

MEDICINAL PLANT-BASED PESTICIDES FOR GREEN PEST MANAGEMENT

Dr. Vibha Pandey

Department of Botany

Y.S.N.M. College, Nilamber-Pitamber University

E-mail: vibha09@gmail.com

Abstract

The advent of synthetic pesticides has greatly affected the environment. Its application for crop improvement has resulted in biomagnification of chemicals in the ecosystem serving as mutagens and causing serious diseases, such as cancer, kidney malfunctions, liver dysfunction, eczema, neurological destruction, cardiovascular diseases etc. The synthetic pesticides have proved equally hazardous for the social texture, soil microbes, animals and plants. The menace caused by the chemical pesticides have necessitated to search for an alternative tool which can minimize the environmental hazardousness posed by synthetic pesticides. The development of Biopesticides offer a unique opportunity for reduced risk management. Due to the advantages of Biopesticides, there has been a significant increase in fundamental and applied research activity on the development and potential use of biopesticides in pest management programmes. Considerable amount of research is being carried world over with emphasis on the screening and development of plant products, Phyto-chemicals and other natural products which are eco-friendly in nature. With a great wealth of knowledge on herbal medicine, it is prudent to look for bioactive compounds derived from plants with medicinal properties, commonly known as Medicinal plants.

Keywords: Medicinal plants, biopesticides, sustainability, eco-friendly.

Introduction

Medicinal plants, the world's oldest known health care products have been effectively used for crop protection since ancient times. The secondary plant metabolites or the biologically active natural products synthesized in plants such as alkaloids, flavonoids, terpenoids and phenolics have been found to carry immense pesticidal activity (Rajkumar and Jebanesan, 2005; Narayanswamy, 2006; Dubey *et al.*, 2010). Owing to the safe and non-toxic nature to mammals and other non-target organisms, the use of medicinal plants is being advocated both in developed and developing countries.

Introduced initially as an important factor of green revolution, the chemical pesticides has slowly but steadily impacted ecosystems, bioaccumulating in food chains and causing grave concern for the ecology of the earth. Exposure to Highly Hazardous Pesticides (HHPs) causes severe acute poisoning *vis-à-vis* long-term chronic effects, such as cancer, reproductive and immune system diseases. The long-term exposure to such synthetics is linked to Parkinsonian disease, neurodevelopmental disorders & cognitive deficits, with particular risk to children, pregnant women, and the elderly. A 2018 study by World Health Organization (WHO) reported high rates of symptoms amongst farmers such as dizziness (66%), headaches (56%), muscle pain (51%), and anxiety (44%). The World Health Organization, therefore recommends the adoption of Integrated Pest Management (IPM) methods which includes biological control, habitat manipulation, modification of cultural practices, and the use of resistant varieties. In recent years, biological control of agricultural pests and other insect related diseases has gained preference over their synthetic analogues due to the toxic and non-biodegradable nature of inorganic and synthetic chemical pesticides (Wheeler, 2002).

Development of 'Biopesticides' offers a unique opportunity for reduced risk management. Biopesticides include agents and products derived from biotic sources, e.g. Microbes, Nematodes, Phytochemicals, Plant Extracts & Essential Oils, GMO products, Insect Pheromones etc. (US Environmental Protection Agency, 2008). In the past few decades, plant based extracts and essential oils have emerged as attractive alternatives to synthetic pesticides. Plant Cells produce primary as well as Secondary metabolites. The primary metabolites (e.g. Carbohydrates, lipids and proteins) are directly involved in the growth and metabolism of plants, whereas the secondary metabolites are considered as end products of the primary metabolism, generally not involved in the metabolic activity in plants. They are synthesized in specialized cells at particular developmental stages in small quantities and are restricted to particular taxonomic groups, viz. genus, species or family (Ramawat, 1999). These secondary metabolites are known to have immense medicinal, insecticidal, herbicidal and fungicidal properties. Plants having medicinal value, the Medicinal Plants are rich in the secondary metabolites. Medicinal plants, therefore, serve as potential source of Biopesticides (Dubey *et al.*, 2010).

2. Medicinal plants explored for pesticidal/insecticidal activity

The Royal Botanic Gardens, Kew has estimated in 2016 that around 17,810 plant species have medicinal properties. A survey of literature concerning the research work done by Scientists and researchers across the globe shows that some of them have been studied more often for their insecticidal, larvicidal and pesticidal activities. Amongst such plants, some of the more often studied plants are discussed below.

2.1 *Azadirachta indica* (Neem tree)

Azadirachta indica, commonly known as Neem tree is native to Indian sub-continent. Belonging to the family Meliaceae, this tropical mahogany tree is of immense medicinal value. All parts of the neem tree are commonly used in traditional Indian medicine for household remedy against various human diseases (Drabu *et al.*, 2012). Owing to its immense medicinal value, neem plant parts is being used to manufacture medicines related to skin diseases including leprosy, ulcers, gastro-intestinal problems, oral care, urinary tract diseases, hair problems, diabetes, blood pressure and cholesterol, on a large scale (Venugopalan, 2013). It is one of the most researched medicinal tree in the world for its insecticidal/pesticidal property. Extracts of neem fruit, seeds, seed kernels, twigs, stem bark and root bark have been shown to possess repellent, anti-feedant, insect growth regulators (IGR), anti-ovipositional, fecundity and fitness reducing properties on insects (Schmutterer H., 1990). Many species of insects are known to be sensitized by neem formulations (Pravin Kumar R *et al.* 2007). Besides insecticidal activity, neem extract has also been found effective against against phytopathogenic fungi such as powdery mildews (Locke, 2001). Senthin Nathan *et al.* (2006) evaluated the toxicity and behavioural effects of neem limonoids on the biology and mortality of *Cnaphalocrocis medinalis* (Guenee), the rice leaf folder larvae. Charleston *et al.*, (2006) studied the impact of botanical pesticides derived from *Melia azedarach* and *Azadirachta indica* plants on the emission of volatiles that attract parasitoids of the Diamondback moth, *Plutella xylostella* (L.) to cabbage plants. Diamondback moth is a major pest of crucifer crops and is found throughout the world (Talekar and Shelton, 1993). Siddiqui *et al.*, (2004) identified 27 compounds from the ethanolic extract of fresh fruit coatings of neem, which showed pesticidal activity.

The aforesaid diverse biological properties of neem are due to many secondary metabolites found in various parts of the tree. Its secondary metabolite pool consist of triterpenoids and limonoids such as Azadirachtin, Azadirone, Gedunin, Meliacarpin, Nimbin, Salannin, Vilasinin (Siddiqui *et al.*, 1999). Azadirachtin, its most famous secondary metabolite belongs to tetraterpenoid class and exist in many forms of which Azadirachtin A and Azadirachtin B are well documented (Ley *et al.*, 1993). The other prominent secondary metabolites are epimers such as, Nimbidin, Nimbidinin, Salannolactame I and II, hydroxyazadiradione, Isomagosinolide & Dihydrogedunin, compounds with same molecular weight but different molecular structure (Hatti *et al.*, 2014). Anjali *et al.*, 2010 reported the enhanced insecticidal activity of neem oil in nanoemulsion formulation.

Neem oil obtained from the seeds has been developed into a commercial triple-action biopesticide product, with activity against fungal pathogens, insects and spider mites. The crude extract, containing 1% azadirachtin, is often sold as commercial product. Besides, a large number of companies are already in the market with several neem based products, e.g. Neemix 90EC, Neemazid, Margosan-O, Azatin, Azo Technical etc.

2.2 *Allium* species

The *Allium* species, *Allium sativum* and *Allium cepa* are commonly used as spices in dishes all over the world. Herbs of the family Liliaceae, they are widely grown and is easy to cultivate in gardens. The biocidal properties of *Allium sativum* and *Allium cepa* are attributed to organosulfur compounds, flavonoids and saponins which attribute antimicrobial, antioxidant and therapeutic benefits to *Allium* spp. Since ancient times, Onion and garlic have been known for their medicinal value and cure for several epidemic diseases,- e.g. typhus, cholera, diphtheria and tuberculosis etc.

The key bioactive compounds include allicin, alliin, ajoene, quercetin, anthocyanins which endows the *Allium* spp. with distinct flavours, odours and health properties. The bulb of garlic is a rich source of essential oils and contains a number of secondary metabolites – methyl disulfide, diallyl sulfide, diallyl trisulfide and diallyl tetrasulfide (Lawson, 1993; Douiri *et al.*, 2013).

The insecticidal activity of two disulfides have been evaluated on termites (Augur *et al.*, 2004). Ligouri *et al.*, 2017 have studied the effect of compound organosulphur on growth of micro-organisms. Santos *et al.*, 2010 found the effectiveness of quercetin in inhibiting the growth of *M. luteus* and *S. aureus*. The *Lycoriella ingenua* and Japanese termite (*Reticulitermes speratus* Kolbe) have been shown to be immune to the essential oils and components of onion and garlic plants (Park and Shin, 2005; Park *et al.*, 2006). These essential oils have been found to have 100% mortality rate against termites. Mann *et al.* (2011) experimented with 1:1 mixture of dimethyl disulfide and dimethyl trisulfide to suppress *Diaphornia citri*'s reaction to citrus volatiles and found it to have an additive impact. It has also been found that dry powder of onion played an important role in minimizing egg deposition. Chaubey, 2014 evaluated the activity of *Allium sativum* essential oil against pulse beetle (*Callosobruchus chinensis*) and found that *Allium sativum* essential oil significantly repelled the bruchid adults at a very low concentration. It also reduced egg laying capacity and hatching rate. Garlic oil based insecticide has been produced in the United States.

2.3 *Tephrosia* spp.

Tephrosia spp. belonging to the family Leguminosae is widely distributed in tropical and sub-tropical regions, with strong presence in the Indian sub- continent, Africa, Asia and Australia (Stevenson *et al.*, 2012; Touqueer *et al.*, 2013). It has over 350 species majorly growing in poor, dry and rocky soils. It is hardy, drought- tolerant and nitrogen-fixing plant. Commonly known as sharapunka, this legume is of immense medicinal value (Sarin *et al.*, 1976). *Tephrosia purpurea* is used as a treatment for the heart, liver, spleen and asthma in Ayurveda traditional medicine in India (Bhadada and Goyal, 2015). Various parts of the plant are used as a remedy for bronchitis, gonorrhoea, rheumatism, ulcer, tumors, leprosy, impotency and asthma (Singh *et al.*, 2002; Rehman *et al.*, 1985; Hegazy *et al.*, 2009). The dried herbs are effective as laxative, diuretics and used in the treatment of bronchitis, febrile attack, boils, pimples and bleeding piles (Rajan *et al.*, 2011). Extracts of the genus has exhibited insecticidal, antiviral, antiprotozoal, antiplasmodial and cytotoxic activities (Sinha *et al.*, 1982; Kole *et al.*, 1992; Sanchez *et al.*, 2000; Ganapaty *et al.*, 2008; Muiva *et al.*, 2009).

The genus owes its properties to the presence of the secondary metabolites- flavonoids, which are the predominant constituents of this genus (Chen *et al.*, 2014). The flavonoids include flavones, flavonols, flavanonols, flavans, Isoflavones and

Chalcones (Smalberg *et al.*, 1974; Venkataratnam *et al.*, 1987; Gomez-Garibay *et al.*, 2002; Madhusudhana *et al.*, 2010; Juma *et al.*, 2011). *Tephrosia vogelii* is a rich source of bioactive rotenoids (rotenone, deguelin, tephrosin and toxicarol) found in leaves, roots and pods. These compounds act as potent insecticides, fish poisons and antiparasitics. They function by inhibiting the mitochondrial respiration.

Simmonds *et al.*, 1990 reported the antifeedant activity of a series of 21 Chalcones, flavanes and flavanonols isolated from the genera *Tephrosia* and *Lonchocarpus* against the larvae of *Spodoptera littoralis* and *Spodoptera exempta*. Kole *et al.*, 1992 isolated another rotenoid, Amorpholone from the air-dried stems and leaves of *T. candida* and evaluated its insecticidal activity against the larvae of *Spodoptera litura* F. (armyworm). The LD50 value of the pure compound was found to be 0.31 µg/g. Lapointe *et al.*, 2003 tested the toxicity and repellency of the leaves of the leaves of *Tephrosia candida* D.C. against the larvae and adults of the Diaprepes root weevil, *Diaprepes abbreviatus* (L.) and found that the diet incorporation of lyophilized roots of the plant, when incorporated into an artificial diet, increasingly inhibited the growth of the larvae and increased the larval mortality with increased concentration of roots.

Most commercial products of rotenone are manufactured in Central and South America (Ling, 2002). Rotenone almost insoluble in water and very soluble in organic solvents is unstable in light and air and not persistent in environment (Casacchia *et al.*, 2009). It degrades rapidly under natural conditions (Dzenda *et al.*, 2007). It is applied as an overall spray to give good cover of the foliage and is often used as a component of mixtures. The product is sold as dispersable powder (DP), emulsifiable concentrate (EC) and wettable powder (WP) formulations with trade names that include Chem sect, Cube Root and Rotenone Extract (all Tifa), Noxfire and Rotenone FK-11 (AgroEvo Environmental Health) and Prenfish (mixture), Prentiss, Synpren Fish (mixture) and Prentax (all Prentiss).

2.4 Piper spp.

The genus *Piper*, belonging to the family Piperaceae consists of 700 species growing in various parts of the world (Parmar *et al.*, 1997). It is the largest genus in the family widely used in the tropical regions of the world as medicine, condiments in regional cuisine and as pest control agents (Schultes and Raffauf, 1990). These *spp.* are mostly shrubs, climbing herbs or trees often cultivated for their seeds and leaves which have pungent aroma and it makes them important spices. *Piper* spp. have been traditionally consumed for curing fever, headache, diarrhoea, boils, scabies and stomach problems (Chakraborty and Shah, 2011; Sharkar *et al.*, 2013; Aziz *et al.*, 2015).

Piper species are rich in bioactive compounds such as amides, alkaloids, flavonoids, tannins, saponins, glycosides, terpenoids and phenolic compounds (Scott *et al.*, 2008; tang *et al.*, 2010; Vadlapudi and Kaladhar, 2012). Phenolic compounds such as flavonoids, phenolic acids, tannins, stilbenes and lignans are present in *Piper* species. Phenolic compounds have been reported to have anticancer, antimicrobial and antimutagenic properties (Huang *et al.*, 2009).

The wide variety of secondary plant compounds found in *Piper* have been suggested as potential leads for novel insecticides (Miyakado *et al.* 1989). Extracts of *Piper* spp. have been used in traditional control of insects that are vectors of disease and damage stored crops (Okorie and Ogunro, 1992; Mbata *et al.* 1995, Keita *et al.* 2000). Park *et al.*, 2002 determined the toxicity of two piperidine alkaloids (piperonaline and piperoctadecalidine) isolated from *Piper longum* L. against five species of arthropod pests. The most potent insecticidal activities of both alkaloids piperonaline (LD50 = 125mg/l) and Piperoctadecalidine (LD50 = 95.5 mg/l) were against *Spodoptera litura* (Lepidoptera: Noctuidae). Both alkaloids also showed insecticidal activities towards *Myzus persicae* Sulzer (Hemiptera: Sternorrhynche: Aphididae). Yang *et al.* (2002) examined the larvicidal activity of piperonaline derived from the fruits of *P. longum* L. against the 4th instar larvae of *Aedes aegypti* mosquitoes. Chaithong *et al.* 2006, evaluated the efficacy of ethanolic extracts derived from 3 spp. of *Piper* namely, *P. longum* L., *P. ribesoides* Wall. and *P. sarmentosum* Roxb. Ex Hunt., against early 4th instar larvae of *Aedes argyptii* mosquitoes. Pereda-Mirinda (1997) studied the toxicity of EtOH extract of *P. guanacastensis* aerial parts against the 2nd instar larvae of *Aedes atropalpus* L. and isolated the mixtures of prenylated benzoic acid derivatives, methyl 4-hydroxy-3-(3'-methyl-2'-butenyl) benzoate and its ethyl ester analog rich in insecticidal activity. This was the first evaluation of prenylated benzoic acid derivatives as a potential "green insecticide". *P. nigrum* seed oil formulation have been found effective in protecting stored wheat from stored grain pests (Sighamony *et al.*, 1986). Dev and Koul, (1997) isolated three piperamides- pipericide, pellitorine and piperine from *P. nigrum* which ranged in toxicity from 0.15, 2 and 20µg/ male *C. chinensis*. Keita *et al.* 2000 reported that essential oils from *Piper guineense* seed mixed with Kaolin powder at 150µl/g reduced the average adult emergence of *C. maculatus* by 100% after 30 days treatment. Siddiqui *et al.* 2004 have isolated two new insecticidal amides, pipnoohine and pipyahyine from the petroleum ether extracts of *P. nigrum* whole fruits.

Piperamides are degraded quickly under full sunlight (Scott *et al.* 2003, 2004). This indicates that the use of these extracts are more promising in protecting stored grains. Further, Scott *et al.* 2005 found that when *P. nigrum* extracts were applied to the soil, the residual activity was longer. The benefit of short residual activity is that *Piper* seed extracts are more acceptable for organic certification. Thus, Piperamides singly or in combination could be an alternative to synthetic insecticides such as carbamates, organophosphates and pyrethroids for which resistance has developed (Scott *et al.* 2008).

2.5 Catharanthus roseus

Catharanthus roseus L. is a potent medicinal plant renowned for being a natural repository of anti-cancerous alkaloids. It is one of the 21,000 main medicinal plants listed by World Health Organization. Belonging to the family Apocyanaceae, this annual herb is commonly known as sadabahar or periwinkle. It is known to be originated from the island of Madagascar and therefore, it is also known as Madagascar periwinkle. Once considered as an endangered wild plant, it is now common in many tropical and sub tropical regions of the world (Banskota *et al.*, 2005). An evergreen perennial herb with a height of 30 cm to 1m, it has the capability to tolerate high temperatures, drought conditions and heavy rainfall. The plants are mostly found in warm places growing in

different types of soils such as slightly acidic or soils with high moisture content and in low to full sunlight (Sain *et al.* 2013). The plant has been traditionally used in the treatment of diabetes, high blood pressure, skin conditions, inflammation, sore throat, cough, nose bleed, mouth ulcers and bleeding gums.

The plant produces nearly 130 alkaloids, namely vinblastine, vincristine, vincentine, reserpine and ajmalicine. Vincristine and vinblastine are used for the treatment of various types of cancer such as Hodgkin's disease, breast cancer, skin cancer & lymphoblastic leukemia. Vindoline, Catharanthine, vindolinine and leurosine sulphate lowers blood sugar levels, reserpine and serpentine are powerful tranquilizers and vincristine, vinblastin have anti-cancerous properties (Sandeep *et al.* 2014).

Studies have been conducted on the insecticidal activity of the plant extract. Singh *et al.* 2003 reported insecticidal activity from leaf extract of *C. roseus* against the larvae of *Spodoptera litura* Fab. Ramya *et al.* 2008 evaluated the biological activity of solvent extracts of *C. roseus* L. against the larvae of gram pod borer *Helicoverpa armigera* (Lepidoptera: Noctuidae) and on the basis of the results suggested that *C. roseus* holds a potential to be used as bio-pesticide for the control of destructive polyphagous agricultural pest- *Helicoverpa armigera*.

LIMITATION AND IMPLEMENTATION CHALLENGES

Scientific studies worldwide have proved time and again that medicinal plants possess immense potential to be used as biopesticides and can be a sustainable alternative to synthetic pesticides. However, medicinal plant-based biopesticides are still lagging behind the chemical pesticides in the market. An introspection of the causes responsible for limited production of biopesticides suggests that:

- a) Field performance varies due to environmental and climatic factors.
- b) The action of biopesticides on target organisms is slower compared to synthetic pesticides.
- c) Challenges exist in formulation stability, shelf life, and large-scale commercialization.
- d) It requires strategic application planning and strong implementation policies.
- e) Capacity building and awareness programmes are critical for successful adoption.

CONCLUSION

Medicinal plants play a crucial role in Integrated Pest Management (IPM) by providing sustainable, eco-friendly, and cost-effective alternatives to synthetic pesticides. They function as botanical pesticides (neem, garlic), repellents, and antifeedants, effectively controlling pests (insects, nematodes, fungi) while sparing non-target organisms and reducing environmental pollution. Medicinal plants as Biopesticides represent a scientifically sound and environmentally sustainable alternative to chemical pesticides. Their adoption significantly minimizes environmental hazards associated with conventional pest control. It is envisioned that a strategic and policy-supported approach can ensure long-term sustainability and food security.

REFERENCES

- [1] Anjali, C.H., Sudheer Khan, S., Margulis-Goshen, K., Magdassi, S., Mukherjee, A. and Chandrasekaran, N. 2010. Formulation of water-dispersible nanopermethrin for larvicidal applications. *Ecology and Environmental Safety*, 73: 1932-1936.
- [2] Augur, J., Arnault, I., Diwo-Allian, S., Ravier, M., Molia, F. and Pettiti, M. 2004. Insecticidal and fungicidal potential of *Allium* substances as biofumigants. *Agroindustria*, 3: 367-370.
- [3] Aziz, D.M., Hama, J.R. and Alam, S.M. 2015. Synthesizing a novel derivatives of piperine from black pepper (*Piper nigrum* L.). *Journal of food measurement and characterization*, 3: 324-331.
- [4] Bhadada, S.V. and Goyal, R.K. 2015. Effect of aqueous extract of *Tephrosia purpurea* on cardiovascular complications and cataract associated with Streptozotocin induced Diabetes in Rats. *Indian Journal of Pharmaceutical Sciences*, 77(5): 522-529.
- [5] Chaithong, U., Choochote, W., Kamsuk K., Jitpakdi A., TippawangKosal P., Chaiyasit, D., Champakaew, D., Tuetun, B. and Pitasawat B. 2006. Larvicidal effect of Pepper plants on *Aedes aegypti* (L.) (Diptera: Culicidae). *Journal of Vector Ecology*, 31(1): 138-144.
- [6] Chakraborty, D. and Shah, B. 2011. Antimicrobial, anti-oxidative and anti-hemolytic activity of *Piper* betel leaf extracts. *International Journal of Pharmacy and Pharmaceutical Sciences*, 3: 192-199.
- [7] Charleston, D.S., Gols, R. Hordjik, K.A., Kfir, R. Vet, L.E.M. and Dicke, M. 2006. Impact of botanical pesticides derived from *Melia azedarach* and *Azadirachta indica* plants on the emission of volatiles that attract parasitoids of the diamond back moth to cabbage plants. *Journal of Chemical Ecology* (published online).
- [8] Chaubey, M. 2014. Biological activities of *Allium sativum* essential oil against pulse beetle, *Callosobruchus chinensis* (Coleoptera: Bruchidae). *Herba Polonica*, 60(2): DOI: 10.2478/hepo-2014-0009.
- [9] Chen, Y., Yan, T., Gao, C., Cao, W. and Huang, R. 2014. Natural products from the genus *Tephrosia*. *Molecules*, 19(2): 1432-1458.
- [10] Dabru, S., Khatri, S. and Babu, S. 2012. Neem: Healer of all ailments. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 3: 120-126.
- [11] Dalwadi, P.P., Patel, J.L. and Patani, P.V. 2014. *Tephrosia purpurea* Linn (Sharpunka, wild indigo): A Review on Phytochemistry and Pharmacological Studies. *Indian Journal of Pharmaceutical and Biological Research*. 2: 108-121.
- [12] Das, M. and Sharangi, A.B. 2017. Madagascar periwinkle (*Catharanthus roseus* L.): Diverse medicinal and therapeutic benefits to humankind. *Journal of Pharmacognosy and Phytochemistry*, 6(5): 1695-1701.
- [13] Dev, S. and Koul, O. 1997. *Insecticides of natural origin*. Amsterdam: Hardwood Academic Publishers, 365 pp.

- [14] Douiri, L., Boughdad, A., Assobhei, O. and Moumni, M. 2013. Chemical composition and biological activity of *Allium sativum* essential oils against *Callosobruchus maculatus*. IOSR Journal of Environmental Science and Toxicology and Food Technology, 3: 30-36.
- [15] Dubey, N.K., Shukla, R., Kumar, A., Singh, P. and Prakash, B. 2010. Prospects of botanical pesticides in managing plant diseases. In recent trends in integrated pest management (pp. 129-143). Research periodicals and Books.
- [16] Ganapaty, S., Nyamathulla, S., Srilakshmi, G.V.K. and Prasad, R. 2008. Chemical and anti-microbial studies of the roots of *Tephrosia villosa* (L) Pers. Asian Journal of Chemistry, 20(6): 4498-4502.
- [17] Gomez-Garibay, F., Tellez-Valdez, O., Morreno-Torres, G. and Calderon, J.S. 2002. Flavonoids from *Tephrosia major*. A new prenyl- β -hydroxychalcone. Z Naturforsch, 57(7-8): 579-583.
- [18] Hatti, K.S., Muralitharan, L., Hegde, R. and Kush, A. 2014. NeeMDB: Convenient Database for Neem Secondary Metabolites. Bioinformation, 10(5): 314-315.
- [19] Hegazy, M.E.F., El-Razek, M.H.A., Nagashima, F., Asakawa, Y. and Pare, P.W. 2009. Rare prenylated flavonoids from *Tephrosia purpurea*. Phytochemistry, 70(11): 1474-1477.
- [20] Huang, W., Cai, Y. and Zhang, Y. 2009. Natural phenolic compounds from medicinal herbs and dietary plants: potential use for cancer prevention. Nutrition and Cancer, 62: 1-20.
- [21] Juma, W.P., Akala, H.M., Eyase, F.L., Muiva, L.M., Heydenreich, M., Okalebo, F.A., Gitu, P.M., Peter, M.G., Walsh, D.S. and Imbuga, M. 2011. Terpuriflavone: An antiplasmodial flavone from the stem of *Tephrosia purpurea*. Phytochemical letters, 4: 176-178.
- [22] Keita, S.M., Vincent, C., Schmit, J., Ramaswamy, S. and Belanger, A. 2000. Effect of various essential oils on *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Stored Products Research, 36(4): 355-364.
- [23] Kole, R.K., Satpathi, C., Chowdhury, A., Ghosh, M.R. and Adityachaudhary, N. 1992. Isolation of amorpholone, a potent rotenoid insecticide from *Tephrosia candida*. Journal of Agricultural Food Chemistry, 40: 1208-1210.
- [24] Lawson, L.D. 1993. Bioactive organosulphur compound of garlic and garlic products: role in reducing blood lipids. In: Kinghorn, A.D. and Balandrin, M.F., editors, Human medicinal agents from plants. Washington: American Chemical Society, 1993. pp. 306-330 (ACS Symposium Series, n.534).
- [25] Ley, S.V., Denholm, A.A. and Wood, A. 1993. The chemistry of Azadirachtin. Natural Product Reports, 109-157.
- [26] Ligouri, L., Califano, R., Albanese, D., Raimo, F., Crescitelli, A. and Di Matteo, M. 2017. Chemical composition and anti-oxidant properties of 5 white onion (*Allium cepa* L.) landraces. Journal of Food Quality, 1-9.
- [27] Locke, J.C. 2001. Identification and development of biological control agents and natural plant products as biopesticides. Aps Msa annual meeting.
- [28] Madhusudana, J., Reddy, R.N., Reddy, B.A., Reddy, M.V., Gunasekar, D., Deville, A. and Bodo, B. 2010. Two new geranyl flavonones from *Tephrosia villosa*. Natural Product Research, 24(8): 222-227.
- [29] Mann, R.S., Rouseff, R.L., Smoot, J.M., Castle, W.S. and Stelinski, L.L. 2011. Sulfur volatiles from *Allium* spp. affect Asian citrus psyllid, *Diaphorina citri*, Kuwayama (Hemiptera: Psyllidae), response to citrus volatiles. Bulletin of Entomological Research, 101: 89-97.
- [30] Miyakado, M., Nakayama, I. and Ohno, N. 1989. Insecticidal unsaturated isobutylamides. In book: Insecticides of Plant Origin, pp 173-187.
- [31] Muiva, L.M., Yenesew, A., Derese, S., Heydenreich, M., Peter, M.G., Akala, H.M., Eyase, F., Waters, N.C., Mutai, C., Keriko, J.M. and Walsh, D. 2009. Antiplasmodial- β -hydroxydihydrochalcone from seedpods of *Tephrosia elata*. Phytochemical letters, 2(3): 99-102.
- [32] Narayanswamy, P. 2006. Traditional wisdom of plants in pest control in Agriculture. In: Trivedi, PC (ed), Medicinal Plants Traditional Knowledge, pp 159-184. IK International Publishing House Pvt. Ltd., New Delhi.
- [33] Park, I.K., Lee, S.G., Shin, S.C., Park, J.D. and Ahn, Y.J. 2002. Larvicidal activity of isobutylamides identified in *Piper nigrum* fruits against three mosquito spp. Journal of Agricultural and Food Chemistry, 50: 1866-1870.
- [34] Park, I.K. and Shin, S.C. 2005. Fumigant activity of plant essential oils and components from garlic (*Allium sativum*) and clove bud (*Eugenia caryophyllata*) oils against the Japanese termite (*Reticulitermes speratus* Kolbe). Journal of Agricultural and Food Chemistry, 53 (11): 4388-4392.
- [35] Parmar, V.S., Jain, S.C., Bisht, K.S., Jain, R., Taneja, P., Jha, A., Tyagi, O.D., Prasad, A.K., Wengel, J. and Olsen, C.E. 1997. Phytochemistry of the genus *Piper*. Phytochemistry, 46: 597-673.
- [36] Pereda-Mirinda, R., Bernard, C.B., Durst, T., Arnason, J.T., Sanchez-Vindas, P., Poveda, L. and San Roman, L. 1997. Journal of Natural Products, 60(3): 282-284.
- [37] Pravin Kumar, R., Manoj, M.N., Kush, A. and Annadurai, R.S. 2007. In silico approach of azadirachtin binding with actins. Insect Biochemistry and Molecular Biology, 37: 635-640.
- [38] Punia, S., Kaur, J. Kumar, R. and Kumar, K. 2014. *Catharanthus roseus*: A medicinal plant with potent anti-tumour properties. International Journal of Research in Ayurveda and Pharmaceuticals, 5(6): 652-656.
- [39] Rahman, H., Kashifudduja, M., Syed, M. and Saleemuddin, M. 1985. Hypoglycemic activity of TP Linn. seeds. Indian Journal of Medical Research, 81: 418-421.
- [40] Rajan, S., Thirunalasundari, T. and Jeeva, S. 2011. Anti-enteric bacterial activity and phytochemical analysis of the seed kernel extract of *Magnifera indica* L. against *Shigella dysenteriae* (Shiga, Corrig.) Castellani and Chalmers. Asian Pacific Journal of Tropical Medicine, 4: 294-300.
- [41] Ramawat, K.G. 1999. Secondary plant products in nature. In: Ramawat KG and Merillon JM (eds), Biotechnology, Secondary Metabolites, pp 11-37.
- [42] Ramya, S., Rajasekaran, C., Kalaivani, T., Sundararajan, G. and Jayakumararaj, R. 2008. Biopesticidal effect of leaf extracts of *Catharanthus roseus* L (G) Don. on the larvae of gram pod borer- *Helicoverpa armigera* (Hubner). Ethnobotanical Leaflets, 12: 1096-1101.
- [43] Sain, M. and Sharma, V. 2013. Effect of plant growth regulators on micro-propagation of *Catharanthus roseus*. International Journal of Advanced Biotechnology Research, 4(1): 123-130.

- [44] Santas, J., Almajano, M.P. and Carbo, R. 2010. Antimicrobial and antioxidant activity of crude onion (*Allium cepa* L.) extracts. *International Journal of Food Science & Technology*, 45(2): 403-409.
- [45] Sarkar, D., Kundu, S. De, S. Hariharan, C. Saha, P., Manna, A., Chattopadhyay, S. and Chatterjee, M. 2013. The antioxidant activity of allylpyrocatechol is mediated via decreased generation of free radicals alongwith escalation of antioxidant mechanisms, 27: 324-329.
- [46] Schmutterer, H. 1990. Properties and potential of natural pesticides from the Neem tree, *Azadirachta indica*. *Annual Review of Entomology*, 35: 271-297.
- [47] Scott, I.M., Gagnon, N. Lesage L., Philogene, B.J.R. and Arnason, J.T. 2005. Efficacy of botanical insecticides from *Piper* spp. (Piperaceae) extracts for control of European chafer (Coleoptera scarabaeidae). *Journal of Economic Entomology*, 98: 845-855.
- [48] Scott, I.M., Jensen, H., Nicol, R., Lesage, L. Bradbury, R., Sanchez-Vindas, P., Poveda, L., Arnason, J.T. and Philogene, B.J.R. 2004. Efficacy of *Piper* (Piperaceae) extracts for the control of common home and garden insect pests. *Journal of Economic Entomology*, 97: 1390-1403.
- [49] Scott, I.M., Jensen, H., Scott, J.G., Isman, M.B., Arnason, J.T. and Philogene, B.J.R. 2003. Botanical insecticides for controlling agricultural pests: piperamides and the Colorado potato beetle *Leptinostara decemlineata* Say (Coleoptera: Chrysomelidae). *Archives of Biochemistry and Physiology*, 54: 212-225.
- [50] Scott, I.M., Jensen, H.R., Philogene, B.J.R. and Arnason, J.T. 2008. A review of *Piper* spp. (Piperaceae) phytochemistry, insecticidal activity and mode of action. *Phytochemistry reviews*, 7: 65-75.
- [51] Senthil Nathan, S., Kalaivani, K., Sehoon, K. and Murugan, K. 2006. The toxicity and behavioural effects of neem limonoids on *Cnaphalocrois medinalis* (Guenee), the rice leaf folder. *Chemosphere*, 62(8): 1381-1387.
- [52] Siddiqui, B.S., Ghiasuddin, G., Faizi, S. and Rasheed, M. 1999. Triterpenoids of the fruit coats of *Azadirachta indica*. *Journal of Natural Products*, 62(7): 1006-1009.
- [53] Siddiqui, B.S., Gulzar, T., Mahmood, A., Begum, S., Khan, B. and Afshan, F. 2004. New insecticidal amides from Petroleum ether extract of dried *Piper nigrum* L. whole fruits. *Chemistry Pharmaceutical bulletin (Tokyo)*, 52(11): 1349-1352.
- [54] Siddiqui, B.S., Rasheed, M., Ilyas, F., Gulzar, T., Tariq, R.M. and Naqvi, S.N. 2004. Analysis of insecticidal activity of *Azadirachta indica* A. Juss. Fractions. *Z Naturforsch*, 59: 104-112.
- [55] Sighamony, S., Anees, I., Chandrakala, T. and Osmani, Z. 1986. Efficacy of certain indigenous plant products as grain protectants against *Sitophilus oryzae* (L.) and *Rhyzophthera dominica* (F.). *Journal of Stored Products Research*, 22: 21-23.
- [56] Simmonds, M.S.J., Blaney, W.M., Delle, M.F. and Marini Bettolo, G.B. 1990. Insect antifeedant activity associated with compounds isolated from species of *Lonchocarpus* and *Tephrosia*. *Journal of chemical Ecology*. 16: 365-380.
- [57] Singh, A.K., Raghubanshi, A.S. and Singh, J.S. 2002. Medical ethnobotany of the tribals of Sonaghat of Sonbhadra district, Uttar Pradesh, India. *Journal of Ethnopharmacology*, 81(1): 31-41.
- [58] Singh, D., Sucheta, S.M., Neoliya, N.K., Shukla, Y.N. and Mishra, M. 2003. New possible insect growth regulators from *Catharanthus roseus*. *Current Science*, 84(9): 1184-1186.
- [59] Sinha, B., Natu, A.A. and Nanavati, D.D. 1982. Prenylated flavonoids from *Tephrosia purpurea* seeds. *Phytochemistry*, 21(6): 1468-1470.
- [60] Smalberger, T.M., Vleggaar, R. and Weber, J.C. 1974. Flavonoids from *Tephrosia*-VII: the constitution and absolute configuration of lupinifolin and lupinifolinol, two flavanones from *Tephrosia lupinifolia* Burch (DC). *Tetrahedron*, 30(21): 3927-3931.
- [61] Stevenson, P.C., Kite, G.C., Lewis, G.P., Forest, F., Nyirenda, S.P., Belamin, S.R., Sileshi, G.W. and Veitch, N.C. 2012. Distinct chemotypes of *Tephrosia vogelii* and implications for their use in pest control and soil enrichment. *Phytochemistry*, 78: 135-146.
- [62] Tang, G., Chen, D., Qin, B., Sheng, L., Wang, Y., Hu, G., Zhao, F., Ma, L., Wang, H., and Huang, Q. 2010. Cytotoxic amide alkaloids from *Piper boehmeriaefolium*. *Journal of Natural Products*, 74: 45-49.
- [63] Touqeer, S., Saeed, M.A. and Ajaib, M. 2013. A review on the phytochemistry and pharmacology of genus *Tephrosia*. *Phytopharmacology*, 4: 598-637.
- [64] Vadlapudi, V. and Kaladhar, D. 2012. Phytochemical evaluation and molecular characterization of some important medicinal plants. *Asian Pacific Journal of Tropical Disease*, 2: 526-532.
- [65] Venkataratnam, G., Rao, E.V., Vilain, C. 1987. Flavonoids of *Tephrosia procumbens*- Revised structure for praecansone A and configuration of praecansone B. *Journal of Chemical Society Perkin Transactions 1*, 12: 2723-2727.
- [66] Venugopalan, S.K. and Vishweswaran, N. 2013. Neem (*Azadirachta indica*): Prehistory to contemporary medicinal uses to humankind. *Asian Pacific Journal of Tropical Biomedicine*, 3(7): 505-514.
- [67] Wheeler, W.B. 2002. Role of research and regulation in 50 years of pest management in agriculture. *Journal of Agriculture and Food Chemistry*, 50: 4151-4155.
- [68] Yang, Y.C., Lee, S.G., Lee, H.K., Kim, M.K., Lee, S.H. and Lee, H.S. 2002. A piperidine amide extracted from *Piper longum* L. fruit shows activity against *Aedes aegypti* mosquito larvae. *Journal of Agricultural and Food Chemistry*, 50: 3765-3767.