FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 4, December, 2020, pp 484 - 491
DOI: https://doi.org/10.33003/fjs-2020-0404-506

NEEM, Azadirachta indica L. (A. Juss): AN ECO-FRIENDLY BOTANICAL INSECTICIDE FOR MANAGING FARMERS' INSECTS PEST PROBLEMS - A REVIEW

*[1]Muhammad, A. and [2]Kashere, M. A.

[1]Department of Crop Production and Protection, Federal University Dutsin-ma, Katsina State, Nigeria
[2]Department of Agricultural Technology, Federal College of Horticulture, PMB 108, Dadin Kowa, Gombe State, Nigeria.

*Corresponding email address: amuhammad1@fudutsinma.edu.ng +2348024776111

ABSTRACT

The search for reducing risks associated with the use of chemicals has necessitated use of pest control using plant products. Neem is perhaps one of the most useful medicinal plant in the tropics. Each part of the tree has huge insecticidal property. Apart from the chemistry of the neem compounds, considerable progress has been achieved regarding the biological activity and insecticidal uses of neem. It is now considered as a valuable source of unique natural product for botanical insecticides against various pests. Farmers in tropical countries commonly used its leaves, seed kernels and its oil in various forms. Neem is utilized in form of powders, extracts or as an emulsifiable oil. Researches had shown that neem consists of pesticidal ingredients called triterpenes (limonoids). Trials conducted on the effect of neem products revealed secondary metabolites affect metabolic processes that include feeding and oviposition deterrence; metamorphosis inhibition, protein synthesis, changes in biological fitness, impaired sexual communication and chitin synthesis. Azadirachtin in particular interferes with chemoreception and exerts direct negative effects on many insect tissues such as muscles and digestive epithelial cells as well as insect mortality. Neem derived biopesticides are cheap, available in all ecological zone, posed no hazard to applicator and the environment as it is biodegradable. Insects such as Aphids, African migratory locust, legume pod-borer, coreid bugs and storage insect pests such as cowpea seed bruchid were controlled using neem. Sustainable insect pest control can be achieved with the use of neem based biopesticides.

Keywords: Neem, Azadirachta indica, eco-friendly, managing, pest, problems

INTRODUCTION

Neem, Azadirachta indica (A. Juss) syn. (Melia azadirachta) is a tree that is widely known as neem. It is a native to India and Burma sub-continent (Lokanadhan et al., 2012 and NRC, 1992). It belongs to the same family with Mahogany-Meliaceae and hence referred to as botanical cousin (NRC, 1992). The centre of origin of this tree was believed to be around India. The tree is commonly called neem or Indian Lilac (English), Margousier (French), Margosa (Spanish), Niembaum (Germany), Dogon-Yaro or Bedi in Hausa Language-Nigeria (NRC,1992).

Pesticidal plants, also referred to as botanicals have been used for centuries in pest management. Evidence of their use in agriculture dates back to Greek, Roman and Egyptian empires. They were the main method of crop pest management until the development of synthetic pesticides in the mid-twentieth century. Although synthetic pesticides can work very well, overuse and misuse of synthetics has led to considerable human and environmental health problems. The menace posed by the use of synthetic chemicals on the environment, non-target pests, the applicator and other beneficial insects necessitated the search for alternative control measures using plant products (Muhammad and Bashir, 2017; Ahmed et al., 2009). The bioactivity of neem based products has been extensively evaluated and proven. Though, many plant chemicals have been reported to be suitable for this, neem is the only plant from which the biopesticides were commercially manufactured, found effective, eco-friendly and acceptable to farmers (Neem Foundation, 2014). Neem has been use in the treatment of pests and diseases as well as in human sickness as insecticide, fungicide and anticonceptionals (Benisheikh et al, 2019). In other words, neem is capable of solving global agricultural, public health, population and environmental problems (Neem Foundation, 2014). Neem products are effective against more than 350 species of arthropods, 12 species of nematodes, 15 species of fungi, three viruses, two species of snails and one crustacean species (Elanchezhyan et al., 2015). Globally, pesticide usage continued to increase as it possesses quick-knock action. However, there were associated consequences with time. This review was undertaken in order to bring out the successes achieved by use of neem in insect pest control. This will go a long way in meeting the yearnings and aspirations for pesticide free food. Consequently, reducing health risks as well as preventing environmental contamination.

PARTS OF NEEM TREE USE IN INSECT PEST CONTROL

Leaves

Neem leaves are evergreen and possess an excellent medicinal, pest and disease management control properties. The leaves are mostly being used fresh. The crushed leaves are soaked in water and left over night. According to Neem Foundation (2014), 80 kg of green neem leaves is required ha-1 for the control of field insect pests. The next day, the leaves are stirred thoroughly and filtered using a muslin cloth. The resultant filtrate thus gives the crude extract. Alternatively, the leaves are shade dried, ground and sieved into fine particles (powder) for use (Muhammad et al., 2018, Muhammad et al., 2019; Muhammad and Bashir, 2017; Ogunwolu and Idowu, 1997).

Neem seed kernel (NSK)

The neem fruit is small, smooth ellipsoidal drupe. The outer skin is green when row but at maturity, the colour changed to yellow or greenish yellow and comprised of a seed embedded in sweet pulp. After washing the pulp, the seeds can be shade or sun dried. Mechanically, the seeds are cracked and cotyledons removed from the shell (sometimes two or three kernels are found). It is this part of the fruit that is mostly used in the pest control. Preparing neem seed kernel extract according to Neem Foundation (2014), 50g neem kernel powder is wrapped in clean muslin cloth with an emulsifier (such as a bar soap). The pouch is soaked in 1L of water and left over night. The next day, the mixture is squeezed and the resultant filtrate form the neem kernel extract for spray against field insect pests (Muhammad et al., 2019, Abdourahamane et al. 2019). The NSK powder may also be utilized in controlling storage insect pests (Muhammad and Bishir, 2017, Ekeh et al., 2013, Suleiman and Yusuf., 2011, Rahman and Talukder, 2006, Ogunwolu and Idowu, 1997). Although, bioactive compounds are found throughout the tree, those in the seed kernels are the most concentrated and accessible (NRC, 1992). Neem seed kernel (NSK) is the most important source of triterpenoids (Elteraifi and Hassanali, 2011). However, those active ingredients were slightly soluble in water but freely soluble in organic solvent such as hydrocarbons; alcohols, ketones and ethers. Neem kernel powder is sometimes used in soil amendment or as organic pesticide in protecting plant roots against soil insects and nematodes. Neem cake prepared through this process is an excellent livestock feed and natural pesticides (Neem Foundation, 2014).

Neem oil

Neem kernels are important sources of neem oil. The kernels were found to contain the following an approximate of oleic acid 52.8%, stearic acid 21.4%, palmitic acid 12.6%, linoleic acid 2.1% and lower fatty acid 2.3%. (Neem Foundation, 2014). The oil in neem is very bitter with garlic/sulphur smell obtained through mechanically pressed; steam and high pressure extraction or by solvent extraction methods. The product obtained after oil extraction is the neem cake. Such products are used in a number of ways. Either used as animal feed or as organic fertilizer-by provision of organic nitrogen (Neem Foundation, 2014). Several researches were carried out using neem oil on some insects. Joans and Jans (2000) reported the antifeedant activity on Sesamia nonagrioides (Lefebvre) in Spain. Bruce et al. (2004) also reported oviposition deterrence, fecundity and egg laid viability of S. calamistis and Elderna saccharina compared with the control at IITA, Republic of Benin. Lokanadhan et al. (2012) attributed the pest control in rice due to insecticidal and medicinal properties of neem oil.

Neem tree bark

Neem bark is cut, dried and ground into powder. The finely divided particles are used in admixture in storage pests control (Ogunwolu and Idowu, 1997). According to Neem Foundation (2014), the bark contains tannin as one of its active secondary metabolites that are pesticidal in activity. Ramadass and Subramanian (2018) observed that it is the presence of secondary metabolites in plants that is responsible for some biological activity in man and animals.

CHEMICAL COMPOSITION OF NEEM

Shannag et al. (2015) stated that, neem tree is the most promising plant species being utilized for synthesis of biopesticides. Many compounds with biological activity were extracted from its various parts but seeds are the main source of bioactive compounds for neem-based insecticide formulations. The various parts of the tree are composed of multiple of pesticidal ingredients with which the plant protects itself from biotic stresses of the environment. These pesticidal ingredients were categorized into a mixture of 3 or 4 related compounds including other minor but yet important in one way or the other. These compounds were generally known as Triterpenes (Elteraifi and Hassanali, 2011) and consists of the following:

Limonoids

The most important and significantly used neem compounds in pest control are the Azadirachtin (Az), Salanin, Meliantriol and Nimbin.

Azadirachtin (Az)

An important ingredient that forms majorly the highest proportion in neem is the Azadirachtin (Az) Mulla and Su (1999). It is considered to be the compound of the most important biological interest (Elteraifi and Hassanali, 2011) as it caused about 90% of the neem effects on most pests. It does not kill pest instantly but however, repels, deter feeding and disrupts insect's growth and reproduction. Parmar (1987) reported that azadirachtin caused a prolonged development period, wing deformities, non-plasticization of wing lobes, development of wingless adults and larval mortality on application to various stages of Dysdercus koenigii F. (Hemiptera: Pyrrhocoridae). Mondal and Chakraborty (2016) further reported that Az compounds affect chitin synthesis (exo-skeleton development), disruption of sexual communication between both sexes, Changes in biological fitness that included reduced lifespan, high mortality, loss of flying ability, low absorption of nutrients], immunodepressions enzyme inhibition and disruption of biological rhythms.

Salanin

Another triterpenoid isolated from neem which exhibit similar biological properties, to a greater or lesser extent (Elteraifi and Hassanali, 2011). It actively inhibits insect feeding ability. This is very important especially insects with biting and chewing mouth part (NRC, 1992).

Meliantriol

It is another feeding inhibitor at extremely low concentration. Herbaceous insects are mostly being affected by this category of neem ingredient.

Nimbin and Nimbidin

These are also neem components that were found to be antiviral in action. The bitterness in neem was attributed to the presence of nimbin (NRC, 1992).

BIOLOGICAL EFFECTS OF NEEM COMPOUNDS ON INSECTS

Research has shown that neem application to crops in the field or under storage conditions affect insect pests in many ways. Among these it causes feeding deterrence, oviposition deterrence, moulting/metamorphosis inhibition and insect repellence (Ferdenache et al. 2019; Kraiss and Cullen, 2008).

Antifeedant

This term may as well mean feeding deterrence. Takulder (2006) defined antifeedant as chemicals in plants/products that inhibit feeding, although do not kill the insect directly. Neem bioactive constituents, Azadirachtin and AZ-containing extracts show distinct antifeedant activity, primarily by chemoreception (primary antifeedancy), but also through reduction in food intake due to toxic effects after consumption (secondary antifeedancy) in lethal quantities Mulla and Su (1999). The chemicals turn the product unattractive and sweet less (less palatable) thereby starving the insect. Occasionally the insect may die of hunger. Similarly, the odour in neem that is almost similar to that of garlic/sulphur repels insects away. NRC (1992) attributed antifeedant of neem due to meliantriol and selanin constituents. Olaifa and Akingbohungbe (1987) observed antifeeding effect of neem treated cowpea seedlings fed to grasshopper, Zonocerus variegatus L. (Orthoptera: Pyrgomorphidae) in a screen house trial in Ile-Ife, Nigeria. Jocobson (1987) and Parrmar (1987) also reported complete inhibition of Mexican bean beetle, Epilachna varivestis Muls for 6 days when exposed to azadirachtin concentration. Mulla and Su (1999) also reported antifeedancy in insect orders such as Isoptera, Hemiptera, Coleoptera, Lepidoptera, and Diptera.

Oviposition deterrence

Oviposition deterrence is another effect of neem on insect pests. Insects' life cycle begins with the laying of eggs on a given substrate. However, when eggs were not laid, the metamorphosis process is affected, except in a few species of insects such as Aphids, Aphis craccivora Koch that exhibit parthenogenesis and viviparous. According to Lale (1996) parthenogenesis is a phenomenon in which insect eggs under certain circumstances (not fully understood) develop into normal adult without fertilization. The property of neem to disallow female insect from laying eggs on a given substrate is referred to as oviposition deterrence. Researches on oviposition deterrence were conducted especially on stored products (Ogunwolu and Idowu, 1997; Bruce et al., 2004; Rahman and Talukder, 2006; Suleiman and Yusuf, 2011 and Ratnasekera and Rajapakse, 2012). The findings showed control treatments recorded the highest mean number of eggs compared to the neem treated.

Metamorphosis inhibition

The changes that occur in the development of an insect from egg to adult are referred to as metamorphosis. The number of stages however differed among insects with 3 and 4 depending on the insect type. Among some of the effects of neem on insect metamorphosis as reported by NRC (1992) include disrupting the development of eggs, larvae or pupae, blocking moulting of larvae or nymph. Neem Foundation (2014) identified azadirachtin (Az) as one of the constituents of neem that eventually affect the normal functioning of Juvenile hormone in larvae and ecydysome enzyme secretion to initiate moulting. One of the function of Az is it has hormonal effects, affecting both ecdysteroid and juvenile hormone titers (Mulla and Su (1999). This action was by inhibiting the release of morphogenetic peptide, prothoracicotropic hormone (PTTH), and allatotropins from the brain-corpus cardiacum complex (Ascher 1993: Mondal and Chakraborty, 2016). Jacobson (1987) reported life cycle of yellow mealworm, Tenebrior molitor (L.) being inhibited when the larva was treated with 0.1μg azadirachtin. The larvae maintained juvenile characteristics but failed to moult. Adults of Antestia bugs, Antestiopsis ortitalis Bechuacina observed metamorphosis defects when the 5th nymphal stage of the insect was treated with methanolic extract of neem kernel extract. Similar effects were reported by Schumutter (a), Schumutter (b) and Dorn et al. (1987). Many past authors have reported action of neem oil on insect life cycle development among which include Plate I-III (NRC, 1992; Neem Foundation, 2005).

Insect repellence

Insects are known to study the environment around them with their antennae. They are tactile organs, acting as olfactory organs and a few cases as organs of hearing (Dike, 2014). Any change in the environment, the insect responded by going towards the stimulus if it is food source or run away if it is danger. Studies carried out by past researchers (Ahmed et al., 2009; Rahman and Talukder, 2006 and Muhammad et al., 2018) reported significant lower population of insect on neem treated plots compared with the controls. The mechanism of repellence could be attributed to repulsive neem odour.

Insects Affected by Neem Products

Research conducted by Sokame et al. (2015), Ekeh et al. (2013), Suleiman and Yusuf (2011), Oparaeke et al. (2005a), Ogunwolu and Idowu (1997) had shown that neem and its products were identified to cause toxicity to many insects in addition to other pest organisms such as mites and nematodes. NRC (1992) and Neem Foundation (2014) reported that about 200 insect species, mites and nematodes are controlled using neem. These insect pests fall within various insect orders widely believed to be injurious to crops. Such orders include but not limited to, Coleoptera e.g. red flour beetle (Herbst), Tribolium confusum (Coleoptera: Tenebrionidae); cowpea weevil, Callosobruchus maculatus Fab. (Coleoptera: Chrysomilidae) and colorado potato beetle, Leptinotersa decemlineata Thomas (Coleoptera: Chrysomilidae); Lepidoptera e.g. diamondback moth, Plutella xylostella Linnaeus, (Lepidoptera: Yponomeutidae), fall armyworm, Spodoptera frugiperda J. E. Smith (Lepidoptera: Noctuidae) and pink bollworm, Pectinophora gossypiella Saunders (Lepidoptera: Gelechiidae); Orthoptera e.g. grasshopper, Zonocerus variegates Linnaeus (Orthoptera: Pyrgomorphidae), mole cricket, Gryllotalpha africana Palisot de Beauvois (Orthoptera: Gryllidae) and African migratory locust, Locusta migratoria migratorioides Linnaeus (Orthoptera: Acrididae); Hemiptera e.g. aphid, Aphis craccivoraKoch (Hemiptera: Aphididae), potato leaf hoppers, Empoasca fabae (Harris) (Hemiptera: Cicadellidae) and white flies, Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae); Thysanoptera e.g. Megalothrips sjostedtii Tybom (Thysanoptera: Thripidae); Diptera e.g. house fly, Musca domestica Linnaeus (Diptera: Muscidae), Mediterrranean fruit fly, Ceratitis capitata (Wieldemann) (Diptera: Tephritidae) and sorghum midge, Contarinia sorghicola Conquillett (Diptera: Cecidomyiidae). Other insects reported are presented in Table 1.

NEEM SAFETY ON SOME NATURAL ENEMIES

Effect of neem on predators

Effect of neem was observed on non-arthropod predators like spider, Lycosa pseudoannulata Boes (Aranae: Lycosidae) and predatory mites and were found to be able to survive even if Neem Azal is sprayed (Shukla et al., 1988). Safety of various botanicals against Chrysoperla carnea Stephens (Neuroptera: Chrysopidae) was also stressed (Jayaraj and Regupathy, 1999), mirid bug on Bemisia tabaci Gennadius (Homoptera: Aleyrodidae) (Jazzer and Hamed, 1999; Tetragnatha javana Thorell (Aranae: Tetragnathidae) and C. carnea (Abdul Kareem et al., 1999) and Rhynocoris marginatus Fab.

(Hemiptera: Reduviidae) on cotton aphid, Aphis gossypii (Hemiptera: Aphididae) (Sahayaraj and Karthickraja, 2003) and no adverse effect was observed on the larval and pupal duration, development and feeding potential of C. carnea, the lacewing predator commonly used for inoculative releases in groundnut, cotton etc. when fed with neem treated.

Effect of neem on parasitoids

Neem seed kernel extract 2% was found safe without affecting the behavior of T. indica on Planococcus indicus Avasthi & Shafee (Hemiptera: Pseudococcidae) (Mani and Krishnamurthy, 1996); Telenomus remus Nixon (Hymenoptera: Platygastridae) on Spodoptera litura Lin. (Lepidoptra: Noctuidae) (Chari and Muralidharan, 1996), Tetrastichus pyrillae Chrawford on Pyrilla (Deepak and Chowdary, 1998). Neem applied either as neem oil or any neem formulations like Neemark 0.3% or Achook 0.3%. NSKE did not record any deleterious effect on the development, fertility, oviposition, fecundity or hatchability of the egg parasitoid, Trichogramma chilonis Ishii (Hymenoptera: Trichogrammatidae) (Balasubramanian and Regupathy, 1994; Jayaraj and Regupathy, 1999) and were found to also encouraged the activity of larval parasitoids like Cotesia flavipes Lam (Hymenoptera: Braconidae) on Chilo sacchariphagus indicus Kapur (Lepidoptera: Crambidae) (Reddy and Srikanth, 1996); C. plutella on diamondback moth, Plutella xylostella (Lepidoptera: Yponomeutidae) (Mani, 1995; Srivastava et al., 1997). In rice ecosystem, neem formulations like Fortune Aza 0.1% and Neem Azal 0.3% showed high percentage of parasitization (79%) by T. japonicum (Hymenoptera: Trichogrammatidae) on yellow stem borer, Scirpophaga incertulas (Jhansi Lakshmi et al., 1997).

CONCLUSION

Although, plant products cannot completely replace synthetic insecticides in insect pest control, however, their availability and reduced health hazards on the applicator and the eco-system is greatly minimized. An eco-friendly plant that not only control insect pest but also increases the nutrient status of soils can effectively be utilized by low income farmers. Neem tree when fully harnessed can serve as an alternative means of insect pest control especially by poor resourced farmers in any ecological zone. This is because it posed no danger to the environment, no residual effects neither development of pest resistance.

REFERENCES

Abdourahamane, M. H., Baoua, I, Lawali, S., Tamò, M., Amadou, L., Mahamane, S. et Pittendrigh, B. et al. (2019). Essai comparatif de l'utilisation des extraits du Neem et du virus entomopathogène MaviNPV dans la gestion des insectes ravageurs du niébé en milieu paysan au Niger. International Journal of Biology and Chemical Sciences, 13(2): 950-961. Available online at http://www.ifgdg.org

Abdul Kareem, A., Guna Sekharan, K., Ambalaga, G., Regupathy A., (1999). Safety of new neem formulations against natural enemies of agro ecosystem, Neem Newsletter, 16, p32.

Ahmed, B. I., Onu, I., Mudi, L. and Aliyu, M. (2007). Comparative efficacies of some selected plant derived pesticides for the control of insect pests of cowpea (Vigna unguiculata (L.) Walp in Katsina State, Nigeria. Korean Journal Crop Science.52 (2), 183-197.

Ahmed, B. I., Onu, I. and Mudi, L. (2009). Field bioefficacy of plant extracts for the control of post flowering insect pests of cowpea, Vigna unguiculata (L.) Walp. in Nigeria. Journal of Pesticides. 2(1), 37-43.

Ascher, K. R. S. (1993). Nonconventional insecticidal effects of pesticides available from the neem tree, Azadirachta indica. Arch. Insect Biochemical Physiology, 22: 433-449.

Balasubramanian V., Regupathy A., (1994). Effect of neem oil 50 EC and NSKE on the ovipositional preference and fecundity on Trichogramma chilonis. In: Goel, S.C. (Ed.), Biological control of insect pests. U.P. Zoological Society, Sanatan Dharm College, Muzaffarnagar, 166.

Bruce, Y. A., Gounou, S., Chabi-Olaye, A., Smith, H. and Schulthess, F. (2004). The effect of (Azadirachta indica A. Juss) oil on oviposition, development and reproduction potentials of Sesamia calamistis Hompson (Lepidoptera: Noctuidae) and Eldana saccharina Walker (Lepidoptera: Pyralidae). Agricultural and Forest Entomology, 6: 223-232.

Chari, M. S., and Muralidharan, C. M., (1996). Neem (Azadirachta inidca Linn.) as feeding deterrent of castor semilooper (Achoea janata Linn.). Journal of Entomological Research, 9, 243.

Deepak, K. D., Chowdary, A. K. (1998). Toxicity of some insecticides to Tetrastichus pyrillae, egg parasite of sugarcane leaf hopper, Pyrilla perpusilla. Annals of Plant Protection Sciences, 8: 233.

Dike, M. C. (2014). Morphology and Physiology of Insects. First ed., Zaria, P.A. Ndahi printing, 83 Pp.

Dorn, A. Rademacher, J. M. and Sehin, E. (1987). Effects of Azadirachtin on reproductive organs and fertility on the large Milkweed bug, Oncopeltus fasciatus, pp 273-288. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Ekeh, F. N., Onah, I. E. Atama, C. I. Ivoke, N. and Eyo, J. E. (2013). Effectiveness of botanical powders against Callosobruchus maculatus (Coleoptera: Bruchidae) in some stored leguminous grains under laboratory conditions. African Journal of Biotechnology, 12(12):1384-1391.

Elanchezhyan, K., and Vinothkumar. B. (2015). Neem: An Eco-Friendly Botanical Insecticide in Pest Management. Journal of Insect Science, Photon, 116: 207-217. https://sites.google.com/site/photonfoundationorganization/home/the-journal-of-insect-science.

Elteraifi, I. E. and Hassanali, A. (2011). Oil and Azadirachtin contents of neem (Azadirachta indica A. Juss) seed kernels collected from trees growing in different habitats in Sudan. International Journal of Biological and Chemical Science, 5(3): 1063-1072. Available online at http://ajol.info/index.php/ijbcs

Ferdenache, M., Bezzar-Bendjazia, R., Marion-Poll, F. and Kilani-Morakchi, S. (2019). Transgenerational effects from single larval exposure to azadirachtin on life history and behavior traits of Drosophila melanogaster, Scientific Reports, 9:17015. https://doi.org/10.1038/s41598-019-53474-x

Jayaraj, S., Regupathy, A. (1999). Evaluation of neem and other plant products for bio-instensive IPM and for production of 'Green Cotton'. World Neem Conference, 19 – 21 May, 1999. University of British, Columbia, Van Couver, Canada. Abstract, p.6.

Jazzer, C. L., Hammed, E. A. F. (1999). Effect of semi qualitative ageing classes of Melia azadirach on Bemisia tabaci and a predator mirid. World Neem Conference, 19 – 21 May, 1999. University of British, Columbia, Van Couver, Canada. Abstract, p.6.

Jhansi Lakshmi, V., Katti, G., Krishnaiah, N.V., Lingaiah, T. (1997). Laboratory evaluation of commercial neem formulations vis-à-vis insecticides against egg parasitoid, Trichogramma japonicum. Journal of Biological control, 11: 29 – 32.

Joans, A. and Sans, A. (2000). Antifeedant activity of fruit and seed extract of Melia azedirach and Azadirachta indica on larvae of Sesamia nonagrioides. Phytoparasitica, 28:311-319.

Jocobson, M. (1987). Neem research in the northern hemisphere, pp 33-44. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Ketkar, C. M. (1987). Use of three derived non-edible oils as surface protectants for stored legumes against Callosobruchus maculatus and C. chinensis, pp 535-542. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Kraiss, H. and Cullen, E. M. (2008). Insect growth regulator effects of azadirachtin and neem oil on survivorship, development and fecundity of Aphis glycines (Hemiptera: Aphididae) and its predator, Harmonia axyridis (Coleoptera: Coccinellidae). Pest Management Science, 1541-1549. DOI: 10.1002/ps.

Lale, N. E. S. (1996). Dictionary of Entomology, Maiduguri, Borno State, Mole publication (Nig.) Ltd, 133pp.

Lokanadhan, I. S., Muthukrishman, P. and Jeyaraman, S. (2012). Neem product and their agricultural application. Journal of Biopesticides, 5(supplementary): 72-76.

Mani, M. (1995). Studies on the toxicity of pesticides to Cotesia plutellae, a parasitoid of diamond back moth, Plutella xylostella. Journal of Insect Science, 8: 31 – 33.

Mani, M., Krishnamoorthy, A. (1996). Response of the oriental mealy bug Planococcus lilacinus to different pesticides. Indian Journal of Plant Protection, 24: 80.

Muhammad, A. and Bashir,A. K. (2017). Callosobruchus maculatus (Fab.) control by plant products in cowpea grains under storage-a review. Journal of Medicinal Botany. 1: 51- 57.Doi:10.25081/jmb.2017.v1.897. http://updatepublishing.com/journals/index.php/jmb

Muhammad, A., Malgwi, A. M. and Nahunnaro, H. (2018). Effect of Sowing Dates, Intra-row Spacings and Pesticides on Maruca vitrata (Fab.) (Lepidoptera: Pyralidae) Damage on Cowpea in Samaru, Northern Guinea Savanna. Nigeria Journal of Entomology. 34: 87-98. DOI: 10.36180/NJE/8102/43(0101).

Muhammad, A., Malgwi, A. M. and Nahunnaro, H. (2019). Maruca vitrata (Fab.) [Lepidoptera: Pyralidae] Damage on Cowpea (Vigna unguiculata L. Walp.) in Katsina, Sudan Savanna, Nigeria: The Role of IPM. Biochemistry and Molecular Biology, 4(6): 86-93. http://www.sciencepublishinggroup.com/j/bmb doi: 10.11648/j.bmb.20190406.12

Mulla, M. S. and Su, E. T. (1999). Activity and biological effects of neem products against arthropods of medical and veterinary importance. Journal of the American Mosquito Control Association' 15(2):133-152, 1999.

National Research Council (1992). Neem, a tree for solving global problems. A report of an adhoc panel of the Board on Science and Technology for International Development. Washington, D.C, National Academy Press, 141pp.

Neem Foundation (2014). Spreading the Neem Revolution. An informal compilation of some of the investigations and developments done on Neem in the recent pasts. Neem Foundation. www.neemfoundation.org/invest.htm. Retrieved on 20/12/2019.

Olaifa, J. I. and Akingbohungbe, A. E. (1987). Antifeedant and insecticidal effects of extra effects of Azadirachta indica, Petiveria alliacea and Piper guineense on the Zonocerus variegatus, pp 405-418. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Ogah, E. O. (2013). Field Evaluation of Plant Extracts in the Management of Megalurothrips sjostedti and Maruca vitrata of Cowpea in Southeastern Nigeria. World Essays Journal. 1 (1), 11-17. Available online at www. worldessaysj.com.

Ogunwolu, O. and Idowu, O. (1994). Potential of powdered Zanthoxylum zanthoxyloides (Rutacea) root bark and Azadirachta indica (Meliaceae) seed for the control of the cowpea seed bruchid, Callosobruchus maculatus (Bruchidae) in Nigeria. Journal of Zoology, 108:521-528.

Oparaeke, A. M. (2006). Effect of aqueous extract of tropical plants for management of Maruca vitrata Fab. and Clavigralla tomentosicollis Stal. on Cowpea, Vigna unguiculata (L.) Walp. plants. Journal of Entomology, 3(1): 70-75.

Oparaeke, A. M., Dike, M. C. and Amatobi, C. I. (2005). Evaluation of botanical mixtures for insect pests management on cowpea plants. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 106 (1): 41–48.

Oparaeke, A. M., Dike, M. C. and Amatobi, C. I. (2005). Field evaluation of an extract of five Nigerian species for control of post-flowering pests of cowpea, Vigna unguiculata (L.) Walp. Plant Protection Sciences. 41: 14-20.

Parmar, B. S. (1987). An over view of neem research and use in India during the year 1983-1986, pp 55-60. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Rahman, A. and Talukder, F. A. (2006). Bioefficacy of some plant derivatives that protect grain against the pulse beetle, Callosobruchus maculatus. Journal of Insect Science, 6(3):1-10. Available online: insectscience.org/6.03.

Ramadass, N. and Subramanian, N. (2018). Study of phytochemical screening of neem (Azadirachta indica). International Journal of Zoology Studies, 3(1): 209-212. www.zoologyjournals.com

Ratnasekera, D. and Rajapakse, R. (2012). The potential use of indigenous plant materials against Callosobruchus chinensis L. and Callosobruchus maculatus L. (Coleoptera: Bruchidae) in stored legumes in Sri Lanka. Journal of Biopesticides, 5(supplementary): 88-94.

Reddy P. V. R., and Srikanth J. (1996). Effect of plant extracts on larval parasitoid, Cotesia flavipes and its parasitization efficacy. Insect Environment, 2: 106.

Sahayaraj K., and Karthickraja S. (2003). Effect of biopesticides on Rhynocoris marginatus (Fabricius) (Heteroptera: Reduviidae). Journal of Biological Control, 17: 43.

Schumtterer, H. (1987a). Introduction pp 15-17. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Schmutterer, H. (1987b). Fecundity-reducing and sterilizing effects of neem seed kernel extract in the control of Colorado potato beetle, Leptinotersa decemlineata, pp 351-360. In: H. Schmutterer and K. R. S. Ascher (eds.) Proceedings of the third International Neem Conference, Nairobi, Kenya, 10-15 July, 1986.

Shukla, B. C., Srivastava, S. K. and Gupta, R. (1988). Evaluation of neem oil for control of rice pets. Final Workshop of IRRI – ADB – EWC Project on Botanical pest control in rice based cropping system, IRRI, Philippines.

Sokamè, B. M., Tounou A. K., Datinon, B., Dannon, E. A., Agboton, C., Srinivasan, R., Pittendrigh, B. R. and Tamò, M. (2015). Combined activity of Maruca vitrata multi-nucleopolyhedrovirus (MaviMNPV), and oil from neem, Azadirachta indica Juss and Jatropha curcas L., for the control of cowpea pests. Crop Protection. 72: 150-157.

Subhakara, K. (1998). Studies on exploring the potential of neem formulations for IPM in Tea. Ph.D. Thesis, TNAU, Coimbatore, pp. 105.

Suleiman, M. and Yusuf, M. A. (2011). The potential of some plant powders as biopesticides against Sitophilus zeamais (Motsch.) (Coleoptera: Curculionidae) and Callosobruchus maculatus (F.) (Coleoptera: Bruchidae) on stored grains: a review. Bayero Journal of Pure and Applied Sciences, 4(1): 204-207.

Srivastava, M., Paul, A.V.N., Rengaswamy, S., Kumar, J., Parmer, B.S. (1997). Effect of neem seed kernel extracts on the larval parasitoid, Bracon brevicornis, Journal of Applied Entomology, 121, 51.

Talukder, F. A. (2006). Plant Products as potential stored-product insect management agents. A mini review. Emirate Journal Agric. Sci. 18(1):17-32.

Wudil, B. S., Ahmed, B. I. and Yusuf, S. R. (2013). Field evaluation of two essential oils and a synthetic insecticides for the control of some major insect pests of Cowpea (Vigna unguiculata (L.) Walp in Bauchi State, Nigeria. Nigerian Journal of Entomology. 30: 114-135.

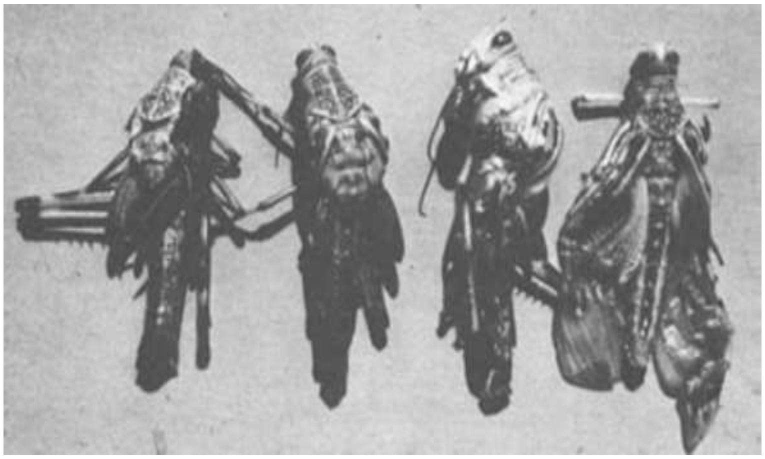

Plate I: 5th instar desert locusts treated with neem oil (Adopted from NRC, 1992)

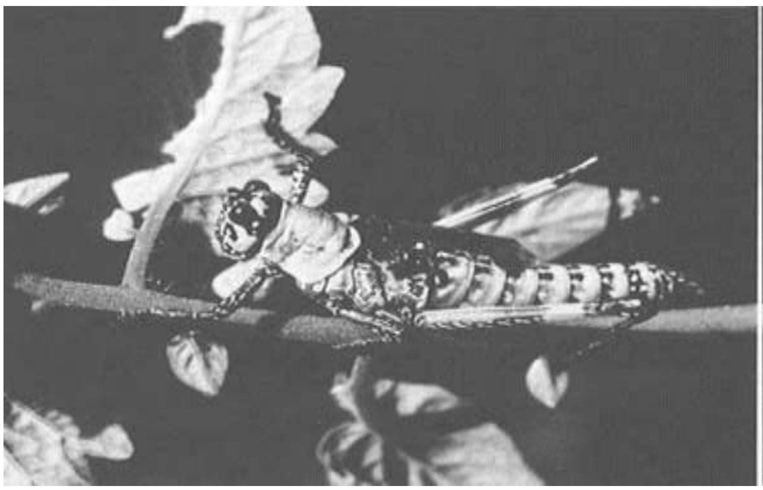

Plate II: A third instar variegated grasshopper, Zonocerus variegatus (L.), adult emerged with no antenna and defective wings (Adopted from NRC, 1992)

Plate III: A colorado potato beetle, Leptinotersa decemlineata treated with neem oil had malformed wings that can neither function in flight nor be folded flat (Adopted from NRC, 1992)

Table 1: List of some insects reported to be affected by neem products

Common name	Scientific name	Order and Family	Neem action	Parts used	Source
Flower bud trips	*Megalothrips sjostedtii* (Trybom)	Thysanoptera: Thripidae	M	1, 5, 4	Sokame *et al.* (2015), Ogah (2013), Oparaeke *et al.* (2005a)
Cowpea pod borer	*Maruca vitrata* (Fab.)	Lepidoptera: Pyralidae	M	1, 4, 5	Sokame *et al.* (2015), Muhammad *et al.* (2018), Ogah (2013), Wudil *et al.* (2013), Oparaeke (2006), Oparaeke *et al.* (2005a), Abdourahamane *et al.* (2019)
Aphids	*Aphis craccivora* Koch	Homoptera: Aphididae	M	1	Sokame *et al.* (2015)
Cowpea bruchid	*Callosobruchus maculatus* (Fab.)	Coleoptera: Chrysomelidae	M, Od	4	Ekeh *et al.* (2013), Ogunwolu and Idowu (1997), Muhammad and Bashir (2017), Rahman and Talukder (2006), Suleiman and Yusuf (2011)
Giant coreid bug	*Anoplocnemis curvipes* Fab.	Hemiptera: Coreidae	R, M	4, 1	Ahmed *et al.* (2009), Wudil *et al.* (2013)
Spiny brown bug	*Clavigralla tomentoscollis* Stal	Hemiptera: Coreidae	R, M	4, 1	Ahmed *et al.* (2009), Wudil *et al.* (2013), Oparaeke (2006), Oparaeke *et al.* (2005b)
Pink stalk borer	*Sesamia calamistis* (Hompson)	Lepidoptera: Noctuidae	Od	1	Bruce *et al.* (2004)
Sugar cane s/borer	*Eldana saccharina* (Walker)	Lepidoptera: Pyralidae	MI	1	Bruce *et al.* (2004)
Tomato Fruit worm	*Heliothis armigera* (Hubner)	Lepidoptera: Noctuidae	Od	1	Saxena and Rembold (1984)
European corn borer	*Ostrinia nubilalis* (Arneson)	Lepidoptera: Crambidae	Af	4	Juan and Sans (2000)
Maize weevil	*Sitiphilus zeamais* (Mostch)	Coleoptera: Curculionidae	Od, R	3	Suleiman and Yusuf (2011), Paragrug and Raxas (2008)
Leaf eating beetle	*Ootheca mutabilis*	Coleoptera: Chrysomelidae	M	4	Ahmed *et al.* (2007)
leafhopper	*Empoasca dolichi*	Homoptera: Cicadellidae	M	4	Ahmed *et al.* (2007)
	Ophiomyia phaseoli	Diptera: Agromyzidae	M	4	Ahmed *et al.* (2007)
Southern armyworm	*Spodoptera eridania* (Stoll)	Lepidoptera: Noctuidae	Af, MI	1	Shannag *et al.* (2015)

Key: 1 = neem seed oil, 2 = neem leaves powder, 3 = neem seed kernel powder, 4 = neem seed kernel extract, 5 = neem leaves extract; M = mortality, Od = oviposition deterrent, R = repellent, MI = metamorphosis inhibition, Af = Antifeedant