}, LC_{90} മൂല്യങ്ങൾ ആമ വണ്ടിനെതിരെ യഥാക്രമം 0.26 ഉം 4.35 ശതമാനവും മീലി മുട്ടക്കെതിരെ യഥാക്രമം 0.37 ഉം 7.64 ഉം ആണെന്ന് കണ്ടെത്തി.

0.05, 0.075, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4, 5% എന്നിങ്ങനെ വ്യത്യസ്ത സാന്ദ്രതകളിലുള്ള CNSL വഴുതന സസ്യങ്ങളിൽ പ്രയോഗിക്കുകയും തൻമൂലം ചെടിയിൽ ഉണ്ടാകുന്ന വിഷലിപ്തത ലക്ഷണങ്ങൾ പഠിക്കുകയും ചെയ്തു. കുറഞ്ഞ സാന്ദ്രതയിൽ (0.05 മുതൽ 1 % വരെ) യാതൊരു വിധ സസ്യവിഷലിപ്തത ലക്ഷണങ്ങളും കാണുവാൻ സാധിച്ചില്ല. CNSL @ 2 %, 3 % എന്നിവ തളിച്ച സസ്യങ്ങളിൽ നേരിയ (നിസാരമായ) വിഷലിപ്തത ലക്ഷണങ്ങൾ കണ്ടെത്തി. 5 % CNSL പ്രയോഗിച്ച

സസ്യങ്ങൾ കടുത്ത കോശമരണവും തുടർന്നുള്ള ഇല വീഴ്ചയും ഉള്ള കടുത്ത വിഷലിപ്തത ലക്ഷണങ്ങൾ പ്രകടമാക്കി.

സസ്യവിഷലിപ്തത ലക്ഷണങ്ങൾ പ്രകടമാക്കാത്ത CNSL @ 0.25 %, 0.5 %, 1 %, 2 % എന്നിവ കൂടുതൽ ലബോറട്ടറി വിലയിരുത്തലിനായി തിരഞ്ഞെടുത്തു. സാധാരണയായി ഉപയോഗിക്കുന്ന സസ്യജന്യ കീടനാശിനികളായ, വേപ്പ് എണ്ണ 2 %, പൊങ്കം എണ്ണ 1 %, എന്നിവയും രാസ കീടനാശിനി ഇമാമെക്റ്റിൻ ബെൻസോയേറ്റ് 5 % SG @ 0.04 % എന്നിവയും പരീക്ഷിച്ചു. 0.25 % ഒഴികെയുള്ള എല്ലാ CNSL ചികിത്സകളും രണ്ടാം ദിവസത്തിനു ശേഷം നിയന്ത്രണത്തെക്കാൾ മികച്ച മരണനിരക്ക് സൃഷ്ടിച്ചു. മൂന്നാം ദിവസത്തിൽ, CNSL 1 %, 2 % എന്നിവ മറ്റുള്ളവയെക്കാൾ ഉയർന്ന മരണനിരക്ക് രേഖപ്പെടുത്തി. ഇത് രാസകീടനാശിനിയ്ക്ക് തുല്യമായി കണ്ടു. അഞ്ചും ഏഴും ദിവസത്തിൽ, എല്ലാ CNSL ചികിത്സകളും വേപ്പ് എണ്ണയും 2 % രാസ കീടനാശിനിയേക്കാൾ താഴ്ന്നതാണെങ്കിലും നിയന്ത്രണത്തെക്കാൾ മികച്ച മരണനിരക്ക് ഉൽപാദിപ്പിച്ചു. എല്ലാ ഇടവേളകളിലും പൊങ്കം എണ്ണ 1 % ഫലപ്രദമല്ലെന്ന് കണ്ടെത്തി.

ലബോറട്ടറി പരീക്ഷണങ്ങളെ അടിസ്ഥാനമാക്കി ഫലപ്രദമായ CNSL സാന്ദ്രതകൾ ചട്ടികളിൽ വളർത്തിയ വഴുതനയിൽ (വെള്ളായണി ലോക്കൽ) പരീക്ഷിച്ചു. വേപ്പ് എണ്ണയുമായുള്ള (CNSL 0.25 % + വേപ്പ് എണ്ണ 1 %, CNSL 0.5 % + വേപ്പ് എണ്ണ 1 %, CNSL 1 % + വേപ്പ് എണ്ണ 1%) സംയോജിത മിശ്രിതവും പരീക്ഷിച്ചു. എമമെക്റ്റിൻ ബെൻസോയേറ്റ് 5 % SG 0.04 %,

തയോമെത്തോക്സാം 25 % WG 0.015 % എന്നിവ രാസ കീടനാശിനികളായും ഉപയോഗിച്ചു.

CNSL 1 %, എമാമെക്റ്റിൻ ബെൻസോയേറ്റ് 5 % SG @ 0.04 % എന്നിവ പ്രയോഗിച്ച സസ്യങ്ങളിൽ കുറഞ്ഞ കീടബാധ കാണപ്പെട്ടു. മറ്റെല്ലാ CNSL സാന്ദ്രതകളും സംയോജിത മിശ്രിതത്തെക്കാളും രാസ കീടനാശിനിയേക്കാളും താഴ്ന്നതാണെങ്കിലും നിയന്ത്രണത്തെക്കാൾ മികച്ച കീട നിയന്ത്രണം കണ്ടെത്തി. CNSL 0.5 %, 1 % എന്നിവ രാസ കീടനാശിനിയെപ്പോലെ ഫലപ്രദമാണെന്ന് കണ്ടെത്തി. വേപ്പ് എണ്ണ 1 % ആയുള്ള CNSLന്റെ എല്ലാ സംയോജിത മിശ്രിത ചികിത്സകളും കീട നിയന്ത്രണത്തിന് ഫലപ്രദമാണെന്ന് കണ്ടെത്തി. എന്നാൽ മീലി മുട്ടയുടെ എണ്ണത്തിലും വിളവിലും കാര്യമായ വ്യത്യാസം കാണുവാൻ സാധിച്ചില്ല. ഈ പഠനത്തിൽ ഉപയോഗിച്ച സാന്ദ്രതകൾ
ഒന്നുംതന്നെ സസ്യ വിഷ ലക്ഷണങ്ങൾ പ്രകടമാക്കിയില്ല. CNSL @ 1 % അല്ലെങ്കിൽ അതിൽ താഴെ ഉള്ള സാന്ദ്രതകൾ സസ്യങ്ങളിൽ വിഷലിപ്തത ലക്ഷണങ്ങൾ ഉണ്ടാക്കുകയോ സസ്യത്തിന്റെ വളർച്ചയെ പ്രതികൂലമായി ബാധിക്കുകയോ ഉണ്ടായില്ല. അയതിനാൽ CNSL 1 % വീര്യത്തിൽ, വഴുതന കീടങ്ങൾക്കെതിരെ ഒരു സസ്യജന്യ കീടനാശിനിയായി ഉപയോഗിക്കവുന്നതാണ്.