VOL. XL NO. 6 JUNE 2016 ISSN 0970-3012

40th Year

PESTOLOGY

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IN THE FRONTLINE OF SERVICE TO AGRICULTURE

REVIEW

ARECANUT

MOLLUSCICIDAL ACTIVITIES OF PLANTS WITH SPECIAL EMPHASIS ON ARECANUT (*Areca catechu* L.) – A REVIEW

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ABSTRACT

Snails and slugs are considered to be the intermediate hosts of different parasitic worms whose final hosts in most of the cases are livestock or human being causing several diseases in them. Use of chemical pesticides for the management of these vectors pose severe environmental hazards and problems for non target animals. Phytochemicals of plant origin are found to be effective alternatives for them. Areca palm (*Areca catechu* L.), which is grown abundantly in several parts of the world including India, contains good amount of tannin and alkaloids in its seeds, which are reported to be toxic to molluscs. The LC50 value of areca seed extract against the fresh water vector snail *Lymnaea acuminata,* an intermediate host of the liver-fluke *Fasciola hepatica* and *F. gigantica* which cause fascioliasis in man and livestock, at 96h was 12.3 mg/l. The toxicity of arecanut seed extract was found to increase significantly with the addition of synergist compounds such as piperonyl butoxide and MGK-264. The LC50 value of arecanut seed extract with PB and MGK-264 at 96h was found to be as high as 3.8mg/l and 3.86mg/l, respectively. Such studies are urgently needed to confirm the toxicity of arecanut on other species of mollusks also and identify the active principle responsible for such activity.

KEY WORDS: **Arecanut, *Areca catechu* L., Phytochemicals, Mollusca, Toxicity, Management.**

Introduction

The snails and slugs which come under the order Mollusca are considered to be the pests of agriculture and also act as the carriers of the intermediate stages of the parasites of several dreaded diseases of man. Aquatic snails such as *Lymnaea acuminata*, *Indoplanobis exustus* act as vectors for the immature stages of the trematode parasites (liver-flukes) like *Fasciola hepatica* and *F. gigantica* which cause the dreaded disease fascioliasis in man and livestock in India and other countries (Singh, *et al.,* 2009, 2013; Yadav, 2015). Schistosomiasis is a major human disease caused by the trematodes (flatworms), *Schistosoma mansoni* (mainly in Africa, South America, Saudi Arebia, etc), *S. haematobium* (in Africa and Middle East) and *S. japonicum* (endemic in Asia). The obligate intermediate hosts of these flatworms are fresh water snails such as *Oncomelania hupensis, Biomphalaria glabrata, B. pfeifferi* and several species of *Bulinus* (Liu, *et al.*, 1997; Ojewole, *et al.,* 2005; Rapado, *et al.*, 2011; Alzanbagi, 2013). Some garden snails and slugs are also reported to be the pests of several agricultural crops including fruits, vegetables and ornaments (Singh and Agarwal, 1981; Barker, 2002).

Control of snails and slugs by using chemical pesticides is becoming increasingly difficult and dangerous because of the development of resistance in molluscs and the hazards the chemical pesticides do to the environment. With the growing awareness of environmental pollution and toxicity to non target animals caused by the use of synthetic pesticides, the use of bio-pesticides derived from plants and having molluscicidal properties would be an appropriate alternative as the latter is a simple, inexpensive, biodegradable and fairly acceptable technology for the control of these vectors.

The mollusicidal activities of several plants have

been reported from different parts of the world (Schaufelberger and Hostettmann, 1983; Okunji and Iwu, 1988; Singh *et al.*, 1996; Liu, *et al.*, 1997; Singh and Singh, 1998; Hassan, *et al.*, 2012; Truiti, *et al.*, 2005; Ojewole, *et al.*, 2005; Sherbini, *et al.*, 2009; Yadav and Singh, 2013). Plants contain many important biologically active compounds such as tannins, saponins, terpenoids, steroids, alkaloids, flavonoids, etc., which naturally give them certain amount of protection against herbivore grazing animals and also from different types of pests and diseases. Several such plant derived compounds have already been reported to be of potential molluscicidal properties (Singh, *et al.*, 1996).

The areca palm, *Areca catechu* L. (family Palmaceae) is a tall palm known for its medicinal, phytochemical and pharmacological properties (Aman, 1969; Rao, 1982; Badanaje, 2008; Jaiswal, *et al.*, 2011; Amudhan, 2011; Amudhan, *et al.*, 2012; Peng, *et al.*, 2015). The World Health Organization (2009) has listed out as many as 25 different beneficial effects of *A. catechu*. This plant is widely distributed in several southern and southeast Asian countries including India, Indonesia, China, Malaysia, the Philippines, Burma, Thailand, Sri Lanka, etc. (Balasimha and Rajagopal, 2004). In India this palm is mainly grown in the States of Karnataka, Kerala, Assam and Maharastra (Thomas and Balasimha, 2011). Total area under this crop in our country during 2013-14 was assessed to be around 4.5 lakh hectares (Directorate of Arecanut and Spices Development, Calicut, India -Figures for 2013-14: Arecanut- Area, production and productivity).

Chemical composition of arecanut:

The areca fruit, commonly called as arecanut or *betelnut / supari* contains: 11.1–29.8% polyphenols (including flavonoids and tannins); 17.3–25.7% polysaccharides; 6.2–9.4% proteins; 8.1– 15.1% fats; 8.2–15.4% fibres; 0.11–0.24% alkaloids and 1.1–2.5% minarals (Shivashankar *et al.*, 1969). The alkaloid fraction of arecanut contains: arecoline, arecaidine, guvacoline and guvacine, the first one being the primary pharmacologically active component. Polyphenols decrease with maturity, whereas polysaccharides, fat, fibre and alkaloid contents increase with maturity of the nuts (Mathew, *et al.*, 1964). The Fatty acid composition of arecanut are: lauric acid (19.5%), myristic acid (46.2%), palmitic acid (12.7%), oleic acid (6.2%), linoleic acid (5.4%), hexadecenoic acid (7.2%) and minor proportions of stearic acid, decanoic acid and monoethylenic acids (Pathak and Mathur, 1954).

Phytochemicals responsible for molluscicidal activity:

Several reports confirmed the toxic effects of different phytochemicl compounds of plant origin against molluscs. Tannins, alkaloids including arecoline, saponins, phenols, flavonoid, terpenoid, etc have been reported to be toxic against several vector snails (Singh, *et al.*, 1996; Chen, *et al.*, 2007; Rawani, *et al.*, 2014; Alzerreca and Hart, 1982). Amoung the phenolic acids tested, Lahlou (2004) reported that gallic acid was the most toxic one with LC50 of 3.60 ppm against the snail *Bulinus truncates,* the intermediate host of the trematode parasite *S. haematobium*, responsible for the urinary schistosomiasis.

Schaufelberger and Hostettmann (1983) reported that the aqueous and methanolic extracts of a series of typical tannin containing plants exhibited strong molluscicidal activities against the fresh water snail, *Biomphalaria. glabrata*. Ayoub and Yankov (1986) screened several tannin-bearing plants in Sudan for their molluscicidal activities and reported that the hydrolysable and condensed tannins were the common molluscicidal factors in these plants.

Alkaloids of plant origin were also found to have molluscicidal activities. Okunji and Iwu (1988) screened 53 medicinal plants of Nigeria for their molluscicidal activities against three vector snails, *Bulinus globosus, Biomphalaria pfeifferi* and *L. natalensis* and reported that the alkaloids present in these plants might be responsible for their molluscicidal actions. Hammami, *et al.* (2011) reported that the alkaloid fraction isolated from the immature fruits of *Solanum nigrum* by methanolic extract was highly toxic with LC50 of 1.65 mg/L against the snail vector, *Galba truncatula* an intermediate host of the trematode parasite, *F. hepatica* responsible for the disease fascioliasis. The alkaloid fraction isolated from the fruits of *Macleaya cordata*, a perennial plant of the family Papaveraceae was found to be toxic to the snail *O.*

hupensis, the intermediate host of *S. japonicum* in China (Ming *et al.*, 2011).

It was also reported that the tannins, flavonoids and saponins of plant origin were toxic not only to adult snails but also to its eggs. In different studies conducted on the eggs and different growth stages of a land snail, *Sublina octona,* it was observed that there were significant reduction on the hatchability and survival of offspring when treated with sub-lethal concentrations of the aqueous extracts of *Bidens pilosa* (Souza, *et al.*, 2013) and *Mikania glomerata* (Souza, *et al.*, 2014) containing the above phytochemicals. It was reported that the egg laying capacity and egg hatchability of the snail *B. alexandrina* was substantially reduced by the exposure of water suspension of the flowers of *Ammi majus* (Rawi, *et al.*, 2011).

Ideal solvents and plant parts for extraction of phytochemicals:

The molluscicidal activities of plants vary depending on the solvent used for extraction of phytochemicals. Hanif and Singh (2012); Upadhyay and Singh (2011); Singh, *et al.* (2012); Ahmed, *et al.* (2001); Jaiswal and Singh (2009); Kumar and Singh (2006); Soni and Singh (2015) reported that the ethanolic extracts of plants were more toxic than other organic solvent extracts such as ether, carbon tetrachloride, acetone and chloroform, whereas Alzanbagi (2013) while reviewing the work done on the molluscicidal activities of three common plants of the family Euphorbiaceae in Saudi Arebia, *Jatropa gluaca, Euphorbia helioscopia* and *E. schimperiana* reported that the methanol and chloroform extracts were most promising than acetone and hexane extracts from the molluscicidal point of view with the LC50 values ranging from 10 to 100 ppm. Santos, *et al.* (2014) evaluated the toxicities of chloroform, hexane, ethyl acetate and methanol fractions of the extracts of *Schinopsis brasiliensis* (Anacardiaceae) against the snail vector, *B. glabrata* and reported that the chloroform and ethyl acetate fractions were more toxic than others with the LC50 values of 68 and 73 µg/ml, respectively. Rawani *et al.* (2014) evaluated six solvent extracts such as petroleum ether, benzene, ethyl acetate, chloroform: methanol (1:1 v/v), acetone and absolute alcohol of mature fresh leaves of *S. nigrum* and found that the benzene extract was most potent against the snail *L. acuminata.* In a study on the effectiveness of four solvent extracts, namely petroleum ether, chloroform, acetone and methanol, of Solanum spp on the molluscicidal activities against the vector snail, *B. alexandrina,* responsible for causing human schistosomiasis, it was found that the maximum mortality was recorded at a concentration of 90 ppm with ethanol extract of mature leaf of *S. nigrum* than other extracts (Sherbini, *et al.*, 2009).

Azare, *et al.* (2007) while studying on the molluscicidal activity of crude water extract of the leaf of *Alternanthera sesselis* on the snail vector *B. globosus* reported that the availability of the active component responsible for molluscicidal action was more in fresh leaves than in dried leaves. They also reported that the unevaporated crude water extract was more potent than the evaporated extract. Further, it was found that there were seasonal variations in the toxicity of plant extracts against molluscs. Ahmed and Ramzy, 1998 studied the molluscicidal activity of *S. nigrum* collected at different seasons against vector snail, *B. alexandrina* in Egypt and found that the leaves collected in autumn had the highest molluscicidal effect (LC50 = 35.4) followed by those collected during spring (LC50 = 44.36), summer (LC50 = 46.7) and winter (LC50 = 46.7). On the other hand, Alzanbagi (2013) reported that the molluscicidal activities of the plant extracts of certain Euphorbiales were more during winter months and there were no significant changes in such activities at acidic pH ranging from 3 to 5, but in alkaline solution much of the molluscicidal activities were lost. Ahmed *et al.* (2001) reported that the concentrated ethanol extract could be stored at room temperature for six months without any change in its activity. Sunlight and pH also did not affect its activity.

The plant molluscicides could also be used effectively by mixing with baits. Tiwari (2013) observed that by using food pellets containing a strong attractant amino acid proline and agar + a specific molluscicide of plant origin could effectively control the population of the vector snail *I. exustus.*

Arecanut is having rich source of tannins and alkaloids including arecoline (Shivashnkar *et al.*,

1969; Shivashankar, *et al.*, 1976). Some work has been done on the molluscicidal activity of this plant. Jaiswal and Singh (2008) studied the molluscicidal activity of the seeds of *A. catechu* and *Carica papaya* against the freshwater vector snail *L. acuminata* and found that the ethanolic extract was more toxic than other extracts with the LC50 values of 17.21 mg/l and 53.38 mg/l for areca and papaya seeds, respectively at 24 h period. The LC50 values for these plant extracts at 96h were 12.32 and 61.56mg/l for arecanut and papaya seeds, respectively. The LC50 of column-purified fraction of *A. catechu* seed at 96 h was 3.99 mg/l, whereas that of *C. papaya* seed it was 7.06 mg/l. They further reported that both arecanut and papaya could be used as potent molluscicides since the concentrations used to kill the snails were not found toxic for the common freshwater fish *Colisa fasciatus* which shares the same habitat with that of this snail. The active compound responsible for the molluscicidal activity in arecanut was found to be arecoline and in papaya it was papain and their actions were mainly by inhibiting the activities of acetylcholinesterase and alkaline phosphatase in the nervous tissue of this snail (Jaiswal, *et al.*, 2008).

It was reported that the molluscicidal activities of plant extracts could be increased substantially by adding synergistic compounds such as piperonyl butoxide (PB) or MGK-264 which are generally used to enhance the toxicity of synthetic pesticides such as carbamates, organophosphates and pyrethroids (Rao and Singh, 2001; Singh, *et al.*, 2010; Hanif and Singh, 2013). At 24h exposure time, the toxicity of binary combination of the seed powder of *A. catechu* with MGK-264 and PB was reported to be increased by 1.95 and 2.34 times, respectively against the snail *L. acuminata* than the treatment with areca seed powder alone (Hanif and Singh, 2013). They also reported that after exposure for 96h, the toxicity of the *A. catechu* seed powder in combination with MGK-264/PB was increased by 3.19/3.24 fold. The LC50 values of areca seed powders were 3.80 mg/l with PB and 3.86 mg/l with MGK-264, whereas the LC50 value of the arecanut seed powder alone was as high as 12.3mg/l. They also reported that the binary combination of arecoline, one of the main active principles of arecanut, with MGK-264 and PB at 24 h was increased by 1.03 and 0.35 times, respectively to *L. acuminata* than the treatment with arecoline alone. The LC50 value of arecoline was 0.06mg/l with MGK-264 and 0.13mg/l with PB. Thus it was suggested to incorporate the synergists PB and MGK-264 with the extracts of *A. catechu* seeds to increase its toxicity against snails and slugs.

Summary

Studies revealed that the nuts of areca palm are having potent molluscicidal properties. As the natural biopesticides derived from plants are having several advantages, including their safeness and easy availability, over synthetic chemical pesticides, it is suggested to use such compounds more and more in the integrated vector management programmes. Areca palm, which is grown abundantly in several parts of India, could be exploited effectively in such programmes. Certain chemical, pharmaceutical or similar other industries should take initiative in isolation and commercialization of such active compounds which are very effective against molluscs and at the same time much safe for our environment.

Bibliography

Ahmed, A.H. and Ramzy, R.M. 1998. Seasonal variation in molluscicidal activity of *Solanum nigrum* L. *J. Egypt Soc. Parasitol.* 28: 621-629.

Ahmed, A.H., Kamal, I.H. and Ramzy, R.M. 2001. Studies on the molluscicidal and larvicidal properties of *Solanum nigrum* L. leaves ethanol extract. *J Egypt. Soc Parasitol.* 31: 843-852.

Alzanbagi, N.A. 2013. Review of using plants as molluscicidal, larvicidal and Schistosomicidal in Saudi Arebia. *Aust. J. Basic Appl. Sci.* 7: 110-120.

Alzerreca, A. and Hart, G. 1982. Molluscicidal steroid glycoalkaloids possessing stereoisomeric spirosolane structures. *Toxicol. Lett.* 12: 151-155.

Aman, 1969. *Medicinal secrets of your food. - Areca nut*, Published by: Secretary, Indo-American Hospital, N R Mohalla, Mysore-7, India. pp700-702.

Amudhan, M.S. 2011. Studies on biopotential of *Areca catechu* seed extract. Ph.D thesis, Dept of Siddha Medicine, Faculty of Science, Tamil University, Thanjavur, T.N., 292 p.

Amudhan, M.S., Begum, V.H. and Hebbar, K.B. 2012. A review on Phytochemical and Pharmacological potential of *Areca catechu* L seed. *IJPSR* 3: 4151-4157.

Ayoub, S.M.H. and Yankov, L.K. 1986. The molluscicidal factor of tannin-bearing plants. *Int. J. Crude Drug Res.* 24: 16-18.

Azare, B.A., Okwute, S.K. and Kela, S.L. 2007. Molluscicidal activity of crude water leaf extracts of *Alternanthera sesselis* on *Bulinus* (phy) *globosus. Afr. J. Biotech.* 6: 441-444.

Badanaje, S.B. 2008. *Arecanut - medicinal and alternative uses.* Arecanut Research and Development Foundation®, Varanashi Towers, Mission Street, Mangaluru-575 001, India. 104p.

Balasimha, D. and Rajagopal, V. 2004. Introduction. In: *Arecanut.* (Eds: D. Balasimha and V. Rajagopal). Central Plantation Crops Research Institute, Kasaragod-671 124, Kerala, India. pp1-6.

Barker, G.M. 2002. *Molluscs as crop pests.* CAB International, Wallingford, UK. 441p.

Chen, S.X., Wu, L., Yang, X.M., Jiang, X.G. Li, L.G., Zhang, R.X., Xia, L. and Shao, S.H. 2007. Comparative molluscicidal action of extract of *Ginko bilobasarcotesta,* arecoline and niclosamide on snail hosts of *Schistosoma japonicum. Pesticide Biochem. Physiol.* 89: 237-241.

Hammami, H., Jarraya, R.M., Damak, M. and Ayadi, A. 2011. Molluscicidal activity of various solvent extracts from *Solanum nigrum* var. villosum L. aerial parts against *Galba truncatula. Parasite* 18: 63-70.

Hanif, F. and Singh, D.K. 2012. Molluscicidal activity of *Morus nigra* against the freshwater snail *Lymnaea acuminata. J. Biol. Earth Sci.* 2: B54-B62.

Hanif, F. and Singh, D.K. 2013. Binary combination of *Carica papaya, Areca catechu* and *Myristica fragrans* with Piperonyl butoxide / MGK-264 against freshwater snail *Lymnaea acuminata. Trop. Life Sci. Res.* 24: 1-11.

Hassan, A.A., Mahmoud, A.E., Attia, A.H. and Huseein, E.A.M. 2012. Evaluation of the ethanolic extracts of three plants for their molluscicidal activities against snails intermediate hosts of *Schistosoma mansoni* and *Fisciola. Int. J. Basic Appl. Sci.* 1: 235-249.

Jaiswal, P., Kumar, P., Singh, V.K. and Singh, D.K. 2011. *Areca catechu* L.: A valuable herbal medicine against different health problems. *Res. J. Med. Plants* 5: 145-152.

Jaiswal, P. and Singh, D.K. 2008. Molluscicidal activity of *Carica papaya* and *Areca catechu* against the freshwater snail *Lymnaea acuminata. Vet. Parasitol.* 152: 264-270.

Jaiswal, P. and Singh, D.K. 2009. Molluscicidal activity of nutmeg and mace (*Myristica fragrans* Houtt.) against the vector snail *Lymnaea acuminata. J. Herbs Spices Med. Plants* 15: 177-186.

Jaiswal, P., Singh, V.K. and Singh, D.K. 2008. Enzyme inhibition by molluscicidal component of *Areca catechu* and *Carica papaya* in the nervous tissue of vector snail *Lymnaea acuminata. Pestic. Biochem. Physiol.* 92: 164-168.

Kumar, P. and Singh, D.K. 2006. Molluscicidal activity of *Ferula asafetida, Syzygium aromaticum* and *Carum carvi* and their active compounds against the snail *Lymnaea acuminata. Chemosphere* 63: 1568-1574.

Lahlou, M. 2004. Study of the molluscicidal activity of some Phenolic compounds: Structure-activity relationship. *Pharmaceutical Biology* 42: 258-261.

Liu, S.Y., Sporer, F., Wink, M., Jourdane, J., Henning, R., Li, Y.L. and Ruppel, A. 1997. Anthraquinones in *Rheum palmatum* and *Rumex dentatus* (Polygonaceae), and phorbol esters in *Jatropa curcas* (Euphorbiaceae) with molluscicidal activity against the schistosome vector snails *Oncomelania, Biomphalaria* and *Bulinus. Trop Med Int Health* 2: 179-188.

Mathew, A.G., Venkataramu, S.D. and Govindarajan, V.S. 1964. Studies on arecanut: part 1. Changes in chemical composition and physical characteristics of nuts with maturity. *Indian J. Tech.*, 2: 90-96.

Ming, Z., Yin,L.G., Guo, Z.J., Li, Z., Long, H.K., Ming, S.J., Xiao, L. and Yuan, W.W. 2011. Evaluation of molluscicidal activities of benzo©phenanthridin alkaloids from *Macleaya cordata* (Willd) R.Br. on snail hosts of *Schistosoma japonicum. J. Med. Plants Res.* 5: 521-526.

Ojewole, J.A.O., Nundkumar, N. and Adewunmi, C.O. 2005. Molluscicidal, cercariacidal, larvicidal and antiplasmodial properties of *Barringtonia recemosa* fruit and seed extracts. *BLACPMA* 3: 88-92.

Okunji, C.O. and Iwu, M.M. 1988. Control of schistosomiasis using Nigerian medicinal plants as molluscicides. *Int. J. Crude Drug Res.* 26: 246-252.

Pathak, S.P. and Mathur, S.S. 1954. The component acids and glycerides of arecanut (*Areca catechu*) fat. *J. Sci. Food Agri.*, 5: 461-465.

Peng, W., Lie, Y.J., Wu, N., Sun, T., He, X.Y., Gao, Y.X. and Wu, C.J. 2015. *Areca catechu* (Arecaceae): A review of its traditional uses, botany, phytochemistry, pharmacology and toxicology. *J. Ethnopharma.* 164: 340-356.

Rao, M.M. 1982. Introduction. In: *The Arecanut Palm.* (Eds: K.V.A. Bavappa, M.K. Nair and T.P. Kumar). Central Plantation Crops Research Institute, Kasaragod, Kerala, India. pp1-9.

Rao, I.G. and Singh, D.K. 2001. Combinations of *Azadirachta indica* and *Cedrus deodara* oil with piperonyl butoxide, MGK-264 and *Embelia ribes* against *Lymnaea acuminata. Chemosphere* 44: 1691-1695.

Rapado, L.N., Nakano, E., Ohlweiler, F.P., Kato, M.J., Yamaguchi, L.F., Pereira, C.A.B. and Kawano, T. 2011. Molluscicidal and ovicidal activities of plant

extracts of the Piperaceae on *Biomphalaria glabrata* (Say, 1818). *J. Helminthol.* 85: 66-72.

Rawani, A., Ghosh, A. and Chandra, G. 2014. Laboratory evaluation of molluscicidal & mosquito larvicidal activities of leaves of *Solanum nigrum* L. *Ind. J. Med Res.* 140: 285-295.

Rawi, S.M., Hazmi, M.A. and Nassr, F.S.A. 2011. Comparative study of the molluscicidal activity of some plant extracts on the snail vector of *Schistosoma mansoni, Biomphalaria alexandrina. Int. J. Zool. Res.* 7: 169-189.

Santos, C.C.S., Araujo, S.S., Santos, A.L.L.M., Almeida, E.C.A., Dias, A.S., Damascena, N.P., Santos, D.M., Santos, M.I.S., Junior, K.A.L.R., Pereira, C.K.B., Lima, A.C.B., Shan, A.Y.K.V., Sant'ana,A.E.G., Estevam, C.S. and Araujo, B.S. 2014. Evaluation of the toxicity and molluscicidal and larvicidal activities of *Schonopsis brasiliensis* stem bark extract and its fractions. *Rev. Bras. Farma.* 24: 298-303.

Schaufelberger, D. and Hostettmann, K. 1983. On the molluscicidal activity of tannin containing plants. *Planta Medica* 48: 105-107.

Sherbini, G.T.E., Zayed, R.A. and Sherbini, E.T.E. 2009. Molluscicidal activity of some Solanum species extracts against the snail *Biomphalaria alexandrina. J. Parasitol. Res.* 2009: 1-5.

Shivashankar, S., Dhanaraj, S., Mathew, A.G., Murthy, S.S., Vyasamurthy, M.N. and Govindarajan, V.S. 1969. Physical and chemical characteristics of processed arecanuts. *J. Food Sci. Tech.* 6: 113-116.

Shivashankar, S., Mathew, A.G., and Natarajan, C.P. 1976. Post-harvest technology of arecanut. *Arecanut & Spices Bulletin* 7: 59-63.

Singh, A., Kumar, P., Singh, D.K. and Singh, V.K. 2010. Toxicity of binary combination of *Saraca asoca* and *Thuja orientalis* with synergist piperonyl butoxide and MGK-264 against the freshwater snail *Lymnaea acuminata. The Bioscan* 5: 13-18.

Singh, A., Singh, D.K., Misra, T.N. and Agarwal, R.A. 1996. Molluscicides of plant origin. *Biol Agric. Hort.* 13: 205-252.

Singh, K.L., Singh, D.K. and Singh, V.K. 2012. Characterization of the molluscicidal activity of *Bauhinia variegate* and *Mimusops elegy* plant extracts against the Fasciola vector *Lymnaea acuminata. Rev. Inst. Med. Trop. Sao. Paulo* 54: 135-140.

Singh, O. and Agarwal, R.A. 1981.Toxicity of certain pesticides to two economic species of snails in Northern India. *J. Ecol. Entomol.* 74: 568-571.

Singh, S. and Singh, D.K. 1998. Molluscicidal activity of *Nerium indicum* bark. *Br. J. Med. Biol. Res.* 31: 951-954.

Singh, S.K., Singh, S.K. and Singh, A. 2013. Molluscicidal and piscicidal properties of three medicinal plants of family Apocynaceae – a review. *J. Biol. Earth Sci.* 3: B194-B205.

Singh, S.K., Yadav, R.P. and Singh, A. 2009. Molluscicides from some common medicinal plants of eastern Uttar Pradsh, India. *J. Appl. Toxicol.* 230: 1-7.

Soni, N. and Singh, V.K. 2015. Molluscicidal activity of *Tamarindus indica* and *Terminalia arjuna* against *Indoplanorbis exustus*: a causative agent of trematoidiasis. *Sci. Agri.* 12: 163-170.

Souza, B.A., Silva, L.C., Chicarino, E.D. and Bessa, E.C.A. 2013. Preliminary phytochemical screening and molluscicidal activity of the aqueous extract of *Bidens pilosa* Linne(Asteraceae) in *Subulina octona* (Mollusca, Subulinidade). *An. Acad. Bras. Cienc.* 85: 1557-1566.

Souza, B.A., Silva, L.C., Chicarino, E.D. and Bessa, E.C.A. 2014. Phytochemical and molluscicidal activity of *Mikania glomerata* Sprengel (Asteraceae) in different lifestages of *Subulina octona* (Mollusca, Subulinidade). *Braz. Arch. Biol. Technol.* 57: 261-268.

Thomas, G.V. and Balasimha, D. 2011. Arecanut palm: crop scenario and relevance of cropping systems. In: *Arecanut based cropping/ farming systems* (Eds: G.V. Thomas, V. Krishnakumar, H.P. Maheswarappa, R. Bhat and D. Balasimha). Central Plantation Crops Research Institute, Kasaragod, Kerala, India. pp 1-5.

Tiwari, F. 2013. Molluscicidal activity of bait formulation in attractant food pellets against vector snail, *Indoplanorbis exustus. Nat. Sci.* 11: 81-85.

Truiti, M.C.T., Ferreira, I.C.P., Zamuner, M.L.M., Nakamura, C.V., Sarragiotto, M.H. and Souza, M.C. 2005. Antiprotozoal and molluscicidal activities of five Brazilian plants. *Braz. J. Med. Biol. Res.* 38: 1873-1878.

Upadhyay, A. and Singh, D.K. 2011. Molluscicidal activity of *Sapindus mukorossi* and *Terminalia chubula* against the freshwater snail *Lymnaea acuminata. Chemosphere* 83: 468-474.

Yadav, R.P. 2015. Efficacy of plant origin Molluscicides: control of Fascioliasis. *Sci. Int.* 3: 103-106.

Yadav, R.P. and Singh, A. 2013. Toxic effect of two common Euphorbiales against freshwater target snail *Lymnaea acuminata* and *Indoplanorbis exustus* in ponds. *New York Science J.* 6(6): 18-25.

World Health Organization, 2009. *Areca catechu* L. pp 30-31. In: *Medicinal Plants of Papua New Guinea,* World Health Organization, Geneva, Switzerland, 302p.