CERTIFICATE

This is to certify that the thesis entitled **"SYNERGY OF NEEMSWEET FORMULATION WITH OTHER PLANT ORIGIN INSECTICIDES AGAINST DIAMONDBACK MOTH, *Plutella xylostella* (Linnaeus) AND TOBACCO CATERPILLAR, *Spodoptera litura* (Fabricius)"** submitted in part fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a bonafide record of research work carried out by **Mr. S. RAJA** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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SYNERGY OF NEEMSWEET FORMULATION WITH OTHER PLANT ORIGIN INSECTICIDES AGAINST DIAMONDBACK MOTH, *Plutella xylostella* (Linnaeus) AND TOBACCO CATERPILLAR, *Spodoptera litura* (Fabricius)

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

CENTRE FOR PLANT PROTECTION STUDIES

TAMIL NADU AGRICULTURAL UNIVERSITY

COIMBATORE - 641 003

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Thesis submitted in part fulfilment of the requirements for the degree of

MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL ENTOMOLOGY

to the Tamil Nadu Agricultural University, Coimbatore - 641 003

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2009

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ABSTRACT

Synergy of NeemSweet formulation with other plant origin insecticides against diamondback moth, *Plutella xylostella* (Linnaeus) and tobacco caterpillar, *Spodoptera litura* (Fabricius)

By

S. RAJA

Degree : M**aster of Science in Agricultural Entomology**

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Coimbatore – 641 003.

Year : **2009**

Investigations were carried out to test a new neem based formulations developed using seed extracts of neem (*Azadirachta indica*; A. juss), Pungam (*Pongamia glabra* Vent.), and Poison nut or nuxvomica or *Etti* (*Strychnos nuxvomica* Lin.), rhizome extracts of sweet-flag (*Acorus calamus* Linn.) and leaf extracts of lemonbush or *Poduthalai* (*Lippia nodiflora* Burm.f), chast tree or *Notchi* (*Vitex negundo* Lin.) for behavioural and physiological effects against the diamondback moth, *Plutella xylostella* (Lin.) and tobacco caterpillar, *Spodoptera litura* (Fab.) under laboratory and its efficacy under field conditions.

NeemSweet (Neem+ Sweet-flag extract - NS) was the base combination to mix other botanical extracts like *Pungam* (P), *Strychnos* (S), *Lippia* (L) and *Vitex* (V) to formulate as NSS 60 EC (Neem + Sweetflag + *Strychnos*), NSL 60 EC (Neem + Sweetflag + *Lippia*), NSV 60 EC (Neem + Sweetflag + *Vitex*) and NSP 60 EC (Neem + Sweetflag + *Pungam*) and evaluate their bioefficacy.

Among the combinations NSS 0.5% recorded improved efficacy over the NSKE 5% in deterring *S. litura* larvae from feeding and adults from oviposition. NSL 0.5% deterred *P. xylostella* adults which recorded only 4.13 per cent oviposition. NSS 0.5% registered the high antifeedant index (93.39 and 81.65) on second and fourth instar of *P. xylostella* respectively. Food intake was reduced in third and fifth instar larvae of *S. litura* fed on NSS 0.5% treated cauliflower leaves followed by NSV 0.5%. Consumption index, growth rate, ingestion and postingestive utilization of foods were reduced in second and fourth instar of *P. xylostella* fed on NSS 0.5% treated cauliflower leaves followed by NSP 0.5%.

Higher larval-pupal intermediate and least pupation percentage was recorded in NSL 0.5% (30.00 % and 40.00 % respectively) on third instar larvae of *S. litura*. Higher percentage of larval pupal intermediate was recorded in NSP 0.5% (26.67%) and lowest percentage of pupation was recorded in NSV 0.5% (66.67%) on fifth instar larvae of *S.litura.* Emergence of malformed adults was higher in NSV 0.5% (50.08% and 50.00%) on third and fifth instar of *S. litura* respectively. Formation of larval-pupal intermediate was significantly higher in NSV 0.5% (18.87% and 22.64%) and pupation percentage was low in NSS 0.5% (59.45% and 62.74%) on second and fourth instar larvae of *P. xylostella* respectively. Emergence of malformed adults was higher in NSL 0.5% (22.49%) and highest percentage of malformed adults emerged in NSL 0.5% (38.76) on second and fourth instar of *P. xylostella* respectively.

Under field condition both NSS 60 EC 2 ml l^{-1} (64.09% and 65.53%), NSP 60 EC 2 ml l^{-1} (61.71% and 62.10%) had significantly reduced population of tobacco caterpillar followed by NeemAzal 2 ml l^{-1} (54.03% and 54.43%), respectively in field trial I and II. Also, NSS 2 ml l^{-1} treatment was found to be effective in reducing caterpillar damage

(20.31 and 13.09%) followed by NSP 2 ml l^{-1} (21.70 and 14.10%) and NeemAzal 2 ml l^{-1} (22.01 and 15.09% respectively) in both consecutive trials.

In both field trials I and II, NSS 60 EC 2 ml l^{-1} (81.91 and 80.66%) recorded highest reduction in larval population of diamondback moth and followed by NSP 60 EC 2 ml l^{-1} (75.91 and 77.13 %) and NeemAzal 2 ml l^{-1} (69.76 %) respectively. With regard to per cent leaf damage, NSS 2 ml l^{-1} (33.67 and 29.29%) treated plot had significantly lower diamondback moth damage followed by NSP 2 ml l^{-1} (34.17 and 29.73%) and NeemAzal 2 ml l^{-1} (34.79 and 30.27%) respectively. However, the untreated check had significantly higher diamondback moth damage in both field trials.

ACKNOWLEDGEMENT

"THE INFLUENCE OF THE TEACHER NEVER ENDS'' ***- Henry Adams***

I extol and implore the almighty, which guides and showers mental strength and ecstasy victory all my life.

I respect and thank the guiding lights of this world, the noble teaching community who have groomed me, helped me to step up to this height, inculcated me with knowledge and wisdom.

I express my wholehearted thanks to my chairman, ***Dr. S. Raguraman****, Professor, Department of Agricultural Entomology, a versatile personality who helped me in bringing out this thesis by his whole hearted care, innovative guidance, altruistic efforts, patience, appeal and facilitate amazing contextual explanations, motivation throughout the period of my study. It's rare to find a mentor like my sir.*

I am extremely grateful to my Advisory Committee members, *Dr. K. Gunasekaran* ***Professor (Entomology) for his benevolent guidance, constant encouragement and care towards me and*** *Dr. P. Paramaguru****, Professor (Horticulture) for his kind concern, expert advice and timely guidance throughout the period of my research.***

I am privileged to place my special note of thanks and gratitude to our batch PG Coordinator, *Dr. S. Chandrasekaran****, Professor (Entomology) for helping us to get the PG lab for his inspiration, selfless effort and the cordial moral support. I profoundly thank*** *Dr. N. Ganapathy****, Professor (Entomology, Agri Business Development) for his benevolent guidance, constant encouragement and care towards me. I also thank*** *Dr. P. Sivasubramanian (Professor and Head), Dr. Kalyanasundaram* ***Professor (Entomology) and*** *Dr. M. Kannan (Young Scientist)* ***for providing me the facilities to do the research work.***

A special note of laud and gratefulness goes to my senior guides *JP, Mani Tmt. N. Boomathi, Ravi, Murali, Sampath, Govindhan, Arul prakash, Raghavan* ***with a sound calibre and strong acuity, acumen, enthuse, passion, trigger and zeal for science, a role model personality who can mould any clay. I am grateful to him for his novel lead ideas, guidance with constant encouragement and constructive criticisms.***

Friends make our life beautiful. It is superfluous to say a word of thanks, my hearty thanks goes to my best friends *Parames, Velan, Niru, Anand, Kicha, Ravi, Amudhan, AP, Selva, Logu, Arun, Kanagu, Thariq, Bhuva, Kannan, Oli, Manick, Arul, Santosh, Thomas, Poun, Daniel, Alagendran, Beski, Mani, Kulandai, Phlomin, Arockium, Kousal, Visnu, Raju, Desi, Sakthi, Mathi, Karuna, Abi* ***for their cooperation and friendly behavior and resource sharing nature, ever willing to support, strengthen and help me during the period of study.***

I thank the future scientists, my class mates ***Chris, Kumar, Siddu, Ragu, Senthil, Gokul, Aravind, Reddy, Jegan, Chitra, Nafeesa, Divya*** *and* ***Maha*** *for making these two years evergreen, memorable and cherishable****.***

I am indebted to my dear friends *Ramesh, Kicha, Nandhu, Karuppu, Ghouse, Mani, Susi, Mohan, Selva, Arun, Karpooram, Belli, Karthi, Adiyaman, Prasanna, Kesavan* ***and all other friends for their heartfelt assistance and sustained efforts.***

I thank my dear junior friends ***Senthil, Mani, Kaliyamurthy, Bundy*** *for their intellectual hold and gallant assist all the way through. I thank* ***Tmt. Rani, Mr. Marimuthu, Mr. Siva, Tmt. Santha*** *of the insectary who assisted me in carrying out the research. I thank all the office staff, SRFs and other members of Entomology for their timely help rendered towards me.*

Words can never articulate my gratitude to my parents, for their constant adoration and hold, which care me the most with love, commendable sacrifice, hard work for bringing up me with invariable encouragement, prayers and blessings which guided me all the way of this study. I extend my devotional thanks to beloved living God's in my soul my father Thiru R. Subramani (late) my mother Smt. S. Tamilselvi. I thank the god for giving me such wonderful parents, without them all my hard work, success, laurels and limelight is meaningless.

I am very much elated to convey my appreciation to my beloved *Mottayappan, Chitrapalanisami, Ravi, Priyaranjani, Nithya, Senthil* ***who showered their fondness and warmth all through.***

I am very much grateful to my farmers, *Mr. Aaruchamy* ***and*** *Mr. Subramani****,*** ***Narasipuram for providing hands to conduct the field trials.***

(S. RAJA)

CHAPTER I

INTRODUCTION

Vegetables play a vital role in human nutrition. India is the second largest producer of vegetables with a harvest of approximately 110 million tonnes from 6 million hectares of cultivated area with productivity of 15.2 t ha^{-1} during 2005-2006 (APEDA, 2008). In addition, the availability of vegetable is 140 g / caput / day, which is far below the minimum requirement of 285 g / caput / day.

In vegetable cultivation, more than 40 per cent yield loss is caused by insect pest infestation. Nearly 18 per cent of total pesticides used are utilized in vegetable cultivation. The persistence of toxic residues in/on edible part(s) limits the choice of pesticides and makes the management of pests of vegetables more sensitive and challenging.

Cauliflower and cabbage are important cole crops grown in India. These crops are infested by several insect species including diamondback moth, *Plutella xylostella (*Lin*.),* tobacco caterpillar, *Spodoptera litura* (Fab.), cabbage butterfly, *Pieris brassicae* (L.), head borer, *Hellula undalis* (Fab.), webworm, *Crocidolomia binotalis* (Zell.) and semilooper, *Trichoplusia ni* etc.,

Diamondback moth (DBM), *Plutella xylostella* (Lin.) (Lepidoptera; Plutellidae) is a major pest of cruciferous vegetables throughout the world. DBM was first recorded in India in 1914 on cruciferous vegetables (Fletcher, 1914). Now, it has become very serious in many regions because of its ability to establish in newer areas, coupled with high reproductive potential and shorter life cycle and the year-round availability of the host plants. The crop loss due to DBM varied from 52 to 100 per cent (Calderon and Hare, 1986). The main method of control adopted the use of insecticides. Its control on cruciferous crops worldwide costs about $ 1 billion per annum, primarily with insecticides (Talekar, 1992; Talekar and Shelton, 1993).

Spodoptera litura (Fab) commonly known as tobacco caterpillar is one of the serious insect pests of crucifers. In India, it is considered as a pest of national

importance on account of its polyphagous nature attacking several agricultural and horticultural crops. It has been reported from 51 countries causing damage to 112 species of plants belonging to 44 families. In India, it feeds on 74 species of cultivated crops including some wild plants (Moussa and Kotby, 1960). Besides crucifers, it attacks groundnut, tobacco, cotton, pulses and several vegetable crops (Raja Reddy and Divakar, 2007).

In recent years, due to the availability of early varieties and the prospects of higher value in the off season, cabbage and cauliflower crops are grown almost throughout the year necessitating the alarming use of insecticide in India. As a result of excessive selection pressure exerted by the intensive use of insecticides, the field population of both the insects has developed resistance to most of the insecticides used (Verma and Sandhu, 1968).

Botanical pesticides are the best alternatives to manage the pests below the economic threshold level (ETL) and provide security to mankind from the residues of pesticides. In view of their environmental safety, botanicals are also the best alternatives to synthetic organic pesticides. Plant origin pesticides are emerging as viable components of integrated pest management (IPM). It is estimated that there are about 2, 50,000 to 5, 00,000 different species of plants in the world today (Dhaliwal and Arora, 2004). As many as 2400 plant species have been reported to possess pest control properties. Among these plant origin pesticides, neem (*Azadirachta indica* A. Juss) has been used since time immemorial in India. Its pest controlling properties were scientifically documented in laboratory and field tests (Pradhan *et al.,* 1962; Rajendran and Kareem, 1977; Raguraman, 1987 and 1994; Schmutterer, 1990; Singh, 1993; Isman, 1996). Besides neem, pungam (*Pongamia glabra* Vent.) and sweet-flag (*Acorus calamus* Linn.), poison nut or nuxvomica (*Strychnos nuxvomica* Linn.), chast tree (*Vitex negundo* Linn.) and lemonbush or *Poduthalai* (*Lippia nodiflora* Burm.) also possess highly odoriferous chemical compounds possessing insecticidal properties and are gaining importance in modern pest management programmes.

In the use of botanical pesticides, the major limiting factor is their faster photo degradability of biologically active compounds under field conditions. Hence, studies are undertaken to stabilize or to increase the toxicity/ efficacy of the neem compounds with other botanicals both in laboratory and field to ascertain their use in eco-friendly pest management strategy. The objectives of this present study are:

- To study the joint action efficacy of NeemSweet (Neem + Sweet-flag extract) with leaf extracts of *Lippia nodiflora* and *Vitex negundo* and seed extract of *Strychnos nuxvomica* and *Pongamia glabra* on behaviour and physiology of diamondback moth, *Plutella xylostella* and tobacco caterpillar, *Spodoptera litura* in laboratory.
- To evaluate the field efficacy of NeemSweet (Neem+Sweet-flag extract) with leaf extracts of *Lippia nodiflora* and *Vitex negundo* and seed extract of *Strychnos nuxvomica* and *Pongamia glabra* against diamondback moth, *Plutella xylostella* and tobacco caterpillar, *Spodoptera litura.*

CHAPTER II

REVIEW OF LITERATURE

The extensive use of broad-spectrum synthetic insecticides has resulted in many negative consequences like residue problem, development of resistance in target pests, resurgence of secondary pests, deleterious effects on non-target insects and environmental pollution. In this context, to avoid the ill effects of synthetic pesticides, use of plant origin insecticides and microbial pesticides is gaining importance as a viable alternative. Hence, the information on the progress made in the management of insect pests of important crops and in particular, diamondback moth, *Plutella xylostella* (Lin.) and tobacco cutworm, *Spodoptera litura* (Fab.) by ecofriendly methods has been reviewed hereunder.

2.1. Botanicals in pest management

The role of botanicals in IPM is indispensable and effective. Over 2400 plant species are known to contain insecticidal and insect repellent constituents. Benerji *et al.* (1985) listed out different indigenous plant species belonging to 27 families possessing insecticidal and antifeedant properties. A bird's eye view on literature scanning revealed that extracts of seeds of neem, nuxvomica and *Pungam,* leaves of *notchi* and lemonbush and rhizomes of sweet-flag have shown multiarray of activities through behavioural and physiological effects on insect pests, which are detailed below.

2.1.1. Neem

The neem tree or Indian lilac, (*Azadirachta indica* A. Juss : Meliaceae) is indigenous to India. All parts of the neem tree possess insecticidal properties, but seed kernel is the most potent. Neem contains bioactive compounds in the form of triterpenes or limonoids such as azadirachtin, azadirone, gedunin, meliontriol, nimbin, nimbolinin, nimbicidine, nimbolin, salanin, saponin, vepinin, vilasinin and a bitter principle margosine which are considered as repellents, antifeedants, growth inhibitors or oviposition suppressants (Schmutterer, 1984). Azadirachtin directly interacts with the endocrine activities by interfering the ecdysteroid and juvenile hormone titers in insects (Rembold *et al.,* 1987; Subramanyam *et al*., 1989). Azadirachtin, the most important

biologically active principle of neem seed kernel, showed phagodeterrent and toxic effects at 0.1 to 1000 ppm, when incorporated into the diets of different insect species (Singh, 1993). Neem products have so far been evaluated against more than 400 insect species, which are reported to be susceptible at different concentrations (Opender Koul and Seema Wahab, 2004).

2.1.1.1. Ovipositional deterrent effect

The ovipositional deterrent effect of neem seed kernel extract (NSKE) was reported against green leafhopper and brown planthopper on rice (Saxena *et al.,* 1981 and Islam, 1984); *Amrasca devastans* (Dist.) on okra (Sojitra and Patel, 1992); *Spodoptera litura* (Fab.) on tobacco (Chari and Ramprasad, 1993); *Helicoverpa armigera* (Hubner) on cotton (Gavigouda *et al.,* 1996) chickpea (Singh *et al.,* 1996), and castor (Patel and Patel, 1998); and *Earias vittella* (Fab.) on marigold (Saminathan *et al.,* 2000). There was no egg laying by *S. litura* on tobacco treated with 0.01% methanolic extract of neem seed kernel (Ayyangar and Rao, 1989). Methanolic extract of neem seed kernel (2%) reduced egg laying in *Crocidolomia binotalis* (Zell). (Fagoonee and Lauge, 1981). Rajapakse *et al*., (1998) reported the ovipositional deterrency of neem leaf powder at 0.2 per 40 g of seeds against *Callosobruchus maculatus* (Fab.) on cowpea.

Prabal Saikia *et al.* (1996) found that NeemAzal® exhibited multiple modes of action *viz.*, ovipositional deterrency, ovicidal, antifeedant property, contact toxicity and controlled brown planthopper effectively. Nauman and Isman (1995) reported that 1% crude oil emulsion significantly reduced the proportion of eggs by *S. litura* on treated plants. Significant increases in larval mortality, antifeedant and ovipositional repellency were found in radish terminal leaves treated with *Azadirachta* / neem (Kumar *et al*., 1997). Rajamohan and Regupathy (1999) reported that Neem Gold® (0.15% EC) and TNAU Neem (0.03% EC) reduced the oviposition of *S. litura*.

Aqueous extract (5%) and methanolic extract (1%) of neem seed significantly affected the fecundity of *H. armigera* on cotton (Morale *et al.,* 2000). All the neem formulations effectively deterred the oviposition of *Chilo partellus* (Swinhoe.) moths except NeemAzal® on

cumbu variety (Arun composite) as compared to control (Bhanukiran and Panwar, 2000). Neem seed oil proved to be an effective anti-ovipositional compound against *Dicladispa armigera* (Oliv.) in rice (Bora and Hazarika, 2001).

Five per cent aqueous extracts of neem seed kernel showed higher ovipositional deterrency against *S. litura* (Suresh *et al.,* 2003). Methanolic extract of Neem+Sweet-flag+Pungam (NSP) extract was the most effective as oviposition deterrent to pigeonpea pod borer, *H. armigera* (Boomathi, 2003). Neem oil 3% significantly reduced the oviposition against *H. armigera* in tomato (Sathish, 2003); Diamond back moth *Plutella xylostella* (Lin.) on cauliflower (Roopa *et al*., 2003). The methanol and chloroform extracts of neem kernel and nicotine sulphate were very effective against the oviposition of *H. armigera* (Bajpal and Sehgal, 2003).

Singh (1996) recorded that the number of eggs laid by *S. litura* females on Neemolin treated groundnut leaves was very minimum compared to untreated leaves. Methanol extract of *Melia azedirach* leaves at 5 % concentration inhibited the oviposition by *P. xylostella* adults completely (Suman Sharma and Metha, 2006). Dilawari *et al*. (1994) revealed that the adults of DBM laid significantly lesser number (upto 71 %) of eggs on the surfaces treated with methonal extract 5 % of neem seeds. Ge-Mei Liang *et al.* (2003) observed that commercial neem based insecticides, Agroneem (4.8 mg AZA/l), Ecozin (20 mg AZA/l) and Neemix (20 mg AZA/l) significantly reduced egg laying of *P. xylostella* on cabbage leaves and aluminium foil sheets. Neem based insecticide Repelin at 1% recorded the lowest number of eggs and more than 70 % reduction in egg laying over control but was at par with Nimbecidine 0.2% and Gronim 0.6% against mustard saw fly, *Athalia lugens proxima* Klug. on radish (Patel and Jhala, 1999). Coria *et al*. (2008) found that *Melia azedirach* leaf extract at 1 g / l of water fully deterred oviposition by the mosquito *Aedes aegyptii* L.

2.1.1.2. Ovicidal action

Saxena *et al.* (1981) observed reduced hatchability of eggs of *Cnaphalocrosis medinalis* on rice plants sprayed with 25 or 50 per cent neem oil as ultra low volume spray. Dip treatment of eggs of *S. littoralis* (Boisdual.) with neem suspension (2%)

reduced hatchability by 90% (El-Sayed, 1985). Ovicidal activity of neem oil on the eggs of *Phthorimaea operculella* (Zell.) (Shelke *et al.,* 1987) and *Dicladispa armigera* (Bora and Hazarika, 2001) was well documented.

Methanolic extract of neem seed extract adversely affected hatching of *S. litura* eggs (Gujar and Mehrotra, 1993). NSKE containing 2.5% azadirachtin caused significant mortality on eggs of *H. armigera* on lab lab (Hassan, 1999). Cent per cent ovicidal action by recommended neem formulations *viz.,* NeemAzal®, Multiplex®, and Achook® against stem borer, *Chilo partellus* (Swinhoe.) was reported by Bhanukiran and Panwar (2000). Boomathi (2003) found that NSP 0.18% significantly reduced the egg hatchability against pigeonpea pod borer, *H. armigera.* Ovicidal action of neem oil on the eggs of red cotton bug, *Dysdercus koenigii* (Fab) (Bhatal *et al*., 1991) was also reported.

Robert verkerk and Dennis wright (1993) reported that application of azadiractin at 10,100 and 1000 µg azadiractin / ml gave 11, 21 and 48 per cent mortality respectively on *P. xylostella* larva. When eggs were treated with commercial formulations of neem pesticides viz., Agro neem(4.8 mg AZA / l) Ecozin (20 mg AZA/ l) and Neemix (20 mg AZA/l), 61.6, 66.2 and 75.2 per cent of *P. xylostella* developed to neonates respectively (Ge-Mei Liang *et al*., 2003). A severe reduction in egg viability occurred in eggs treated with Neem seed kernel extract at 10% concentration in *Maruca vitrata* and *Clavigralla tomentosicollis* (Ekesi, 2000). Methonal extract of Neem leaves at 5 per cent completely inhibited the hatchability of cabbage butterfly, *Pieris brassicae* eggs (Suman Sharma, 2008).

2.1.1.3. Antifeedant effect

Pradhan *et al.* (1962) confirmed the antifeedant activity of neem against desert locust, *Schistocerca gregaria* (Forsk.). Extract of chinaberry leaves deterred feeding of corn earworm, *H. zea* (Boddie.) and fall armyworm, *S. frugiperda* (Smith.) when it was applied to corn seedlings (Millan *et al.,* 1969). Neem seed oil and cake were widely acknowledged for their antifeedant, repellent and insecticidal (Krishnaiah and

Kalode, 1984, Raguraman, 1987, Rajasekaran *et al.*, 1987; Lamb and Saxena, 1988; Murray Isman, 2006) properties.

The repellent and antifeedant effects of neem have been reported against a wide range of insect pests including migratory locust, *Locusta migratoria;* rice planthoppers, *Nilaparvata lugens* (Stal.) and *Sogatella furcifera* (Horvath.); the leaf folder, *C. medinalis* and ear eating caterpillar, *Mythimna seperata* (Ketker, 1976; Saxena, 1989). Azadirachtin (Koul *et al.,* 1996); methanolic extract of neem seed kernel (Ayyangar and Rao, 1989); neem leaf extracts (Koshiya and Ghelani, 1993); neem oil emulsion and NSKE (Rajendran and Kareem, 1977) and NSKE alone (Ayyasamy *et al.,* 1999; Murugan *et al.,* 1999) showed strong antifeedant activities against *S. litura*.

NSKE 5% was an effective antifeedant to pod borer of pigeonpea (Kareem, 1978). Low settlement and subsequently very low feeding of *S.litura* on neem treated leaves were recorded (Singh and Bathal, 1992). NeemAzal® formulations were effective as repellents and antifeedants besides being directly toxic to many sucking and chewing insects (Peter, 1994). Krishnaiah *et al.* (2000) reported that neem formulations *viz*., NGH®, Rakshak® and NeemAzal® significantly inhibited the feeding of all the hoppers in rice. Recently, Opender koul (2004) has compiled a comphensive account on insect antifeedant principles where he listed 900 compounds of which the bitter principle of neem ranks number one.

Srinivasa rao *et al*. (1999) reported that azadirachtin oil based formulation 1500 ppm at 0.0015% concentration showed 87.31 per cent reduction in feeding over control against gram pod borer, *H. armigera*. Lower feeding preference index was observed on neemolin groundnut treated leaves at 1% against *S. litura* (Singh *et al.,* 1996). Subramanium *et al*. (2006) found that NeemAzal T/S (1%) at 35 ppm resulted in 85.77 per cent feeding inhibition on *S. litura* 24 HAT. Azadirachtin at 1000 ppm was very effective in reducing *S. frugiperda* feeding on treated cotton upto 98.3 per cent (Kennath Raffa, 1987). Azadirachtin strongly suppressed feeding in *S. littoralis* larvae (Meisner *et al*., 1980); *E. insulana* (Meisner *et al*., 1981), methanol extracts of neem seeds in *Crocidolomia binotalis* (Fagoonee and Lauge, 1981) even at 0.001 % cocentration.

Michael Bomford and Murray Isman (1996) observed that under choice conditions, 1.3 ng of azadirachtin per cm^2 leaf area offered good protection to treated leaves, resulting in 50-75 per cent feeding deterrence in fifth instar larva of *S. litura*. When 5% methanol extract of neem seed kernel treated with food, reduced feeding significantly to second instar larva of *P. xylostella* (Dilawari *et al*., 1994); azadirachtin (10 µg/ml) significantly reduced weight gain by *P. xylostella* (Robert Verkerk and Wright, 1993). Dayani *et al*. (2000) observed that azadirachtin based insecticide (1ml/l) suppressed the feeding of the fourth instar larvae of *P. xylostella*.

Ge-Mei Liang *et al*. (2003) found that three neem based insecticides, Agroneem (4.8mg AZA / l), Ecozin (20 mg AZA/l) and Neemix (20 mg AZA/l) showed significant reduction in feeding on cabbage leaves by *P. xylostella*. Srinivasa Rao *et al.* (1996) revealed that botanical pesticide from neem acted as effective phagodeterrent (79.52 %) at 0.1% concentration against third instar larvae of *Achaea janata*. Petroleum ether extract of Neem leaves at 1% concentration completely inhibited the feeding of second instar grubs of *Henosepilachna vigintioctopunctata* (Muralikrishna Rao *et al*., 1990). Dodia *et al*. (1995) revealed that *Achaea janata* larvae failed to damage when fed with two plant extracts viz., neem leaves 10% and NSKE 5% after 24 hours feeding and NSKE 5% showed very good antifeedancy against this pest after 72 and 96 HAT. Patel and Jhala (1999) found that Margocide CK at 0.1% recorded highest leaf area consumption (72.27) was found most effective antifeedant against mustard sawfly, *Athalia lugens proxima* (Klug.) on radish. Samuel Praveen Kumar and Sundara Babu (1999) recorded that NeemAzal-F (5%) at 1ml/l gave 97.40, 81.19 and 98.24 per cent protection over control against leaf feeders of brinjal viz., *Acherontia styx, H. vigintioctopunctata* and *Mylloceros subfasciatus* respectively.

Murugan *et al*. (1992) found that azadirachtin at 2 ppm produced the highest feeding deterrence (82.25%) than all other limonoids like salanin, gedunin and deacetylgedunin at all concentrations against *H. armigera*. Feeding of *S. littoralis* larvae with 10-10000 ppm Suneem oil caused cessation or reduction in feeding (Adel and sehnal, 2000). In terms of antifeedant activity (Antifeedant Index AI_{50}), the most active

tetrahydroazadirachtin-A (90%) showed a value of 14 mgl^{-1} after 48h. against *H. armigera* (Vandana Sharma *et al*., 2006). When second instar larvae of gypsy moth, *Lymantria dispar* was fed with Bioneem 0.5% treated oak tree leaves gave 93% protection against feeding even upto 5 days (Miroslav Kostic *et al*., 2008). The effective doses which deter half of the aphid, *A. craccivora* population were neem oil (0.2%) and NSKE (1.7%) (Swaran Dhingra *et al*., 2008).

Kubo and Klocke (1982) proved that azadirachtin isolated from neem possessed antifeedent property on *H. zea* and *S. frugiperda*. Kumar and Sangappa (1984) observed that NSKE 5% and neem oil 3% reduced the pod damage by *H. armigera* in Bengal gram. Low settlement and subsequently very low feeding of *S. litura* on treated leaves were recorded (Singh and Bathal, 1992). Also, the antifeedant property of azadirachtin has been reported by many workers (Murray Isman, 1993 and 2006; Jeyarajan *et al*., 1993) on noctuids. Neem cake soil application @ 500 kg/ha + 1% neem oil emulsion spray at weekly interval recorded minimum incidence of *H. armigera.* (Mallikarjuna Rao *et al.,* 1999).

2.2.1.4. Insect growth regulatory activity

Kubo and Klocke (1982) proved that azadirachtin isolated from neem inhibited the larval ecdysis in *H. zea, S. frugiperda* and *H. virescens*. Azadirachin prolonged larval period, arrested growth and development and caused mortality of *H. armigera* (Sathyanarayana and Srivastava, 1984; Barnby and Klocke, 1987); against *S. litura* (Singh and Bathal, 1992; Isman, 1993; Jeyarajan *et al*., 1993). Neem products are known for their growth regulatory action in several insects (Schmutterer, 1990). Neem extract is a potent growth regulator affecting more than 16 species of insects (Opender Koul and Seema Wahab, 2004). Neem oil extracted by hexane was found effective in inhibiting growth and development of the *H. armigera* (Naumann and Isman, 1995). Methanolic extracts of neem seed kernel adversely affected larval growth and induced pupal and adult deformities in *S.litura* and Ailanthus defoliator, *Eligma narcissus indica* (Roth.) (Joseph, 2000).

Gupta *et al*. (1998) reported the effect of neem seed powder as soil amendment against the quiescent stages of *H. armigera*. After 120 h of NSKE treatment pupal formation in *H. armigera* was adversely affected (Jeyakumar and Gupta, 1999). Pre-pupae subjected to neem seed powder treated soil witnessed an abnormal metamorphosis and an inverse proportionate relationship in adult emergence (Mahapatro and Padmaja, 2000). Morale *et al*. (2000) studied the effect of some plant products against *H. armigera* and found that neem oil, karanj oil, cotton seed oil and neem seed extract (metanolic) 1 per cent and neem seed extract (aqueous) 5 per cent significantly affected the larval period. *H. armigera* larvae treated with azadirachtin rich fractions did not develop further into stages or if developed into adults, died during eclosion or showed frizzled or curled wings (Gupta and Birah, 2001).

Singh (1996) reported that larval survival and per cent pupation of *S. litura* were low at 0.5 % Neemolin treated groundnut leaves. Eric Haubruge *et al*. (1994) reported that Margosan- O 0.1 % concentration prolonged the development time and inhibited the larval growth in the fifth and sixth instar of the *S. littoralis* larvae. Nadia Dimetry *et al*. (1998) observed 5 % petroleum ether extract of neem fruits prolonged the time required for *S. littoralis* larvae to reach pupal stage upto 5.75 days also inhibited fertility of females that emerged from treated larvae. Sueli *et al*. (2001) found that the action of azadirachtin on the development of *Spodoptera littoralis* was prolonged at 1 ppm concentration. The third instar larvae had prolonged to 3.8 days than control (2.8 days). The effective concentration (EC_{50}) of azadirachtin 500 ppm to inhibit the 50 per cent population of second instar of *S. litura* was 2.9 ppm (Gurmeet singh *et al*., 2006).

Sannaveerappananavar and Viraktamath (1997) observed the growth regulatory activity and complete mortality of third and fourth instar DBM larvae within 5- 11 days at 2.4 %. When azadarachtin and NeemAzal at 1 µg azadirachtin ml^{-1} concentration were applied on *P. xylostella,* the larval growth and development were delayed (Nagesh and Sashi verma, 1997). Ramarethinam and Marimuthu (1998) found that Neem formulations like neem leaf extract, Nimbecidine (0.03%), Neem oil and NSKE at 0.2 %

reduced the larval growth index drastically and increase in percentage of malformations than control in *Pericallia ricini* (Fab.).

Krishnaiah and Kalode (1990) reported that spraying of NSKE at 5% adversely affected the growth of rice BPH (at 5000 ppm) and GLH (at 25000 ppm) and Neem oil at 3% affected orientation and settling behavior of BPH and GLH. Sharma (1992) recorded that topical application of azadirachtin –A at 10 µg / larvae strongly inhibited adults emergence (21.7%) and increased number of malformed adults (38.5%) in rice moth *Corcyra cephalonica*. Singh *et al*. (1996) observed that *Spilosoma obliqua* larval period extended from 17.25 days in control to 30.75 days at 0.5 % concentration with differences in pupal period, larval weight, pupal weight as well as adult emergence when fed with 0.4, 0.5 and 1 % concentration Neemolin treated leaves. Treatment with Neemazal-T/S significalntly reduced fecundity, longevity at 0.5% concentration against aphid, *Aphis craccivora*. (Nadia dimetry and Fatma EL- Hawary, 1997).

Azadirachtin SSF 22 very effectively retarded the growth rate of second instar larvae of *H. armigera* for the next 5 days period was found to be 0.516 mg/mg/ day for control and 0.177 mg/mg/day for azadiractin treatment at 40 µg concentration (Gujar, 1997) . The fecundity of *Caryedon serratus* was reduced to 33-35 % and 25-30% when exposed to *Acacia* and tamarind seeds treated with 0.5 and 1 g of neem leaf pellets (Murugesan *et al*., 2008). Neem formulation Ozoneem at 1% exhibited 59.39 % larval mortality, 25.99% deformed larva against *P. ricini* (Prathibha Misra *et al.*, 2007). Vandhana Sharma *et al*. (2006) revealed that Tetrahydro azadirachtin – A (90%) and azadirachtin –A (90%) with respective IC_{50} values of 280 and 390 mg l^{-1} inhibited 50 per cent of the adult emergence of the *H. armigera*. Feeding of second instar of *S. littoralis* with 10-1000 ppm suneem oil (0.1 -10 ppm azadirachtin) resulted in delaying of molts, death of larvae and pupae and sterility of emerged adults; with 10 ppm suneem oil, the number of progeny is reduced by 20-32 per cent (Adel and sehnal, 2000).

2.1.1.5. Insecticidal action and field efficacy

Neem oil and neem cake were tested for insecticidal properties against insect pests like aphids, locusts, tobacco cutworm and cotton bollworms (Sinha and Gulati, 1964; Goyal *et al.,* 1971; Thangavel *et al.,* 1975; and Meisner *et al*., 1980). When NSKE 5% was applied, maximum mortality of *Maruca testulalis* (Geyer.) was reported five days after treatment (Ramasubramanian and Sundara Babu, 1981). Neem oil has been reported to possess antifeedant and insecticidal properties against leaf and planthoppers and leaf folder of rice (Saxena *et al*., 1981; Heyde *et al*., 1984; Saxena and Khan, 1985 and Srinivasalu and Jeyarajan, 1988). The detrimental effect of neem oil against gall midge, leaf folder and stemborer of rice (Krishnaiah and Kalode, 1985; Logiswaran *et al*., 1988) was also documented. Neem products proved effective against insect pests of rice (Saxena *et al.,* 1986; Murugesan *et al*., 1987; Raguraman, 1987; and Mohan, 1989).

Neem emulsion (0.125%) and NSKE (5%) recorded about 42 per cent reduction in pod borer infestation on chickpea (Singh, 1990). NSKE 5% and neem oil 60 EC registered low pod borer damage of 16.3 and 16.8 percentage, respectively on pigeonpea (Durairaj and Ganapathy, 1998); on chickpea (Sharma and Dahiya, 1986) and on chilli (Rao *et al.,* 1998). Krishnaiah *et al*. (2000) recorded the least LC_{50} values in NeemAzal® against green leafhopper, NGH® against brown planthopper and Rakshak® against white backed planthopper.

Sarode *et al.* (1995) reported that two applications of NSKE 5% were found most effective against pod borer of pigeonpea, which had given maximum larval reduction of 63.69 and 53.48 per cent, respectively. In tomato, weekly spray application of 5% aqueous neem seed extract effectively controlled *H. armigera* (Ostarmann and Dreyer, 1995). Krishnamurthi *et al.* (1999) observed that ethanolic plant extracts (10%) showed equal effect as that of proven neem oil 3%, NSKE 5% and chlorpyriphos spray in reducing the population of rice leaf folder and rice brown spot.

Neem treatments were found effective against green leafhopper, yellow stem borer, rice gall midge, rice leaf folder and grasshopper (Nanda *et al*., 1993). Roshan Lal

(2000) reported that neem formulations *viz*., NeemGold® and NeemAzal® were significantly reduced the leaf folder damage. Granular neemorate formulation was found to be effective against stem borer, gall midge and whorl maggot in rice (Ratna Sudhakar, 2000). Sprays of NeemAzal® 5% @ 1.0 and 0.5 ml/l were effective against rice leaf folder, *Cnaphalocrocis medinalis* and yellow stem borer, *Scirpophaga incertulus* (Walk.), respectively (Dhaliwal *et al*., 2002).

Sitaramaiah *et al*. (1986) reported that NSKS 2% was more effective in controlling *S. litura* on tobacco nurseries in 2 days after spraying. Application of 20 per cent aqueous methanol defatted neem extract exhibited most pronounced effect on first and second instar of *Sylepta derogata* larva where 100 per cent mortality was recorded (Cobbinah and Osei Owusu, 1988). Ramarethinam *et al*. (2008) recorded the LC_{50} value of Nimbecidine 0.03% as 6.156 ml l^{-1} against early third instar of *S. litura*. NSKE (5%) recorded about 69.77 per cent reduction in leaf hopper, *Amrasca devastans* infestation on Okra (Alagar and Subramanian, 2006). Mane *et al*. (2008) found that NSKE 5 per cent and 10 per cent showed 45 per cent and 70 per cent mortality respectively against third instar of *S. litura*. When azadirachtin 1500 ppm sprayed at 750 g *ai*./ ha on groundnut exhibited 37.5 per cent population reduction in *S. litura* (Raja Reddy and Divakar, 2007).

Shivankar *et al*. (2008) observed that sprays of Azadirachtin 3000 ppm against *S. litura* resulted in greater mortality over soil application of phorate 3G on sugarbeet. The lowest population of GLH, *Nephotettix virescens* was recorded with application of neem cake at 5kg/0.032ha of rice nursery, followed by foliar spray of NSKE 5% in the main field (Rajappan *et al*., 2000). Shankaramurthy *et al*. (2006) reported that four commercial formulations viz., Soluneem (0.15%), Econeemplus (0.3%), Vijayneem (0.3%) and Neemark (0.6%) were significantly reducing the population of diamondback moth, *P. xylostella* on cabbage. NSKE 5% was most effective in causing larval mortality (58.02%) in DBM, *P. xylostella* (Sewak *et al.,* 2008; Rakesh pandey and Raju, 2003). Nagesh and Sashi verma (1997) revealed that NeemAzal (0.002%) was more effective in reducing population (71.40%) of *P. xylostella* on cabbage and its larval mortality

(at day 13) was found to increase with increasing exposure time fed with Azadirachtin treated Chinese cabbage (Robert Verkerk and Wright, 1993).

Nathu Ram *et al*. (2001) found that neem oil (0.5%), NSKE (3.25%) exhibited 50.93% and 56.07% mortality on *P. xylostella* larva respectively. Ojah and Singh (2003) recorded that spraying of Nimbecidine 0.03 EC at 7.5ml/l reduced the percentage infestation of *P. xylostella* from 38.30% to 30% on cauliflower. Bhavani and Punnaiah (2004) recorded that neem oil 100 EC at 1% concentration gave 68.5, 59.73, 66.58 and 70.63% protection against *H. undalis, C. binotalis, P. xylostella* and *S. litura* larvae respectively. One per cent neem oil spray reduced the mealybugs, *Centrococcus insolitus* population to 1.84 insects / leaf at seventh day after spray against the pre observation value of 8.31 insects/ leaf. Also reduction of 50 per cent insect population was recorded with 0.75% of neem oil spray 3 and 5 days after spray in brinjal (Poomalai Pugalenthi *et al*., 1996). Latif *et al.* (1996) revealed that Nimbecidine at 0.3% showed 38% and 14.3% pod damage and Ahook at 0.5% exhibited 66.77 per cent and 7 per cent pod damage against pod fly and podbug in comparison with untreated control 61.7 per cent and 14.1 per cent respectively in pigeonpea.

Neem oil 50 EC at 0.3% concentration (TNAU formulation) recorded high larval mortality (93.33%) 24 h. after treatment against serpentine leaf miner, *Liriomyza trifolii* burg. (Jeyakumar and Uthamasamy, 1997). Ahuja and Kalyan (2001)revealed that Neemgold (3ml l^{-1}) was found superior in reducing capsule damage by sesame gall fly, *Asphondylia sesami* and also gave maximum seed yield (500kg/ha.) which was at par with NSKE 5% (497 kg/ha.), Nimbecidine at 5ml/l (495 kg/ha.). Neemark at 1% recorded maximum larval mortality (56.64 was in equal efficacy with Gronim 0.6%, Nimbecidine 0.2% and Margocide CK 0.1% against mustard sawfly on radish (Patel and Jhala, 1999).

NeemAzal-F at 25 and 50 ppm spray levels were found toxic by contact (84.74 and 88.93% mortality respectively) against rice BPH and also NeemAzal-F (5%) at 1ml l^{-1} caused mortality (60.05%) against rice leaf folder (Prabal Saikia *et al*., 1996; Prabal Saikia and Parameswaran, 1999). Raveendran *et al*. (1998) revealed that spraying of Achook (1500 ppm) at 0.3% concentration resulted in 96.09 per cent population reduction in

groundnut leaf miner, *Aproaerema modicella* after 14 days of second spraying. The toxicity of azadirachtin to the second instar larvae of *H. armigera* (5.31 ±1.55 µg body weight) by topical treatment was estimated as LD_{50} of 4.415 µg/ insect (Gujar, 1997). NSKE at 0.5%, 0.75% and 1% concentrations gave significant protection to the tobacco against *S. litura* (Joshi *et al.,* 1984).

Tanu Sharma (2007) observed that *Mylabris phalreata* adults indicated the highest mortality of 73 per cent at 1% concentration of NSKE. Mohapatra and Srivastava (2008) reported that NSKE (5%) showed better performance in reducing the pod damage on redgram against spotted pod borer, *Maruca vitrata*. Raguraman *et al*. (2008) found that azadirachtin (3000 ppm) at 0.3% showed lesser (8.21%) pod damage at maturity compared to control (35.27%) against *H. armigera* on chickpea. Spraying of NSKE 10% on tomato reduced this pest population (Swaroop Singh *et al*., 2007); NSKE 5% spray reduced population of mango hoppers significantly (Vijaya Bhaskar, 2007). Kumaran *et al*. (2007) found that TNAU Neem oil (C) 60 EC at 30 ml l^{-1} and NeemAzal 1% showed 65.83 per cent and 70.16 per cent protection over control against red spider mite, *Tetranychus urticae* on Okra. Spraying of Econeem 1% at 0.1% reduced damage upto 6.35 per cent and increased yield of brinjal (44.37%) over control against shoot and fruit borer, *Leucinodes orbonalis* Gunee (Singh and Viswanath, 2007).

NeemAzal (5% azadirachtin) at 1 ml l^{-1} gave better performance than Achook 0.15% at 3 ml l^{-1} against okra fruit borer (Sinha and Sharma, 2007). *M. adedirach* leaf extract at 1g l^{-1} of water showed a strong larvicide activity against *A. aegyptii* and all larvae died before pupation where atleast 85 per cent larvae reared in water or ethanol solution survived to pupate (Coria *et al*., 2008). Spraying of NSKE 5% and Nimbecidine 0.03% resulted in significant reduction of population against diamondback moth and aphid on cabbage (Waghmere *et al*., 2006). Vairamuthu *et al*. (2005) revealed that spraying of NSKE 5% and Neem oil 3% gave 72.3 per cent, 14 per cent and 84 per cent, 13 per cent population reduction over control against aphids and tobacco army worm respectively. Santhakumar *et al*. (2005) found that there was 59.43 per cent reduction of *H. armigera* when Azadirect at 1.2 ml l^{-1} was sprayed on cotton. Gunnhild Jaastad *et al*.

(2009) revealed that Azadirachtin at 500ml/100l was more effective in reducing the populations of mirid bugs in apple trees than phosalone and diflubenzuron.

2.1.2. Sweet-flag

Sweet-flag, *Acorus calamus* (L.) (Family: Araceae) is called '*vasambu*' in Tamil. It is a rhizomatous perennial herb. The rhizomes were reported to contain mainly β-asarone (Mazza, 1985). Other constituents reported were palmitic acid, n-heptylic acid, asaronaldehyde and butyric ester (Guenther, 1976). β-asarone showed mutagenic (Jocobson, 1983), sterilizing (Schmidt, 1993) and antioviposition (Nelson, 1996) properties in insects.

2.1.2.1. Ovicidal action

Ovicidal action of *A. calamus* oil against the eggs of *Callosobruchus chinensis* (Lin.) (Chander and Ahamed, 1982) and the eggs of *Sitophilus granarius* (Linn.) and *S. oryzae* (Linn.) (Risha *et al.,* 1990) was well documented. Petroleum ether extract of *Acorus* exhibited egg hatchability upto 43 per cent in *Sitotroga cereallela* (Oliv.) (Shanthi and Logiswaran, 1996). Nair and Thomas (2000) reported the LC_{50} value of 0.03% for methanolic extract of *A. calamus* against the eggs of *Bactrocera cucurbitae* (Coq.) Hexane and methanol extract of *A. calamus* root showed significant ovicidal and ovipositional deterrent activity against *S. litura* (Raja *et al*., 2003).

2.1.2.2. Antifeedant effect

The petroleum ether extract (Mukherjee and Govind, 1959) and essential oil of *A. calamus* (Singh and Singh, 1991) were found to be repellents against *Musca sp*. Cent per cent feeding inhibition over untreated check was observed against the larvae of *Athalia lugens proxima* (Klug.) in mustard with 2.5% petroleum ether extract of *A. calamus*, whereas hexane soluble fractions recorded 98.83 per cent (Banerji *et al.,* 1982). Sharma *et al.* (1990) reported the antifeedant activity of *Acorus* oil against *S. litura.*

Compounds from *A. calamus* exhibited significant antifeeding activity against the larvae of *Leptinotarsa decemlineata* (Say.) (Britskii, 1992). Nelson (1996) reported that

Acorus powder 10% showed strong antifeedant effect upto 80% against second and third instar larvae of *S. litura.* Desai and Patil (2000) reported that *A. calamus* was found to possess strong antifeedant activity against *S. litura* on the basis of minimum per cent feeding and maximum protection over untreated check. Packiam *et al.* (2003) observed that hexane extract of *A. calamus* showed higher antifeedant activity against *S. litura.*

Opender Koul (1987) observed that a distillate of essential oil of the rhizomes of Indian calamus at 1% and 2% reduced the ingestion by *S. litura* larvae and also an antifeedant effect was exhibited at these levels and feeding ratio remained below 0.1. Chandel *et al*. (2001) revealed that oral application of rhizome extract of *A. calamus* against *Tribolium castaneum* through food, suggest that both adults and larvae to be appear to be repelled antifeedancy and as a result of starvation continuously for 7 weeks. Opender Koul and Isman (1990) found that second instar larvae of *Peridroma saucia* exposed to calamus oil containing diet consumed less with poor growth. At concentrations of 625 and 1250 ppm, larvae weighed 64.2 and 25.7 per cent as much as control respectively after 7 days. Pandey *et al*. (1977) revealed that Sweetflag extractat 0.5% and 0.1% concentration completely inhibited feeding of third instar of sawfly,

A. l. proxima on radish leaves. Hemchandra and Singh (2006) observed that rhizome extract of sweetflag gave 74.52 per cent protection over control against *P. xylostella*.

2.1.2.3. Insect growth regulatory activity

Under no choice tests, larval growth of *S. litura* was impaired by 1% and 2% concentrations calamus oil. At 0.5% survival was 60 per cent and growth extended till tenth day and 50 per cent of the surviving larvae pupated (Opender koul, 1987). Growth inhibitiory effect of *Acorus* oil against *Peridroma saucia* (Hub) was reported by Opender Koul and Isman (1990). Nelson (1996) observed the development of larval-pupal and pupal-adult intermediates in *S.litura* when treated with 10 per cent *Acrous* water extract. Petroleum ether extracts of *A. calamus* significantly affected the adult emergence in

S. cerealella (Shanthi and Logiswaran, 1996). Morphogenetic effects of sweet-flag

extracts against *S. litura* were observed both in leaf dip and topical bioassays by Behera and Satapathy (1997).

2.1.2.4. Insecticidal action and field efficacy

Trehan (1956) reported that 50 per cent aqueous suspension of *A. calamus* was toxic to *Amrasca devastans* (Dist.) and *Aulocophora foveicollis* (Lucas.). The rhizome extract of *A. calamus* caused mortality of *Dysdercus cingulatus* (Fab.) (Rajendran and Gopalan, 1979). Petroleum ether extracts of *A. calamus* had more insecticidal activity (72.22%) against *H. armigera* (Pandey *et al.,* 1982). Insecticidal properties of *Acorus* oil were reported against painted bug (*Bagrada cruciferarum* (Kirk.) (Verma and Pandey, 1987), *Tribolium castaneum* (Herbst.) (Chander *et al*., 1990) and *Lasioderma serricorne* (Fab.) (Su, 1991).

Nelson (1996) obtained effective control of *A. devastans* and *E. vitella* on bhendi with 5% *Acorus* water extract and 10% *Acorus* dust. According to Senguttuvan and Dhanakodi (1999) effective control of *Aproaerema modicella* (Deventer) was obtained with 5% rhizome extract of sweet-flag. Methanolic extract of *Acorus* recorded LC_{50} value of 0.07% against the adults of *B. cucurbitae* (Nair and Thomas, 2000). Shankaramurthy *et al*. (2006) showed that spraying of *A. calamus* rhizome extract at 10% level yielded 66.29 per cent marketable heads whereas unsprayed plots gave 49.79% heads on cabbage against DBM*, P. xylostella*. Rahman *et al*. (2008) found that chloroform and methanol extract of *A. calamus* leaves at 1% showed 33.33 and 16.67% mortality against looper caterpillar, *Buzura suppressaria* (Guen.) in tea. Essential oil obtained from rhizoids of *A. calamus* produced mortality against second instar of larvae of *H. armigera* (88%), *P. xylostella* (93%), *A. craccivora* (98%) and adults of *T. urticae* (93%) at 1 per cent concentration (Dhanajaya Tewary *et al*., 2005).

Hee-Kwon Lee *et al*. (2002) revealed that Cis asarone derived from *A. gramineus* caused the mortality in *N. lugens* (100%), *Myzus persicae* (53%) and third instar of *P. xylostella* (100%) and *S. litura* (13 %) at 2000 ppm. At 1000 ppm, 100% mortality was observed in the neonates of *Peridroma saucia* after seven days (Opender Koul and

Isman, 1990). Teotia and Tewari (1977) found that LC_{50} values of petroleum ether and ether extracts of sweet flag were 1.312 and 1.384 against *Sitotroga cerealella* and also petroleum ether extract was 1.05 times more toxic than ether extract. Pandey *et al.* (1977) revealed that sweet flag extract at 0.5 and 1 % concentration completely killed the 3rd instar of mustard sawfly on radish leaves after 24 h.

2.1.3. Pungam

The Indian beech popularly called as pungam, *Pongamia glabra* (Fierre.) (Family: Papilionaceae) is indigenous. The active principle in pungam has been identified as karanjin, a furaflavone. Various types of bioactivities observed in pungam extracts used against insects were antioviposition, antifeedant, insect growth regulatory activity, sterility and toxicity (Arora and Dhaliwal, 1994; Mukesh Kumar and Ram Singh, 2002).

2.1.3.1. Ovipositional deterrent effect

Shelke *et al*. (1985) reported that pungam oil (0.1%) deterred *Phthorimaea operculella* Zell. from oviposition on potato tubers. Mixture of pungam oil (5-10 ml/kg) with mung bean effectively prevented oviposition by *C. chinensis* (Babu *et al*., 1989). High ovipositional deterrent effects of pungam extract against *C. chinensis* was recorded in bengalgram (Kahare *et al*., 1993). Methanolic extracts of pungam seeds at concentration from 2.5 to 10% showed strong ovipositional deterrent effect and reduced the effect to *Plutella xylostella* (Sureshgouda Patil *et al*., 2003)

Reena and Ramsingh (2007) revealed that methanolic seed extracts of *P. pinnata* showed good deterrence activity against female *E. vitella* at 10% concentration with 76.39 per cent reduction over control whereas Karanj oil (1%) exhibited 27.71 per cent protection over untreated check. Sharma and Bhatnagar (1993) observed good ovipositonal deterrent effect and reduced feeding activity of *C. partellus* on maize was treated with pungam oil.

2.1.3.2. Ovicidal action

Pungam oil (1-10%) and seed kernel extracts (5-10%) had ovicidal effect on *P. operculella* eggs (Shelke *et al*., 1987). Pungam extracts caused mortality of eggs of *C. chinensis* on gram (Kahare *et al*., 1994). Combination of neem, pungam and madhuca extracts showed ovicidal effects on *Aleurolobus barodensis* (Maskell) on sugarcane (Murthy *et al*., 1994). Pungam oil was effective against the eggs of *C. partellus* and LC_{50} was 0.37622% and 0.39858% against two and three day old eggs, respectively (Bhatnagar and Sharma, 1995). Aqueous extracts of pungam had exhibited ovicidal action against *Helopeltis theivora* (Waterhouse) (Deka *et al*., 1998). Adults of *Plutella xylostella* when fed with fraction of karanjin or extracts of pungam seeds laid fewer eggs with poor hatching (Sureshgouda Patil *et al*., 2003).

Padmaja *et al*. (2007) recorded the effects of Karanjin extracted from the seeds of *P. pinnata* against *A. aegyptii*. They found that ovicidal activity of the karanjin at the highest concentration of 1000 ppm was 53.4 per cent while it was 13.34% at 100 ppm. Similarly percentage hatchability was less in highest concentration (1000 ppm) and more (86.66%) in lower concentration. There was significant reduction in hatching of *E. vitella* eggs treated with methonalic seed extract of *P. pinnata* at 10 % concentration (Reena and Ram singh, 2007).

2.1.3.3. Antifeedant activity

Antifeedant activity of karanjin and karanji oil against the larvae of *S. litura*, was reported by Srimannarayana and Rao (1985) and Rajasekaran and Kumaraswami (1985) respectively. Pungam oil reduced survival and feeding activity of *C. partellus* on maize (Sharma and Bhatnagar, 1993). Hazra *et al*. (1994) reported antifeedant activity of pungam against aphids on tea. Chloroform extracts of pungam seed significantly reduced the number of stylet probes by *H. theivora* on tea (Deka *et al*., 1998).

Pungam seed kernel extract at 5% and Pungam oil 80 EC at 0.03% reduced the weight gain and increased the pupal mortality of leaf miner, when fed with treated ground nut leaves, which indicated the feeding inhibition and growth disruption nature of pungam (Ayyasamy *et al*., 1999). Murali Krishna Rao *et al*. (1990) recorded the complete antifeedency property of petroleum ether leaf extract of *P. glabra* when second instar larvae of *H. vigintiotopunctata* were treated with 0.5 and 1 %

concentration. Reena and Ramsingh (2007) recorded that *P. pinnata* seed methanolic extract at 5% and 10% concentration showed 73.09 and 83.83% antifeedant activity against first instar larvae of *E. vitella* respectively.

2.1.3.4. Insect growth regulatory activity

Padmaja *et al*., (2007) reported that pupae of mosquito treated with karanj at 1000 ppm resulted in unequal size of ovaries, inhibition of oogenesis and vitellogenesis and a few oocytes developing in the ovaries. While in case of adults, highly inactive for 1 or 2 days and were unable to take blood meal for 2 to 3 days. The effect on biological parameters of *H. armigera* when third instar larvae fed with methanolic seed extract of pungam at 2.5, 5.0, 7.5 and 10 % concentration for 48 hrs resulted in decrease in larval survival (16.67-73.33%) larval weight (354.5 -385.18 mg), pupation (10-63.33%) and adult emergence (6.67-63.33%), while the prolongation of larval (13.49-16.50 days) and pupal period (12.17-14.67 days) was noticed (Reena and Ramsingh, 2007). Rajasekhar *et al*. (2007) found that pungam seed extract at 2.5 % concentration exhibited severe reduction in pupation, adult emergence and prolongation of pupal period against third instrar of *S. litura*.

2.1.3.5. Insecticidal action and field efficacy

Kumar and Sangappa (1984) reported the insecticidal effect of Indian beech oil/ pungam oil on white grub (*Holotrichia consanguinea* (Blanchard) and gram pod borer *H. armigera,* respectively. Varghese and Tandon (1990) showed that Indian beech oil reduced the survival of grape mealy bug, *Maconellicoccus hirsutus* (Green) from 90.44% to 56.87%. Pungam seed cake-water extract was found effective in protecting tobacco from *S. litura* damage (Chari and Ramaprasad, 1993).

Pungam oil and kernel extracts were found to be effective against *Plutella xylostella* (L.) on cabbage (Sathapathi and Ghatak, 1990); *Henosepilachna viginctiotopunctata* (Fab.) on brinjal (Reddy *et al*., 1990); bollworms on cotton (Nimbalkar *et al*., 1993); *E. vittella* on okra (Shukla *et al*., 1996); *S. litura* on castor (Behara and Satapathy, 1997); *Aphis gossypii* (Glov.) and *Amrasca devastans* on cotton

(Kulat *et al*., 1997) and *A. devastans, H. armigera* and *S. litura* on cotton (Jayaraj and Regupathy, 1999). Kumbhar *et al*. (1999) reported that pungam extracts showed better repellent and insecticidal activities.

Vairamuthu *et al*. (2005) reported that there was 96.63 per cent and 15.66 per cent population reduction of aphid and tobacco army worm, when pungam oil at 3% sprayed on groundnut. Kumaran *et al*. (2007) found that spraying of pongamia oil (20ml l^{-1}) was effective in controlling the populations of *T. urticae* (45.2%) in okra over untreated check. There was a high larvicidal activity (93.33%) when the 4^{th} instar mosquito larvae treated with Karanjin at 1000ppm while at 100ppm it was 30 per cent (Padmaja *et al*., 2007). The capsule infestation (10.3%) by sesame capsule borer, *Antigastra catalaunalis* was recorded in the plots treated with Karanj oil 2 per cent than control (14.2%) (Singh and Singh, 1997). Karsoliya *et al*. (2007) recorded that spraying of karanj oil at 2 per cent gave 42.75 per cent population reduction over control against pod borer, *H. armigera* in chickpea after 7 days.

2.1.4. Chast tree

Chast tree (*Vitex negundo*, Verbenaceae) is commonly known as *Notchi* in Tamil. The extract of leaves contain alkaloids, glycoside namely 6, 8 dimethyl ether leucocyanidin and posses various pesticidal activities against insects, microorganisms, fungi, *etc*.,

The bags impregnated with *Vitex* extract showed reduced infestation of *Sitotroga cerealella* with the per cent of infestation levels of 17 and 18.75 per cent at 30 and 50 days after treatment respectively (Srinivasan and Nadarajan, 2005). Suryakala *et al.* (1995) reported that *Vitex* extract exhibited the inhibition in egg hatch in *S. litura* was 45-90 per cent and 25- 80 per cent in *Dysdercus koenigii* at 100mgl^{-1}.

Rajappan *et al*. (2000) recorded that spraying of leaf extract of *V. negundo* at 10% significantly reduced the population of GLH, *N. virescens* on rice. Hemachandra and Singh (2006) reported that leaf extract of *Vitex trifolia* strongly inhibited the feeding of third instar larvae of *P. xylostella*. Murugesan *et al*. (2008) found that *Vitex* dried leaf

powder was a more potent antifeedant and ovipositional deterrent against groundnut bruchid, *Caryedon serratus*. At a dose of 0.5 and 1 g in 250 g of seeds of *Acacia* and tamarind seeds, *Vitex* powder exhibited highest antifeedent activity (87%) as reflected from the very low level of seed damage, reduction in pupal and adult survival periods. The fecundity (anti ovipositional effect) was reduced to 33-35 per cent and 25-30 per cent at 0.5 and 1 g *Vitex* powder respectively.

Spraying of *notchi* leaf extract 10% gave 16 per cent and 89.6 per cent protection over control against tobacco army worm and Aphid respectively (Vairamuthu *et al*., 2005). Baskaran *et al*. (2005) found that spraying of *Vitex* leaf extract at 5 kg/ha resulted in 33.56, 31.36 and 32.17 per cent population reduction over control against *N. virescens, Sogatella furcifera* and *Cofana spectra* on rice respectively. Sangeetha *et al*. (2005) ascertained that spraying of Notchi leaf extract 5% reduced the flower damaged by *Mylabris pustulata* (7.01%) in comparison with control. Shankaramurhy *et al.* (2006) revealed that field spraying of leaf extract of *V. negundo* at 10% concentration gave 54.95 per cent of marketable heads of cabbage whereas in the control, it was produced 49 per cent marketable heads against *P. xylostella*. Kumaran *et al*. (2007) observed that *Vitex* dry leaf extract and fresh leaf extract at 50 g /l showed a 50.16 and 35.44 per cent population reduction of *T. urticae* over control on okra.

2.1.5. Lemon bush

Lippia nodiflora (Burm.f.) belonging to the botanical family Verbenaceae is commonly known as fever tea or lemon bush or frogfruit or matgrass or *Poduthalai* in Tamil. It is a small herb with aromatic leaves. This plant is well known for medicinal use to many African tribals and many avid herbalists and herbal gardeners. Leaves contain 8 per cent tannin and plant yields two glycosides *viz.,* nodiflorin A and nodiflorin B.

Suryakala *et al*. (1995) recorded 30-60% and 25-40% inhibition in hatching of eggs of *S. litura* and *D. koenigii* when eggs were topically applied with *Lippia nodiflora* root extract at 5, 10, 50 and 100 µg / ml concentration. Carvalho *et al*. (2003) ascertained the larvicidal activity of the essential oil from *L. sidoides* against *Aedes*

aegyptii. Pure essential oil gave 100 % mortality within five minutes whereas Thymol is constituent of essential oil had larvicidal activity from concentration of 0.017 % with in 1 ½ hr, whilst at higher concentration (0.04%) 100 % mortality was achieved in ½ hr. Julius Olaifa *et al*. (1987) reported that essential from *Lippia adonensis* at 2.5 % concentration produced 100 per cent mortality against defoliator, *Acrae eponina* on jute within 24 hrs and also *Lippia* recorded LD_{50} of 0.32, 1.84, 0.52 and 0.85 µl/ larvae against cowpea flea beetle, *Ootheca mutabilis, Riptortus dentipes, A. eponina* and cotton stainer, *Dysdercus superstitiotus* respectively.

Topical application of *Lippia nodiflora* leaf extract to the freshly moulted 5^{th} instar nymphs of red cotton bug, *D. koenigii* resulted in morphological abnormalities and recorded the 10% nymphal mortality, 26 per cent super nymphs, 33 per cent adultoids and 60 per cent insect growth regulatory activity. The inhibition dose (ID_{50}) was 180 µg/ nymph (Suryakala *et al*., 2007). Pavunraj *et al*. (2007) revealed that ethyl acetate leaf extract fractions of *Lippia javanica* showed potent antifeedant activity and larvicidal activity against 4^{th} instar larvae of *S. litura*.

2.1.6. Poison nut

Strychnos nuxvomica (L.) belonging to Loganiaceae is commonly known as poison nut or *Strychnos* tree and *Etti* in Tamil. The seeds contain indole alkaloids, the major one is strychnine (approximately 50% of the alkaloids) others include strychnine N-oxide, brucine and its N-oxide, alpha and beta colubrine, diboline, pseudostrychnine, pseudobrucine and vomicine. Glycoside loganin also present. Pseudostrychnine is non toxic. The alkaloidal content of the seeds ranges from 1.5 to 5.3 per cent. The leaves contain strychnine and brucine (together 1.6%), strychnine 0.025 per cent. Vomicine is the major constituent of leaves. The bark contains 9.9 per cent total alkaloids (brucine 8% and strychnine 1.58%); pseudostrychnine, pseudobrucine and beta colubrine in small amounts. The roots contain 0.99 per cent alkaloids (brucine 0.28% and strychnine 0.71%). Dried blossoms contain 1.023% (Khare, 2007). *Strychnos* is utilized by ayurvedic physicians as detoxicant.

Craig Ramey *et al*. (1992) observed that strychnine is a single dose poision that is highly toxic to mammals, birds and other animals. Strychnine is a very toxic, colourless crystalline alkaloid used as a pesticide, particularly for killing small vertebrates such as rodents (LD_{50} = 10mg). Murray Isman (2002) reported that strychnine, indole type alkaloid from *S. nuxvomica* exhibited potent antifeedant activity against caterpillars.

2.2. Neem with other botanicals

Increased efficacy of NSKE against stored product insect when combined with custard apple seed extract was observed by Quadri and Rao (1977). The synergist sesamax improved the effects of methanolic neem seed kernel extract against *Epilachna varivestis* (Muls.) and *P. xylostella* (Lange and Schmutterer, 1982). According to Schauer (1984), addition of lecithin II and sesame oil to NSKE caused high mortality of aphids, *Acyrthosiphon pisum* (Harris) and *Aphis fabae* (Scop).

Jayasree (1984) reported the joint action potentials of neem oil or pungam oil with sesame oil in 5:1 ratio against *A. devastans* and *A. gossypii* on cotton. Rajasekaran and Kumaraswami (1985) indicated that sesame oil could be used to improve the efficacy of NSKE against *S. litura*. Mixtures of neem, pungam and madhuca extracts showed increased efficacy against eggs, nymphs and adults of *A. barodensis* on sugarcane (Murthy *et al*., 1994). Raguraman and Singh (1997) reported the combined potential of neem oil and cedar wood oil against *C. chinensis*. Growth inhibitory activity of neem oil along with pungam oil 60 EC at 3% was demonstrated on *Cnaphalocrocis medinalis* (Guenee) (Saikia and Parameswaran, 1999).

Increased mortality of aphids, leafhoppers and whiteflies on beans was reported when treated with mixture of neem and green chilli extracts rather than treating with neem alone (Kumbhar *et al*., 1999). Joint action potentials of alcoholic extracts of neem with pungam and sweet-flag extracts @ 1:1:1 was demonstrated in controlling *A. devastans* and *E. vitella* on bhendi (Srinivasa Rao, 2001; Srinivasa Rao *et al*., 2003) The combination of ethanolic extracts of neem, sweet-flag and pungam (NSP) @ 0.18% recorded significantly reduced the population of *H. armigera* (1.14 numbers/10 plants)

as compared to untreated check (19.74 numbers/10 plants) 52 days after transplanting in tomato plants (Sathish, 2003). Boomathi (2003) found that the botanical mixture NSP @ 0.18% significantly reduced pod damage and population of *H. armigera* in pigeonpea.

Nadia Dimetry and Hawary (1997) reported that efficacy of NeemAzal –T/S was increased significantly when additive sesame oil against Aphid, *A. craccivora*. Zaddakavitharaghavan *et al.* (2006) regarded that NSP (1:1:1 ratio) formulation showed high antifeedancy with the least honeydew area of 94mm^2 against BPH, *N. lugens*. The number of eggs laid per plant was 13 when compared to 72 in untreated control. The efficacy of NSP (1:1:1) and NSP (2:1:1) formulation was more in reducing the per cent hatchability and population build up than neem alone.

Boomathi *et al.* (2005) recorded that ovipositional deterrent activity, antifeedant activity and growth inhibitory activity of Neem-Sweet flag-Pungam (NSP 60 EC) formulation against *H. armigera*. Sangeetha *et al.* (2005) found that spraying of NSP at 0.25% on redgram resulted in 33% population reduction over control against blister beetle, *M. pustulata*. Mariapakiam *et al*. (2007) revealed that spraying of mixture of botanicals (Neem oil (44.5%) + pongamia oil (44.5%) + Azadirachtin 500 ppm + emulsifier (10%) + stabilizer (1%)) resulted in maximum antifeedant activity (84%) against fourth instar of *S. litura*. Punithavalli (2005) reported that oviposition deterrent activity, antifeedant index and growth inhibitory activity of NSP 60 EC formulation was superior to NSKE 5% against rice leaf folder, *Cnaphalocrocis medinalis.*

The extensive use of broad spectrum synthetic insecticides has resulted in many negative consequences like residue problem, development of resistance in target insects, resurgence of secondary pests. In the context, to avoid the ill effects of synthetic insecticides, use of plant origin insecticides is gaining as a viable alternative. Although sufficient information on neem and sweetflag extracts are available on the efficacy against insect pests, the information on the joint action potential of plant origin insecticides is limited. Hence, the present study is taken up to determine the joint action efficacy of NeemSweet formulation with other plant origin insecticides like *Lippia, Strychnos* and *Vitex* against *S. litura* and *P. xylostella.*

CHAPTER III

MATERIALS AND METHODS

The materials used and methods followed in the laboratory and field experiments on the evaluation of neem seed kernel extract with other botanicals *viz.,* Sweet-flag, *Pungam, Poduthalai, Etti* and *Notchi* for the management of diamondback moth, *Plutella xylostella* and tobacco caterpillar, *Spodoptera litura* on cauliflower are described hereunder.

3.1. Botanicals

Six plant species *viz*., neem (*Azadirachta indica*; A. juss), sweet-flag (*Acorus calamus* Linn.), Pungam (*Pongamia glabra* Vent.), lemonbush or matgrass or frogfrruit or *Poduthalai* (*Lippia nodiflora* Burm.f), *Notchi* (*Vitex negundo* Lin.) and Poison nut or nuxvomica or *Etti* (*Strychnos nuxvomica* Lin.) were chosen for this study. Seeds of neem, *etti* and *pungam,* leaves of *Poduthalai* and rhizomes of sweet-flag were collected from local market and leaves of *notchi* were collected from Thondamuthur village, Coimbatore, Tamil Nadu, India.

3.1.1. Extraction and formulation of botanicals

The extracts of seed kernels of Neem (N), Pungam (P) and *Strychnos* (S) and rhizomes of sweet-flag (S) and leaf extracts of *Lippia* and *Vitex* (V) were prepared using methanol as solvent, Seed kernels or rhizomes were ground to fine powder in pulverizer. One hundred gram of seed kernel or rhizomes or leaf powder was stirred with 500 ml methanol for 3 hours using magnetic stirrer and filtered through whatman No. 1 filter paper. The content was restirred with 500ml of methanol in a distillation unit at 50^{o} C under reduced pressure. The extract was concentrated to free from methanol in vacuum evaporator.

Neem and sweet-flag extracts were formulated by mixing 1:1:1 ratio of other four extracts. The emulsifier contains soap oil, emulsifier at the ratio of 3:1. NeemSweet was added with extracts of *pungam*, *Lippia, Vitex* and *Strychnos* at known proportion

and mixed thoroughly. The different NeemSweet formulations were made *viz*., NSS 60 EC (Neem + Sweet-flag + *Strychnos*), NSL 60 EC (Neem + Sweet-flag + *Lippia*), NSV 60 EC (Neem + Sweet-flag + *Vitex*) and NSP 60 EC (Neem + Sweet-flag + *Pungam*) (Plate 1).

The powdered neem seed kernals weighing about 50 g were soaked in 1 litre of water for overnight. Next day, the content was filtered using muslin cloth and filterate was used for experiments.

Formulation	Composition of the formulation	Ratio
NSS 60 EC	Neem + Sweet-flag + *Strychnos* + emulsifier	1: 1: 1
NSL 60 EC	Neem + Sweet-flag + *Lippia* + emulsifier	1: 1: 1
NSV 60 EC	Neem + Sweet-flag + *Vitex* + emulsifier	1: 1: 1
NSP 60 EC	Neem + Sweet-flag + *Pungam* + emulsifier	1: 1: 1
NS 60 EC	Neem + Sweet-flag + emulsifier	1: 1

3.2. Test Insects

3.2.1. Mass culturing of diamondback moth, *P. xylostella* (L.)

The test insects required for experiments were obtained from the culture maintained on mustard and cauliflower at the Insectary, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

The soil mixture required for raising mustard seedlings was prepared by mixing soil, compost and leaf litter at the ratio of 1:1:1 and which was was sterilized in an autoclave. Plastic cups (6 x 3cm) with holes at the bottom were filled with sterilized soil mixture to a height of 2.5cm. Mustard seeds, treated with carbendazim (200mg/100g), were sown evenly over the entire soil surface and watering was done once in two days. The seeds germinated in about three days at a room temperature of 30±4°C. The seedlings, at a height of 4 to 5cm, were used for oviposition by female DBM.

The DBM culture was initiated from the larvae collected from the field near Coimbatore. The collected larvae were reared on cauliflower leaves. When they

pupated, 30 of them (15 males and 15 females) were transferred to adult emergence cages (Plate 2a) of 30x30x30cm. Male moths having short and pointed abdomen where as females pocessing long abdomen (Talekar and Shelton, 1993). Sugar solution (10%) fortified with multi-vitamin drops was provided as adult diet for the moths. A day after the emergence of adults, mustard seedlings were provided for oviposition. The moths laid eggs on both the surfaces of leaves as well as on petioles. Fresh seedlings were provided once in two days until all the adults died.

Larval rearing was carried out in cages of 30x30x30cm. The first instar larvae hatched in about 3 to 4 days was initially fed by mining into the mustard leaves and later on the entire leaves. For second instar larvae, tender cauliflower leaves were provided as feed. For transferring the larvae from mustard seedlings to cauliflower leaf, a cauliflower leaf with its petiole wrapped with wet cotton was placed over mustard seedlings (Plate 2c). Most of the larvae migrated to cauliflower leaf within a day. Then the larvae were transferred to fresh cauliflower leaves kept in conical flask. The larvae were provided with fresh leaves every day. To meet the daily requirement of leaves, plants were grown continuously in pots. The larval stage lasted for 12 to 14 days and the pupation mostly occurred on the lower surfaces of the leaves. The larvae pupated at different dates were collected by using a camel hair brush. To synchronise the emergence of moths, the collected pupae were stored in a refrigerator. When all the larvae became pupae, they were taken out from the refrigerator and kept in the adult emergence cage. The pupal period lasted for 5 to 6 days.

On fourth or fifth and tenth or eleventh day after hatching (Plate 2a), the second and fourth instar larvae measuring 0.25mm and 0.61mm head capsule width, respectively, were used in most of the bioassay studies.

The rearing of DBM was carried out under laboratory conditions at a photoperiod of 12:12 (light: dark), temperature of 30±4.0°C and RH 65-80%.

3.2.2. Mass culturing of tobacco caterpillar, *S. litura*

The test insect, *S. litura* was cultured following method of Natesan (1979) using castor leaves. The culture of *S. litura* was started from single egg mass obtained from a pure culture maintained in the insectary of the Department of Agricultural Entomology, TNAU, Coimbatore.

A day prior to hatching, the eggs were transferred to leaves of castor, (*Ricinus communis* L.) which were washed with water and kept in plastic buckets. The leaves were kept turgid by keeping the tips of the petioles dipped in water contained in plastic containers. The plastic buckets were covered with moist muslin cloth. The leaves remained turgid for 3 days. The larvae were reared upto 5 days in this manner and subsequently transferred to glass troughs in batches of 30 larvae per trough and the troughs were covered with moist muslin cloth. Fine sand was spread at the bottom to a depth of 2.5 cm to facilitate pupation. An absorbent paper was placed over the sand to collect fecal pellets. Fresh leaves were provided twice in a day *viz*., morning and evening from third day onwards. Larvae showing the symptoms of either viral or bacterial infection were removed immediately and destroyed avoiding further spread. The pupae were collected and kept in adult emergence cage (Plate 3b) till emergence of the moths. On emergence 5 pairs of moths were enclosed in a glass jar 10 per cent sucrose solution dipped in absorbent cotton swab was kept as food. Male moths having short and pointed abdomen measuring about 6 mm and females 8 mm with tuft of hairs measuring 3 mm (Ranga Rao *et al*., 2008). Shoots of Nerium (*Nerium odoratum* L.) with leaves were kept inside the jar for the moths to lay eggs and same were replaced with fresh ones daily. Egg masses laid on the leaves were easily removed with camel hair brush and eggs collected thus were freed from the adhering scales by gentle agitation in the plastic containers. The entire culturing of *S. litura* was carried out at laboratory temperature 28±2^{o}C.

On sixth or seventh day after hatching (Plate 3a), the third instar larvae measuring 0.6-1.1 mm of head capsule width and sixteenth or seventeenth day after

hatching, the fifth instar larva with head capsule width of 2.2-2.95 mm were used in the bioassay studies.

3.3. Biological activities of NeemSweet formulations against diamondback moth, *P. xylostella* and tobacco caterpillar, *S. litura*

Laboratory experiments were conducted to study the joint action of neem seed kernel extract and sweet-flag with other plant extracts on the behavioural and physiological effects in terms of ovipositional deterrency, feeding deterrency or antifeedent activity and toxicity and growth inhibitory activity, ovicidal activity and food consumption and utilization by larvae of diamondback moth, *P. xylostella* and tobacco caterpillar, *S. litura.*

3.3.1. Ovipositional deterrency test

The leaves of cauliflower plants (30 days after transplanting) were sprayed with test concentrations of botanicals as per the treatment structure I. The leaves were kept in conical flask with water. The spraying was done with a hand atomizer and shade dried for 30 seconds. Then the conical flasks were arranged at equidistance inside the oviposition cage.

Freshly emerged adults of *P. xylostella* and *S. litura* were separately confined at two pairs per conical flask in the cage for 72 h and allowed for oviposition on the treated plants (Sharma, 1979) (Plate 4a). Ten per cent sugar solution fortified with vitamin E was provided as food for adults. Three replications were maintained in each treatment.

The number of eggs laid on each treated plant was recorded on 24h, 48h and 72h after releasing of adults, and per cent oviposition was calculated. Relative ovipositinal preference was estimated as suggested by Mehta and Saxena (1970).

Treatment Structure - I

S. No	Treatment	Concentration / Dose
T_1	NSS 60 EC	0.50 %
T_2	NSS 60 EC	0.25 %
T_3	NSL 60 EC	0.50 %
T_4	NSL 60 EC	0.25 %
T_5	NSV 60EC	0.50 %
T_6	NSV 60EC	0.25 %
T_7	NSP 60EC	0.50 %
T8	NS 60EC	0.50 %
T9	NO (C) 60EC	0.50 %
T10	NSKE	5 %
T11	Untreated check	-

$$\text{Per cent oviposition} = \frac{\text{Number of eggs laid in treatment}}{\text{Number of eggs laid in control}} \times 100$$

$$\text{Relative ovipositional preference (ROP)} = \frac{\text{Number of eggs laid in treatment} - \text{Number of eggs laid in control}}{\text{Number of eggs laid in treatment} + \text{Number of eggs laid in control}} \times 100$$

3.3.2. Ovicidal action test

Leaf bearing eggs of diamondback moth, *Plutella xylostella* on cauliflower and tobacco caterpillar, *Spodoptera litura* on nerium was removed after 24 h from oviposition cages and was cut suitably into bits containing 25 eggs. Each bit served as a replicate. These pieces were dipped in the test concentrations as per Treatment Structure I (section 3.3.1) for 30 seconds and shade dried. The treated eggs were transferred to the Petri dishes containing moist filter paper to maintain relative humidity. Each treatment was replicated thrice. Eggs treated with water served as check. The eggs that turned brown, collapsed, or shriveled were considered as dead (Kathuria, *et al.*, 2001). Egg mortality was recorded at 24 h interval still hatching. Eggs with partially hatched larvae were also counted as dead.

3.3.3. Antifeedant test

Cauliflower or castor leaf discs of 3 cm diameter were washed with water, shade dried and dipped in test concentration as per Treatment Structure I (section 3.1.1). Dipping in distilled water was maintained as untreated check. The treated leaves were shade dried for 10 min. and transferred to Petri plates. Ten numbers of third and fifth instar larvae of *S. litura* or second and fourth instar larvae of *P. xylostella* reared on the same host were collected and prestarved for 6 h and released into Petri plates. After 24 hours of feeding the larvae were removed and weighed (Plate 4b). Leaf area fed by the larvae was measured, using leaf area meter. The leaf area fed by the larvae was expressed in cm^2 or mm^2. Three replications were maintained for each treatment.

Feeding deterrency was calculated from the method suggested by Murray Isman *et al*., (1990).

$$\text{Index of feeding deterrency} = \frac{C - T}{C + T} \times 100$$

Where,

C = Area of leaf disc consumed in control

T = Area of leaf disc consumed in treatment.

3.3.4. Growth inhibitory test

Growth and development of the third and fifth instar larvae of *S. litura* and second and fourth instar larvae of *P. xylostella* were studied by feeding the treated leaves of castor and cauliflower, respectively. After two days of feeding, the larvae were transferred into fresh leaves without any treatment. The untreated leaves were provided daily for feeding till pupation. Larval weight was recorded before and after 6 days. Mortality data were recorded daily. Larval pupal intermediate, larval and pupal periods, pupal mortality, adult emergence, malformed adults and total developmental period were also calculated. Larval growth index (LGI) and total developmental growth index (TDGI) were calculated as suggested by Gupta and Birah (2001). The experiment was conducted as per Treatment Structure I (section 3.1.1). Each treatment was replicated three times and ten larvae constitute one replication.

$$\text{Larval growth index (LGI)} = \frac{\text{Pupation (\%)}}{\text{Larval period (days)}} \times 100$$

$$\text{Total development growth index (TDGI)} = \frac{\text{Adult emergence (\%)}}{\text{Total development period (days)}} \times 100$$

3.3.5. Toxicity test

Toxicity of the botanical mixtures was ascertained on neonates of *S. litura* and *P. xylostella.* Pot cultured cauliflower leaves were washed in distilled water, shade dried and dipped in test concentration as per Treatment Structure I (section 3.1.1), for 30

seconds. Three hours of prestarved neonates were released individually to plastic cups containing treated cauliflower leaves. Cauliflower leaves treated with water was maintained as check. After 48 h of feeding by the larvae in treatments they were provided with untreated cauliflower leaves. Mortality data were recorded at regular intervals of 24, 48, 72 and 96 h after treatment as suggested by Rao (2001).

3.3.6. Studies on nutritional effects

The physiological effects of botanicals in terms of influence on nutrition were studied with third and fifth instar larvae of *S. litura* and second and fourth instar larvae of *P. xylostella* prestarved for 6 hours. Fresh and tender leaves were collected from insecticide free pot cultured cauliflower plants, washed with water and shade dried. Leaves were dipped in test concentrations as per Treatment Structure I (section 3.1.1). Prestarved larvae and treated leaves were weighed and transferred to disposable plastic cups and secured tightly with muslin cloth and rubber band. Weighed cauliflower leaves were provided for feeding by larvae. The observations on quantity of food consumed, excreta voided and the weight gained by the larvae from second or third instar to death/pupation were recorded on fresh weight basis. Each treatment was replicated five times with single larvae per replication for *S. litura* and fifty larvae with three replications for *P. xylostella*. The mean weight of insect was calculated by summing up the initial and final weight determined every day and divided by the number of weighings. The following nutritional indices relate on consumption, digestion and utilization of treated cauliflower leaves were calculated according to Waldbauer (1968).

A) Consumption Index (CI) = F / TA

Where,

F – Weight of food eaten

T – Duration of feeding period

A – Mean weight of larvae during feeding period

B) Growth Rate (GR) = G / TA

Where,

G – Weight gained by larvae during feeding period

T – Duration of feeding period

A – Mean weight of larvae during feeding period

C) Efficiency of conversion of ingested food to body substance (ECI)

$$ECI = \frac{\text{Weight gained}}{\text{Weight of food ingested}} X\ 100$$

D) Approximate digestibility (AD)

$$AD = \frac{\text{Weight of food ingested – weight of faeces}}{\text{Weight of food ingested}} X\ 100$$

E) Efficiency of conversion of digested food (ECD) or net efficiency

$$ECD = \frac{\text{Weight gained}}{\text{Weight of food ingested - Weight of faeces}} X\ 100$$

3.4. Field efficacy of NeemSweet formulation with other plant origin insecticides against *P. xylostella* and *S. litura* on cauliflower.

Two field trials (Plate 5) were conducted to evaluate the effect of foliar spray of NeemSweet formulations with other plant origin insecticides against *P. xylostella* and *S. litura* on cauliflower. The details of the treatment are given below.

Crop : Cauliflower

Variety : Bavas

Treatment : Foliar spray

Design : Randomised block Design

Plot size : 3 x 5m^2

Spacing : 40 x 30 cm^2

Season I : September – December, 2008 (Trial I)

Season II : January – March, 2009 (Trial II)

Place : Narasipuram and Thondamuthur at Coimbatore district.

Date of planting : 14.9.2008 (Trial I) and 23.12.2008 (Trial II)

Date of spraying : 9.10.2008 (Trial I) and 20.1.2009 (Trial II)

Treatment Structure of botanicals used in field studies

Treatment Structure - II

S. No	Treatment	Concentration / Dose
T_1	NSS 60 EC	2 ml / l
T_2	NSL 60 EC	2 ml / l
T_3	NSV 60EC	2 ml / l
T_4	NSP 60EC	2 ml / l
T_5	NS 60EC	2 ml / l
T_6	NO (C) 60EC	2 ml / l
T_7	NSKE	5 %
T8	NeemAzal T/S 1%	2 ml / l
T9	Untreated control	-

3.4.1. Observations on pest incidence and per cent reduction

When the incidence of diamond back moth, *P. xylostella* and *S. litura* crossed the ETL level, spraying was effected the next day as per Treatment Structure II (section 3.4). ETL of diamondback moth was 5 larvae per plant counts where as 4 egg masses per 100 m length of the field for *S. litura* (Dhandapani *et al*., 2003) per cent leaf damage were calculated by recording number of damaged leaves per 10 plants before and after treatment from randomly selected and tagged plants in each plot. The observation on reduction in pest incidence was made 3, 5, 7 and 10^{th} day after spraying and per cent larval reduction over control was calculated as following. Observation on reduction in pest incidence was made at 3, 5, 7 and 10^{th} days after spraying. A second spraying was effected 11 days after first spray and again similar observations were made.

$$\text{Per cent damage (\%)} = \frac{\text{Number of damaged leaves/5 plants}}{\text{Total number of leaves/5 plants}} \times 100$$

The per cent reduction over untreated check in field population was corrected, using Henderson and Tilton (1955) formula,

$$\text{Per cent reduction} = \left\{ 1 - \frac{T_a \times C_b}{T_b \times C_a} \right\} \times 100$$

Where,

T_a – No. of insects in the treatment after spraying.

T_b – No. of insects in the treatment before spraying.

C_a – No. of insects in the untreated check after spraying.

C_b – No. of insects in the untreated check before spraying.

3.5. Statistical analysis

For laboratory studies the per cent mortality was corrected using Abbott's formula (Abbot, 1925)

$$\text{Corrected mortality (P)} = \frac{T - C}{100 - C} \times 100$$

Where,

P = Corrected per cent mortality

T = Per cent mortality in treatment

C = Per cent mortality in untreated check

The field data were subjected to statistical analysis by RBD while laboratory experiments were subjected to CRBD. The data collected from all the experiments were subjected to transformations before analysis i.e, percentage values and total number into *arc sine* and square root values, respectively. The mean values of treatment were then separated by least square test (LSD) (Gomez and Gomez, 1984).

CHAPTER IV

EXPERIMENTAL RESULTS

In the present investigation, laboratory and field experiments were carried out to assess the effect of joint action potential of NeemSweet formulation with other botanicals *viz*., *pungam,* nuxvomica*,* lemonbush and *Vitex* on oviposition, egg hatchability, feeding, mortality, growth and development of different larval instars of Diamondback moth, *Plutella xylostella* and Tobacco caterpillar, *Spodoptera litura*. Field efficacy of NeemSweet formulations was also studied against *P. xylostella* and *S. litura*. The results of the experiments are presented in this chapter.

4.1. Laboratory Experiments

4.1.1. Biological effects of NeemSweet formulations against *S. litura* and *P. xylostella*

4.1.1.1. Ovipositional deterrent effect of NeemSweet formulations against *S. litura*

The results presented in Table 1 revealed that the percentage of oviposition was completely inhibited in NSS 60 EC 0.5% , NSP 60 EC 0.5% and NSV 60 EC 0.5% followed by NSS 60 EC 0.25% (0.91%) and NSP 60 EC 0.5% (2.77%), compared to untreated check (46.07%) after 24 h of exposure. Among the mixtures of botanicals the relative ovipositional preference (ROP) was significantly less in NSS, NSP and NSV (–100.00 at 24 h), followed by NSS 0.25% (-96.10 at 24 h).

On 48 h, NSP 60 EC 0.5% and NSS 60 EC 0.5% deterred the *S. litura* adults significantly from oviposition by recording minimum percentages of oviposition, 3.00% and 3.48% respectively. It was followed by NSS 60 EC 0.25% (4.08%), compared to a maximum of 23.33% oviposition recorded in the untreated check. Relative ovipositional preference (ROP) was significantly less in NSP 0.5% (–77.23 at 48 h), followed by NSS 0.5% (-74.05 at 48 h). At 72 h, lower percentage of egg laying was recorded in NSP 0.5%, NSV 0.5% and NSS 0.5% (4.24%, 4.50% and 5.34% respectively). It was followed by Neem oil 60 EC 0.5% (5.93 %), which was significantly lower than untreated check

(16.60%). Among the mixtures of botanicals the relative ovipositional preference (ROP) was significantly less in NSP 0.5% (–59.31 at 72 h), followed by NSS (-57.35 at 72 h).

On 96 h, NSS 0.5% deterred the *S. litura* adults significantly from oviposition by recording minimum percentages of oviposition 2.80%. It was followed by NSS 0.25% (4.12%), Neem oil 60 EC 0.5% (4.84%) and NSV 60 EC 0.5% (4.94%) which was statistically on par with each other, compared to a maximum of 15.02% oviposition recorded in the untreated check. Relative ovipositional preference (ROP) was significantly less in NSS 0.5% (–68.56 at 96 h), followed by NSS 0.25% (-56.96 at 96h). The results also indicated that NSS, NSP and NSV formulations were significantly different from untreated check in the same period and showed superiority in deterrency.

4.1.1.2. Ovipositional deterrent effect of NeemSweet formulations against *P. xylostella*

The results presented in Table 2 revealed that the percentage of oviposition was deterred completely in NSS 0.5% (0.00%) followed by NSV 0.5% (0.61%) and NSL 0.5% (2.42%), compared to untreated check (33.33%) after 24 h of exposure. Among the mixtures of botanicals, the relative ovipositional preference (ROP) was significantly less in NSS 0.5% (–100.00 at 24 h), followed by NSV 0.5% (-96.67 at 24 h).

On 48 h, NSS 0.5% and NSP 0.5% deterred the *P. xylostella* adults significantly from oviposition by recording minimum percentages of oviposition 1.23% and 4.41% respectively. It was followed by NSL 0.5% (5.64%), compared to a maximum of 33.33% oviposition recorded in the untreated check. Relative ovipositional preference (ROP) was significantly less in NSS (–95.21 at 48 h), followed by NSP 0.5% (-81.31 at 72 h).

At 72 h, lower percentage of egg laying was recorded in NSL 0.5% and NSS 0.5% (4.13%, 10.08% respectively). It was followed by NSP 0.5% (13.18 %), which was significantly lower than untreated check (33.33%). Relative ovipositional preference (ROP) was significantly less in NSL 0.5% (–82.25 at 72 h), followed by NSS 0.5% (-61.86 at 72h). The results also indicated that NSS, NSP and NSL at 0.5% were significantly different from untreated check in the same period and showed superiority in deterrency.

4.1.1.3. Ovicidal action of NeemSweet formulations against *S. litura* eggs

Significant increased egg mortality and reduced hatchability of 1-day-old eggs of *S. litura* were noticed in all the botanical mixtures as compared to untreated check. The cumulative per cent mortality of eggs was higher in NSS 0.5% (80.38) and followed by NSL 0.5% (72.92) and NSV 0.5% (67.44) after 96 h (Table 3). Per cent reduction in egg hatching obtained in different treatments ranged from 19.62 to 98.84% at 96 h. Among the botanical mixtures, NSS 0.5% showed lesser hatchability of 19.62 % at 96 h followed by NSL 0.5% and NSV 0.5% (27.08% and 32.56%) compared to untreated check (98.84%).

The results of this experiment indicated that the egg hatchability was low in NSS 0.5% and followed by NSL 0.5% and NSV 0.5% at 96 h. Both of these treatments were significantly different from untreated check at 96 h.

4.1.1.4. Ovicidal action of NeemSweet formulations against *P. xylostella eggs*

All the botanical mixtures significantly reduced the hatchability of one-day-old eggs of *P. xylostella* as compared to untreated check (Table 4).. The cumulative per cent mortality of eggs was higher in NSS 0.5% (100.00) and followed by NSP 0.5% (98.33) and NSV 0.5% (90.67) after 96 h. Per cent reduction in egg hatching obtained in different treatments ranged from 0.00 to 100.00% at 96 h. Among the botanical mixtures, NSS 0.5% completely inhibited hatching at 96 h followed by NSP 0.5% and NSV 0.5% (1.67% and 9.33%) whereas cent per cent hatching was noticed in compared to untreated check (100.00%).

The results of this experiment indicated that the egg hatchability was low in NSS 0.5% and followed by NSP 0.5% and NSV 0.5% at 96 h. Both the treatments were significantly different from untreated check at 96 h.

4.1.1.5. Toxicity of NeemSweet formulations to neonates of S*. litura*

From the Table 5 it was evident that, NSV 0.5% registered 24.44 per cent mortality and NSL 0.5% (21.11%) 24 h after treatment. It was followed by NSS 0.5% and NSP 0.5% (18.89 and 18.81% respectively) which was statistically on par with each other.

Neem oil 0.5% alone recorded the lowest percentage of mortality (3.33 %). After 48 h, NSV 0.5% recorded 65.57 per cent mortality followed by NSS 0.5% (58.89%) and NSL 0.5% (56.67%) treatments were statistically on par, followed by NSP 0.5% which recorded (43.33% mortality).

Three days after treatment, NSV 0.5% was highly toxic to neonates of *S. litura* and 95.56 per cent mortality was recorded. At 96 h, NSS 0.5% and NSV 0.5% treatments also recorded cent per cent mortality and followed by NSL 0.5% (95.565) and NSP 0.5% (84.44%). The results of this experiment indicated that the neonate survival was low in NSS 0.5%, NSV 0.5% and followed by NSL 0.5% and NSP 0.5% at 96 h. The treatments were significantly different from untreated check at 96 h.

4.1.1.6. Toxicity of NeemSweet formulations to neonates of *P. xylostella*

From the Table 6 it was evident that 24 h after treatment, NSS 0.5% exhibited 71.90 per cent mortality. It was followed by NSV 0.5% and NSL 0.5% (59.14 and 53.53% respectively). Neem oil 0.5% alone recorded the lowest percentage of mortality (31.01 %). After 48 h, NSP 0.5% recorded 94.38 per cent mortality followed by NSS 0.5% (89.69%) and NSL 0.5% (84.49%) treatments were statistically on par, followed by NSL 0.5% which recorded (74.65% mortality).

Three days after treatment, NSV 0.5% and NSP 0.5% were highly toxic to neonates of *P. xylostella* and cent per cent mortality was recorded in these treatments. It was followed by NSL 0.5% and NSP 0.5% (95.78 and 91.55% mortality respectively. The results of this experiment indicated that the survival of the newly emerged larvae of *P. xylostella* was low in NSS 0.5%, NSP 0.5% and followed by NSL 0.5% and NSV 0.5% at 72 h. All the treatments were significantly different from untreated check at 72 h.

4.1.1.7. Antifeedant effects of NeemSweet formulations on third and fifth larval instar of *S. litura*

From the Table 7 the antifeedant effect of NeemSweet formulations on third instar larvae of *S. litura* was evident ranged from 19.38 to 79.87 per cent. NSS 0.5% recorded significantly higher antifeedant index (79.87) which was followed by NSL 0.5%

(67.92).On third instar larvae the larval weight gained was less in NSS 0.5% (0.041g) followed by Neem oil 0.5% (0.047g) and NSL 0.5% (0.061g) compared to untreated check (0.114g). The results of this experiment indicated that the antifeedant index was high in NSS 0.5% and followed by NSL 0.5% at 24 h. Both of these treatments were significantly different from untreated check at 24 h.

Table 8 revealed the antifeedant effect of NeemSweet formulations on fifth instar larvae of *S. litura*. NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 71.84 and 64.08 respectively followed by NSL 0.5% (62.63). Larval weight gained by the insect was low in NSKE 5% (0.014g) and followed by NSV 0.5% (0.030 g) and NSP 0.5% (0.031 g) were statistically on par. The results of this experiment indicated that the antifeedant index was high in NSS 0.5% and followed by NSP 0.505 and NSL 0.5% at 24 h. The treatments were significantly different from untreated check at 24 h.

4.1.1.8. Antifeedant effects of NeemSweet formulations on second and fourth larval instars of *P. xylostella*

It was observed that the antifeedant index of NeemSweet formulations on second instar larvae of *P. xylostella* ranged from 49.70 to 93.39 per cent (Table 9). Larval weight gained by larvae and antifeedant index was in NSS 0.5% (0.200 mg and 93.39), NSP 0.5% (0.200mg and 91.54 respectively) were statistically on par and followed by NSL 0.5% (0.440 mg and 77.86). The results of this experiment indicated that the antifeedant index was high in NSS 0.5%, NSP 0.5% and followed by NSL 0.5% at 24 h. Both of these treatments were significantly different from untreated check at 24 h.

Table 10 revealed the antifeedant effect of NeemSweet formulations on fourth instar larvae of *P. xylostella*. NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 81.65 and 79.00 respectively followed by NSL 0.5% (76.25). Larval weight gained by the insect was low in NSS 0.5% (0.072 mg) and followed by NSP 0.5% (0.099 mg) and NSL 0.5% (0.155 mg) compared to untreated check (2.185 mg). The results of this experiment indicated that the antifeedant index was high in NSS 0.5%

and followed by NSP 0.505 and NSL 0.5% at 24 h. Both of these treatments were significantly different from untreated check at 24 h.

4.1.1.9. Growth inhibitory effect of NeemSweet formulations against third and fifth instar larvae of *S. litura*

From the Table 11 it was evident that NeemSweet formulations exhibited growth inhibitory effects on third instar larvae of *S. litura.* Weight gained by larvae was very low in NSKE 0.5% and NS 60EC 0.5% (0.221g and 0.227 g, respectively) and followed by NSP 0.5% (0.249 g). High per cent larval mortality was observed in NSS 0.5% (36.67%) and followed by NSP 0.5% (33.33%) and NSL 0.5% (30.00%). Larval-pupal intermediates were significantly higher in NSL 0.5% (30.00%) followed by NSV 0.5%, NSKE 5%and NS 0.5% were statistically on par (26.67%). Pupation percentage was low in NSL 0.5% and NSP 0.5% (40.00 and 46.67%, respectively) and adult emergence percentage was 64.71 in NSS 0.5% compared to untreated check (96.67%). Emergence of malformed adults was higher in NSV 0.5% (50.08%) and followed by NSV 0.25% (29.41%) and neem oil 0.5% (26.08%) compared to untreated check (0.00%). Low LGI was recorded in NSL 0.5% (3.978) which is significantly on par with NSP 0.5% (4.301) followed by NSV 0.5% and NSS 0.5% (4.525 and 5.472, respectively). Lowest total developmental growth index was observed in NSS 0.5% (2.71) followed by NSP 0.5% (2.87) and NSV 0.5% (3.45).

NeemSweet formulations showed growth inhibitory effects on fifth instar larvae of *S. litura* (Table 12).Weight gained by larvae was very low in NSV 0.5% (0.207 g) which was statistically on par with NSL 0.5% (0.216 g) treatments and followed by NSP 0.5% (0.280 g). Percentage of larval mortality was significantly higher in NSV 0.5% (11.05%) followed by NSP 0.5% (10.85%) which was statistically on par with NSKE 5% (10.80%). Higher percentage of larval pupal intermediates was recorded in NSP 0.5% (26.67%) followed by NSV 0.5% (23.33%) and NSL 0.25% (20.00%). Lowest per cent of pupation was recorded in NSV 0.5% and NSP 0.5% (66.67% and 70.00% respectively) and followed by NSS 0.5% (73.33%). Per cent of Adult emergence was low in NSL 0.5% (30.00). The highest percentage of malformed adults emerged in NSV 0.5% (50.00%) and followed by NSL 0.5% (41.67%). The least larval growth index (LGI) was recorded in NSV (9.08)

followed by NSP 0.5% (9.83). Low total developmental growth index was recorded in NSS 0.5% which was on par with NSL 0.5% (1.82) followed by NSV 0.5% (2.07).

4.1.1.10. Growth inhibitory effect of NeemSweet formulations on second and fourth instar larvae of *P. xylostella*

From the Table 13 it was evident that NeemSweet formulations showed growth inhibitory effects on third instar larvae of *P. xylostella.* Weight gained by larvae was very low in NSS 0.5% (1.023 mg) which was statistically on par with NSP 0.5% (2.008 mg) and followed by NSS 0.25% (2.514 mg). High per cent larval mortality was observed in NSS 0.5% (40.55%) and NSP 0.5% (40.55%) followed by NSV 0.5% (37.78%) and NSL 0.5% (35.55%). Larval-pupal intermediates were significantly higher in NSV 0.5% (18.87%) which was on par with NSL 0.5% (18.05%) and it was followed by NSP 0.5% (15.72) and NSS 0.5% (14.94%) which were statistically on par. Pupation percentage was low in NSS 0.5% and NSP 0.5% (59.45%) and adult emergence percentage was NSS 0.5% (69.16%), NSP 0.5% (71.01%) and NSV 0.5% (71.44%) were on par with each other compared to untreated check (96.67%). Emergence of malformed adults was higher in NSL 0.5% (22.49%) and followed by NSV 0.25% (21.50%) and NSL 0.25% (20.18%) compared untreated check. Low LGI was recorded in NSS 0.5% (7.28) followed by NSP 0.5% (7.76) and NSV 0.5% (8.52).Lowest TDGI was observed in NSS 0.5% (4.43) followed by NSP 0.5% (4.72) and NSV 0.5% (4.94).

Table 14 revealed the growth inhibitory effects of NeemSweet formulations on fifth instar larvae of *P. xylostella.* Weight gained by larvae was very low in NSS 0.5% (0.610 mg) which was statistically on par with NSP 0.5% (0.670 mg) treatments and followed by NSV 0.5% (0.812 mg). Percentage of larval mortality was significantly higher in NSS 0.5% (38.52) followed by NSP 0.5% (37.90%). Higher percentage of larval pupal intermediates was recorded in NSV 0.5% (22.64) which was on par with NSL 0.5% (21.66) followed by NSS 0.5% (20.22). Low per cent pupation was recorded in NSS 0.5% (62.74) followed by NSL 0.5% (69.34). Per cent adult emergence was low in neem oil 0.5% (38.98). The higher percentage of malformed adults emerged in NSL 0.5% (38.76) and followed by NSS 0.25% (28.07) and NSV 0.25% (22.12).The least larval growth index

(LGI) was recorded in NSS (12.91) followed by NSP 0.5% (15.71) which was statistically on par with NSV 0.5% (15.83). Low total developmental growth index was recorded in Neem oil 0.5% (3.81) followed by NSKE 0.5% (4.20) and NSS 0.5% (4.71).

4.1.1.11. Influence of NeemSweet formulations on consumption and utilization of food by third and fifth instar larvae of S*. litura*

4.1.1.11.1. Effect on food consumption

The total food consumed and different nutritional indices are presented in Table 15 and Table 16 for the third and fifth instar larvae of *S. litura*, respectively.

On third instar of *S. litura*, the consumption index (CI) was significantly the lowest in NSP 0.5% (0.19) and NSKE 5% (0.19) which was followed by NSV 0.5% (0.29) and NSL 0.5% (0.35), compared to untreated check (0.72). On fifth instar larvae lowest CI level was recorded in NSV 0.5% (0.35), NSS 0.5% and NSP 0.5% (0.36).

On third instar larvae weight gained was low in NSS 0.5% (0.093g) followed by NSKE 5% (0.122g) and NSV 0.5% (0.139g) compared to untreated check (0.822g).Weight of faeces voided in NSL 0.5% (0.154g) which was statistically on par with NSP 0.5% (0.165g) and NSV 0.5% (0.168g) compared to untreated check (0.769g).On fifth instar larvae the larval weight gained and weight of faeces voided were less in NSL 0.5% (0.279 g, 0.453 g respectively) compared to untreated check (0.760 g and 0.736g respectively).

4.1.1.11.2. Effect on growth rate

The lowest growth rate on third instar larvae of *S. litura* was recorded in NSKE 5% which was on par with NSP 0.5% (0.05) followed by NS 0.5% (0.07) and NSS 0.5% (0.08) which was significantly on par with NSV 0.5% (0.08) (Table 15).

On fifth instar larvae of *S. litura* lowest growth rate was observed in NSL 0.5% (0.07) followed by NSS 0.5% (0.09) and neem oil 0.5% (0.10) as compared to untreated check (0.22) (Table 16).

4.1.1.11.3. Effect on ECI and AD

ECI value indicates the extent to which the ingested food is digested by the larvae. From the Table 15 on third instar larvae, significantly low value was observed in NSS 0.5% (13.72) which was followed by NS 0.5% (19.89%) and NSS 0.25% (22.56%) compared to untreated check (30.10%). On fifth instar larvae ECI value (Table 16) was found lower in NSL 0.5% (17.02%) followed by neem oil 0.5% (20.47%) compared to untreated check (30.59%).

On third instar larvae, AD value was the lowest in NSV 0.25% (58.36%) which was significantly on par with NSKE 5% (58.78%) and NSS 0.5% (61.09%) followed by NSL 0.5% (62.47%). On fifth instar larvae, NSS 0.5% recorded the lowest AD value of 58.02% followed by NSL 0.5% (59.00%).

4.1.1.11.4. Effect on ECD

The extent to which the digested food is converted into body substance is indicated by ECD values (Table 15 and 16). On third instar, NSS 0.5% registered the lowest ECD value of 22.45% and on fifth instar larvae, NSL 0.5% recorded the lowest ECD value of 28.85%.

4.1.1.12. Influence of NeemSweet formulations on consumption and utilization of food by second and fourth instar larvae of *P. xylostella*

4.1.1.12.1. Effect on food consumption

The total food consumed and different nutritional indices are presented in Table 17 and Table 18 for the second and fourth instar larvae of *P. xylostella* respectively.

For the second instar of *P. xylostella*, the consumption index (CI) was significantly the lowest in NSS 0.5% (0.54) and NSP 0.5% (0.62). This was followed by NSV 0.5% (0.64), compared to untreated check (0.89). On fourth instar larvae, the lowest CI level was recorded in NSS 0.5% (0.36) and it was followed by NSP 0.5% (0.47) and NSL 0.5% (0.51).

On second instar larvae weight gained was observed low in NSS 0.5% (0.610mg) which was significantly on par with NSP 0.5% (0.670mg) followed by NSL 0.5% (0.778mg) compared to untreated check (7.159 mg).Weight of faeces voided in NSS 0.5% was 8.069 mg which was followed by NSS 0.25% (9.678 mg) compared to untreated check (12.853 mg).On fourth instar larvae, the weight gained and weight of faeces voided were less in NSS 0.5% (0.610mg and 2.587 mg respectively) compared to untreated check (2.795 mg and 4.121 mg respectively).

4.1.1.12.2. Effect on growth rate

The lowest growth rate on second instar larvae of *P. xylostella* was recorded in NSS 0.5% which was on par with NSP 0.5%, NSL 0.5% and NSV 0.55 (0.02 mg) followed by NSS 0.25% (0.03) (Table 17).

On fourth instar larvae of *P. xylostella* lowest growth rate was observed in NSS 0.5% (0.03) followed by NSV 0.5% (0.04) which was significantly on par with NSP 0.5% (0.04) as compared to untreated check (0.14) (Table 18).

4.1.1.12.3. Effect on ECI and AD

ECI value indicates the extent to which the ingested food is digested by the larvae. From the Table 17 on second instar larvae, significantly low value was observed in NSP 0.5% (2.83%) which was significantly on par with NSS 0.5% (2.88%), NSL 0.5% (2.99%) and NSV 0.5% (3.43%) compared to untreated check (17.76%). On fourth instar larvae, ECI value (Table 18) was lower in NSV 0.5% (6.98%) followed by NSS 0.25% (11.39%) and NSS 0.5% (12.18%) compared to untreated check (12.89%).

On second instar larvae, AD value was low in NSV 0.5% (44.52%) followed by NSKE 5% (50.69%). On fourth instar larvae, NSL 0.5% recorded the lowest AD value of 61.63% followed by NSP 0.5% (63.33%) which was significantly on par with NSV 0.5% (63.75).

4.1.1.12.4. Effect on ECD

On second instar, NSS 0.5% and NSL 0.5% registered the lowest ECD value of 4.66% and 4.90% respectively. On fourth instar larvae NSV 0.5% which recorded the lowest ECD value of 10.95% (Tables 17 and 18).

4.2. Field experiments

4.2.1. Efficacy of NeemSweet formulations against tobacco caterpillar, *Spodoptera litura* on cauliflower (Field trial I).

4.2.1.1. After first spray

Table19a shows that, the pre-treatment count on number of insects per five randomly selected plants and per cent damage of various treatments ranged between 41.33 to 57.67 and 18.85 to 21.90 respectively with no significant difference among the treatments. When *S. litura* incidence reached ETL, spraying was carried out. On 3 DAS, the mean number of larvae/5 plants ranged from 28.67 to 62.33. Among the treatments NSS at 2 ml l^{-1} recorded the lowest larval population (28.67) followed by NSP 2 ml l^{-1} (29.33), NeemAzal 2 ml l^{-1} (30.67) as compared to untreated check (62.33). NSS 2 ml l^{-1} (17.28) was found to be significantly effective in reducing tobacco caterpillar damage followed by NSP 2 ml l^{-1} (17.74) which was significantly on par with NeemAzal 2 ml l^{-1} (17.72).On 5 DAS, the mean no. of larvae/5 plants ranged from 23 to 65.67. Among the treatments NSP at 2 ml l^{-1} recorded the lowest larval population (23) followed by NSS 2 ml l^{-1} (24.33), and NeemAzal 2 ml l^{-1} (27.33) as compared to untreated check (65.67). NSS 2 ml l^{-1} (15.19) and NSP 2 ml l^{-1} (15.36) recorded least caterpillar damage.

On 7 DAS, NSS 2 ml l^{-1} was found to be significantly effective in reducing larval population (27.67) followed by NSP 2 ml l^{-1} (29.33), NeemAzal 2 ml l^{-1} (32.67), compared to untreated check (66.67). Regarding damage level, NSKE 50 ml l^{-1} recorded significantly reduced leaf damage (14.86), while NSP 2 ml l^{-1} and NSS 2 ml l^{-1} effected the reduction of caterpillar damage 16.23 and 16.47, respectively as compared to untreated check (23.36). On 10 DAS, NSS 2 ml l^{-1} recorded the lowest level of larval population (32.33) followed by NSP 2 ml l^{-1} (34.67), NeemAzal 2 ml l^{-1} (38.33) and NSS 2 ml l^{-1}, NSP

2 ml l^{-1} treated plot had significantly lower caterpillar damage (17.20 and 17.78%). The untreated check had significantly higher caterpillar damage (27.36%)

4.2.1.2. After second spray

Due to increased presence of larval population 10 DAS, second spray was taken up on 11 days after first spraying and observations were recorded on 3, 5, 7, 10 DAS (Table 19b). On 3 DAS, NSS 2 ml l^{-1} recorded the least population and lower leaf damage (16.67 and 16.26%) followed by NSP 2 ml l^{-1} (19.67 and 16.26%) respectively. On 5 DAS, NSS 2 ml l^{-1} recorded the least population and low leaf damage (8.55 and 16.26%) followed by NSP 2 ml l^{-1} (11.75 and 16.38) respectively. On 7 DAS lowest population and low leaf damage was observed in NSS 2 ml l^{-1} (17.50 and 17.25%), followed by NSP 2 ml l^{-1} (19.50 and 17.37 %), respectively. On 10 DAS lowest population and low leaf damage was observed in NSS 2 ml l^{-1} (22.70), followed by NSP 2 ml l^{-1} (26.70) and NeemAzal 2 ml l^{-1} (31.70) and NSS 2 ml l^{-1} treatment was found to be effective in reducing caterpillar damage (20.31%) followed by NSP 2 ml l^{-1} (21.70) and NeemAzal 2 ml l^{-1} (22.07%) as compared to untreated check (30.38%).

The cumulative effect of two rounds of sprays resulted in the reduction in the larval population in NSS 2 ml l^{-1} (64.09%) and NSP 2 ml l^{-1} (61.71%), followed by NeemAzal 2 ml l^{-1} (54.03%) over untreated check.

4.2.2. Efficacy of NeemSweet formulations against tobacco caterpillar, *Spodoptera litura* on cauliflower (Field trial II).

4.2.2.1. After first spray

The efficacy of different treatments showed the same trend as in the first field trial (Table 20a). Prior to spray, population of *S. litura* in all the treatments ranged from 43.67 to 53.45 and leaf damage by larvae was from 19.58 to 23.91 per cent. Spraying was done based on Economic threshold level of pest and observations were recorded on 3, 5, 7 and 10 DAS. Among the treatments NSS 2 ml l^{-1} recorded the least population (25.57) followed by NSP 2 ml l^{-1} (28.67) and NeemAzal 2 ml l^{-1} (31.67). Among the treatments, NSS 2 ml l^{-1} recorded low caterpillar damage (15.38%) which was followed by

NSP 2 ml l^{-1} and Neem oil 2 ml l^{-1} with 15.92 and 17.36 per cent leaf damage compared to untreated check (23.33%). On 5 DAS, NSS 2 ml l^{-1} recorded least population (19.67) followed by NSP 2 ml l^{-1} (23.33), NeemAzal 2 ml l^{-1} (26.33). NSP 2 ml l^{-1} and NSS 2 ml l^{-1} recorded minimum leaf damage of 12.94 and 13.59% against tobacco caterpillar.

On 7 DAS, NSS 2 ml l^{-1} registered lowest number of larvae (20.33) and followed by NSP 2 ml l^{-1} (26.67) as compared to untreated check and also NSP 2 ml l^{-1} and NSL 2 ml l^{-1} was recorded leaf damage of 13.42 and 14.54% respectively. On 10 DAS, NSS 2 ml l^{-1} recorded significantly lower population (24.67) followed by NSP 2 ml l^{-1} (30.33), NeemAzal 2 ml l^{-1} (34.67). The seventh DAS efficacy was also observed on 10 DAS with regarding to per cent damage caused by caterpillar larvae.

4.2.2.2. After second spray

Due to slight increase in the larval population 10 DAS, second spray was given on 11 days after first spraying and counting was taken up on 3, 5, 7 and 10 days after second spraying (Table 20b.). On 3 DAS, NSS 2 ml l^{-1} recorded least population (16.67) followed by NSP 2 ml l^{-1} (17.57), NeemAzal 2 ml l^{-1} (20.36) and NSP 2 ml l^{-1} (11.46) and NSS 2 ml l^{-1} (11.87) recorded least caterpillar damage. On 5 DAS, NSS 2 ml l^{-1} recorded least population (9.33) followed by NSP 2 ml l^{-1} (13.67), NSKE 50 ml l^{-1} (18.33) which was on par with NeemAzal 2 ml l^{-1} (18.67) and NSS 2 ml l^{-1} and NSP 2 ml l^{-1} recorded minimum leaf damage of 10.50 and 10.45% which was on par.

On 7 DAS the lowest population observed in NSS 2 ml l^{-1} (13.33), followed by NSP 2 ml l^{-1} (17.33), Neem oil 2 ml l^{-1} (23.67). However, NSP 2 ml l^{-1} treatment was found to be effective in reducing caterpillar damage (20.31) followed by NSL 2 ml l^{-1} (16.62) as compared to untreated check (27.96%) simultaneously. On 10 DAS, NSS 2 ml l^{-1} recorded least no. of larvae (17.67), followed by NSP 2 ml l^{-1} (21.67), and NeemAzal 2 ml l^{-1} (29.36). NSS 2 ml l^{-1} observed 13.09 per cent leaf damage which was followed by NSP 2 ml l^{-1} and NeemAzal 2 ml l^{-1} (14.01 and 15.09% respectively) as compared with untreated check (32.10%).

At the end of two rounds of the sprays, considerable per cent reduction in the larval population in NSS 2 ml l^{-1} (65.53%), followed by NSP 2 ml l^{-1} (62.10%) and NeemAzal 2 ml l^{-1} (54.43) over untreated check was recorded.

4.2.3. Efficacy of NeemSweet formulations against diamondback moth, *Plutella xylostella* on cauliflower (Field trial I)

4.2.3.1. After first spray

Table 21a shows that the pre-treatment count on number of insects per five randomly selected plants and per cent damage of various treatments ranged between 19.25 to 22.17 and 39.33 to 45.67, respectively with no significant difference among them. When *P. xylostella* incidence reached ETL, spraying was carried out. On 3 DAS, the mean number of larvae/5 plants ranged from 7.03 to 22.67. Among the treatments NSS at 2 ml l^{-1} recorded the lowest larval population (7.03) followed by NSP 2 ml l^{-1} (9.11), NSL 2 ml l^{-1} (11.34) as compared to untreated check (22.67). Among botanical insecticides tested, NSL 2 ml l^{-1} (36.21) and NeemAzal 2 ml l^{-1} (36.33) was found to be significantly effective in reducing diamondback moth damage followed by NSV 2 ml l^{-1} (36.67) and NSKE 50 ml l^{-1}. NSS 2 ml l^{-1} (4.21) and NSP 2 ml l^{-1} and NeemAzal 2 ml l^{-1} recorded minimum larvae of 6.12 and 9.67 at 5 DAS. Also, NSS 2 ml l^{-1} recorded least percent damage (35.41) followed by NSV 2 ml l^{-1} (35.67) and NSL 2ml l^{-1} (35.71) which was on par, NeemAzal 2 ml l^{-1} (11.73)

On 7 DAS, NSS 2 ml l^{-1} was found to be significantly effective in reducing larval population (6.07) followed by NSP 2 ml l^{-1} (6.89), NeemAzal 2 ml l^{-1} (11.33), compared to untreated check (26.80). NSS 2 ml l^{-1}recorded significantly reduced leaf damage (35.17), while NSV 2 ml l^{-1} and NSL 2 ml l^{-1} effected the reduction of diamondback moth damage 35.99 and 36.47 respectively as compared to untreated check (23.36). On 10 DAS, NSS 2 ml l^{-1} recorded the lowest level of larval population (9.16) followed by NSP 2 ml l^{-1} (10.11), NeemAzal 2 ml l^{-1} (12.71) and NSL 2 ml l^{-1}, NSKE 50 ml l^{-1} treated plot had significantly lower diamondback moth damage (36.33 and 36.67%). The untreated check had significantly higher diamondback moth damage (47.67%).

4.2.3.2. After second spray

Due to slight increase in the larval population, A second spray was taken up 11 days after first spraying and observations were recorded on 3, 5, 7, and 10 DAS (Table 21b). On 3 DAS, NSS 2 ml l^{-1} recorded the least population (3.66) followed by NSP 2 ml l^{-1} (4.11) and NeemAzal 2 ml l^{-1} (4.33) which was on par with NSL 2 ml l^{-1} (6.51) and NSKE 5% and NSS 2 ml l^{-1} (33.67 and 34.21%) recorded least caterpillar damage. NSS 2 ml l^{-1} (2.59) and NSP 2 ml l^{-1} and NeemAzal 2 ml l^{-1} recorded minimum larvae of 3.97 and 4.33 at 5 DAS. NSS 2 ml l^{-1} recorded least per cent damage (32.60) followed by NSP 2 ml l^{-1} (37.79), NSKE 50 ml l^{-1} (34.37).

On 7 DAS lowest population was observed in NSS 2 ml l^{-1} (3.11), followed by NSP 2 ml l^{-1} (4.71) and NeemAzal 2 ml l^{-1} (5.16). NSS 2 ml l^{-1} treatment was found to be effective in reducing diamondback moth damage (32.11%) as compared to untreated check (48.67%). On 10 DAS lowest population was observed in NSS 2 ml l^{-1} (4.71), followed by NSP 2 ml l^{-1} (5.21) and NeemAzal 2 ml l^{-1} (6.73) and NSS 2 ml l^{-1} treated plot had significantly lower diamondback moth damage (33.67%) followed by NSP 2 ml l^{-1} (34.17%) and NeemAzal 2 ml l^{-1} (34.79%). The untreated check had significantly higher diamondback moth damage (48.67%).

The cumulative effect of two rounds of sprays resulted in the reduction in the larval population in NSS 2 ml l^{-1} (81.91%), followed by NSP 2 ml l^{-1} (75.98%) and NeemAzal 2 ml l^{-1} (69.76 %) over untreated check.

4.2.4. Efficacy of NeemSweet formulations on population reduction of diamondback moth, *Plutella xylostella* on cauliflower (Field trial II)

4.2.4.1. After first spray

The efficacy of different treatments showed the same trend as in the first field trial (Table 22a). Prior to spray, larval numbers and per cent damage of *P. xylostella* in all the treatments ranged from 23.35 to 26.89 and 34.22 to 39.73 per cent respectively. Spraying was done based on ETL of the pest and observations were recorded on 3, 5, 7 and 10 DAS. Among the treatments NSS 2 ml l^{-1} recorded the least population (8.53)

followed by NSP 2 ml l^{-1} (11.05), NSV and NSL 2 ml l^{-1} (13.67 and 13.76) which was on par with each other. Among the treatments, both NSL 2 ml l^{-1} and NeemAzal 2 ml l^{-1} recorded low diamondback moth damage (31.50 and 31.961%) which was on par with other and followed by NSV 2 ml l^{-1} with 31.90 per cent leaf damage compared to untreated check (39.73%). On 5 DAS, NSS 2 ml l^{-1} recorded least population (5.11) followed by NSP 2 ml l^{-1} (7.42), NeemAzal 2 ml l^{-1} (11.73). On 5 DAS, NSS 2 ml l^{-1} recorded least per cent damage (30.81) followed by NSV 2 ml l^{-1} (31.03), NeemAzal 2 ml l^{-1} (31.07) were on par

On 7 DAS, NSS 2 ml l^{-1} registered lowest no. of larvae (7.36) and followed by NSP 2 ml l^{-1} (7.67) and NSS 2 ml l^{-1} and NSV 2 ml l^{-1} was recorded leaf damage of 30.60 and 31.31% respectively as compared to untreated check. On 10 DAS, NSS 2 ml l^{-1} recorded significantly lower population (9.57) followed by NSP 2 ml l^{-1} (11.33), NSV 2 ml l^{-1} (13.67) and NSL 2 ml l^{-1} and NSKE 50% showed least per cent damaged leaves (31.61 and 31.90) followed by NeemAzal 2 ml l^{-1} (32.29).

4.2.4.2. After second spray

A second spray was given on 11 DAS and counting was taken up on 3,5, 7 and 10 days after second spraying (Table 22b). On 3 DAS, NSP 2 ml l^{-1} recorded least population (3.67) followed by NSS 2 ml l^{-1} (5.67), NSV 2 ml l^{-1} (7.67) and NSKE 5% (29.29) recorded least diamondback moth damage which was followed by NSS 2 ml l^{-1} (29.76) and NeemAzal 2 ml l^{-1} (30.45). On 5 DAS, NSS 2 ml l^{-1} recorded least population and lower per cent damage (4.33 and 28.36%) followed by NSP 2 ml l^{-1} (4.82 and 29.33%), NeemAzal 2 ml l^{-1} (5.25 and 29.21%).

On 7 DAS the lowest population observed in NSS 2 ml l^{-1} (5.67) which was on par with NSP 2 ml l^{-1} (5.71) and followed by NeemAzal 2 ml l^{-1} (6.26). Regarding leaf damage, NSS 2 ml l^{-1} treatment was found to be effective in reducing diamondback moth damage (27.94%) followed by NSP 2 ml l^{-1} (29.55%) as compared to untreated check (42.34%). On 10 DAS, both NSS 2 ml l^{-1} and NSP 2 ml l^{-1} recorded least no. of larvae (6.33 and 6.32 respectively), followed by NeemAzal 2 ml l^{-1} (8.16) on par with NSV 2 ml l^{-1} (8.33) and

NSS 2 ml l^{-1} observed 29.29% leaf damage which was followed by NSP 2 ml l^{-1} and NeemAzal 2 ml l^{-1} (29.73 and 30.27% respectively) as compared with untreated check (40.60%).

At the end of two rounds of both the sprays, considerable per cent reduction in the larval population in NSS 2 ml l^{-1} (80.66%), followed by NSP 2 ml l^{-1} (77.13%) and NeemAzal 2 ml l^{-1} (69.76%) over untreated check.

Table 1. Oviposition deterrent activity of NeemSweet formulations against *Spodoptera litura* adults

Treatment	Concentration (%)	24 HAT*		48 HAT*		72 HAT*	
		Per cent oviposition	ROP	Per cent oviposition	ROP	Per cent oviposition	ROP
NSS 60 EC	0.50	0.00 (0.50)^{e}	-100.00	3.48 (6.61)^{d}	-74.05	5.34 (10.68)^{c}	-51.29
NSS 60 EC	0.25	0.91 (3.51)^{de}	-96.10	4.08 (11.61)^{cd}	-70.24	7.15 (15.15)^{bc}	-39.76
NSL 60 EC	0.50	2.77 (7.98)^{cd}	-88.65	4.84 (10.57)^{cd}	-65.63	9.07 (17.52)^{abc}	-29.34
NSL 60 EC	0.25	11.86 (20.06)^{b}	-59.03	14.31 (22.18)^{ab}	-23.95	13.34 (21.40)^{ab}	-10.87
NSV 60 EC	0.50	0.00 (0.50)^{e}	-100.00	5.91 (13.14)^{bcd}	-59.58	4.50 (12.13)^{c}	-57.35
NSV 60 EC	0.25	8.85 (12.59)^{bcd}	-67.75	9.03 (14.55)^{bcd}	-44.18	9.65 (18.10)^{abc}	-26.45
NSP 60 EC	0.50	0.00 (0.50)^{e}	-100.00	3.00 (9.95)^{cd}	-77.23	4.24 (11.88)^{c}	-59.31
NS 60 EC	0.50	8.21 (16.69)^{bc}	-69.71	12.92 (20.95)^{abc}	-28.72	12.06 (20.31)^{ab}	-15.85
NO 60 EC	0.50	9.91 (18.04)^{b}	-64.58	5.50 (12.99)^{cd}	-61.84	5.93 (11.50)^{c}	-47.38
NSKE	5	11.47 (19.74)^{b}	-60.11	14.43 (22.18)^{b}	-23.56	12.11 (20.27)^{ab}	-15.63
Untreated check	-	46.03 (42.68)^{a}		23.33 (28.25)^{a}		16.60 (24.02)^{a}	

*Mean of three replications; ROP – Relative ovipositional preference; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 2. Oviposition deterrent activity of NeemSweet formulations against *Plutella xylostella* adults

Treatment	Concentration (%)	24 HAT*		48 HAT*		72 HAT*	
		Per cent oviposition	ROP	Per cent oviposition	ROP	Per cent oviposition	ROP
NSS 60 EC	0.50	0.00 (4.05)[a]	-100.00	1.23 (3.35)[a]	-95.21	10.08 (18.51)[b]	-61.86
NSS 60 EC	0.25	10.30 (18.72)[f]	-62.16	18.87 (25.74)[h]	-38.81	17.31 (24.58)[d]	-42.93
NSL 60 EC	0.50	2.42 (18.96)[c]	-88.33	5.64 (13.73)[c]	-76.12	4.13 (11.73)[a]	-82.25
NSL 60 EC	0.25	7.27 (15.64)[e]	-63.53	8.58 (17.03)[d]	-62.87	21.71 (27.76)[e]	-32.96
NSV 60 EC	0.50	0.61 (14.46)[b]	-96.67	12.99 (21.12)[e]	-49.35	16.80 (24.19)[d]	-43.41
NSV 60 EC	0.25	10.30 (18.72)[f]	-55.00	16.91 ()24.28[g]	-39.47	21.45 (27.58)[e]	-33.56
NSP 60 EC	0.50	3.64 (10.99)[d]	-83.85	4.41 (12.12)[b]	-81.31	13.18 (21.28)[c]	-52.81
NS 60 EC	0.50	20.00 (26.56)[h]	-25.07	12.25 (20.49)[e]	-50.45	25.06 (30.04)[f]	-26.04
NO 60 EC	0.50	9.70 (18.14)[f]	-54.67	14.71 (22.55)[f]	-46.89	20.16 (26.67)[e]	-37.15
NSKE	5	15.76 (23.38)[g]	-35.8	14.95 (22.74)[f]	-43.	24.03 (29.35)[f]	-27.

			5		55		92
Untreated check	-	33.33 (35.26)[i]		33.33 (35.26)[i]		33.33 (35.26)[g]	

*Mean of three replications; ROP – Relative ovipositional preference; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 3. Ovicidal action of NeemSweet formulations against *Spodoptera litura eggs*

Treatment	Concentration (%)	Per cent cumulative unhatched eggs *				Per cent egg hatchability
		24 HAT	48 HAT	72 HAT	96 HAT	
NSS 60 EC	0.50	17.74 (24.91)^{a}	45.66 (42.51)^{a}	72.08 (58.13)^{a}	80.38 (63.78)^{a}	19.62 (26.75)^{a}
NSS 60 EC	0.25	8.46 (16.91)^{cd}	34.23 (35.80)^{bc}	55.77 (48.32)^{cd}	62.69 (52.36)^{cd}	37.31 (37.65)^{d}
NSL 60 EC	0.50	10.00 (18.43)^{b}	30.42 (33.47)^{d}	58.33 (49.80)^{b}	72.92 (58.68)^{b}	27.08 (31.35)^{b}
NSL 60 EC	0.25	8.14 (16.57)^{cd}	30.81 (33.71)^{d}	54.65 (47.67)^{bcd}	62.21 (52.08)^{cd}	37.79 (37.93)^{de}
NSV 60 EC	0.50	8.84 (17.29)^{c}	31.63 (34.22)^{cd}	56.74 (48.88)^{bc}	67.44 (55.23)^{c}	32.56 (34.79)^{c}
NSV 60 EC	0.25	6.25 (14.47)^{e}	20.45 (26.88)^{f}	48.30 (44.03)^{e}	55.11 (47.94)^{ef}	44.89 (42.07)^{f}
NSP 60 EC	0.50	6.31 (14.55)^{e}	27.03 (31.22)^{e}	53.60 (47.07)^{cd}	60.81 (51.25)^{d}	39.19 (38.75)^{de}
NS 60 EC	0.50	8.00 (16.43)^{d}	30.22 (33.34)^{d}	55.56 (48.20)^{bcd}	62.67 (52.35)^{cd}	37.33 (37.66)^{d}
NO 60 EC	0.50	5.51 (13.57)^{f}	31.36 (34.05)^{d}	41.95 (40.36)^{f}	50.42 (45.24)^{f}	49.58 (44.76)^{g}
NSKE	5	8.33 (16.77)^{cd}	36.11 (36.93)^{b}	52.08 (46.19)^{de}	58.33 (49.80)^{de}	41.67 (40.20)^{ef}
Untreated check	-	0.00 (4.05)^{g}	0.29 (3.09)^{g}	1.16 (6.18)^{g}	1.16 (6.18)^{g}	98.84 (84.27)^{h}

*Mean of three replications; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s)(s) are not significantly different (p = 0.05) by LSD

Table 4. Ovicidal action of NeemSweet formulations on *Plutella xylostella* eggs

Treatment	Concentration (%)	Per cent cumulative unhatched eggs *				Per cent egg Hatchability
		24 HAT	48 HAT	72 HAT	96 HAT	
NSS 60 EC	0.50	28.67 (32.37)[a]	61.67 (51.76)[a]	89.33 (71.21)[a]	100.00 (90.00)[a]	0.00 (4.05)[a]
NSS 60 EC	0.25	13.65 (21.38)[d]	29.67 (33.50)[cd]	61.31 (51.55)[d]	82.19 (65.13)[d]	17.81 (24.96)[e]
NSL 60 EC	0.50	20.33 (26.80)[c]	48.24 (43.99)[b]	73.58 (59.10)[c]	87.67 (69.63)[cd]	12.33 (20.55)[d]
NSL 60 EC	0.25	8.33 (16.77)[e]	33.67 (35.46)[c]	56.47 (48.72)[de]	71.67 (57.87)[e]	28.33 (32.15)[f]
NSV 60 EC	0.50	22.39 (28.24)[b]	49.67 (44.81)[b]	74.64 (59.80)[c]	90.67 (72.57)[c]	9.33 (17.78)[c]
NSV 60 EC	0.25	7.68 (16.09)[ef]	32.33 (34.65)[cd]	52.67 (46.53)[e]	67.59 (55.32)[e]	32.41 (34.70)[g]
NSP 60 EC	0.50	27.67 (31.73)[a]	59.33 (50.38)[a]	84.67 (67.08)[b]	98.33 (83.98)[b]	1.67 (7.42)[b]
NS 60 EC	0.50	5.33 (13.35)[f]	22.33 (28.20)[ef]	34.59 (36.02)[g]	56.67 (48.84)[f]	43.33 (41.16)[h]
NO 60 EC	0.50	6.33 (14.57)[g]	24.67 (29.78)[e]	44.67 (41.94)[f]	68.33 (55.77)[e]	31.67 (34.24)[g]
NSKE	5	6.97 (15.30)[fg]	20.33 (26.80)[f]	42.00 (25.80)[f]	70.67 (57.24)[e]	29.33 (32.79)[f]
Untreated check	-	0.00 (4.05)[i]	0.00 (4.05)[g]	0.00 (4.05)[h]	0.00 (4.05)[g]	100.00 (90.00)[i]

*Mean of three replications; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s)(s) are not significantly different (p = 0.05) by LSD

Table 5. Toxicity of NeemSweet formulations against neonates of *Spodoptera litura*

Treatment	Concentration (%)	Per cent cumulative mortality *			
		24 HAT	48 HAT	72 HAT	96 HAT
NSS 60 EC	0.50	18.89 (25.76)^{c}	58.89 (50.13)^{b}	84.44 (66.90)^{b}	100.00 (90.00)^{a}
NSS 60 EC	0.25	12.22 (20.46)^{d}	37.78 (37.92)^{d}	51.11 (45.64)^{f}	64.44 (53.41)^{ef}
NSL 60 EC	0.50	21.11 (27.35)^{b}	56.67 (48.84)^{b}	76.67 (61.17)^{c}	95.56 (80.12)^{b}
NSL 60 EC	0.25	8.89 (17.34)^{e}	26.67 (31.09)^{e}	52.22 (46.27)^{f}	63.33 (52.74)^{ef}
NSV 60 EC	0.50	24.44 (29.63)^{a}	65.56 (54.08)^{a}	95.56 (80.12)^{a}	100.00 (90.00)^{a}
NSV 60 EC	0.25	8.89 (17.34)^{e}	37.78 (37.92)^{d}	66.67 (54.75)^{d}	75.56 (60.41)^{d}
NSP 60 EC	0.50	18.89 (25.76)^{c}	43.33 (41.17)^{c}	77.78 (61.93)^{bc}	84.44 (66.90)^{c}
NS 60 EC	0.50	12.22 (20.46)^{d}	40.00 (39.23)^{cd}	64.44 (53.41)^{d}	73.33 (58.94)^{d}
NO 60 EC	0.50	3.33 (10.52)^{g}	17.78 (24.93)^{f}	41.11 (39.88)^{g}	56.67 (48.84)^{f}
NSKE	5	7.78 (16.19)^{f}	27.78 (31.80)^{e}	56.67 (48.84)^{f}	67.78 (55.43)^{de}
Untreated check	-	0.00 (4.05)^{h}	0.00 (4.05)^{g}	1.11 (6.05)^{h}	2.22 (8.57)^{g}

*Mean of three replications; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 6. Toxicity of NeemSweet formulations against neonates of *Plutella xylostella*

Treatments	Concentration (%)	Per cent cumulative mortality*		
		24 HAT	48HAT	72 HAT
NSS 60 EC	0.50	71.90 (58.02)^{a}	89.69 (71.56)^{b}	100.00 (90.00)^{a}
NSS 60 EC	0.25	49.77 (44.57)^{cd}	71.52 (57.78)^{c}	87.83 (69.79)^{cd}
NSL 60 EC	0.50	53.53 (47.02)^{c}	74.65 (59.81)^{c}	95.78 (80.50)^{b}
NSL 60 EC	0.25	38.44 (38.31)^{c}	55.00 (47.87)^{de}	81.71 (64.77)^{de}
NSV 60 EC	0.50	59.14 (50.28)^{b}	84.49 (66.94)^{b}	91.55 (73.53)^{c}
NSV 60 EC	0.25	47.91 (43.80)^{d}	59.14 (50.28)^{d}	73.26 (58.89)^{ef}
NSP 60 EC	0.50	70.43 (57.08)^{a}	94.38 (77.36)^{a}	100.00 (90.00)^{a}
NS 60 EC	0.50	46.47 (42.97)^{d}	59.14 (50.28)^{d}	66.20 (54.47)^{fg}
NO 60 EC	0.50	31.01 (33.83)^{f}	42.24 (40.54)^{f}	54.92 (47.83)^{h}
NSKE	5	36.63 (37.24)^{e}	49.30 (44.60)^{ef}	60.58 (51.12)^{gh}
Untreated check	-	0.00 (4.05)^{g}	0.00 (4.05)^{g}	0.00 (4.05)^{i}

*Mean of three replications; HAT – Hours after treatment

Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 7. Antifeedant effect of NeemSweet formulations against third instar larvae of *Spodoptera litura*

Treatment	Concentration %	Weight gained by larva (g)*	Leaf Area consumed (cm^2)	Antifeedant Index (AI)
NSS 60 EC	0.50	0.041 (1.165)^{a}	5.68 (13.79)^{a}	79.87 (63.41)^{a}
NSS 60 EC	0.25	0.081 (1.634)^{e}	18.89 (25.74)^{e}	45.81 (42.59)^{d}
NSL 60 EC	0.50	0.061 (1.411)^{c}	9.70 (18.14)^{b}	67.92 (55.52)^{b}
NSL 60 EC	0.25	0.078 (1600)^{e}	34.29 (35.84)^{h}	19.38 (26.11)^{g}
NSV 60 EC	0.50	0.113 (1.923)^{g}	17.06 (24.39)^{d}	49.70 (44.83)^{d}
NSV 60 EC	0.25	0.063 (1.442)^{cd}	27.68 (31.74)^{g}	29.44 (32.85)^{f}
NSP 60 EC	0.50	0.067 (1.487)^{d}	17.26 (24.54)^{de}	49.26 (44.58)^{d}
NS 60 EC	0.50	0.093 (1.750)^{f}	13.30 (21.38)^{c}	58.56 (49.90)^{c}
NO 60 EC	0.50	0.047 (1.242)^{b}	21.25 (27.45)^{f}	40.99 (39.90)^{e}
NSKE	5	0.059 (0.392)^{c}	18.84 (25.72)^{de}	45.87 (42.63)^{d}
Untreated check	-	0.114 (2.934)^{g}	50.18 (45.45)^{i}	-

*Mean of three replications; Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 8. Antifeedant effect of NeemSweet formulations against fifth instar larvae of *Spodoptera litura*

Treatment	Concentration %	Weight gained of larva (g)*	Leaf Area consumed (cm^2)	Antifeedant Index (AI)
NSS 60 EC	0.50	0.046 $(1.221)^{cd}$	15.94 $(23.36)^{a}$	71.84 $(59.29)^{a}$
NSS 60 EC	0.25	0.060 $(1.400)^{d}$	45.07 $(42.13)^{bcde}$	36.67 $(39.11)^{bc}$
NSL 60 EC	0.50	0.039 $(1.125)^{bc}$	22.79 $(28.25)^{abc}$	62.63 $(54.04)^{ab}$
NSL 60 EC	0.25	0.095 $(1.765)^{ef}$	68.10 $(56.17)^{e}$	17.64 $(27.50)^{d}$
NSV 60 EC	0.50	0.030 $(0.983)^{b}$	22.46 $(28.28)^{abc}$	62.48 $(53.66)^{ab}$
NSV 60 EC	0.25	0.102 $(1.826)^{f}$	59.08 $(51.01)^{de}$	24.42 $(32.44)^{cd}$
NSP 60 EC	0.50	0.031 $(1.009)^{b}$	21.29 $(26.06)^{ab}$	64.08 $(56.94)^{a}$
NS 60 EC	0.50	0.068 $(1.489)^{de}$	38.10 $(37.66)^{abcd}$	43.70 $(43.76)^{abcd}$
NO 60 EC	0.50	0.046 $(1.218)^{bcd}$	49.01 $(44.43)^{acde}$	32.99 $(36.99)^{bcd}$
NSKE	5	0.014 $(0.619)^{a}$	35.61 $(35.72)^{bcd}$	46.39 $(47.52)^{abcd}$
Untreated check	-	0.203 $(2.579)^{g}$	97.26 $(83.6)^{f}$	-

*Mean of three replications; Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 9. Antifeedant effect of NeemSweet formulations against second instar larvae of *Plutella xylostella*

Treatment	Concentration (%)	Weight gained by larva (mg)	Leaf area consumed (mm^2)	Antifeedant index (AI)
NSS 60 EC	0.50	0.200 (2.560)[a]	1.02 (5.80)[a]	93.39 (75.83)[a]
NSS 60 EC	0.25	0.400 (3.630)[b]	7.32 (15.69)[ef]	60.65 (51.15)[d]
NSL 60 EC	0.50	0.440 (3.800)[b]	3.72 (11.12)[c]	77.86 (61.99)[b]
NSL 60 EC	0.25	0.920 (5.500)[d]	10.04 (18.47)[g]	49.70 (44.83)[f]
NSV 60 EC	0.50	0.440 (3.800)[b]	5.11 (13.06)[d]	70.79 (57.31)[bc]
NSV 60 EC	0.25	1.120 (6.070)[f]	7.52 (15.91)[f]	59.79 (50.65)[de]
NSP 60 EC	0.50	0.200 (2.560)[a]	1.32 (6.60)[b]	91.54 (73.52)[a]
NS 60 EC	0.50	1.000 (5.740)[e]	9.68 (18.12)[g]	51.06 (45.61)[ef]
NO 60 EC	0.50	0.640 (4.590)[c]	6.72 (15.02)[e]	63.28 (52.71)[cd]
NSKE	5	0.600 (4.440)[c]	7.20 (15.56)[ef]	61.17 (51.46)[d]
Untreated check	-	1.400 (6.790)[g]	29.88 (33.13)[h]	

*Mean of three replications; Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 10. Antifeedant effect of NeemSweet formulations against fourth instar larvae of *Plutella xylostella*

Treatment	Concentration (%)	Weight gained by larva (mg)	Leaf area consumed (cm^2)	Antifeedant index (AI)
NSS 60 EC	0.50	0.072 (1.540)[a]	0.087 (1.69)[a]	81.65 (34.72)[a]
NSS 60 EC	0.25	0.247 (2.850)[d]	0.287 (3.07)[d]	50.00 (45.00)[d]
NSL 60 EC	0.50	0.155 (2.260)[c]	0.211 (2.63)[c]	60.63 (51.15)[c]
NSL 60 EC	0.25	0.577 (4.360)[g]	0.415 (3.69)[fg]	34.95 (36.24)[g]
NSV 60 EC	0.50	0.166 (2.330)[c]	0.116 (1.95)[b]	76.25 (60.88)[b]
NSV 60 EC	0.25	0.400 (3.630)[f]	0.395 (3.60)[f]	37.10 (37.52)[fg]
NSP 60 EC	0.50	0.099 (1.800)[b]	0.101 (1.82)[b]	79.00 (62.79)[ab]
NS 60 EC	0.50	0.757 (4.990)[h]	0.445 (3.82)[g]	31.84 (34.34)[g]
NO 60 EC	0.50	0.300 (3.140)[e]	0.311 (3.20)[d]	46.87 (43.20)[de]
NSKE	5	1.202 (6.290)[i]	0.356 (3.42)[e]	41.50 (40.10)[ef]
Untreated check	-	2.185 (8.500)[j]	0.861 (5.35)[h]	

*Mean of three replications; Values in parentheses are *arc sine* transformed.

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 11. Growth inhibitory effect of NeemSweet formulations against third instar larvae of *Spodoptera litura*

Treatment	Concentration (%)	Larval Weight (g) *		weight gained (g)	Larval mortality (%)	Larval pupal intermediates (%)	LGI	Pupation (%)	Adult emergence (%)	Malformed adults (%)	TDGI
		Before treatment	7 days after treatment								
NSS 60 EC	0.50	0.094	0.540 (4.21)^{bcd}	0.368 (3.48)^{bcd}	36.67 (37.88)^{a}	6.67 (15.31)^{b}	5.472 (13.52)^{de}	56.67 (48.85)^{de}	64.71 (53.42)^{d}	18.18 (25.24)^{f}	2.71 (9.46)^{f}
NSS 60 EC	0.25	0.096	0.481 (3.98)^{c}	0.385 (3.56)^{bc}	10.00 (25.79)^{de}	23.33 (29.22)^{a}	6.799 (15.13)^{c}	66.67 (54.78)^{c}	80.00 (63.80)^{bc}	12.50 (20.70)^{h}	4.22 (11.87)^{bcd}
NSL 60 EC	0.50	0.098	0.366 (4.47)^{de}	0.268 (2.97)^{ef}	30.00 (35.31)^{b}	30.00 (33.52)^{a}	3.978 (11.51)^{f}	40.00 (39.15)^{g}	75.00 (59.39)^{bc}	22.22 (28.12)^{d}	3.71 (11.03)^{cd}
NSL 60 EC	0.25	0.093	0.526 (4.16)^{b}	0.433 (3.77)^{b}	20.00 (31.35)^{cde}	16.67 (24.47)^{a}	6.134 (14.34)^{cd}	63.33 (52.78)^{cd}	84.21 (66.53)^{bc}	12.50 (20.70)^{h}	4.40 (12.11)^{bc}
NSV 60 EC	0.50	0.106	0.413 (3.68)^{cd}	0.307 (3.18)^{de}	23.33 (32.73)^{abc}	26.67 (31.41)^{a}	4.525 (12.30)^{ef}	50.00 (45.00)^{ef}	80.00 (63.44)^{bc}	50.00 (45.00)^{a}	3.45 (10.74)^{de}
NSV 60 EC	0.25	0.104	0.461 (3.89)^{c}	0.357 (3.42)^{cd}	13.33 (27.65)^{ab}	20.00 (26.92)^{a}	6.322 (14.55)^{cd}	66.67 (54.78)^{c}	85.00 (67.16)^{bc}	29.41 (32.84)^{b}	4.15 (10.75)^{bcd}
NSP 60	0.50	0.10	0.35	0.2	33.3	20.00	4.3	46.6	71.4	20.00	2.87

EC		3	3 (3.39)^{e}	49 (2.84)^{ef}	3 (36.69)^{ab}	(26.92)^{a}	01 (11.95)^{f}	7 (43.08)^{fg}	3 (58.07)^{cd}	(26.56)^{e}	(9.79)^{ef}
NS 60 EC	0.50	0.097	0.323 (3.26)^{e}	0.227 (2.73)^{f}	10.00 (20.96)^{e}	26.67 (31.41)^{a}	5.938 (14.10)^{cd}	63.33 (52.78)^{cd}	78.95 (62.81)^{bc}	20.00 (26.56)^{e}	3.73 (11.16)^{cd}
NO 60 EC	0.50	0.108	0.412 (3.68)^{cd}	0.304 (3.16)^{de}	6.67 (19.11)^{e}	3.33 (11.29)^{b}	10.351 (18.80)^{b}	90.00 (71.57)^{b}	85.19 (67.65)^{b}	26.08 (30.71)^{c}	4.85 (12.72)^{b}
NSKE	5	0.106	0.327 (3.27)^{e}	0.221 (2.69)^{f}	13.33 (27.65)^{cde}	26.67 (31.41)^{a}	5.556 (13.64)^{de}	60.00 (50.77)^{cd}	77.78 (62.18)^{bcd}	14.28 (22.00)^{g}	4.14 (11.76)^{bcd}
Untreated check	-	0.113	0.870 (5.35)^{a}	0.756 (4.99)^{a}	0.00 (4.05)^{f}	0.00 (4.05)^{b}	12.931 (21.09)^{a}	100.00 (89.50)^{a}	96.67 (83.52)^{a}	0.00 (4.05)^{i}	7.04 (15.39)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed

LGI – Larval growth index; TDGI – Total developmental growth index

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 12. Growth inhibitory effect of NeemSweet formulations against fifth instars larvae of *Spodoptera litura*

Treatment	Concentration (%)	Larval Weight (g) *		weight gained (g)	Larval mortality (%)	Larval pupal intermediates (%)	LGI	Pupation (%)	Adult emergence (%)	Malformed adults (%)	TDGI
		Before treatment	3 days after treatment								
NSS 60 EC	0.50	0.381	0.732 (4.908)^{cd}	0.351 (3.394)^{cd}	10.36 (19.23)^{abc}	16.67 (24.47)^{d}	11.02 (19.38)^{ef}	73.33 (58.94)^{de}	36.67 (37.26)^{ef}	19.44 (26.52)^{f}	1.82 (7.76)^{g}
NSS 60 EC	0.25	0.411	0.783 (5.076)^{bcd}	0.372 (3.497)^{bc}	9.81 (18.72)^{c}	13.37 (21.83)^{e}	14.37 (22.27)^{c}	86.67 (68.76)^{b}	53.33 (46.91)^{c}	12.22 (20.89)^{h}	3.53 (10.83)^{c}
NSL 60 EC	0.50	0.440	0.656 (4.645)^{e}	0.216 (2.665)^{f}	10.06 (18.96)^{bc}	16.67 (24.47)^{d}	12.12 (20.37)^{de}	76.67 (61.17)^{c}	30.00 (33.21)^{f}	41.67 (40.49)^{b}	1.82 (7.76)^{g}
NSL 60 EC	0.25	0.412	0.809 (5.158)^{b}	0.397 (3.611)^{b}	10.33 (19.21)^{abc}	20.00 (26.92)^{c}	12.11 (20.36)^{de}	80.00 (63.51)^{c}	53.33 (46.91)^{c}	12.22 (20.89)^{h}	3.44 (10.69)^{cd}
NSV 60 EC	0.50	0.415	0.622 (4.524)^{e}	0.207 (2.607)^{f}	11.05 (19.86)^{a}	23.33 (29.22)^{b}	9.08 (17.54)^{g}	66.67 (54.75)^{e}	40.00 (39.23)^{de}	50.00 (45.29)^{a}	2.07 (8.28)^{f}
NSV 60 EC	0.25	0.404	0.736 (4.920)^{cd}	0.332 (3.301)^{d}	10.54 (19.41)^{abc}	16.67 (24.47)^{d}	11.20 (19.55)^{e}	76.67 (61.17)^{c}	56.67 (48.84)^{c}	30.00 (33.52)^{c}	3.37 (10.58)^{cd}
NSP 60 EC	0.50	0.387	0.668	0.280	10.85	26.67 (31.41	9.83	70.00	33.33	22.22 (28.4	1.59 (7.23

			(4.686)^{e}	(3.035)^{e}	(19.41)^{ab}	)^{a}	(18.27)^{fg}	(56.81)^{e}	(35.26)^{ef}	6)^{e}	)^{h}
NS 60 EC	0.50	0.402	0.798 (5.132)^{bc}	0.396 (3.607)^{b}	10.67 (19.52)^{ab}	10.00 (18.90)^{f}	12.99 (21.12)^{cd}	90.00 (71.87)^{b}	50.00 (45.00)^{cd}	20.56 (27.31)^{ef}	2.91 (9.82)^{e}
NO 60 EC	0.50	0.396	0.786 (5.085)^{bcd}	0.390 (3.579)^{b}	8.69 (17.65)^{d}	10.00 (18.90)^{f}	18.24 (25.28)^{b}	90.00 (71.87)^{b}	76.67 (61.17)^{b}	26.19 (31.10)^{d}	5.53 (13.59)^{b}
NSKE	5	0.383	0.729 (4.898)^{d}	0.346 (3.379)^{cd}	10.80 (19.64)^{ab}	13.33 (21.83)^{e}	12.28 (20.51)^{de}	86.67 (68.76)^{b}	46.67 (43.09)^{cd}	15.00 (23.18)^{g}	3.13 (10.19)^{de}
Untreated check	-	0.394	1.060 (5.911)^{a}	0.667 (4.683)^{a}	0.00 (4.05)^{e}	0.00 (4.05)^{g}	24.96 (29.97)^{a}	100.00 (90.90)^{a}	96.67 (80.42)^{a}	0.000 (4.05)^{i}	9.65 (18.10)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed

LGI – Larval growth index; TDGI – Total developmental growth index

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 13. Growth inhibitory effect of NeemSweet formulations against second instar larvae of *Plutella xylostella*

Treatment	Concentration (%)	Initial weight (mg)	Final weight (mg)	Weight gained (mg)	Larval mortality (%)	Larval pupal intermediaries (%)	LGI	Pupation (%)	Adult emergence (%)	Mal formed adults (%)	TDGI
NSS 60 EC	0.50	0.950	1.973 (8.07)^{a}	1.023 (5.80)^{a}	40.55 (39.84)^{a}	14.94 (23.13)^{b}	7.28 (15.65)^{g}	59.45 (50.45)^{f}	69.16 (56.29)^{f}	9.44 (18.38)^{f}	4.43 (12.15)^{f}
NSS 60 EC	0.25	0.870	2.514 (9.12)^{b}	1.644 (7.37)^{b}	27.78 (32.12)^{c}	12.60 (21.22)^{d}	10.64 (19.03)^{d}	72.22 (58.22)^{cd}	82.32 (65.23)^{cd}	14.94 (23.14)^{d}	6.23 (14.45)^{c}
NSL 60 EC	0.50	0.930	2.738 (9.52)^{bc}	1.808 (7.73)^{bc}	35.55 (36.90)^{b}	18.05 (25.51)^{a}	8.72 (17.17)^{e}	64.45 (53.41)^{ef}	76.70 (61.19)^{ef}	22.49 (28.65)^{a}	5.42 (13.45)^{d}
NSL 60 EC	0.25	0.960	4.741 (12.57)^{e}	3.781 (11.21)^{e}	22.78 (28.85)^{de}	13.68 (22.12)^{c}	12.09 (20.34)^{bc}	77.22 (61.54)^{bc}	78.42 (62.38)^{bc}	20.18 (27.04)^{b}	6.58 (14.86)^{c}
NSV 60 EC	0.50	1.000	2.967 (9.92)^{c}	1.967 (8.06)^{c}	37.78 (38.22)^{b}	18.87 (26.10)^{a}	8.52 (16.97)^{ef}	62.22 (52.08)^{f}	71.44 (57.73)^{f}	12.49 (21.12)^{e}	4.94 (12.84)^{de}
NSV 60 EC	0.25	0.840	5.443 (13.49)^{f}	4.603 (12.39)^{f}	23.88 (29.59)^{d}	9.32 (18.26)^{e}	12.18 (20.42)^{bc}	76.12 (60.79)^{bc}	78.10 (62.03)^{bc}	21.50 (27.97)^{ab}	6.71 (15.01)^{c}
NSP 60 EC	0.50	0.860	2.008 (8.14)^{a}	1.148 (6.15)^{a}	40.55 (39.84)^{a}	15.72 (23.74)^{b}	7.76 (16.17)^{fg}	59.45 (50.45)^{f}	71.01 (57.45)^{f}	17.09 (24.80)^{c}	4.72 (12.55)^{ef}
NS 60 EC	0.50	0.960	5.070 (13.01)^{ef}	4.110 (11.69)^{ef}	20.55 (27.31)^{e}	3.10 (10.94)^{g}	12.88 (21.03)^{b}	79.45 (63.11)^{b}	84.60 (67.03)^{b}	11.58 (20.33)^{e}	7.32 (15.69)^{b}
NO 60 EC	0.50	0.800	3.430 (10.67)^{d}	2.630 (9.33)^{d}	27.78 (32.12)^{c}	4.42 (12.81)^{f}	11.29 (19.63)^{cd}	72.22 (58.22)^{cd}	86.94 (68.99)^{cd}	4.43 (12.83)^{g}	6.63 (14.92)^{c}
NSKE	5	0.950	3.416 (10.65)^{d}	2.466 (9.03)^{d}	29.82 (33.40)^{c}	3.62 (11.70)^{g}	10.64 (19.03)^{d}	70.18 (56.93)^{de}	86.27 (68.42)^{de}	9.17 (18.11)^{f}	6.59 (14.87)^{c}
Untreated check	-	1.080	6.834 (15.15)^{g}	5.754 (13.88)^{g}	0.00 (4.05)^{f}	0.00 (4.05)^{h}	17.16 (24.46)^{a}	100.00 (90.00)^{a}	99.45 (86.40)^{a}	0.00 (4.05)^{h}	9.30 (17.76)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed
LGI – Larval growth index; TDGI – Total developmental growth index
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 14. Growth inhibitory effect of NeemSweet formulations against fourth instar larva of *Plutella xylostella*

Treatment	Concentration (%)	Initial weight (mg)	Final weight (mg)	Weight gained (mg)	Larval mortality (%)	Larval pupal intermediaries (%)	LGI	Pupation (%)	Adult emergence (%)	Mal formed adults (%)	TDGI
NSS 60 EC	0.50	3.640	4.250 (11.89)^{e}	0.610 (4.48)^{h}	38.52 (38.65)^{a}	20.22 (27.07)^{h}	12.91 (21.05)^{g}	62.74 (52.39)^{e}	56.90 (48.97)^{d}	13.05 (21.60)^{c}	4.71 (12.54)^{f}
NSS 60 EC	0.25	3.680	4.696 (12.51)^{cd}	1.016 (5.78)^{f}	26.98 (31.61)^{d}	15.12 (23.28)^{e}	23.66 (29.10)^{c}	76.66 (61.16)^{d}	49.54 (44.74)^{e}	28.07 (32.30)^{g}	5.25 (13.24)^{de}
NSL 60 EC	0.50	3.260	4.112 (11.70)^{e}	0.852 (5.30)^{g}	32.68 (35.17)^{c}	21.66 (28.08)^{i}	17.83 (24.97)^{e}	69.34 (56.40)^{e}	49.64 (44.79)^{e}	38.76 (38.79)^{h}	4.76 (12.60)^{ef}
NSL 60 EC	0.25	3.420	4.900 (12.79)^{bc}	1.480 (6.99)^{c}	22.42 (28.60)^{e}	16.42 (24.28)^{f}	25.29 (30.19)^{c}	78.66 (62.55)^{d}	66.90 (54.89)^{c}	27.86 (32.17)^{g}	7.96 (16.39)^{c}
NSV 60 EC	0.50	3.640	4.452 (12.18)^{de}	0.812 (5.17)^{g}	35.84 (37.07)^{b}	22.64 (28.75)^{i}	15.83 (23.44)^{f}	66.66 (54.75)^{e}	62.02 (51.96)^{cd}	16.11 (24.05)^{d}	5.57 (13.64)^{d}
NSV 60 EC	0.25	3.600	4.716 (12.54)^{cd}	1.116 (6.06)^{e}	22.16 (28.42)^{e}	11.18 (19.98)^{d}	21.03 (27.29)^{d}	78.66 (62.55)^{d}	88.15 (70.09)^{b}	22.12 (28.40)^{f}	9.90 (18.34)^{b}
NSP 60 EC	0.50	3.740	4.410 (12.12)^{de}	0.670 (4.69)^{h}	37.90 (38.29)^{ab}	18.86 (26.10)^{g}	15.71 (23.34)^{f}	65.34 (53.95)^{e}	59.17 (50.29)^{b}	22.40 (28.59)^{f}	5.24 (13.24)^{de}
NS 60 EC	0.50	3.760	4.985 (12.90)^{bc}	1.225 (6.35)^{b}	15.24 (23.37)^{g}	3.72 (11.85)^{b}	29.61 (32.96)^{b}	87.34 (69.35)^{bc}	60.29 (50.95)^{d}	17.74 (25.28)^{e}	7.43 (15.82)c
NO 60 EC	0.50	3.590	4.976 (12.89)^{bc}	1.386 (6.76)^{c}	11.92 (20.63)^{h}	5.30 (13.93)^{c}	24.11 (29.40)^{c}	90.66 (72.56)^{b}	38.98 (38.63)^{f}	9.45 (18.38)^{d}	3.81 (11.25)^{g}
NSKE	5	3.440	5.238 (13.23)^{b}	1.798 (7.70)^{b}	17.54 (25.13)^{f}	4.34 (12.71)^{b}	21.55 (27.66)^{b}	85.34 (67.63)^{c}	42.96 (40.95)^{f}	18.17 (25.59)^{e}	4.20 (11.83)^{g}
Untreated check	-	3.880	5.931 (14.09)^{a}	2.051 (8.23)^{a}	0.00 (4.05)^{i}	0.00 (4.05)^{a}	46.51 (43.00)^{a}	100.00 (90.00)^{a}	99.34 (86.25)^{a}	0.00 (4.05)^{a}	13.99 (21.96)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed
LGI – Larval growth index; TDGI – Total developmental growth index
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 15. Influence of NeemSweet formulations on consumption and utilization of food (=cauliflower leaves) by third instar larvae of *Spodoptera litura*

Treatment	Concentration (%)	Weight of food consumed (g)*	Weight of faeces (g)*	Feeding period (days)	Weight gained (g)	CI	GR	AD	ECI	ECD
NSS 60 EC	0.50	0.676 (4.713)^{d}	0.263 (2.938)^{e}	6.50 (14.76)^{cd}	0.093 (1.744)^{g}	0.62 (4.51)^{b}	0.08 (1.67)^{de}	61.09 (51.44)^{d}	13.72 (21.73)^{h}	22.45 (28.27)^{e}
NSS 60 EC	0.25	0.847 (5.278)^{c}	0.316 (3.220)^{cd}	7.26 (15.62)^{e}	0.191 (2.504)^{d}	0.39 (3.66)^{de}	0.09 (1.71)^{de}	62.71 (52.39)^{cd}	22.56 (28.35)^{f}	35.99 (36.85)^{bc}
NSL 60 EC	0.50	0.541 (4.215)^{e}	0.154 (2.251)^{g}	6.00 (14.17)^{bc}	0.140 (2.146)^{e}	0.35 (3.38)^{f}	0.09 (1.72)^{d}	71.45 (57.79)^{a}	25.96 (30.62)^{cd}	36.33 (37.05)^{bc}
NSL 60 EC	0.25	1.008 (5.59)^{b}	0.378 (3.524)^{b}	8.15 (16.58)^{f}	0.249 (2.858)^{c}	0.42 (3.69)^{d}	0.10 (1.83)^{c}	62.47 (52.25)^{cd}	24.69 (29.78)^{cdef}	39.53 (38.95)^{ab}
NSV 60 EC	0.50	0.527 (4.162)^{e}	0.168 (2.344)^{g}	6.80 (15.11)^{de}	0.139 (2.137)^{ef}	0.29 (3.10)^{g}	0.08 (1.59)^{ef}	68.24 (55.76)^{abc}	26.39 (30.90)^{bc}	38.67 (38.44)^{abc}
NSV 60 EC	0.25	0.813 (5.171)^{c}	0.339 (3.334)^{c}	5.20 (13.17)^{a}	0.186 (2.470)^{d}	0.50 (4.07)^{c}	0.12 (1.95)^{b}	58.36 (49.83)^{d}	22.87 (28.56)^{ef}	39.19 (38.74)^{abc}
NSP 60 EC	0.50	0.561 (4.292)^{e}	0.165 (2.327)^{g}	8.80 (17.25)^{f}	0.141 (2.151)^{e}	0.19 (2.48)^{h}	0.05 (1.24)^{g}	70.57 (57.23)^{ab}	25.15 (30.08)^{cde}	35.63 (36.64)^{c}
NS 60 EC	0.50	0.656 (4.641)^{d}	0.235 (2.777)^{f}	6.80 (15.11)^{de}	0.130 (2.068)^{ef}	0.36 (3.45)^{ef}	0.07 (1.54)^{f}	64.57 (53.26)^{bcd}	19.89 (26.47)^{g}	31.00 (33.82)^{d}

NO 60 EC	0.50	0.960 (5.620)[b]	0.302 (3.148)[d]	5.65 (13.74)[a b]	0.276 (3.009)[b]	0.69 (4.76)[a]	0.20 (2.55)[a]	64.15 (55.95)[ab c]	28.74 (32.41)[ab]	41.94 (40.35)[a]
NSKE	5	0.517 (4.119)[e]	0.213 (2.644)[f]	8.80 (17.25)[f]	0.122 (2.003)[f]	0.19 (2.50)[h]	0.05 (1.22)[g]	58.78 (50.07)[d]	23.66 (29.09)[def]	40.26 (39.37)[a]
Untreated check	-	2.698 (9.448)[a]	0.769 (5.028)[a]	11.42 (19.74)[g]	0.822 (5.167)[a]	0.72 (4.85)[a]	0.22 (2.66)[a]	71.50 (57.82)[a]	30.10 (33.26)[a]	42.09 (40.44)[a]

*Mean of three replications; Values in parentheses are *arc sine* transformed
CI-Consumption index; GR-Growth rate; AD-Approximate digestibility;
ECI- Efficiency of conversion of ingested food; ECD-Efficiency of conversion of digested food
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 16. Influence of NeemSweet formulations on consumption and utilization of food (=cauliflower leaves) by fifth instar larvae of *Spodoptera litura*

Treatment	Concentration	Weight of food consumed (g)*	Weight of faeces (g)*	Feeding period (days)*	Weight gained (g)*	CI	GR	AD	ECI	ECD
NSS 60 EC	0.50	1.387 (6.759)[e]	0.582 (4.373)[cd]	6.50 (14.76)[ab]	0.355 (3.415)[de]	0.36 (3.46)[f]	0.09 (1.75)[f]	58.02 (49.63)[c]	25.62 (30.40)[cd]	44.16 (41.64)[a]
NSS 60 EC	0.25	1.659 (7.395)[cd]	0.538 (4.204)[d]	5.25 (13.24)[e]	0.390 (3.58)[d]	0.49 (4.00)[b c]	0.11 (1.94)[c d]	67.56 (55.34)[a]	23.53 (29.01)[d e]	34.83 (36.16)[b]
NSL 60 EC	0.50	1.641 (7.356)[cd]	0.673 (4.702)[ab]	6.15 (14.35)[bcd]	0.279 (3.028)[f]	0.43 (3.75)[d e]	0.07 (1.55)[g]	59.00 (50.21)[b c]	17.02 (24.36)[g]	28.85 (32.48)[c]

NSL 60 EC	0.25	1.348 (6.663)^{e}	0.453 (3.857)^{e}	5.75 (13.87)^{cde}	0.392 (3.587)^{d}	0.37 (3.48)^{f}	0.11 (1.87)^{de}	66.39 (54.62)^{a}	29.08 (32.62)^{ab}	43.81 (41.44)^{a}
NSV 60 EC	0.50	1.554 (7.157)^{d}	0.573 (4.340)^{d}	6.80 (15.11)^{a}	0.343 (3.353)^{e}	0.35 (3.41)^{f}	0.08 (1.66)^{g}	63.11 (52.63)^{abc}	22.04 (27.98)^{ef}	34.92 (36.21)^{b}
NSV 60 EC	0.25	1.855 (7.822)^{b}	0.641 (4.591)^{bc}	5.20 (13.17)^{e}	0.531 (4.175)^{b}	0.53 (4.19)^{b}	0.15 (2.24)^{b}	65.42 (54.02)^{ab}	28.61 (32.32)^{ab}	43.74 (41.39)^{a}
NSP 60 EC	0.50	1.652 (7.380)^{cd}	0.542 (4.219)^{d}	6.75 (15.05)^{ab}	0.487 (4.000)^{bc}	0.36 (3.42)^{f}	0.11 (1.86)^{de}	67.19 (55.11)^{a}	29.49 (32.88)^{ab}	43.90 (41.49)^{a}
NS 60 EC	0.50	1.742 (7.580)^{bc}	0.562 (4.298)^{d}	6.80 (15.11)^{a}	0.481 (3.974)^{c}	0.39 (3.58)^{ef}	0.11 (1.88)^{de}	67.72 (55.44)^{a}	27.60 (31.68)^{bc}	40.76 (39.66)^{a}
NO 60 EC	0.50	1.568 (7.189)^{d}	0.538 (4.204)^{d}	5.65 (13.74)^{de}	0.321 (3.246)^{e}	0.47 (3.95)^{cd}	0.10 (1.78)^{ef}	65.69 (54.19)^{a}	20.47 (26.89)^{f}	31.17 (33.92)^{bc}
NSKE	5	1.983 (7.903)^{b}	0.693 (4.773)^{ab}	6.35 (14.59)^{abc}	0.514 (4.11)^{bc}	0.46 (3.88)^{cd}	0.12 (2.02)^{c}	63.38 (52.80)^{abc}	27.17 (31.40)^{bc}	42.87 (40.90)^{a}
Untreated check	-	2.341 (8.796)^{a}	0.736 (4.918)^{a}	4.15 (11.75)^{f}	0.76 (4.851)^{a}	0.72 (4.88)^{a}	0.22 (2.70)^{a}	68.56 (55.96)^{a}	30.59 (33.56)^{a}	44.61 (41.90)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed
CI-Consumption index; GR-Growth rate; AD-Approximate digestibility;
ECI- Efficiency of conversion of ingested food; ECD-Efficiency of conversion of digested food
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 17. Influence of NeemSweet formulations on consumption and utilization of food (=cauliflower leaves) by second instar larvae of *Plutella xylostella*

Treatment	Concentration (%)	Food ingested (mg)	Faeces voided (mg)	Feeding period (days)	Weight gained (mg)	CI	GR	AD	ECI	ECD
NSS 60 EC	0.50	21.169 (27.389)^{f}	8.069 (16.499)^{a}	8.17 (16.60)^{a}	0.610 (4.479)^{g}	0.54 (4.19)^{f}	0.02 (0.71)^{h}	61.88 (51.88)^{bc}	2.88 (9.77)^{f}	4.66 (12.46)^{f}
NSS 60 EC	0.25	26.991 (31.296)^{bcd}	9.678 (18.122)^{b}	6.79 (15.10)^{d}	1.016 (5.784)^{e}	0.74 (4.95)^{c}	0.03 (0.96)^{f}	64.14 (52.23)^{ab}	3.76 (11.18)^{de}	5.87 (14.02)^{e}
NSL 60 EC	0.50	25.991 (30.647)^{cd}	10.124 (18.550)^{b}	7.39 (15.77)^{bc}	0.778 (5.059)^{f}	0.75 (4.97)^{c}	0.02 (0.86)^{g}	61.05 (51.39)^{bc}	2.99 (9.96)^{f}	4.90 (12.79)^{f}
NSL 60 EC	0.25	29.330 (32.786)^{b}	10.231 (18.651)^{b}	6.39 (14.64)^{def}	1.480 (6.986)^{c}	0.83 (5.21)^{b}	0.04 (1.17)^{c}	65.12 (53.81)^{ab}	5.05 (12.98)^{c}	7.75 (16.16)d
NSV 60 EC	0.50	23.697 (29.126)^{e}	13.147 (21.255)^{cd}	7.30 (15.67)^{bc}	0.812 (5.169)^{f}	0.64 (4.59)^{de}	0.02 (0.85)^{g}	44.52 (41.85)^{f}	3.43 (10.67)^{f}	7.70 (16.10)^{d}
NSV 60 EC	0.25	27.995 (31.940)^{bc}	13.165 (21.271)^{cd}	6.25 (14.47)^{def}	1.116 (6.063)^{de}	0.84 (5.22)^{ab}	0.03 (1.05)^{e}	52.97 (46.71)^{de}	3.99 (11.51)^{d}	7.53 (15.92)^{d}
NSP 60 EC	0.50	23.653 (59.096)^{e}	10.024 (18.455)^{b}	7.66 (16.06)^{ab}	0.670 (4.694)^{g}	0.62 (4.50)^{e}	0.02 (0.71)^{h}	57.62 (49.39)^{cd}	2.83 (9.69)^{f}	4.92 (12.81)f
NS 60 EC	0.50	25.669 (30.436)^{de}	9.703 (18.146)^{b}	6.17 (14.38)^{ef}	1.225 (6.353)^{d}	0.70 (4.78)^{cd}	0.03 (1.04)^{e}	62.20 (52.07)^{bc}	4.77 (12.62)^{c}	7.67 (16.08)d
NO 60 EC	0.50	26.687 (32.100)^{cd}	12.373 (20.591)^{c}	6.71 (15.01)^{de}	1.386 (6.760)^{c}	0.74 (4.94)^{c}	0.04 (1.132)^{d}	53.64 (47.09)^{d}	5.19 (13.17)^{c}	9.68 (18.13)^{c}
NSKE	5	27.331 (31.515)^{bcd}	13.477 (21.534)^{d}	6.60 (14.88)^{de}	1.798 (7.705)^{b}	0.70 (4.79)^{cd}	0.05 (1.23)^{d}	50.69 (45.40)^{e}	6.58 (14.86)^{b}	12.98 (21.11)^{b}
Untreated check	-	40.312 (39.411)^{a}	12.853 (21.005)^{cd}	5.84 (13.98)^{f}	7.159 (15.516)^{a}	0.89 (5.24)^{a}	0.16 (2.28)^{a}	68.12 (55.64)^{a}	17.76 (24.92)^{a}	26.07 (30.70)^{a}

*Mean of three replications; Values in parentheses are *arc sine* transformed.
CI-Consumption index; GR-Growth rate; AD-Approximate digestibility;
ECI- Efficiency of conversion of ingested food; ECD-Efficiency of conversion of digested food.
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 18. Influence of NeemSweet formulations on consumption and utilization of food (=cauliflower leaves) by fourth instar larvae of *Plutella xylostella*

Treatment	Concentration (%)	Food ingested (mg)	Faeces voided (mg)	Feeding period (days)	Weight gained (mg)	CI	GR	AD	ECI	ECD
NSS 60 EC	0.50	7.596 (15.995)^{h}	2.587 (9.254)^{a}	4.86 (12.73)^{a}	0.610 (4.479)^{h}	0.36 (3.43)^{a}	0.03 (3.97)^{h}	65.94 (54.31)^{cde}	8.03 (16.46)^{e}	12.18 (20.42)^{d}
NSS 60 EC	0.25	12.362 (20.581)^{de}	3.445 (10.694)^{cd}	3.24 (10.37)^{d}	1.016 (5.784)^{f}	0.79 (5.11)^{g}	0.07 (1.46)^{d}	72.13 (58.17)^{ab}	8.22 (16.66)^{e}	11.39 (19.72)^{de}
NSL 60 EC	0.50	8.460 (16.906)^{g}	3.246 (10.377)^{bc}	3.89 (11.37)^{bc}	0.778 (5.059)^{g}	0.51 (4.11)^{c}	0.05 (1.25)^{e}	61.63 (51.74)^{e}	9.20 (17.65)^{d}	14.92 (22.72)^{c}
NSL 60 EC	0.25	13.273 (21.362)^{cd}	3.612 (10.954)^{d}	3.42 (10.66)^{d}	1.480 (6.986)^{c}	0.77 (5.05)	0.09 (1.68)^{d}	72.79 (58.59)^{ab}	11.15 (19.50)^{bc}	15.32 (23.04)^{c}
NSV 60 EC	0.50	11.628 (19.934)^{ef}	4.215 (11.845)^{ef}	4.21 (11.84)^{b}	0.812 (5.169)^{g}	0.61 (4.46)^{e}	0.04 (1.18)^{f}	63.75 (52.99)^{de}	6.98 (15.32)^{f}	10.95 (19.32)^{e}
NSV 60 EC	0.25	13.429 (21.493)^{c}	4.221 (11.853)^{ef}	3.74 (11.15)^{c}	1.116 (6.063)^{e}	0.74 (4.95)^{bcd}	0.06 (1.42)^{d}	68.57 (55.92)^{bcd}	8.31 (16.75)^{e}	12.12 (20.37)^{d}
NSP 60 EC	0.50	8.764 (17.217)^{g}	3.214 (10.326)^{bc}	4.16 (11.77)^{b}	0.670 (4.694)^{h}	0.47 (3.91)^{g}	0.04 (1.08)^{g}	63.33 (52.79)^{de}	7.64 (16.05)^{ef}	12.07 (20.33)^{d}
NS 60 EC	0.50	10.840 (19.219)^{f}	3.111 (10.157)^{b}	2.95 (9.89)^{e}	1.225 (6.353)^{d}	0.72 (4.87)^{cd}	0.08 (1.64)^{b}	71.30 (57.64)^{abc}	11.30 (19.64)^{d}	15.85 (23.46)^{bc}

NO 60 EC	0.50	13.440 (21.502)[c]	3.967 (11.486)[e]	3.76 (9.18)[c]	1.386 (6.760)[c]	0.70 (4.81)[d]	0.07 (1.54)[c]	70.48 (57.12)[abc]	10.31 (18.73)[c]	14.63 (22.48)[c]
NSKE	5	14.951 (22.743)[b]	4.321 (11.995)[f]	3.96 (11.48)[bc]	1.798 (7.705)[b]	0.71 (4.82)d	0.08 (1.67)[b]	71.10 (57.51)[abc]	12.03 (20.29)[b]	16.92 (22.48)[b]
Untreated check	-	16.891 (24.263)[a]	4.121 (11.710)[ef]	2.80 (9.62)[e]	2.795 (9.622)[a]	0.87 (5.35)[a]	0.14 (2.17)[a]	75.60 (60.44)[a]	16.55 (24.00)[a]	21.89 (27.89)[a]

*Mean of three replications; Values in parentheses are *arc sine* transformed.
CI-Consumption index; GR-Growth rate; AD-Approximate digestibility;
ECI- Efficiency of conversion of ingested food; ECD-Efficiency of conversion of digested food.
In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD.

Table 19a. Field efficacy of NeemSweet formulations on the populations of *Spodoptera litura* on cauliflower during September – December 2008 – (Trial I) – After first spray

Treatments	Dose	PTC*		3 DAS		5 DAS		7 DAS		10 DAS	
		No. of insects/ * 5 plants	Damage (%)#	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)
NSS 60 EC	2 ml / l	52.31	20.92	28.67 (5.40)[a]	17.28 (25.46)[a]	24.33 (4.98)[b]	15.19 (22.93)[a]	27.67 (5.30)[a]	16.47 (23.94)[c]	32.33 (5.73)[a]	17.20 (24.63)[a]
NSL 60 EC	2 ml / l	53.00	21.90	39.67 (6.34)[c]	18.99 (25.83)[f]	33.67 (5.84)[e]	16.88 (24.25)[e]	41.33 (6.47)[e]	18.00 (25.14)[e]	47.33 (6.91)[e]	20.27 (26.75)[d]
NSV 60 EC	2 ml / l	48.00	21.72	37.67	18.67	31.33	16.80	38.67	17.44	43.33	19.43

				(6.18)[c]	(25.60)[d]	(5.64)[d]	(24.19)[e]	(6.26)[d]	(26.68)[d]	(6.62)[d]	(26.15)[c]
NSP 60 EC	2 ml / l	53.33	19.45	29.33 (5.46)[a]	17.74 (24.90)[b]	23.00 (4.84)[a]	15.36 (23.07)[b]	29.33 (5.46)[b]	16.23 (23.75)[b]	34.67 (5.93)[b]	17.78 (24.93)[b]
NS 60 EC	2 ml / l	41.33	19.65	34.67 (5.93)[b]	19.29 (26.05)[g]	28.67 (5.40)[c]	15.48 (23.16)[b]	39.33 (6.31)[d]	20.14 (26.66)[g]	44.33 (6.69)[d]	20.49 (26.91)[d]
NO 60 (C) EC	2 ml / l	53.33	18.85	39.67 (6.34)[c]	18.22 (25.26)[c]	32.67 (5.76)[de]	16.18 (23.72)[c]	41.67 (6.49)[e]	18.63 (25.57)[f]	46.33 (6.84)[e]	21.40 (27.55)[e]
NSKE	5 %	55.67	20.33	42.67 (6.57)[d]	18.59 (25.53)[d]	38.67 (6.26)[f]	16.36 (23.85)[d]	45.33 (6.77)[f]	14.86 (22.67)[a]	49.67 (7.08)[f]	19.28 (26.04)[c]
NeemAzal T/S 1 %	2 ml / l	50.33	21.07	30.67 (5.58)[a]	17.72 (24.89)[b]	27.33 (5.28)[c]	16.31 (23.82)[d]	32.67 (5.76)[c]	20.25 (26.74)[g]	38.33 (6.23)[c]	19.30 (26.06)[c]
Untreated check	-	57.67	21.36	62.33 (7.92)[e]	22.69 (28.44)[h]	65.67 (8.13)[g]	23.41 (28.93)[f]	66.67 (8.19)[g]	23.36 (28.89)[h]	70.67 (8.43)[g]	27.36 (31.54)[f]

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 19b. Field efficacy of NeemSweet formulations against S*podopt*era *litura* on cauliflower during September – December 2008 – (Trial I) – After second spray

Treatments	Dose	3 DAS*		5 DAS		7 DAS		10 DAS		Mean no. of insects/ 5 plants	Efficacy over untreated check
		No. of insects/ * 5 plants	Damage (%) #	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)		
NSS 60 EC	2 ml / l	16.26 (23.78)[a]	16.67 (4.41)[a]	8.50 (3.00)[a]	17.25 (24.54)[a]	17.50 (4.24)[a]	18.96 (25.81)[a]	22.70 (4.82)[a]	20.31 (26.78)[a]	22.30 (4.77)[a]	64.09 (53.20)[a]
NSL 60 EC	2 ml / l	17.43 (24.67)[b]	32.33 (5.73)[d]	22.50 (4.79)[d]	18.46 (25.44)[b]	31.50 (5.66)[d]	20.28 (26.76)[b]	39.60 (6.33)[f]	22.34 (28.20)[d]	35.99 (6.04)[e]	42.80 (40.86)[d]
NSV 60 EC	2 ml / l	18.29 (25.31)[c]	31.67 (5.67)[d]	27.50 (5.29)[f]	19.24 (26.01)[d]	32.70 (5.76)[e]	20.98 (27.26)[d]	38.30 (6.23)[e]	22.32 (28.19)[d]	35.15 (5.97)[d]	38.33 (38.25)[e]
NSP 60 EC	2 ml / l	16.38 (23.87)[a]	19.67 (4.49)[b]	11.75 (3.50)[b]	17.37 (24.63)[a]	19.50 (4.47)[b]	19.09 (25.90)[a]	26.70 (6.21)[b]	21.70 (27.76)[b]	24.24 (4.97)[b]	61.71 (51.78)[b]
NS 60 EC	2 ml / l	19.25 (26.02)[d]	33.33 (5.82)[d]	26.50 (5.20)[f]	20.17 (26.69)[e]	33.40 (4.82)[e]	21.92 (27.91)[e]	41.50 (6.48)[g]	23.25 (28.82)[e]	35.22 (5.98)[de]	28.23 (32.09)[f]
NO 60 (C) EC	2 ml / l	20.11 (26.64)[e]	35.67 (6.01)[e]	29.70 (5.49)[g]	20.99 (27.26)[f]	36.20 (6.06)[h]	22.70 (28.85)[f]	44.80 (6.73)[h]	24.00 (29.33)[f]	38.34 (6.23)[f]	39.45 (38.91)[e]
NSKE	5 %	18.12	32.67	28.30	19.10	31.50	20.88	36.70	22.25	38.19	42.22

		(25.19)[c]	(5.76)[d]	(5.37)[d]	(25.91)[d]	(5.66)[g]	(27.19)[cd]	(6.10)[d]	(28.14)[d]	(6.22)[f]	(40.52)[d]
NeemAzal 1%	2 ml / l	18.24 (25.28)[c]	23.00 (4.85)[c]	13.58 (3.75)[c]	19.14 (25.94)[c]	22.50 (4.79)[c]	20.79 (27.12)[c]	31.70 (5.67)[c]	22.07 (28.01)[c]	27.47 (5.29)[c]	54.03 (47.31)[c]
Untreated check	2 ml / l	27.60 (31.69)[f]	68.67 (8.31)[f]	70.15 (8.40)[h]	28.06 (31.98)[g]	71.25 (8.47)[i]	29.43 (32.85)[g]	72.30 (8.53)[i]	30.38 (33.44)[g]	68.46 (8.30)[g]	-

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 20a. Field efficacy of NeemSweet formulations against *Spodoptera litura* on cauliflower during January-March 2009 – (Trial II) – After first spray

Treatments	Dose	PTC*		3 DAS		5 DAS		7 DAS		10 DAS	
		No. of insects/ * 5 plants	Damage (%) #	No. of insects / 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)
NSS 60 EC	2 ml / l	43.67	21.74	25.57 (5.10)[a]	15.38 (23.09)[a]	19.67 (4.49)[a]	13.59 (21.62)[a]	20.33 (4.56)[a]	16.82 (24.21)[d]	24.67 (5.02)[a]	17.39 (24.64)[d]
NSL 60 EC	2 ml / l	53.45	18.75	40.33 (6.39)[f]	17.60 (24.80)[d]	34.33 (5.90)[g]	15.17 (22.92)[c]	39.33 (6.31)[h]	14.54 (22.41)[b]	42.67 (6.57)[g]	15.61 (2327)[c]
NSV 60 EC	2 ml / l	51.67	23.91	42.37 (6.55)[g]	21.63 (27.71)[g]	32.67 (5.76)[e]	17.76 (24.92)[f]	38.67 (6.26)[g]	17.71 (24.88)[f]	40.33 (6.39)[f]	17.68 (24.86)[e]
NSP 60 EC	2 ml / l	50.33	19.73	28.67 (5.40)[b]	15.92 (23.51)[b]	23.33 (4.88)[b]	12.94 (21.08)[a]	26.67 (5.21)[b]	13.42 (21.48)[a]	30.33 (5.55)[b]	13.95 (21.93)[a]
NS 60 EC	2 ml / l	45.67	19.60	36.66 (6.09)[e]	17.87 (25.00)[e]	32.67 (5.76)[e]	15.38 (23.09)[d]	33.67 (5.84)[e]	17.28 (24.56)[e]	37.67 (6.18)[e]	18.42 (25.41)[f]
NO 60 (C) EC	2 ml / l	49.35	19.58	34.67 (5.93)[d]	17.36 (24.62)[c]	29.67 (5.49)[d]	15.02 (22.80)[c]	32.33 (5.73)[d]	17.55 (24.77)[f]	35.33 (5.98)[d]	20.00 (26.56)[g]

NSKE	5 %	51.33	22.27	36.33 (6.07)[e]	18.82 (25.71)[f]	29.67 (5.49)[d]	15.58 (23.25)[e]	34.67 (5.93)[f]	15.56 (23.22)[c]	37.67 (6.18)[e]	17.17 (24.47)[d]
NeemAzal T/S 1 %	2 ml / l	48.33	22.22	31.67 (5.67)[c]	17.51 (24.73)[d]	26.33 (5.18)[c]	15.04 (22.82)[c]	29.67 (5.49)[c]	15.48 (23.16)[c]	34.67 (5.93)[c]	14.97 (22.76)[b]
Untreated check	-	47.67	22.00	52.33 (7.27)[h]	23.33 (28.88)[h]	55.36 (7.49)[g]	25.15 (30.09)[g]	56.33 (7.54)[i]	27.96 (31.92)[g]	59.67 (7.76)[h]	31.87 (34.36)[h]

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 20b. Field efficacy of Neem Sweet formulations against *Spodoptera litura* on cauliflower during January-March 2009 – (Trial II) – After second spray

Treatments	Dose	3 DAS*		5 DAS		7 DAS		10 DAS		Mean no. of insects/ 5 plants	Efficacy over untreated check
		No. of insects/ * 5 plants	Damage (%) #	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)		
NSS 60 EC	2 ml / l	16.67 (4.14)^{a}	11.87 (20.15)^{b}	9.33 (3.13)^{a}	10.50 (18.91)^{a}	13.33 (3.72)^{a}	14.12 (22.07)^{b}	17.67 (4.26)^{a}	13.09 (21.21)^{a}	18.41 (4.35)^{a}	65.53 (54.06)^{a}
NSL 60 EC	2 ml / l	31.67 (5.67)^{g}	13.61 (21.65)^{d}	24.36 (4.98)^{f}	12.70 (20.87)^{c}	31.67 (5.67)^{f}	16.62 (23.93)^{d}	37.33 (6.15)^{f}	16.92 (24.29)^{f}	35.21 (5.97)^{g}	46.11 (42.77)^{e}
NSV 60 EC	2 ml / l	29.33 (5.46)^{f}	14.96 (22.75)^{f}	22.33 (4.78)^{e}	15.17 (22.92)^{e}	30.67 (5.58)^{e}	15.07 (22.84)^{e}	35.66 (6.01)^{e}	15.98 (23.56)^{e}	34.00 (5.87)^{f}	46.17 (42.80)^{e}
NSP 60 EC	2 ml / l	17.57 (4.25)^{b}	11.46 (19.78)^{a}	13.67 (3.76)^{b}	10.45 (18.86)^{a}	17.33 (4.22)^{b}	11.80 (20.09)^{a}	21.67 (4.71)^{b}	14.10 (22.05)^{b}	22.41 (4.78)^{b}	62.10 (52.01)^{b}
NS 60 EC	2 ml / l	29.33 (5.46)^{f}	16.31 (23.81)^{f}	26.33 (5.18)^{g}	14.87 (22.68)^{e}	33.67 (5.84)^{g}	15.15 (22.90)^{e}	39.67 (6.34)^{g}	14.86 (22.67)^{bc}	33.71 (5.85)^{f}	39.63 (39.01)^{f}
NO 60 (C) EC	2 ml / l	24.67 (5.02)^{d}	17.65 (24.81)^{h}	19.67 (4.49)^{d}	17.16 (24.46)^{f}	23.67 (4.92)^{c}	18.25 (25.29)^{g}	29.33 (5.46)^{c}	17.71 (24.88)^{f}	28.67 (5.40)^{d}	52.48 (46.43)^{d}
NSKE	5 %	22.33	14.63	18.33	13.65	24.67	15.53	33.67	15.49	29.67	52.72

		(4.78)^{e}	(22.84)^{e}	(4.34)^{c}	(21.68)^{d}	(5.02)^{d}	(23.20)^{f}	(5.84)^{d}	(23.17)^{d}	(5.49)^{e}	(46.56)^{d}
NeemAzal 1 %	2 ml / l	20.36 (4.57)^{c}	12.80 (20.96)^{c}	18.67 (4.38)^{c}	11.98 (20.25)^{b}	24.67 (5.02)^{d}	13.44 (21.50)^{c}	29.36 (5.46)^{c}	15.09 (22.85)^{c}	26.93 (5.24)^{c}	54.43 (47.54)^{c}
Untreated check	-	57.87 (7.65)^{h}	33.33 (35.25)^{i}	60.33 (7.80)^{h}	34.79 (36.14)^{g}	61.67 (7.88)^{h}	34.01 (31.67)^{h}	62.67 (7.95)^{h}	32.10 (34.51)^{g}	58.28 (7.69)^{h}	-

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 21a. Field efficacy of NeemSweet formulations against *Plutella xylostella* on cauliflower during September – December 2008 – (Trial I) – After first spray

Treatments	Dose	PTC*		3 DAS		5 DAS		7 DAS		10 DAS	
		No. of insects/* 5 plants	Damage (%)#	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)
NSS 60 EC	2 ml / l	22.15	41.57	7.03 (2.74)[a]	38.33 (38.25)[d]	4.21 (2.17)[a]	35.41 (36.51)[a]	6.07 (2.56)[a]	35.17 (36.37)[a]	9.16 (3.11)[a]	37.67 (37.86)[a]
NSL 60 EC	2 ml / l	20.76	39.36	11.34 (3.44)[c]	36.21 (36.99)[a]	9.75 (3.20)[c]	35.71 (36.69)[b]	10.67 (3.34)[d]	36.47 (37.15)[c]	12.57 (3.61)[c]	36.33 (37.06)[c]
NSV 60 EC	2 ml / l	20.57	39.41	12.57 (3.61)[e]	36.67 (37.27)[b]	10.67 (3.34)[d]	35.67 (36.67)[b]	11.07 (3.40)[e]	35.99 (36.86)[b]	13.74 (3.77)[d]	37.67 (37.86)[b]
NSP 60 EC	2 ml / l	20.67	43.41	9.11 (3.10)[b]	39.67 (39.04)[e]	6.12 (3.54)[b]	37.33 (37.66)[d]	6.89 (3.72)[b]	37.11 (37.53)[d]	10.11 (3.26)[b]	38.33 (38.25)[d]
NS 60 EC	2 ml / l	19.67	41.00	13.41 (3.73)f	40.67 (39.62)[f]	12.87 (3.66)[f]	38.41 (38.29)[e]	13.51 (3.74)[h]	39.41 (38.88)[e]	15.51 (4.00)[f]	39.33 (38.84)[e]
NO 60 (C) EC	2 ml / l	22.17	45.67	13.33 (3.72)[f]	43.33 (41.16)[g]	10.64 (3.34)[d]	41.17 (39.91)[f]	12.63 (3.62)[b]	41.57 (40.14)[f]	17.79 (4.28)[g]	41.78 (40.27)[f]
NSKE	5 %	21.33	39.33	12.17 (3.56)[d]	37.67 (37.86)[c]	11.67 (3.49)[e]	36.33 (37.06)[f]	12.97 (3.67)[f]	36.67 (37.27)[c]	14.91 (3.92)[e]	36.67 (37.27)[c]
NeemAzal T/S 1 %	2 ml / l	19.25	41.67	13.76 (3.76)[g]	36.33 (37.06)[a]	9.67 (3.19)[c]	35.71 (36.69)[b]	11.33 (6.44)[c]	36.65 (37.25)[c]	12.71 (3.63)[c]	37.11 (37.53)[c]
Untreated check	-	21.45	45.33	22.67 (4.81)[h]	45.67 (42.51)[h]	24.33 (4.98)[g]	46.33 (42.89)[g]	26.80 (5.22)[i]	46.65 (43.08)[g]	27.13 (5.26)[h]	47.67 (43.66)[g]

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 21b. Field efficacy of NeemSweet formulations against *Plutella xylostella* on cauliflower during September – December 2008 – (Trial I) – After second spray

Treatments	Dose	3 DAS*		5 DAS		7 DAS		10 DAS		Mean no. of insects/ 5 plants	Efficacy over untreated check
		No. of insects/ 5 plants*	Damage (%) #	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)		
NSS 60 EC	2 ml / l	3.66 (3.04)^{a}	34.21 (35.79)^{b}	2.59 (1.76)^{a}	32.60 (34.81)^{a}	3.11 (1.90)^{a}	32.11 (35.45)^{a}	4.71 (2.28)^{a}	33.67 (35.46)^{a}	5.07 (2.36)^{a}	81.91 (64.92)^{a}
NSL 60 EC	2 ml / l	6.51 (2.65)^{c}	35.27 (36.43)^{cd}	4.17 (2.16)^{c}	34.67 (36.67)^{c}	6.71 (2.68)^{d}	35.21 (36.39)^{d}	7.57 (2.84)^{d}	36.71 (37.29)^{e}	8.66 (3.03)^{c}	67.00 (54.96)^{d}
NSV 60 EC	2 ml / l	7.37 (2.80)^{d}	35.33 (36.87)^{d}	5.31 (2.41)^{d}	35.11 (36.33)^{d}	7.67 (2.86)^{e}	36.17 (36.97)^{f}	8.37 (2.98)^{e}	37.33 (37.66)^{f}	9.60 (3.18)^{e}	63.10 (52.61)^{e}
NSP 60 EC	2 ml / l	4.11 (2.15)^{b}	35.41 (36.51)^{d}	3.97 (2.11)^{b}	33.71 (35.49)^{b}	4.71 (2.28)^{b}	33.97 (35.65)^{b}	5.21 (2.39)^{b}	34.17 (35.77)^{b}	6.28 (2.60)^{b}	75.98 (60.70)^{b}
NS 60 EC	2 ml / l	9.71 (3.19)^{f}	36.41 (37.11)^{e}	10.11 (3.26)^{e}	35.97 (36.85)^{e}	13.41 (3.73)^{h}	36.17 (36.97)^{f}	14.67 (3.89)^{h}	37.67 (37.86)^{g}	12.90 (3.66)^{h}	48.13 (43.93)^{g}
NO 60 (C) EC	2 ml / l	10.21 (3.27)^{g}	39.21 (38.77)^{f}	11.07 (3.40)^{f}	37.67 (37.26)^{f}	11.91 (3.52)^{g}	37.79 (37.93)^{g}	12.17 (3.56)^{f}	38.67 (38.45)^{h}	12.47 (3.60)^{b}	55.52 (48.17)^{f}
NSKE	5 %	9.67	33.67	10.07	34.37	11.47	34.67	13.57	35.17	12.06	55.27

		(2.19)^{f}	(35.46)^{a}	(3.25)^{e}	(35.89)^{c}	(3.46)^{f}	(36.07)^{c}	(3.75)^{g}	(36.37)^{d}	(3.54)^{f}	(48.03)^{f}
NeemAzal 1 %	2 ml / l	7.67 (2.86)^{e}	35.00 (36.27)^{c}	4.33 (2.20)^{c}	33.57 (35.40)^{b}	5.16 (2.38)^{c}	35.57 (36.61)^{e}	6.73 (2.69)^{c}	34.79 (36.14$^{)c}$	8.92 (6.07)^{d}	69.76 (56.66)^{c}
Untreated check	-	26.71 (5.22)^{h}	48.33 (44.04)^{g}	28.67 (5.40)^{g}	48.33 (44.04)^{g}	29.40 (5.47)^{i}	48.67 (44.24)^{h}	31.26 (5.63)^{i}	46.67 (43.09)^{i}	27.12 (5.25)^{i}	-

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 22a. Field efficacy of NeemSweet formulations against *Plutella xylostella* on cauliflower during January-March 2009 – (Trial II) – After first spray

Treatments	Dose	PTC*		3 DAS		5 DAS		7 DAS		10 DAS	
		No. of insects/ 5 plants*	Damage (%) #	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)
NSS 60 EC	2 ml / l	26.87	36.17	8.53 (3.00)[a]	33.35 (35.27)[d]	5.11 (2.37)[a]	30.81 (33.71)[a]	7.36 (2.80)a	30.60 (33.58)[a]	9.57 (3.17)[a]	32.77 (34.92)[d]
NSL 60 EC	2 ml / l	25.18	34.24	13.76 (3.77)[c]	31.50 (34.14)[a]	11.83 (3.51)[c]	31.07 (33.87)[b]	12.94 (3.67)[c]	31.73 (34.28)[c]	15.25 (3.97)[d]	31.61 (34.20)[a]
NSV 60 EC	2 ml / l	24.95	34.29	13.67 (3.76)c	31.90 (34.39)[b]	12.94 (3.67)[d]	31.03 (33.85)[b]	13.43 (3.73)[d]	31.31 (34.02)[b]	13.67 (3.76)[c]	32.77 (34.92)[d]
NSP 60 EC	2 ml / l	25.07	37.77	11.05 (3.40)[b]	34.51 (35.97)[e]	7.42 (2.81)[b]	32.48 (34.74)[d]	7.67 (2.86)[b]	32.29 (34.62)[d]	11.33 (3.44)[b]	33.35 (35.27)[e]
NS 60 EC	2 ml / l	23.86	35.67	18.23 (4.33)[g]	35.38 (36.50)[f]	16.48 (4.12)[f]	33.42 (35.31)[e]	17.33 (4.22)[g]	34.29 (35.84)[e]	18.81 (4.39)[g]	34.22 (35.80)[f]
NO 60 (C) EC	2 ml / l	26.89	39.73	16.17 (4.08)[e]	37.70 (37.87)[g]	12.91 (3.66)[d]	35.82 (36.76)[f]	13.67 (3.76)[de]	36.17 (36.96)[f]	18.33 (4.34)[f]	36.35 (37.07)[g]
NSKE	5 %	25.87	34.22	14.76 (3.91)[d]	32.77 (34.92)[f]	13.67 (3.76)[e]	31.61 (34.20)[c]	14.33 (3.85)[f]	31.90 (34.39)[c]	17.33 (4.22)[e]	31.90 (34.39)[b]
NeemAzal T/S 1 %	2 ml / l	23.35	36.25	16.69 (4.15)[f]	31.61 (34.20)[a]	11.73 (3.50)[c]	31.07 (33.87)[b]	13.74 (3.77)[e]	31.89 (34.38)[c]	15.42 (3.99)[d]	32.29 (34.62)[c]
Untreated check		26.02	39.44	27.50	39.73	29.51	40.31	32.51	40.59	32.91	41.47

				(5.29)^{h}	(39.07)^{h}	(5.48)^{g}	(39.41)^{g}	(5.74)^{h}	(39.57)^{g}	(5.78)^{h}	(40.09)^{h}

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

Table 22b. Field efficacy of NeemSweet formulations against *Plutella xylostella* on cauliflower during January-March 2009 – (Trial II) – After second spray

Treatments	Dose	3 DAS*		5 DAS		7 DAS		10 DAS		Mean no. of insects/ 5 plants*	Efficacy over untreated check#
		No. of insects/ 5 plants*	Damage (%) #	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)	No. of insects/ 5 plants	Damage (%)		
NSS 60 EC	2 ml / l	5.67 (2.48)[b]	29.76 (33.06)[b]	4.33 (2.20)[a]	28.36 (32.17)[a]	5.67 (2.48)[a]	27.94 (31.90)[a]	6.33 (2.61)[a]	29.29 (32.76)[a]	6.57 (2.66)[a]	80.66 (63.99)[a]
NSL 60 EC	2 ml / l	9.67 (3.19)[e]	30.68 (33.63)[cd]	5.06 (2.36)[c]	30.16 (33.31)[c]	7.56 (2.84)[c]	30.63 (33.60)d	9.18 (3.11)[c]	31.94 (34.41)[e]	10.66 (3.34)[cd]	66.53 (54.67)[d]
NSV 60 EC	2 ml / l	7.67 (2.86)[c]	30.74 (33.67)[d]	5.78 (2.51)[d]	30.55 (33.55)[d]	7.67 (2.86)[c]	31.47 (34.12)[f]	8.33 (2.97)[b]	32.48 (34.74)[f]	10.40 (3.30)[c]	67.05 (54.99)[d]
NSP 60 EC	2 ml / l	3.67 (2.04)[a]	30.81 (33.71)[d]	4.82 (2.31)[b]	29.33 (32.78)[b]	5.71 (2.49)[a]	29.55 (32.93)[b]	6.32 (2.61)[a]	29.73 (33.04)[b]	7.25 (2.78)[b]	77.13 (61.49)[b]
NS 60 EC	2 ml / l	12.67 (3.63)[g]	31.68 (34.25)[e]	11.33 (3.42)[f]	31.29 (34.01)[e]	16.27 (4.09)[f]	31.47 (34.12)[f]	18.67 (4.38)[f]	32.77 (34.92)[g]	16.22 (4.09)[g]	46.22 (42.83)[g]
NO 60 (C) EC	2 ml / l	12.38 (3.59)[g]	34.11 (35.73)[f]	13.33 (3.72)[g]	32.77 (34.92)[f]	14.45 (3.87)[e]	32.88 (34.98)[g]	14.76 (3.91)[e]	33.64 (35.45)[h]	14.50 (3.87)[f]	57.36 (39.24)[f]
NSKE	5 %	10.67 (5.34)[f]	29.29 (32.76)[a]	9.67 (3.19)[e]	29.90 (33.15)[c]	11.33 (3.44)[d]	30.16 (33.31)[c]	13.67 (3.76)d	30.60 (33.58)[d]	13.18 (3.70)[e]	59.72 (50.61)[e]

NeemAzal 1 %	2 ml / l	9.30 (3.13)^{d}	30.45 (33.49)^{c}	5.25 (2.40)^{c}	29.21 (32.91)^{b}	6.26 (2.60)^{b}	30.95 (33.80)^{e}	8.16 (2.94)^{b}	30.27 (33.37)^{c}	10.82 (3.36)^{d}	69.76 (56.66)^{c}
Untreated check	-	32.40 (5.73)^{h}	42.05 (40.42)^{g}	34.78 (5.94)^{h}	42.05 (40.42)^{g}	35.66 (6.01)^{g}	42.34 (40.59)^{h}	37.92 (6.20)^{g}	40.60 (39.58)^{i}	32.90 (5.78)^{h}	-

*Mean of three replications; PTC – Pre treatment count, DAS – Days after spraying

Values in parentheses are *arc sine* transformed.

* Values in parentheses are *square root* transformed

In a column, means followed by same letter(s) are not significantly different (p = 0.05) by LSD

CHAPTER V

DISCUSSION

Cauliflower is the one of the important vegetable crop grown in India. But the crop is highly vulnerable to many insects including diamondback moth, *Plutella xylostella,* tobacco caterpillar, *Spodoptera litura* which are major impediments to production and productivity universally. Insecticides are widely used to combat this insect menace. However, their indiscriminate use has resulted in adverse effects like resistance and resurgence to pests, contamination of food materials, animal and human ill-health and environmental pollution.

The repeated failure of unilateral approach of using chemical pesticides, and the increasing concern for environmental safety and global demand for pesticide residue free food necessitated the use of effective, economically viable, eco-friendly and biodegradable pest control materials with greater selectivity. The natural pesticides such as botanical sources evoked a great deal of interest owing to their unique advantages over conventional synthetic insecticides. Therefore present study was carried out for testing the joint action potentials of botanical insecticides and their judicious combinations. The results of these studies are discussed in this chapter.

5.1. Behavioural and physiological activities of botanical insecticides

Neem has emerged as one of the important source of natural pesticides with least or no side effects. Azadirachtin, a tetranortriterpenoid, is the most active insecticidal compound found in neem seeds and leaves (Butterworth and Morgan, 1968). The active compound has a number of biological activities including repellency, feeding and ovipositional deterrency, moult inhibition, toxicity, growth disrupting activity and low mammalian toxicity (Jotwani and Srivastava, 1981; Mehrotra and Gujar, 1986; Raguraman, 1987; Saxena, 1989; Schumutterer, 1990; Ramarethinam and Marimuthu, 1998; Desai and Patil, 2000; Boomathi, 2003; Sathish, 2003; Punithavalli. 2005; Suman Sharma and Metha, 2006; Subramaniam *et al*., 2006; Prathibha Misra *et al*., 2007; Coria *et al*., 2008; Miroslov Kostic *et al*., 2008), and field efficacy against insect pests (Sarode *et al*., 1995; Bhatnagar and Sharma, 1995; Rao *et al*., 1998; Singh and Tripathi, 1996 and Gowri *et al*., 2002; Boomathi, 2003; Sathish; 2003; Punithavalli, 2005; Alagar and Subramanium, 2006; Tanu Sharma, 2007; Sewak *et al*., 2008; Gunnhild

Jaastad *et al*., 2009). Also, behavioural toxicity of rhizomes of sweet-flag (Koul and Isman, 1990; Schmidt, 1993; Nelson, 1996; Desai and Patil, 2000), seeds of *pungam* (Deka *et al*., 1998; Jeyaraj and Regupathy, 1999; Saminathan *et al.*, 2000), seeds of nuxvomica (Blom, 1978; Murray Isman, 2002), leaves of *poduthalai* (Suryakala *et al*., 1995; Carvalho *et al*., 2003; Suryalala *et al*., 2007; Pavunraj *et al*., 2007) and leaves of *notchi* (Suryakala *et al*., 1995; Rajappan *et al*., 2000, Vairamuthu *et al*., 2005; Shankaramurthy *et al*., 2006; Murugesan *et al*., 2008) have very well been documented.

5.2. Ovipostional deterrent effect

The ovipostional deterrent effects of neem seed kernel extracts, neem oil and pure components of NSKE (Raguraman, 1987; Schmutterer, 1990; Singh, 1993; Isman, 1996 and Suresh *et al.,* 2003), sweet-flag extracts (Nelson, 1996) and pungam seed extracts (Sharma and Bhatnagar, 1993) had been reported on many crop pests. But there is only little information available on antioviposition effects of *poduthalai, notchi* and nuxvomica. There was little or no information available on the joint action potentials of neem with other botanicals on ovipostional behavior of insect pests.

In the present study, egg laying of *S. litura* females was completely inhibited by NSS 60 EC at 0.5%, NSP 60 EC at 0.5% and NSV 60 EC at 0.5% at 24 h (Figure 1and 2). This may be due to strong olfactory repellency and ovipositional deterrency of botanical mixture immediately after exposure. The present findings are in line with the recent reports of Boomathi (2003) and Punithavalli (2005).

Similarly, egg laying of *P. xylostella* females was deterred completely in NSS 0.5% followed by NSV 0.5% (0.61%) and NSL 0.5% (2.42%) at 24 h. This may be due to strong olfactory repellency and ovipositional deterrency of botanical mixture immediately after exposure. Oviposition deterrent effects of *notchi* was reported by Murugesan *et al*. (2008) At present no information is available on the ovipositional deterrency effect of nuxvomica and lemonbush hence, a detailed investigation on the possible effects on *S. litura* and *P. xylostella* are warranted.

5.3. Ovicidal effect

Ovicidal action of neem compounds was well documented (Saxena *et al*., 1981, Shelke *et al*., 1987; Murugan *et al.*, 1999; Bhanukiran and Panwar, 2000; Bora and Hazarika, 2001; Punithavalli, 2005). In the present study, NSS 0.5% showed lesser hatchability (19.62 %) of *S. litura* eggs at 96 h followed by NSL 0.5% and NSV 0.5% (27.08% and 32.56%). Hatchability of *P. xylostella* eggs was completely inhibited by NSS 0.5% at 96 h followed by NSP 0.5% and NSV 0.5% (1.67% and 9.33%) among the botanical mixtures (Figure 3 and 4). Neem in combination with other botanicals caused a high rate of mortality to eggs of both insects. This may be because of increased toxicity bought about by the botanicals in combination. These findings are in agreement with findings of Srinivasa Rao and Rajendran (2003) on *E. vitella* and Boomathi (2003) and Sathish (2003) on *H. armigera*. This might also be due to high level contact toxicity of azadirachtin and Strychnine alkaloids; hence detailed investigation is needed on this aspect.

5.4. Toxicity effect

Neem oil and neem cake were tested for insecticidal properties against insect pests like aphids, locusts, tobacco caterpillar and cotton bollworms (Sinha and Gulati, 1964; Goyal *et al.,* 1971; Thangavel *et al.,* 1975; and Meisner *et al*., 1980; Tanu Sharma, 2007). Toxicity of rhizome extracts of sweet-flag to insects was also reported (Nair and Thomas, 2000; Hee-Kwon Lee *et al*., 2002; Rahman, 2008). But, the effect of botanical mixtures on neonates is lacking. The present findings are the first of its kind.

In the present study, mortality of neonates of *S. litura* by NSS 0.5% and NSV 0.5% was cent per cent, followed by NSL 0.5% (95.56%) and NSP 0.5% (84.44%) on four days after treatment and three days after treatment (Figure 5). NSV 0.5% and NSP 0.5% were highly toxic to neonates of *P. xylostella* and cent per cent mortality was recorded in these treatments (Figure 6). This could be attributed to contact and stomach toxicity and antifeedant properties, which were superior in botanical mixtures. The mortality of larvae apart from contact toxicity might also be due to reduction in

feeding that was also observed after topical application or injection of neem derivatives (Schumutterer, 1990).

5.5. Antifeedant effect

The information on the antifeedant effect of mixtures of plant extracts against insect pests is lacking. But neem seed kernel extracts (Raguraman, 1987; Saxena, 1989; Krishnaiah and Kalode, 1984; Schmutterer, 1990; Joseph, 2000; Padmasheela and Devi, 2002; Sathish, 2003; Punithavalli, 2005; Murray Isman, 2006; Vandana Sharma *et al*., 2006; Swaran Dhingra *et al*., 2008) sweet flag extracts (Banerji *et al*., 1982; Sharma *et al*., 1990; Desai and Patil, 2000; Chandel, 2001; Packiam *et al*., 2003; Hemchandra and Singh, 2006) and pungam extracts (Parmer and Gulati, 1969; Rajasekaran, et al., 1987; Hazra et al., 1994, Deka et al., 1998;Reena and Ramsingh, 2007) poduthalai (Pavunraj *et al*., 2007) have been reported to deter feeding of almost all the insects tested so far.

In the present investigation, antifeedant index for third instar of *S. litura* was significantly higher in NSS 0.5% (79.87) which was followed by NSL 0.5% (67.92). NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 71.84 and 64.08 respectively followed by NSL 0.5% (62.63) on fifth instar (Figure 7). These findings are in agreement with Subramanium *et al*. (2006) on *S. litura*. The antifeedant activity of nuxvomica and lemonbush was reported by Murray Isman (2002) and Pavunraj *et al*. (2007), respectively.

In second instar of *P. xylostella*, antifeedant index was 93.39 in NSS 0.5% and 91.54 in NSP 0.5% and followed by NSL 0.5% (77.86). NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 81.65 and 79.00 respectively followed by NSL 0.5% (76.25) on fourth instar larvae (Figure 8). These findings are similar to the findings of Dayani *et al*. (2000) on fourth instar of *P. xylostella* and also Boomathi (2003) and Sathish (2003) reported antifeedant potential of NSP 60 EC on *H. armigera.*

Feeding deterrency may be explained by the behavioural antifeedant effect due to perception by the peripheral chemoreceptors in insects (Simmonds and Blaney, 1984). Feeding deterrence was also shown to be due to the action of botanicals on the centers that control gut mobility and metabolism (Dorn and Trumm, 1993). The feeding deterrency may be attributed to the action of some major compounds like salanin, which is reported to deter feeding of insects (Rembold and Siber, 1981). As azadirachtin and other limonoids of neem are not volatile in nature only gustatory sensilla of insects are affected. In neem seed kernels, salanol, salannolacetate, 3-deacetyl salanin, azadirachtin, 14-epoxyazadirodion, and deacetylnimbin showed high antifeedant activity (Schumutterer, 1990). Neem also affects neural responsiveness of the taste sensilla (Simmonds and Blaney, 1984). This is because the neem affects the centers that control feeding or hormones that are involved in food metabolism (Barnby and Klocke, 1987). The functional property of fatty acid in the NSKE plays an inhibitory role on feeding (Sridhar and Chetty, 1989).

Strychnine evokes a response in two gustatory sensilla (i.e. the medial styloconic and the epipharyngeal sensillum). Strychnine inhibits food intake and make the food unpalatable in *Pieris brassicae* L. and *Mamestra brassicae* L. (Blom, 1978). Thus the reduction in food intake is not only regulated by sense organs in mouthparts but also non-gustatory. Higher concentration of azadirachtin has antifeedant effect that prevents uptake of sufficient quantities of the compound to cause IGR effects. But at lower concentration there was little or no antifeedant activity and the IGR effects were more evident. Antifeedant effects of neem products are reported to persist after replacement of treated leaves with untreated ones and this confirms the anorectic activity of neem extracts (Schumutterer, 1990).

5.6. Growth inhibitory effect

The growth regulating effects of neem was already reported by several workers (Kubo and Klocke, 1982; Sathyanarayana and Srivastava, 1984; Barnby and Klocke, 1987; Singh and Bathal, 1992; Murray Isman, 1993; Jeyarajan *et al*., 1993; Schmutterer, 1990; Opender Koul and Murray Isman, 1990; Opender Koul *et al.,* 1996; Naumann and Isman,

1995; Joseph, 2000; Mahapatro and Padmaja, 2000; Morale *et al.,* 2000; Gupta and Birah, 2001; Sueli *et al*., 2001) sweet-flag extracts (Shanthi and Logiswaran, 1996; Koul and Isman, 1990; Nelson, 1996; Opender koul, 1987) *pungam* seed extracts (Padmaja *et al*., 2007; Reena and Ramsingh, 2007; Rajasekar *et al*., 2007) *notchi* leaf extracts (Suryakala *et al*., 1995).

In the present study, low LGI was recorded in NSL 0.5% (3.978) significantly on par with NSP 0.5% (4.301) followed by NSV 0.5% and NSS 0.5% (4.525 and 5.472 respectively). Lowest developmental growth index was observed in NSS 0.5% (2.71) followed by NSP 0.5% (2.87) and NSV 0.5% (3.45) on third instar and least larval growth index (LGI) was recorded in NSV (9.08) followed by NSP 0.5% (9.83). Low total developmental growth index was recorded in NSS 0.5% which was on par with NSL 0.5% (1.82) followed by NSV 0.5% (2.07) on fifth instar of *S. litura* (Figure 9a and 9b, Plate 6).

Low LGI and TDGI was recorded in NSS 0.5% (7.28 and 4.43) followed by NSP 0.5% (7.76 and 4.72) and NSV 0.5% (8.52 and 4.94) respectively on second instar of *P. xylostella* and least larval LGI was recorded in NSS 0.5% (12.91) followed by NSP 0.5% (15.71). Low total developmental growth index was recorded in Neem oil 0.5% (3.81) followed by NSKE 5% (4.20) and NSS 0.5% (4.71) on fourth instar of *P. xylostella* (Figure 10a and 10b).

The growth inhibitory effect of various plant derived principles and their implication on the physiology have been recorded in many insect pests (Ramarethinam *et al*., 1997). But reports on the effect on the effect botanical mixtures on growth and development are lacking. Neem as an antifeedant induces starvation in herbivore and then indirectly causes developmental deviance and thus stimulates a growth inhibitory effect. Azadirachtin has two profound effects on insects, behavioural and physiological, thus making it potential growth regulatory chemical for insect control. Such growth inhibitory effects of neem ranging from delay in moulting with the production of deformed to the complete inhibition of growth at higher doses have been reported in various insect species (Schumutterer, 1990). Growth regulatory effects of azadirachtin are mostly concerned with its interference in the neuroendocrine system of the insects (Mordue

and Nisbet, 2000). The main hormones involved in growth regulation in insects are ecdysone and 20 hydroxy-ecdysone (moulting hormones) juvenile hormone. They are respectively produced in the prothoracic glands and *corpora allata*, through stimulation of hormones secreted in the brain (Wigglesworth, 1972). The present findings are in accordance with the findings of Srinivasa Rao (2001); Boomathi (2003) and Sathish (2003) where larvae lost their body weight rapidly during development due to excessive defecation and feeding inhibition and transformed into small size and shriveled pupae and in many cases larvae were unable to produce silken cocoon and transformed in to naked pupae. Insect growth regulatory activity can be expressed by morphogenic defects as larval-pupal intermediates, pupal deformities and abnormal adults with crippled wings and malformed legs (Vandana Sharma *et al*., 2006).

Excessive defecation is a biological process by which the ingested toxic metabolites are excreted to avoid accumulation of compounds and hence relatively less quantity of food material is allocated to body matter and is positively dose dependent (Srinivasa Rao, 2001; Boomathi, 2003; Sathish, 2003). Reduced larval after exposure to botanicals might be caused by metabolic defeat resulting from the lack of storage protein in the fat body and also due to antifeedant properties that weakened the larvae and made them poor feeders. Larvae exposed to Azadirachtin at the third instar took longer to reach pre-pupa in comparison with control insects. In the present study, those findings are obtained.

In the present study neem with other botanicals induced deformities in the developing larvae, pupae and adults, resulting in larval-pupal intermediates and deformed adults of *P. xylostella* and *S. litura.* This might probably due to the interference by azadirachtin, β-asarone pongamin, nodiflorin A and B, strychnine and brucine with endocrine system. Among the treatments NSP 0.5% recorded higher percentage of larval pupal intermediates on third instar and fifth instar larvae of *S. litura*. The present findings are in accordance with findings of Sathish, (2003) on *H. armigera*. In *P. xylostella*, NSV 0.5% recorded the highest percentage of larval pupal

intermediates on second and fifth instar larvae. This might be due to interference of glycoside namely 6, 8 dimethyl ether leucocyanidin with endocrine system of the insect.

Azadirachtin treatments to the last instar larvae affected the insects more severely and led to rapid appearance of anomalies in pre-pupae. Similarly, *S. littoralis* last instar larvae fed on 0.5% neem aqueous suspension presented 53% malformation in adults (El-Sayed, 1982). Besides the very high mortality of pre-pupae, many insects were not able to pupate properly and formed larva-pupa intermediates. Larva-pupa intermediates had a pupal cuticle which was usually tanned on the abdomen, and on the dorsal region of the head and thorax. The remaining parts became darker and finally black when the insect was close to death. Larva-pupa intermediates could also be produced in *Manduca sexta* by injecting high doses of moulting hormone (20-hydroxyecdysone) into pre-pupae shortly before pupating (Schluter *et al*., 1985). These results in combination reinforce the theory that azadirachtin affects the neurosecretory system and is more likely to kill the insect by disturbing the ecdysteroid regulation than by being toxic to the insect. During pupation and the pupa-adult moult, the insects undergo transformations that involve complex neuroendocrine processes that do not occur at the same intensity during larva to larva moults (Nijhout, 1994). This different level of neuroendocrine activity at the larva to pupa moult could explain the lower growth disruption effects of azadirachtin on third-instar larvae. In addition, that insects excrete around 90% of the compound within seven to 24h has been reported for locusts (Rembold *et al*., 1988) and for *Rhodnius* (Garcia *et al*., 1989). Therefore a lower amount of azadirachtin would remain in the body of these insects at the pre-pupa and pupa stage in comparison with insects treated at the last larval instar. In addition, the reduced consumption by both insects *P. xylostella* and *S. litura* on treated cauliflower leaves is likely to be the main cause of growth inhibition. Botanical mixtures influence the antifeedant and growth inhibitory effect in all stages of growth (Banerji *et al*., 1982, Sharma *et al*., 1990; Packiam *et al*., 2003).

5.7. Effect on nutritional indices

Allelochemicals from the Indian neem tree are the classic examples of chemicals which impart defense. Amongst these only azadirachtin, a tetranortriterpenoid, has been extensively studied as an anti-insect compound which inhibits feeding and growth in a wide variety of insect taxa (Koul, 1992; Mordue and Blackwell, 1993). In terms of nutritional physiology, it has been shown with lepidopteran species that avoidance of primary antifeedant activity can be achieved quite easily after applying azadirachtin (Koul and Isman, 1991) the effects of azadirachtin on gut physiology are mostly related to efficacy of diet conversion (Ayyangar and Rao, 1989; Timmins and Reynolds, 1992; Peter and Ananthakrishnan, 1993, Koul *et al*., 1996) or inhibition of digestive enzymes. Disfunction of midgut due to necrosis following azadirachtin treatment in locusts has also been demonstrated (Nasiruddin and Mordue, 1993). Similarly, effect on food consumption and digestion by sweetflag extracts treated food fed insects (Opender Koul and Isman, 1990) *pungam* seed extracts (Reena and Ramsingh, 2007).

S. litura larvae consumed less food and gained less weight on azadirachtin, salanin and nimbinene treated diets compared to control. Azadirachtin being most active compound followed by salanin and nimbinene respectively. The efficiencies of converting ingested and digested food into biomass (ECI and ECD) were significantly affected. The major effect on consumption with a contaminant reduction in growth, suggesting sensory detection i.e, feeding deterrence – a characteristic of many antifeeding compounds (Schoonhoven and Jermy, 1977; Schoonhoven, 1981; Simmonds and Blanny, 1984; Koul and Isman, 1991). These behavioural effects of neem allelochemicals was significant in leaf experiments.

In the present study, nutritional imbalances following application of neem with other botanicals to *S. litura* and *P. xylostella* larvae revealed a significant reduction in dietary intake (consumption index and weight gained by larvae) and utilization (ECI and ECD) with a concomitant decrease in growth rate and consumption. Ingestion of food and weight gained by *S. litura* larvae were low in NSP 0.5% (0.561g and 0.141g) and NSKE 5% (0.517g and 0.122g) on third instar and NSS 0.5% (1.387g and 0.355g) on fifth instar larvae. CI was low in NSP 0.5% and NSKE 5% (0.19) on third instar (Figure 11a) and

on fifth instar larvae lowest CI level was recorded in NSV 0.5% (0.35), NSS 0.5% and NSP 0.5% (0.36) (Figure 11b).

On second instar of *P. xylostella*, ingestion of food and weight gained by larvae were low in NSS 0.5% (21.169mg and 0.610mg) and on fourth instar and NSS 0.5% (7.596 mg and 0.610 mg). The consumption index (CI) was significantly the lowest in NSS 0.5% (0.54) and NSP 0.5% (0.62) on second stage (Figure 12a). On fourth instar larvae lowest CI was recorded in NSS 0.5% (0.36) and it was followed by NSP 0.5% (0.47) and NSL 0.5% (0.51) compared to untreated check (Figure 12b). The weight loss in this case can be correlated with poor consumption of food. Reduced larval weight after exposure to botanicals might be due to metabolic defect resulting from the lack of storage protein in the fat body and also due to antifeedant properties that debilitated the larvae rendering them poor feeders. Sathish (2003) reported that reduced food consumption of *H. armigera* on botanicals treated tomato fruits might be the main cause of growth inhibition.

In the present study, Growth rate values were significantly reduced on treated cauliflower because of both reduced palatability and post-ingestion toxicity. This inhibition in larval growth could be attributed to varied physiological age brought about by reduced food intake and weight gain as reported in *H. virescens* (Barnby and Klocke, 1987). In addition, the approximate digestibility of *S. litura* was the lowest in NSV 0.25% (38.36%) and NSKE 5% (58.78%) on third and fifth instar and NSV 0.5% (44.52%) and NSL 0.5% (61.63%) on second and fourth instar of *P. xylostella* compared to untreated check, which might be due to more retention of food in the midgut brought about by inhibited gut mobility (Mordue *et al.,* 1985; Dorn and Trumn, 1993; Senthil Nathan and Kalaivani, 2005).

This reduction must result from a reduction in the efficiency to convert food stuffs into growth. Probably the energy is diverted from biomass production to detoxification that increase in costs this also confirms an earlier hypothesis that the mechanism of growth disruption by Azadirachtin is separate from that associated with feeding inhibition (Opender Koul *et al*., 1987).

In the feeding experiments with sweet-flag oil, severe reductions were observed in growth rate, AD, ECI and ECD, which clearly demonstrates that feeding deterrence was the principal mode of action responsible for reduced growth. Reduction in growth may result from behavioural and physiological (post ingestive) effects in larvae of *Peridroma saucia* (Opender Koul and Isman, 1990). Likewise rate of food consumption, assimilation and production by fifth instar of *Euproctis fraterna* larvae, showed a negative correlation with acetone extract of *Pongamia pinnata* leaves (Sridhar and Chetty, 1989).

5.8. Efficacy of NeemSweet formulations against *P. xylostella* and *S. litura* on cauliflower under field conditions

In the present investigation, under field condition, maximum per cent reduction in the larval population and leaf damage caused by larvae was observed in NSS 2 ml l^{-1}, followed by NSP 2 ml l^{-1} and NeemAzal 2 ml l^{-1} over untreated check on *P. xylostella* and *S. litura* on cauliflower in two consecutive trials (Figure 13, 14, 15 and 16). This could be attributed to contact and stomach toxicity and antifeedant properties, which were superior in neem with other botanical mixture. The other causes being deter to moths from oviposition, inhibition of egg hatching and antifeedant properties, which were superior in the botanical mixture as evidenced in the laboratory experiments of the present study.

The best results were obtained with field applications of botanicals to control *S. eridania* larvae closely agree with Liburd *et al*. (2000) and Miguel *et al*. (2008). There was more infestation of grownup larvae at harvest, and several studies have shown that older lepidopteran larvae are less susceptible than young larvae. Studies with *Spodoptera* species, including *S. eridania*, yielded control of old larvae, but the efficacy was conditional on the formulation and dose used (Liburd *et al*., 2000; Prates *et al*., 2003). The present findings are comparable with the findings of Nagesh and Shashi Verma, 1997; Patil *et al.,* 1999; Nathu Ram *et al*., 2001; Vadodaria *et al.,* 2001 and Shivankar *et al*., 2008).

These results are comparable with the findings of Srinivasa Rao (2001) and Boomathi (2003) who observed that NSP 0.24% and NSP 0.18% showed insecticidal toxicity against *E. vitella* and *H. armigera* on bhendi and pigeon pea, respectively, and thereby increased fruit and pod yields. Ojah and Singh (2003) also found insecticidal activity of Nimbecidine at 7.5 ml l^{-1} against *P. xylostella* on cauliflower. Desai and Desai (2006) already reported that *Acorus calamus*, *Azadirachta indica, Pongamia pinnata*, *Strychnos nuxvomica* and *Vitex negundo* extracts gave significant mortality against *Spodoptera litura* and *Lipaphis erysimi*.

It can be inferred that NSS 60 EC formulation can be effectively exploited in the management of *S. litura* and *P. xylostella.* Its enhanced insecticidal activity might be due to the presence of terpenoids in neem (Schmutterer, 1984), asarones in sweet-flag, strychnine and brucine that are phagodeterrent and growth inhibitors in nuxvomica (Rembold *et al*., 1980; Isman, 2002).

From the foregoing discussion it is summarized that the new NeemSweet formulations *viz*., NSS 60 EC, NSP 60 EC, NSL 60 EC and NSV 60 EC showed increased behavioural and physiological activities than the individual components. NSS 60 EC and NSP 60 EC were found to be better alternative to neem application alone and certainly better than NeemAzal spray against *P. xylostella* and *S. litura* on cauliflower both in laboratory and field experiments. In the search of better alternatives to synthetic pesticides, the neem based product namely NSS 60 EC and NSP 60 EC would be fittingly find a place in combating the insects. Hence, safer and effective alternatives such as application of mixtures of botanicals like NeemSweet with other botanical pesticides to chemical pesticides are desirable for an eco-friendly interdisciplinary approach to tobacco caterpillar and diamondback moth management.

CHAPTER VI

SUMMARY

The salient findings of the present study on the joint action potentials of NeemSweet formulation with other botanicals against behaviour and physiology of diamondback moth, *Plutella xylostella* (Linn.) and tobacco caterpillar, *Spodoptera litura* (Fab.) on cauliflower and its efficacy under field conditions are summarized hereunder.

- Cauliflower leaves sprayed with NSS 60 EC 0.5% deterred *S. litura* adults from oviposition (2.8%), which was followed by NSS 60 EC 0.25%, Neem oil 60 EC 0.5% and NSV 60 EC 0.5%. Lower percentage of egg laying was recorded in NSL 0.5% (4.13%), NSS 0.5% (10.08%), which was followed by NSP 0.5% against *P. xylostella* adults.

- Hatching of *S. litura* eggs were inhibited to 80.38 per cent by NSS 0.5% followed by NSL 0.5% (72.92 per cent) and NSV 0.5% (67.44 per cent). Per cent unhatched eggs of *P. xylostella* were higher in NSS 0.5% (100.00 per cent) and followed by NSP 0.5% (98.33 per cent) and NSV 0.5% (90.67 per cent).

- NSS 0.5% and NSV 0.5% treatments recorded cent per cent mortality to neonates of *S. litura* and followed by NSL 0.5% (95.56%) and NSP 0.5% (84.44%). NSV 0.5% and NSP 0.5% were highly toxic to neonates of *P. xylostella* with cent per cent mortality which were followed by NSL 0.5% and NSP 0.5% (95.78 and 91.55% mortality, respectively.

- Antifeedant index was higher in NSS 0.5% (79.87) which was followed by NSL 0.5% (67.92) with poor larval weight gain in NSS 0.5% (0.041g) on third instar larvae of *S. litura*. NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 71.84 and 64.08, respectively followed by NSL 0.5% (62.63) with poor larval weight gain in NSKE 5% (0.014g) on fifth instar larvae of *S. litura.*

- Antifeedant effect of NeemSweet formulations on second instar larvae of *P. xylostella* was very higher in NSS 0.5% (93.39) and NSP 0.5% (91.54) also

recorded least larval weight gained by larvae in NSS 0.5% (0.2 mg), NSP 0.5% (0.2 mg) were statistically on par and followed by NSL 0.5% (0.44 mg).

- NSS 0.5% and NSP 0.5% recorded the highest antifeedant index of 81.65 and 79.00 respectively followed by NSL 0.5% (76.25) on fourth instar larvae of *P. xylostella.* Larval weight gained by the insect was low in NSS 0.5% (0.072 mg) and followed by NSP 0.5% (0.099 mg) and NSL 0.5% (0.155 mg).

- Formation of Larval-pupal intermediate was higher in NSL 0.5% (30.00%) followed by NSV 0.5%, NSKE 5% and NS 0.5% (26.67% respectively). Pupation percentage was low in NSL 0.5% and NSP 0.5% (40.00 and 46.67% respectively) on third instar larvae of *S. litura*. Higher percentage of larval pupal intermediate was recorded in NSP 0.5% (26.67%) followed by NSV 0.5% (23.33%) and NSL 0.25% (20.00%). Lowest percentage of pupation was recorded in NSV 0.5% and NSP 0.5% (66.67% and 70.00% respectively) and followed by NSS 0.5% (73.33%) on fifth instar larvae of *S. litura.* Emergence of malformed adults was higher in NSV 0.5% (50.08% and 50.00%) on third and fifth instar of *S. litura* respectively.

- Formation of larval-pupal intermediate was significantly higher in NSV 0.5% (18.87% and 22.64%) and NSL 0.5% (18.05% and 21.66%) and pupation percentage was low in NSS 0.5% (59.45% and 62.74%) on second and fourth instar larvae of *P. xylostella* respectively. Emergence of malformed adults was higher in NSL 0.5% (22.49%) and followed by NSV 0.25% (21.50%) and NSL 0.25% (20.18%) and highest percentage of malformed adults emerged in NSL 0.5% (38.76) and followed by NSS 0.25% (28.07) and NSV 0.25% (22.12) on second and fourth instar of *P. xylostella* respectively.

- Consumption index was reduced in third and fifth instar larvae of *S. litura* fed with NSS 0.5% treated cauliflower leaves followed by NSV 0.5%. Consumption index, growth rate, ingestion and postingestive utilization of foods were reduced in second and fourth instar of *P. xylostella* fed with NSS 0.5% treated cauliflower leaves followed by NSP 0.5%.

- Under field condition both NSS 60 EC 2 ml l^{-1} (64.09% and 65.53%), NSP 60 EC 2 ml l^{-1} (61.71% and 62.10%) had significantly reduced population of tobacco caterpillar followed by NeemAzal 2 ml l^{-1} (54.03% and 54.43%) respectively in field trial I and II. Under field evaluation of foliar spray of NSS 2 ml l^{-1} treatment was found to be effective in reducing caterpillar damage (20.31 and 13.09%) followed by NSP 2 ml l^{-1} (21.70 and 14.10%) and NeemAzal 2 ml l^{-1} (22.01 and 15.09% respectively) in both consecutive trials
- In both field trials I and II, NSS 60 EC 2 ml l^{-1} 81.91 and 80.66%) recorded highest reduction in larval population of diamondback moth and followed by NSP 60 EC 2 ml l^{-1} (75.91 and 77.13 %) and NeemAzal 2 ml l^{-1} (69.76 %) respectively. With regarding to per cent leaf damage, NSS 2 ml l^{-1} (33.67% and 29.29%) treated plot had significantly lower diamondback moth damage followed by NSP 2 ml l^{-1} (34.17% and 29.73)and NeemAzal 2 ml l^{-1} (34.79% and 30.27%) respectively. However, the untreated check had significantly higher diamondback moth damage in both field trials I and II.

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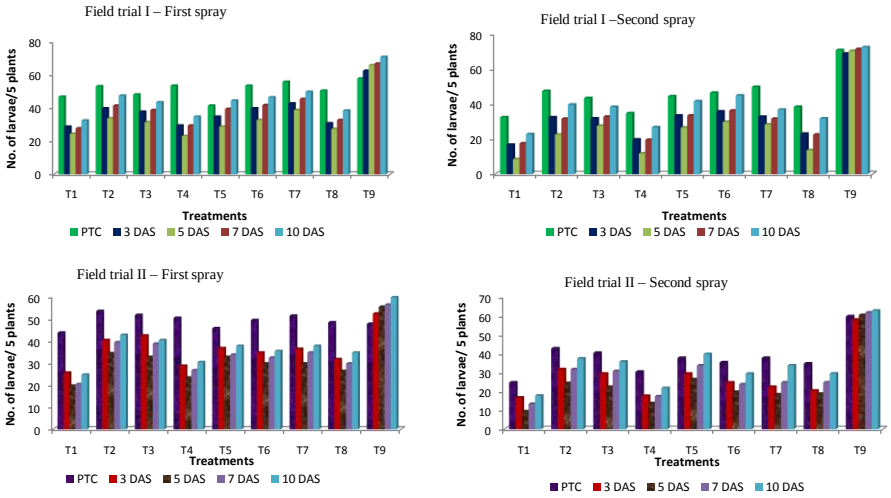
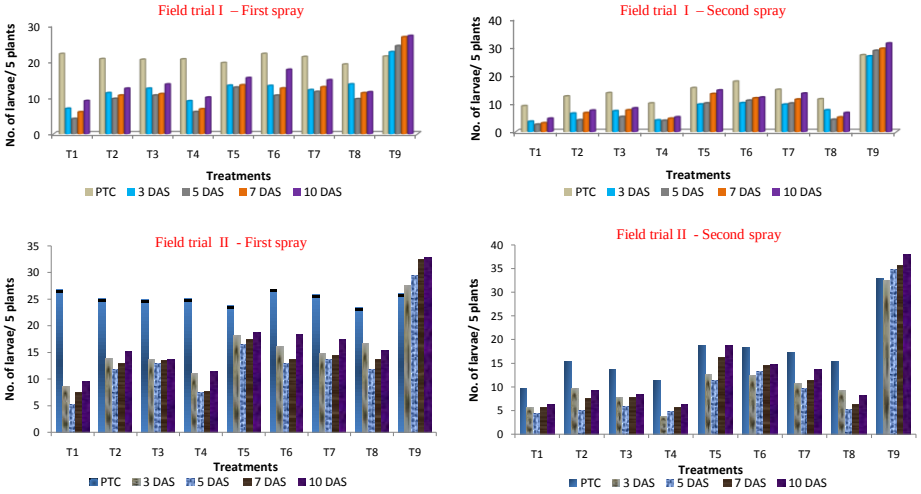
Fig.13. Efficacy of NeemSweet formulations on the populations of *S. litura* on cauliflower



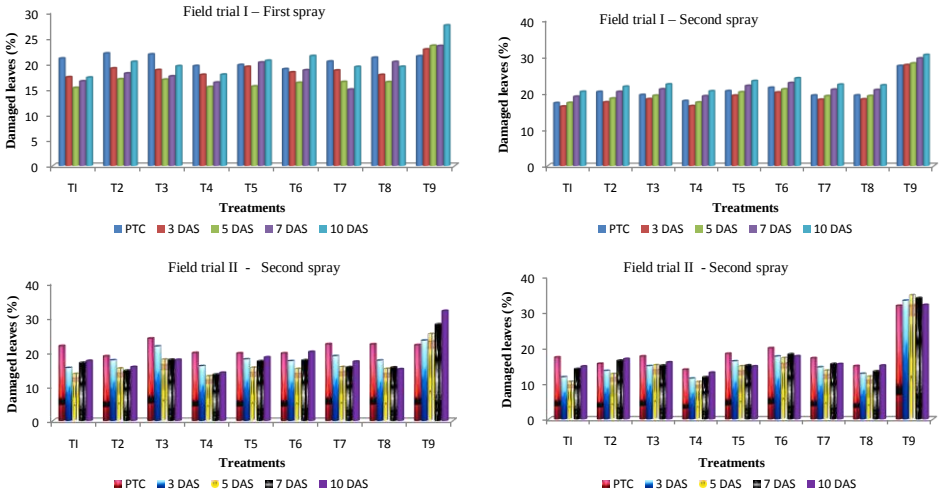
T1 - NSS 60 EC 2 ml l^{-1} T2 - NSS60 EC 2 ml l^{-1} T3 - NSV 60 EC 2 ml l^{-1} T4 - NSLP60 EC 2 ml l^{-1} T5 - NS 60 EC 2 ml l^{-1}
T6 - NO (C) 60 EC 2 ml l^{-1} T7 - NSKE 5% T8 - NeemAzal T/S 1% 2 ml l^{-1} T9 - Untreated check

Fig.14. Efficacy of NeemSweet formulations on the populations of *P. xylostella* on cauliflower



T1 - NSS 60 EC 2 ml l^{-1} T2 - NSS60 EC 2 ml l^{-1} T3 - NSV 60 EC 2 ml l^{-1} T4 - NSLP60 EC 2 ml l^{-1} T5 - NS 60 EC 2 ml l^{-1}
T6 - NO (C) 60 EC 2 ml l^{-1} T7 - NSKE 5% T8 - NeemAzal T/S 1% 2 ml l^{-1} T9 - Untreated check

Fig. 15. Efficacy of NeemSweet formulations against *S. litura* on cauliflower



T1 - NSS 60 EC 2 ml l^{-1} T2 - NSS60 EC 2 ml l^{-1} T3 - NSV 60 EC 2 ml l^{-1} T4 - NSLP60 EC 2 ml l^{-1} T5 - NS 60 EC 2 ml l^{-1}
T6 - NO (C) 60 EC 2 ml l^{-1} T7 - NSKE 5% T8 - NeemAzal T/S 1% 2 ml l^{-1} T9 - Untreated check

Fig. 1. Oviposition deterrent activity of NeemSweet formulations on *S. litura* adults

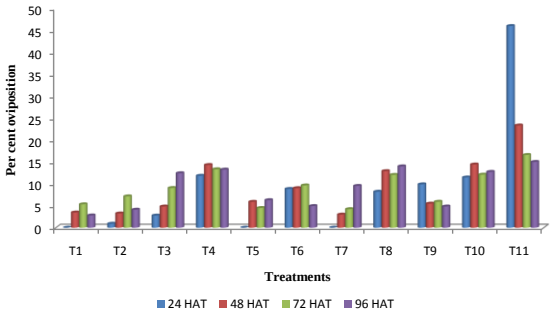
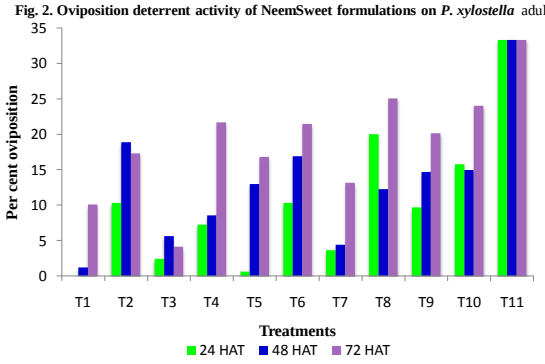


Fig. 2. Oviposition deterrent activity of NeemSweet formulations on *P. xylostella* adults



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig. 3. Ovicidal action of NeemSweet formulations against *S. litura eggs*

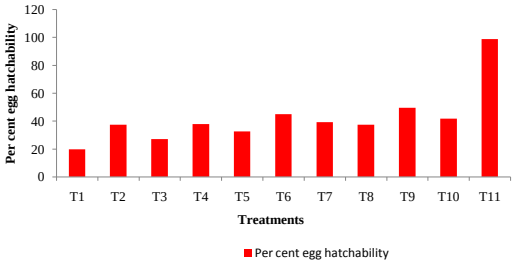
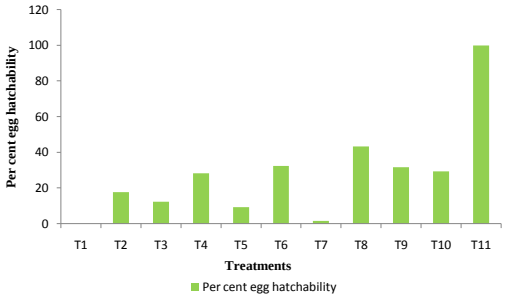


Fig. 4. Ovicidal action of NeemSweet formulations against *P. xylostella eggs*



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig. 5. Toxicity of NeemSweet formulations against neonates of *S. litura*

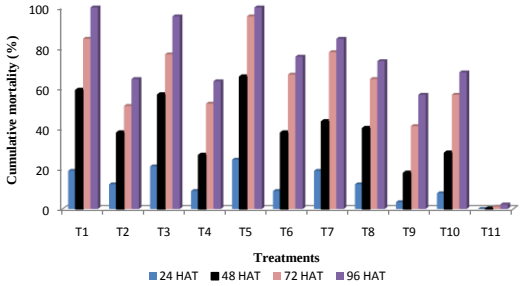
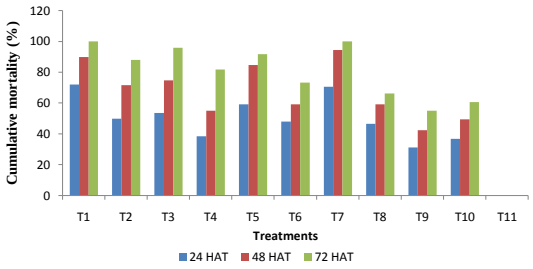


Fig. 6. Toxicity of NeemSweet formulations against neonates of *P. xylostella*



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig.7. Antifeedant effect of NeemSweet formulations against larvae of *S. litura*

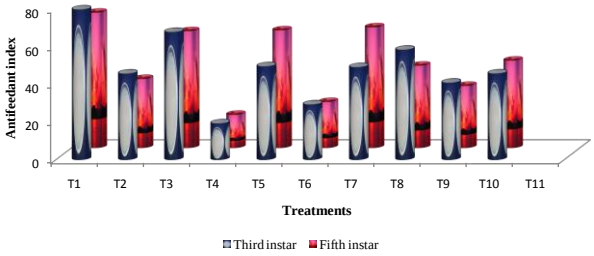
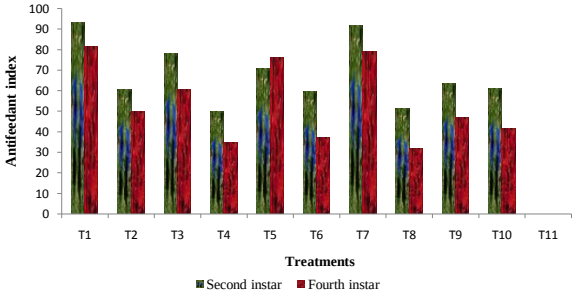


Fig. 8. Antifeedant effect of NeemSweet formulations against *P. xylostella* larvae



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig. 9a.Growth inhibitory effect of NeemSweet formulations against third instar larvae of *S. litura*

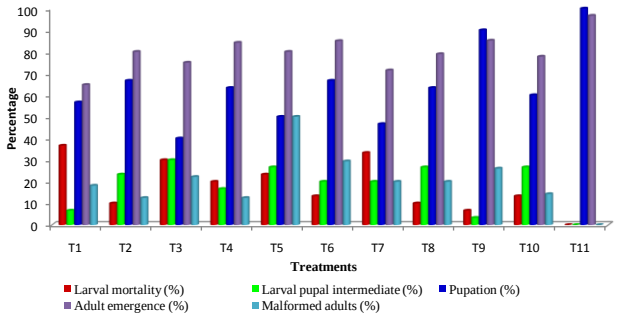
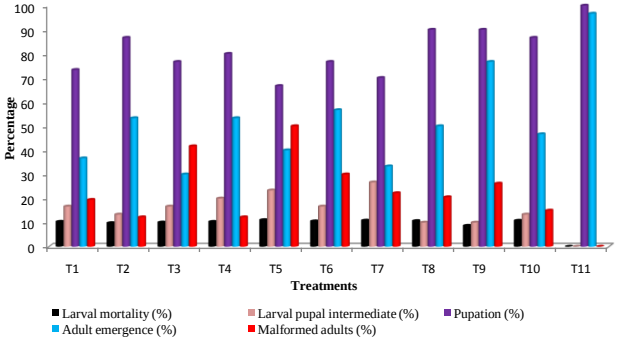


Fig. 9b.Growth inhibitory effect of NeemSweet formulations against fifth instar larvae of *S. litura*



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig. 10a. Growth inhibitory effect of NeemSweet formulations against 2nd instar larva of *P. xylostella*

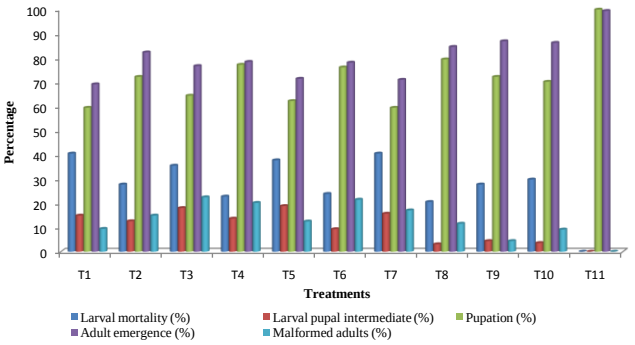
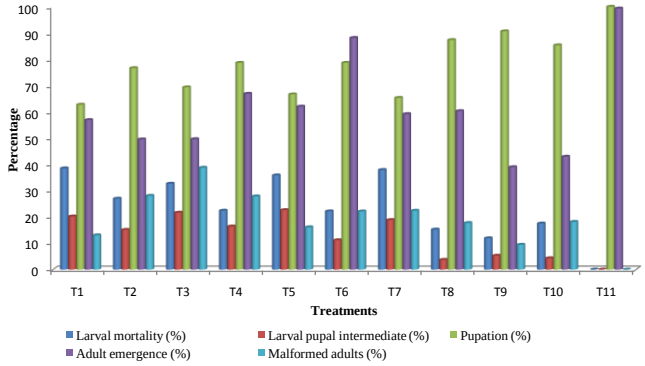


Fig. 10b. Growth inhibitory effect of NeemSweet formulations against 4th instar larva of *P. xylostella*



T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig.11a.Influence of NeemSweet formulations on consumption and utilization of food by third instar larvae of *S litura*

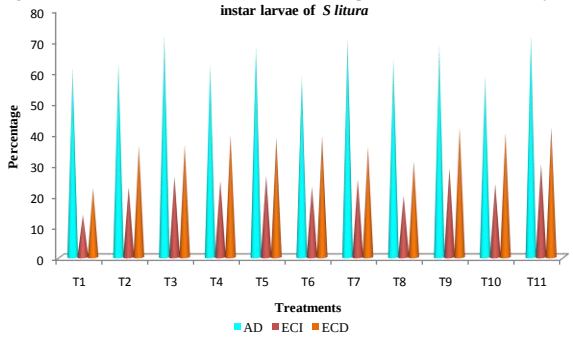
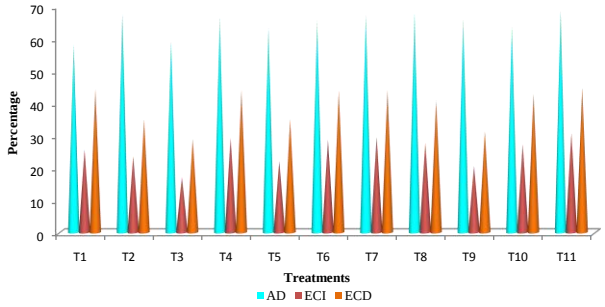


Fig.11b. Influence of NeemSweet formulations on consumption and utilization of food by fifth instar larvae of *S. litura*



AD – Approximate digestibility
ECI – Efficiency of conversion of ingested food
ECD – Efficiency of conversion of digested food

T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

Fig.12a. Influence of NeemSweet formulations on consumption and utilization of food by second instar larvae of *P. xylostella*

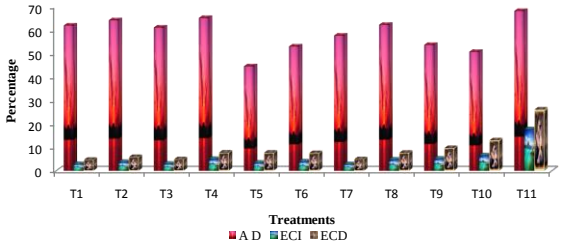
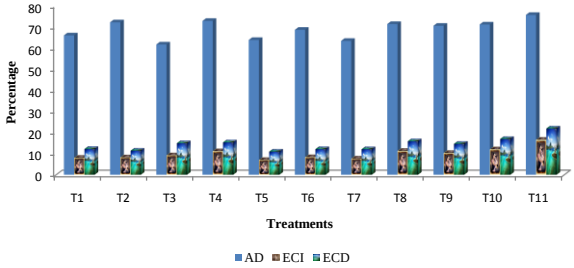


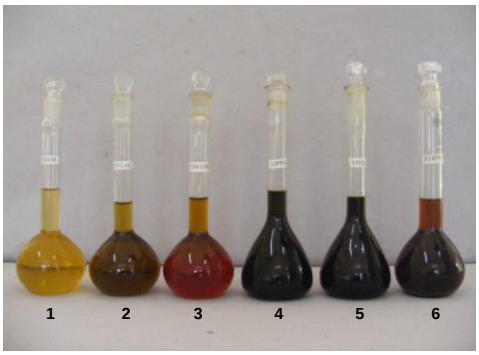
Fig.12b. Influence of NeemSweet formulations on consumption and utilization of food by fourth instar larvae of *P. xylostella*



AD – Approximate digestibility
ECI – Efficiency of conversion of ingested food
ECD – Efficiency of conversion of digested food

T1 - NSS 60 EC 0.5%
T2 - NSS 60 EC 0.25%
T3 - NSL 60 EC 0.5%
T4 - NSL 60 EC 0.25%
T5 - NSV 60 EC 0.5%
T6 - NSV 60 EC 0.25%
T7 - NSP 60 EC 0.5%
T8 - NS 60 EC 0.5%
T9 - NO (C) 60 EC 0.5%
T10 - NSKE 5%
T11 - Untreated check

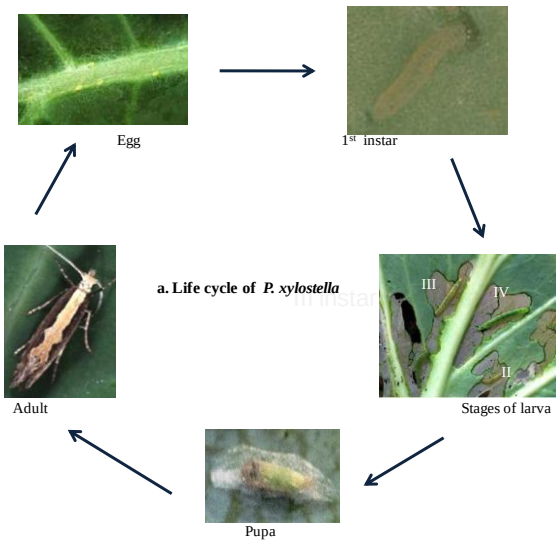
Plate 1. Methanolic extracts of botanicals



1-Neem; 2-Sweet flag; 3-Pungam; 4-Lippia; 5-Vitex; 6-Strychnos

NeemSweet formulations

1-NSS 60 EC; 2-NSL 60 EC; 3-NSV 60 EC; 4-NSP 60 EC

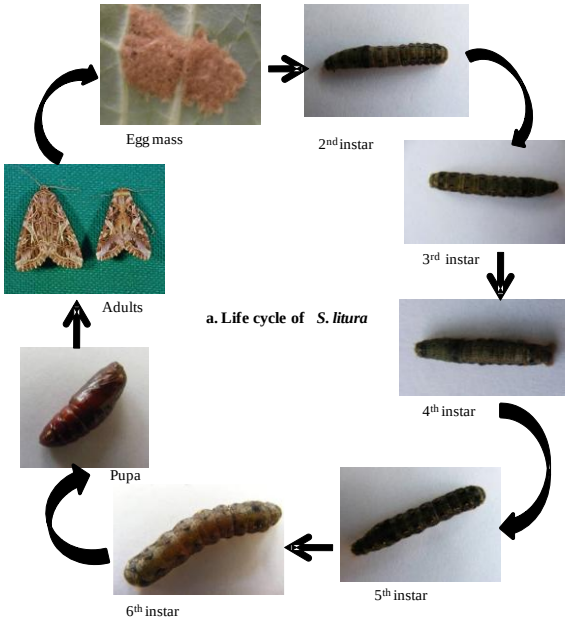


a. Life cycle of *P. xylostella*

b.Adult emergence cage

c. Transfer of larvae from mustard

Plate 2. Mass culturing of *P. xylostella*



a. Life cycle of *S. litura*

b. Adult emergence cage

Plate 3. Mass culturing of of *S. litura*

Plate 4. Experimental set up used for laboratory studies

a. Oviposition deterrency test

b. Antifeedancy test

Plate 5. Field evaluation of NeemSweet formulations

a. Field trial I

b. Field trial II

Plate 6. Growth inhibitory effect of NeemSweet formulations

a. Effect on third and fifth instar larvae of *S. litura*

b. Effect on second and fourth instar larvae of *P. xylostella*