AN OVERVIEW ON THE BIOLOGICAL PERSPECTIVES OF AGLAIA SPECIES

PRIYA R, SOWMIYA P, MEENAKSHI SUNDARAM MUTHURAMAN*
Department of Biotechnology, School of Chemical and Biotechnology, SASTRA Deemed University, Thanjavur – 613 401, Tamil Nadu, India.
Email: msundar@biotech.sastra.edu
Received: 04 April 2018, Revised and Accepted: 29 May 2018

ABSTRACT

Medicinal plants have been identified and used throughout human history for treating various diseases. Plants belonging to genus Aglaia have been used in traditional system of medicine. The genus Aglaia is a member of Meliaceae family. The plants belonging to this genus have various biological activities including antipyretic, astringent, antidiarrheal, antisynergistic, anti-inflammatory, and anticancer activity and are also used in treating skin diseases and tumors. The phytochemistry and the various biological activities of Aglaia sp. such as anticancer, anti-inflammatory, antioxidant, anti-diabetic, and nanoparticle activity are discussed in this review paper.

Keywords: Aglaia, Medicinal plants, Biological activity.

© 2018 The Authors. Published by Innovare Academic Sciences Pvt Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/) DOI: http://dx.doi.org/10.22159/ajpcr.2018.v11i9.26436

INTRODUCTION

Plants provide the richest resource of natural compounds, which are used directly or indirectly for a wide range of applications for the well-being of human population and domestic animals [1]. These compounds are primarily phytomolecules synthesized through primary and secondary metabolic pathways in plants [2]. The dependence of humans on plants for their basic requirements such as food, medicine, clothes, and shelter is as old as mankind itself [3], and still in the modern age, the majority of commercial products including pharmaceutical and health care, food and beverages, textiles, cosmetics, and aromas are obtained from plants. Therefore, plants are and will remain economically, industrially, environmentally, spiritually, historically, and aesthetically important for survival, sustenance, and prosperity of life on the Earth. Since the early 1990s, the use of complementary and alternative medicine, including dietary supplements, has increased substantially. A benchmark national survey revealed that in the United States alone, use of any complementary and alternative medicine modality increased from 33.8% in 1999 to 42.7% in 1997 [4]. A study conducted in 2002 found that 62% of those surveyed used some form of complementary and alternative medicine in the past 12 months [5]. Specifically, dietary supplement use has increased substantially, with herbal supplement use increasing more than the use of other complementary and alternative medicine modalities [6,7].

In the United States, in 2007, about 38% of adults and 12% of children were using some form of traditional medicine. According to a survey by the National Center for Complementary and Alternative Medicine, herbal therapy or the usage of natural products other than vitamins and minerals was the most commonly used alternative medicine [8,9]. In India, herbal medicine is a common practice, and about 960 plant species are used by the Indian herbal industry of which 178 are of a high volume, exceeding 100 metric tons per year [10]. At present, herbs are applied to the treatment of chronic and acute conditions and various ailments and problems such as cardiovascular disease, prostate problems, depression, inflammation, and to boost the immune system, and to name but a few. In China, in 2003, traditional herbal medicines played a prominent role in the strategy to contain and treat severe acute respiratory syndrome, and in Africa, a traditional herbal medicine, the Africa flower, has been used for decades to treat wasting symptoms associated with HIV [11,12].

The use of plants for healing purposes predates recorded history and forms the origin of much of modern medicine. Many conventional drugs originate from plant sources: A century ago, most of the few effective drugs were plant-based. Examples include aspirin (from willow bark), digoxin (from foxglove), quinine (from cinchona bark), and morphine (from the opium poppy). The development of drugs from plants continues, with drug companies engaged in the large-scale pharmacologic screening of herbs [13]. Over the past few decades, there has been a consistent rise in the number of diseases despite the high advancement in medicine [14]. Plants, on the other hand, have always been a vital source of the drug since the ancient times. They have been used due to their minimal toxic nature and are also highly biocompatible when compared with the harmful dosages of chemically synthesized drugs [15]. The family Meliaceae (=Mahogany family, order Sapindales) is an angiosperm plant family of mostly trees and shrubs together with a few herbaceous plants. This family includes about 50 genera and 550 species, with a pantropical geographical distribution [16].

Aglaia is a tree widely distributed in the tropical rainforests of Southeast Asia, Indonesia, and Malaysia. This genus Aglaia belongs to Meliaceae family. The plant is considered as a remedy for dysentery, skin diseases, leprosy, inflammation, leukoderma, and abdominal pain. It is said to have cooling effects and is useful in burning sensation of the body and painful micturition. The plant is a large tree with bright red wood; leaves shortly petiolate, pinnately compound having 5 (rarely 7 or 3) leaflets (Fig. 1); flowers shortly pedicellate (small, 0.2 cm in diameter), yellow (Fig. 2); fruits sub-globose small, and 0.25 cm in diameter.

Vernacular names of Aglaia

| Languages | Common names                  |
|-----------|-------------------------------|
| Hindi     | Priyangu                      |
| Tamil     | Chokkala, chokkala            |
| Malayalam | Nyaki, punniyava, cheeralam   |
| Telugu    | Yerra aduga, erranduga, kondanduga |
| Kannada   | Gadhagaya, kempu nola, thottiu, priyangu |

Phytochemical studies

Balunas et al. have been successful in identifying numerous medicinal plants from tropical rainforest regions with potential anticancer activity. Silvesteral, a compound isolated from the chloroform extract of Aglaia foveolata proved to be cytotoxic to several human cancer cell lines [17]. Nugroho et al. isolated Rocaglamide compounds from fruit extract of Aglaia elliptica and leaves of Aglaia harmsiana. The isolated rocaglamide compounds exhibited strong insecticidal activity [18].
confirmed that rocaglamide significantly sensitized the
investigated the plant-derived
proved phytogenic synthesis of recyclable copper
summarized the discovery of
was studied cytotoxic effects of two minor silvesterol analogs
isolated 8 new compounds and
A. foveolata
agents [24]. Silvesterol, a potential anticancer rocaglate derivative from
that silvesterol and episilvesterol
ATM/ATRChk1/Chk2 checkpoint pathway [23]. Kinghorn
progression of tumor cells at the G1-S Phase through the activation of the
isolated from the medicinal plant
associated bone loss diseases blocking the NF-κB pathway [22].
Luan
is associated with increased apoptosis, decreased proliferation, and
inhibition of angiogenesis. It was proposed that silvesterol mediates
effects on HT-29 cell lines [29]. Ebada
and other new constituents 21-norbaccharane-type triterpene,
3A,4-seco-dammarane triterpenes, eudesmane sesquiterpene,
as well as nine known compounds isolated from a chloroform soluble
fraction of A. foveolata and compared their cytotoxicity against HT-29
cell [26]. Kinghorn et al. investigated rocaglate derivatives of Aaglaia
and compounds from other higher plants for cytotoxic effects against
cancer cells [27]. Pan et al. reported that ethanol extract of twigs, leaves and
fruits and roots of Aglaia has cytotoxicity against HT-29 human
colon cancer cell line [28]. Pan et al. isolated 8 new compounds and
16 existing compounds including silvesterol from methanol extracts
of Aglaia perviridis and tested their cytotoxicity against HT-29 human
colon cancer cell line. Seven rocaglate derivatives had potent cytotoxic
effects on HT-29 cell lines [29]. Ebada et al. confirmed Rocaglamides
(Flavaglines) and other constituents are from Aglaia species have
potent anticancer, antifungal, and antibacterial activities [30].

Nuraqilah Othman et al. focused on silvesterol and other new compounds
isolated from the methanol extract of the stems of Aglaia stellatopilosa,
and tested their cytotoxicity against three human cancer cell lines,
and the compounds were also tested for antimicrobial activity against
bacteria and fungi [31]. Kinghorn et al. summarized the discovery of
anticancer agents from aquatic and terrestrial cyanobacteria, tropical
plants and filamentous fungi and stated that plant-derived compounds
of Aglaia are studied for anticancer activity for human cancer [32].
Cencic et al. evaluated anticancer activity of Aglaia derived silvesterol
compound. It was found that silvesterol exhibits anticancer activity
in human breast and prostate cancer xenograft models and that this
is associated with increased apoptosis, decreased proliferation, and
inhibition of angiogenesis. It was proposed that silvesterol mediates
effects by preferentially inhibiting translation of malignancy-related
mRNAs [33]. Leong et al. investigated the plant-derived single compound cycloartane isolated from hexane extract of Aglaia
exima leaves and reported that cycloartane reduces the viability of
colon cancer cell line through the activation of caspase 8 and 9 and
caspase-3/7, PARP cleavage and the lack of NFkB translocation into the
nucleus. Leading to apoptosis [34].

**Antidiabetic activity**
Sun et al. confirmed prenylated bibenzyls named aglaabrevins
A–D isolated from the leaves of Aglaia abbriviata inhibits protein
tyrosine phosphatase-1B (PTP1B). These prenylated bibenzyls may be
considered as lead compounds for the development of new antiobesity
and antidiabetic agents [35].

**Anti-inflammatory activity**
Liu et al. derived anti-inflammatory activity and other antioxidant,
antimicrobial activities from the medicinal plants honey, made from
different floral sources. Floral honey from Aglaia formosana was
involved in testing of anti-inflammatory activity [36]. Yodsaeue et al.
evaluated triterpenoids and triterpenoids compounds isolated from
the leaf extract of Aglaia odorata and tested the anti-inflammatory
activity by the inhibition of lipopolysaccharide-induced nitric oxide
production in RAW264.7 cell lines [37]. Janaki et al. studied alcoholic
extract of fruits and aerial portion of Aglaia roxburghiana var. beddomei
extract and triterpenes roxburghianol A and B isolated and tested and
observed anti-inflammatory activity [38].

**Antioxidant activity**
Liu et al. evaluated floral honey from A. formosana for antioxidant,
antimicrobial, and anti-inflammatory activity and isolated protein,
flavonoids and phenolic compounds having antioxidant, and other
activities [36].

**Nanoparticle synthesis**
Manjari et al. proved phytogenic synthesis of recyclable copper
oxide nanoparticles, from flower extracts of Aglaia elaeagnoides
prostate cancer cells through the mitochondrial/apoptosome pathway
without any involvement of executioner caspase-3 or -7 [25].

Pan et al. studied cytotoxic effects of two minor silvesterol analogs
and other new constituents 21-norbaccharane-type triterpene,
3A,4-seco-dammarane triterpenes, eudesmane sesquiterpene,
as well as nine known compounds isolated from a chloroform soluble
fraction of A. foveolata and compared their cytotoxicity against HT-29
cell [26]. Kinghorn et al. investigated rocaglate derivatives of Aaglaia
and compounds from other higher plants for cytotoxic effects against
cancer cells [27]. Pan et al. reported that ethanol extract of twigs, leaves and
fruits and roots of Aglaia has cytotoxicity against HT-29 human
colon cancer cell line [28]. Pan et al. isolated 8 new compounds and
16 existing compounds including silvesterol from methanol extracts
of Aglaia perviridis and tested their cytotoxicity against HT-29 human
colon cancer cell line. Seven rocaglate derivatives had potent cytotoxic
effects on HT-29 cell lines [29]. Ebada et al. confirmed Rocaglamides
(Flavaglines) and other constituents are from Aglaia species have
potent anticancer, antifungal, and antibacterial activities [30].

Nuraqilah Othman et al. focused on silvesterol and other new compounds
isolated from the methanol extract of the stems of Aglaia stellatopilosa,
and tested their cytotoxicity against three human cancer cell lines,
and the compounds were also tested for antimicrobial activity against
bacteria and fungi [31]. Kinghorn et al. summarized the discovery of
anticancer agents from aquatic and terrestrial cyanobacteria, tropical
plants and filamentous fungi and stated that plant-derived compounds
of Aglaia are studied for anticancer activity for human cancer [32].
Cencic et al. evaluated anticancer activity of Aglaia derived silvesterol
compound. It was found that silvesterol exhibits anticancer activity
in human breast and prostate cancer xenograft models and that this
is associated with increased apoptosis, decreased proliferation, and
inhibition of angiogenesis. It was proposed that silvesterol mediates
effects by preferentially inhibiting translation of malignancy-related
mRNAs [33]. Leong et al. investigated the plant-derived single compound cycloartane isolated from hexane extract of Aglaia
exima leaves and reported that cycloartane reduces the viability of
colon cancer cell line through the activation of caspase 8 and 9 and
caspase-3/7, PARP cleavage and the lack of NFkB translocation into the
nucleus. Leading to apoptosis [34].

**Antidiabetic activity**
Sun et al. confirmed prenylated bibenzyls named aglaabrevins
A–D isolated from the leaves of Aglaia abbriviata inhibits protein
tyrosine phosphatase-1B (PTP1B). These prenylated bibenzyls may be
considered as lead compounds for the development of new antiobesity
and antidiabetic agents [35].

**Anti-inflammatory activity**
Liu et al. derived anti-inflammatory activity and other antioxidant,
antimicrobial activities from the medicinal plants honey, made from
different floral sources. Floral honey from Aglaia formosana was
involved in testing of anti-inflammatory activity [36]. Yodsaeue et al.
evaluated triterpenoids and triterpenoids compounds isolated from
the leaf extract of Aglaia odorata and tested the anti-inflammatory
activity by the inhibition of lipopolysaccharide-induced nitric oxide
production in RAW264.7 cell lines [37]. Janaki et al. studied alcoholic
extract of fruits and aerial portion of Aglaia roxburghiana var. beddomei
extract and triterpenes roxburghianol A and B isolated and tested and
observed anti-inflammatory activity [38].

**Antioxidant activity**
Liu et al. evaluated floral honey from A. formosana for antioxidant,
antimicrobial, and anti-inflammatory activity and isolated protein,
flavonoids and phenolic compounds having antioxidant, and other
activities [36].

**Nanoparticle synthesis**
Manjari et al. proved phytogenic synthesis of recyclable copper
oxide nanoparticles, from flower extracts of Aglaia elaeagnoides

**Biological activity**

**Anticancer activity**
A phenolic ester isolated from leaves of Aglaia loheri was found to
possess cytotoxic effects toward human CCRF-CEM leukemia cells
and their drug-resistant sublime by reduction of the mitochondrial
membrane potential and induction of apoptosis [19]. Chen et al. studied
the Silvesterol isolated from the fruits and twigs of A. foveolata inhibits
the cell growth and induces cell death in human MDA-MB-435 melanoma
cells through the induction of caspase-mediated apoptosis [20].
Luan et al. confirmed that rocaglamide significantly sensitized the
TRAIL-resistant HCC cells to apoptosis by TRAIL, which resulted from
the Rocaglamide-mediated downregulation of cellular FLICE-like
inhibitory protein and subsequent caspase-8 activations [21]. Li et al.
studied the effects of rocaglamide-A (Roc-A) a component of Aeglaia
plant in osteoblast differentiation. Roc-A prevented TNF-α-mediated
inhibition of osteoblast differentiation and promoted direct osteoblast
differentiation. It was found that Roc-A protected and stimulated
osteoblast differentiation through blocking NF-κB pathway [22].
Neumann et al. proved the natural component Roc-A (Rocaglamide–A)
isolated from the medicinal plant Aglaia, induces phosphorylation of
Cdc25A and its subsequent degradation thus blocking cell cycle
progression of tumor cells at the G1-S Phase through the activation of the
ATM/ATRChk1/Chk2 checkpoint pathway [23]. Kinghorn et al. reported
that silvesterol and episilvesterol from Aeglaia flavoelata are anticanancer
agents [24]. Silvesterol, a potential anticancer rocaglate derivative from
A. foveolata, induced apoptosis in LNCaP (hormone-dependent human

possess great prospects in reduction of pernicious dyes and nitro organic pollutants in water [39]. Gangaraju et al. synthesized silver nanoparticles from the leaf extract of A. elaeagnoides using it as a reducing, capping, and stabilizing agent. The synthesized AgNP was embedded in natural polymer alginate. The preparation of Ag–CA composite was facile, stable, efficient, eco-friendly, easy to recycle, non-toxic, and cost effective for commercial application [40]. Benelli et al. used an aqueous extract of A. elaeagnoides, for synthesizing silver nanoparticles that were toxic to Calex quinquesequis, Aedes aegypti, and Anopheles stephensi mosquitoes [41]. Copper oxide sodium alginate nanocomposite prepared from leaf extract of A. elaeagnoides.

The produced copper oxide sodium alginate nanocomposite was used as a catalyst for the reduction of 4-Nitrophenol in the liquid phase [42]. Antioxidant and catalytic property of synthesized gold and silver nanoparticles from the flower extract of A. elaeagnoides were evaluated by Manjari et al. The study proved that the synthesized nanoparticles have ultra-rapid catalytic properties [43].

CONCLUSION
Plant is one of the most important sources for medicine. WHO portrayed that about 80% of the world’s population believes in the ancient and traditional plant-based treatment for different ailments [44]. Medicinal plants play a key role in Indian traditional medicine. The plants of genus Aegia have been used traditionally and are scientifically reported to have antioxidant, antimicrobial, anticancer, and anti-inflammatory activities. Till date, a large number of herbal products has been screened for their biomedical applications through various experimental models. This has caused the discovery of the several drugs by the pharmaceutical and scientific communities [45].

ACKNOWLEDGMENT
The authors would like to thank the Management, SASTRA Deemed University for providing the necessary facilities. Meenakshi Sundaram M gratefully acknowledges Prof. TRR research grant from SASTRA Deemed university and EMR grant (2.Z8015/07/2018-HPC(EMR)-AYUSH-E) from Ministry of AYUSH.

AUTHORS’ CONTRIBUTION
All authors equally contributed to the preparation of the manuscript.

CONFLICTS OF INTEREST
None.

REFERENCES
1. Khanuja SP. Functional diversity of plant metabolome and microbiome in health services to the human life. Pro Nat Acad Sci India Sect B Biol Sci 2012;82:291-4.
2. Arora DS, Ossare JG, Kaur H. Bioprospecting of Moringa (Moringaceae): Microbiological perspective. J Pharmacogn Phytochem 2013;1:193-215.
3. Goyal BR, Agrawal BB, Goyal RK, Mehta AA. Phyto-pharmacology of Moringa oleifera Lam.: An overview. Nat Prod Radiance 2007;8:291-4.
4. Eisenberg DM, Davis RB, Ettner SL, Brach RJ, Appel S, Wilkey S, Van Rompay M, et al. Trends in alternative and complementary medicine use in the United States, 1990–1997: Results of a follow-up national survey. JAMA 1998;280:1569-75.
5. Barnes PM, Powell-Geriner E, McFann K, Nahin RL. Complementary and alternative medicine use among adults: United States, 2002. Advance Data from Vital and Health Statistics, No. 343. Hyattsville, MD: National Center for Health Statistics; 2004.
6. Slesinski MJ, Subar AF, Kahle LL. Trends in use of vitamin and mineral supplements in the United States: The 1987, 1992, and 2000 National Health Interview Survey results. J Am Diet Assoc 1995;95:921-3.
7. Millen AE, Dodd KW, Subar AF. Use of vitamin, mineral, nonvitamin, and nonmineral supplements in the United States: The 1987, 1992, and 2000 National Health Interview Survey results. J Am Diet Assoc 2004;104:942-50.
8. Ernst E, Schmidt K, Wider B. CAM research in Britain: The last 10 years. Complement Ther Clin Pract 2003;9:17-20.
9. Barnes PM, Bloom B, Nahin R. Complementary and alternative medicine use among adults and children: United States, 2007. CDC National Health Statistics Report #12; 2008.
10. Sahoo N, Manchikanti P, Dev C, Shah S. Herbal drugs: Standards and regulation. Fitoterapia 2010;81:462-71.
11. De Smet P. Herbal medicine in Europe: Relaxing regulatory standards. N Engl J Med 2002;351:1176-83.
12. Tilhurt JC, Kapchtak TJ. Herbal medicine research and global health: An ethical analysis. Bull World Health Organ 2008;86:594-9.
13. Vickers A, Zollman C, Lee R. The ABC of complementary medicine: Herbal medicine. Br Med J 1999;319:1050-3.
14. Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis 1995;1:7-15.
15. Goyal BR, Agrawal BB, Goyal RK, Mehta AA. Phyto-pharmacology of Aegia. Proc Natl Acad Sci India Sect B 2012;82:291-4.
16. Pan L, Chai HB, Kinghorn AD. Discovery of new anticancer agents and A. harmsina. Phytochemistry 1997;45:1579-89.
17. Lanci Z, He Y, He F, Chen Z. Rocaglamide overcomes tumor necrosis factor-related apoptosis-inducing ligand resistance in hepatocellular carcinoma cells by attenuating the inhibition of caspase-8 by cellular FLICE-like-inhibitory protein down regulation. Mol Med Rep 2015;11:203-11.
18. Li Y, Yang L, Geng X, Peng X, Lu T, Deng Y, et al. Rocaglamide - A potentiates osteoblast differentiation by inhibiting NF-κB signaling. Mol Cells 2015;38:941-9.
19. Neumann J, Boeriers M, Kroemer G, Ghiso J, Mrammer PH, Busch H, et al. The natural anticancer compound rocaglamide selectively inhibits the G1-S-phase transition in cancer cells through the ATM/ATR-mediated Chk1/2 cell cycle checkpoints. Int J Cancer 2014;134:1991-2002.
20. Kinghorn AD, De Bingo EJ, Chai HB, Ojala J, Farnsworth NR, Doel Soejarto D, et al. Discovery of anticancer agents of diverse natural origin. Pure Appl Chem 2009;81:1051-63.
21. Kim S, Hwang BY, Su BN, Chai H, Mi Q, Kinghorn AD, et al. Silverstrol, a potential anticancer rocaglamide derivative from Aegia foveolata, induces apoptosis in HeLa cells through the mitochondria- apoptosome pathway without activation of executioner caspase-3 or -7. Anticancer Res 2007;27:2175-83.
22. Pan L, Kardonon LB, Riswan S, Chai H, De Blanco EJ, Pannell CM, et al. Isolation and characterization of minor analogues of silvesterol and other constituents from a large-scale recollection of Aegia foveolata. J Nat Prod 2010;73:1873-8.
23. Kinghorn AD, Pan L, Fletcher JN, Chai H. The relevance of higher plants in lead compound discovery programs. J Nat Prod 2011;74:1539-55.
24. Pan L, Chai HB, Kinghorn AD. Discovery of new anticancer agents from higher plants. Front Biosci (Sch Ed) 2013;4:142-56.
25. Pan L, Acuna UM, Li J, Jena N, Ninh TN, Pannell CM, et al. Bioactive flavaglines and other constituents isolated from Aegia perrivida. J Nat Prod 2013;76:394-401.
26. Pan L, Kaikiewicz N, Porco JA Jr, Li-Weber M, Proksch P. Chemistry and biology of rocaglamides (=flavaglines) and related derivatives from Aegia species (Meliacae). Prog Chem Org Nat Prod 2011;94:1-58.
27. Kinghorn AD, De Blanco EJ, Lucas DM, Rakotondraibe HL, Ojala J, Priya et al. Discovery of anticancer agents of diverse natural origin. Anticancer Res 2016;36:5223-37.
leaves of *Aglaia exima* triggers tumour necrosis factor-receptor 1-mediated caspase-dependent apoptosis in colon cancer cell line. New cycloartane triggers TNFR-1 apoptosis in colon cancer cell line. PLoS One 2016;11:e0152652.

35. Sun P, Jiang CS, Zhang Y, Liu AH, Liang TJ, Li J, et al. Aglaia abbreviata with potent PTP1B inhibitory activity. Chem Pharm Bull 2017;65:295-9.

36. Liu JR, Ye YL, Lin TY, Wang YW, Peng CC. Effect of floral sources on the antioxidant, antimicrobial, and anti-inflammatory activities of honeys in Taiwan. Food Chem 2013;139:938-43.

37. Yodsaoue O, Sonprasit J, Karalai C, Ponglimanont C, Tewtrakul S, Chantarapromma S. Diterpenoids and triterpenoids with potential anti-inflammatory activity from the leaves of *Aglaia odorata*. Phytochemistry 2012;76:83-91.

38. Janaki AS, Vijayasekaran AV, Viswanathan AS, Balakrishna K. Anti-inflammatory activity of *Aglaia roxburghiana* Var. Beddomei extract and triterpenes Roxburghiadiol A and B. J Ethnopharmacol 1999;67:45-51.

39. Manjari G, Saran S, Arun T, Rao AV, Devipriya SP. Catalytic and recyclability properties of phytoprogenic copper oxide nanoparticles derived from *Aglaia elaeagnoidae* flower extract. J Saudi Chem Soc 2017;21:610-8.

40. Gangarapu M, Sarangapany S, Veerabhali KK, Devipriya SP, Arava VB. A high-performance catalytic and recyclability of phyto-synthesized silver nanoparticles embedded in natural polymer. J Clust Sci 2017;2017:265864.

41. Benelli G, Govindarajan M, Senthilmurugan S, Vijayan P, Kadaikunnan S, Alharbi NS, et al. Fabrication of highly effective mosquito nanolarvicides using an Asian plant of ethno-pharmacological interest priyangu (*Aglaia elaeagnoidae*): Toxicity on non-target mosquito natural enemies. Environ Sci Pollut Res Int 2018;25:10283-93.

42. Gangarapu M, Arava VR. Copper nanoparticles encapsulated alginate composite for reduction of aromatic nitro compounds. Int J Sci Eng Res 2017;8:732-5.

43. Manjari G, Saran S, Arun T, Devipriya SP, Rao AV. Facile *Aglaia elaeagnoidae* mediated synthesis of silver and gold nanoparticles: Antioxidant and catalysis properties. J Clust Sci 2017;8:2041-56.

44. Nithya S, Muthuraman MS. An overview on the biological perspectives of *Nardostachys jatamansi* DC. Int J Pharm Pharm Sci 2016;8:31-6.

45. Sujana N, Ramanathan S, Vimala V, Muthuraman MS, Penaiah B. Antitumour potential of *Passiflora incarnata* L against Ehrlich ascites carcinoma. Int J Pharm Pharm Sci 2012;4:17-20.