Review article

A review on Borreria verticillata: A potential bio-nematicide, channeling its significant antimicrobial activity against root-knot nematodes

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ABSTRACT

Phytopesticides are human-friendly beside been easily accessible and bio-degradable, are therefore environmentally friendly compared to the synthetic pesticides which have adverse effects on human, animals and the ecosystem. Plants are large reservoir of secondary metabolites largely untapped or under-tapped for use as pesticides. One problem associated with this is to identify plants which can be assessed and further exploited for this use. Borreria verticillata belongs to Rubiaceae, it is native to South Americas but gained popularity globally. It is known as a weed, showing resistance to many synthetic pesticides and can be grown on a wide range of soil types. B. verticillata is used traditionally against skin diseases such as eczema, infectious dermatitis and scabies. Its antimicrobial application is large and efficient as revealed by most authors. This article inclines to propose and offer current studies with information on the various application of this plant species against various microorganisms, thereby extending its use against plant parasitic nematodes which cause severe yield losses to numerous agricultural crops. Most search engines, journals and dissertation search engines i.e. Google scholar, pubmed, sciencedirect, scopus, web of science, springer, elsevier, like Open-thesis, OATD, ProQuest and EthOs were queried by employing titles such as B. verticillata, Borreria verticillata and biological activity of B. verticillata. The most synonymous name was queried too i.e. Spermacoce verticillata. This review suggests a main point about this resistant weed i.e. its significant antimicrobial activity. It further emphasizes the need exploits this useful effect against nematodes since they are microorganisms. Phytochemistry of the B. verticillata was gathered in this study and the compounds isolated from the plant i.e. terpenes, iridoids, flavonoids and alkaloids (29 compounds) further provide a basis for a significant anthelmintic effect. The review concludes on the need to extend its antimicrobial activity to sustainable agriculture. Since it is a very common plant in Nigeria, it is easily accessible to farmer protect their cultivations from plant-parasitic nematode attacks.

1. Introduction

Meloidogyne incognita (Root-knot nematode) is one of the main plant-parasitic nematode species threatening the yield i.e. quality and quantity, of agricultural crops both annual and perennial ones. Root-knot nematodes are generally widespread and are responsible for considerable yield losses of a wide range of stable crops. Annual crop yield losses due to plant-parasitic nematodes are valued at about $78 billion worldwide (Sasser and Freckman, 1987). Crops that are affected by root-knot nematodes displayed some unique symptoms, these includes stunting and nutrient deficiency, browning of leaves, early wilting, root galling, suppression in plant growth and reduction of photosynthetic pigments which result into yield losses, poor fruit quality and reduced shelf-life (Oka et al., 2014; Kankam et al., 2015). Numerous ways have been used to manage problems created by nematodes globally. Among control methods against plant parasitic nematodes, synthetic chemical takes the main role. Although it brought instant relative and prove to be efficient, they are actually unaffordable by most rural farmers and not easily accessible for the resource-poor farmers in most developing countries. Over the years, people could notice the adverse effects of these pesticides made from chemicals, they are dangerous on plants, ecosystem, animals and humans. They are very toxic, non-biodegradable and posed hazards to farmers and non-target groups (Chitwood, 2002; Oka et al., 2014; Bello et al., 2019a).

The quest for further environmental and toxicological healthy and more suitable and efficient pesticides has been intensified by various
demands. Thus, in plants, an evident solution was tried and found. Secondary metabolites from terrestrial plants have gained much interest in contemporary times as alternative sources for novel biopesticides. The traditional usage of these herbs and species by the indigenes of different regions of the world as antimicrobial and pesticides resources are well known (Dalziel, 1937; Ayensu, 1978; Bello et al., 2017, 2018, 2019b). Possibly, the earliest record shows that tobacco (Nicotiana tabacum) is employed as pesticides. Decoction from the Tobacco leaves are employed to destroy aphids, this leads to the discovery of Nicotine, an alkaloid and a plant from Japan, the plantcKoh-ten with its scientific name referred to as Rhododendron Hortense. Rotenone was isolated as the bioactive compound; it is used from early times as pesticides. Plants are large reservoir of secondary metabolites largely untapped or under-tapped for use as pesticide (Feyisa et al., 2015; Waziri, 2015). This review portrays and abridges the botanical description, folklore uses and the economic impact of B. verticillata but emphases on its biological activity i.e. antimicrobial effects. The review assert that since this plant has a significant antimicrobial activity hence this activity can be drawn against plant-parasitic nematodes. Its significant antimicrobial activity can be channel against root-knot nematodes. Highlight of its phytochemistry was clearly stated because it is the secondaries metabolites responsible for the antimicrobial effects hence the proposed nematicidal ability. Its resistance ability attest to the fact that it can be pursued further as a plant-based herbicide.

B. verticillata is a clambering and climbing yearly or perennial plant which is indigenous to the South Americas. This plant is dispersed broadly then irregularly through the Pacific, Africa, Australia and Asia. Stems sprawling, to 110 cm or more, glabrous or nearly so, usually standing straight and simple or thinly branched, often abundantly branched from the base, usually 40 cm high or less, the stems tetragonal. It is highly resistance hence can grow on a number of lands types but frequently needs some intrusion to establish. B. verticillata do form wide and big tufts which can threaten other plants around. B. verticillata is mostly seen as a major weed for most crops and vegetables, for instance in the South America countries, it creates a big challenge against the growth and yield of cassava, carrots, rice, maize, sugarcane and vegetables (Mascarenhas et al., 1999; PIER, 2016).

2. Synonymous scientific names

Other synonyms scientific names of B. verticillata though Spermacoce verticillata is the foremost popular of these names. There are other scientific names by which B. verticillata is known with: Borreria oaxacana M. Martens & Galeotti, Bigelovia verticillata (L.) Spreng. Borreria globular-oides Cham. & Schltdl, Borreria graminifolia M. Martens & Galeotti, Borreria laevigata M. Martens & Galeotti, Borreria minima DC., Borreria molleri Gand., Borreria stricta G. Mey., Borreria verticillata (L.) G. Mey., Borreria kohautiana Cham. & Schltdl, Borreria oligodonta Steyerm., Borreria thymocephala Griseb, Borreria podocephal DC., Borreria commutata Spreng., Spermacoce graminifolia (M. Martens & Galeotti) Hemsl, Spermacoce oligodonta (Steyerm.) Govaerts, Spermacoce mucronata Rees, Spermacoce podocpehal (DC.) C. Wright, Spermacoce polycpehal (DC.) Hemsl., Spermacoce polycephala Bartl. ex DC., Spermacoce oaxacana (M. Martens & Galeotti) Hemsl., Spermacoce thymocephala (Griseb.) C. Wright, Spermacoce globosa Schumach. & Thonn, Tardavel verticillata (L.) Hiern, Spermacoce reclinata Nees, Spermacoce minimai Pohl ex DC., Spermacoce stellata Willd. ex Roem. & Schult., Spermacoce molleri Gand. Govaerts (The Plant List, 2020).

3. Other names

B. verticillata has many other designations by which it is referred to globally as shown in Table 1. This plant species is popularly called whitehead broom, southern larra flower and shrubby false buttonwood in English language. In West Africa countries, different tribes and ethnic groups have their unique names for this weed (Abdullahi-Gero et al., 2014; Andrioli et al., 2014; Campos et al., 2014).

4. Scientific classification and kingdom

Species: Borreria verticillata/Spermacoce verticillata
Genus: Spermacoce
Family: Rubiaceae
Order: Gentianales
Class: Dicotyledonae
Subphylum: Angiospermae
Phylum: Spermatophyta
Kingdom: Plantae
Traditional Uses

B. verticillata is a common weed in West Africa Countries though it is reputed for its use in traditional medicine in Asia, Africa, Latin America and West Indies. In West Africa region, its decoction (extraction from the upper part) is used topically on the skin for management of skin ailments such as Tinea versicolor (eczema), Tinea capitis (ring worm), pityriasis versicolor, skin itchies, psoriasis, scabies and various infectious dermatitis (Baldé et al., 1991, 2015). Some authors report that the tea from the roots of B. verticillata is employed in the management of leucorrhoas and benorreas (Peixotto Neto and Caetano, 2002). In Brazil, its leaves and flowers’ infusion are employed as analgesic and antipyretic (Moreira et al., 2010; Vieira et al., 1999), the blend from the roots is used as emetic and its broad leaves are employed as anti diarrheal, against hemorrhoids and erysipelas (Lorenzi and Matos, 2002). The decoction of the B. verticillata is prepared with Cuscuta and Zehbra Schnizlein employed in the treatment of amenorrhea, also used against diabetes and dysmenorrhea in West India (Ayensu, 1978) while in the Northern Senegal it is employed against leprosy and skin related diseases (Maynard

Table 1. Other names of B. verticillata.

| Country | Name | Language | References |
|---------|------|----------|------------|
| Spain   | botín blanco; botoncito blanco; cardo de frade | Spanish | Abdullahi-Gero et al. (2014); Andrioli et al. (2014) |
| France  | borreire verticille | French | Andrioli et al. (2014); Campos et al. (2014) |
| Portugal| erbaux; poaia; vassourinha-de-botao | Portuguese | Burger and Taylor (1993) |
| Brazil  | coroa-de-frade; poaia miúda; poaia preta; vassourinha; poaia, coroa-defrade | Portuguese | Moreira et al. (2010); Conserva and Ferreira Júnior (2012) |
| Puerto Rico | jauna la blanca | Spanish | Chiquieri et al. (2004) |
| Saint Lucia | ti ma konin | Creole | Andrioli et al. (2014); |
| Thailand | chat sam chan; ya khi kratai | Thai | Campos et al. (2014) |
| Nigeria | Karya garma | Hausa | Biodiversity India, 2016; Ushie and Adamu (2010) |
| Nigeria | Warhui kpone | Tiv | Chiquieri et al. (2004); Ushie and Adamu (2010) |
| Nigeria | irowo ile | Yoruba | Ushie and Adamu (2010) |
| Nigeria | Abia ikuna | Ibibio | Chiquieri et al. (2004); Ushie and Adamu (2010); |
et al., 1980). The endocarp’s decoction is prepared with Iresine P. Browne and Desmodium in Jamaica and it is employed against amenorrhea and as a diuretic (Asprey and Thornton, 1955).

It is used as purgative against paralysis, gonorrheal sores, leprosy, biaharzia, furuncles, infantile hyperpneaia and ulcers (Bello et al., 2017, 2019; Sofowora, 1982; Ushie et al., 2013). In West Indies, decoction from *B. verticillata* which is usually called Alpha Marrow or Wild Margaret, it is employed to manage high blood pressure and as an abortifacient (Bald/C19e et al., 2015) (see Figure 1).

5. Phytochemistry

Though *B. verticillata* is a weed but its use in traditional medicine is popular and this popularity has resulted into considerable isolation of some secondary metabolites from this plant. Alkaloids, terpenes, iridoids, phenolics and flavonoids are compounds that have been reportedly isolated from the plant. This study reveal that only twenty-nine (29) compounds have been isolated from this plant species so far. Among these compounds, alkaloids and iridoids showed some in vitro or in vivo biological activities. Trease and Evans (1972) identified an alkaloid from aerial parts of *B. verticillata*, the compound was named emetine (3).

Pousset et al. (1973) reported that *B. verticillata* contains two new tetrahydro-β-carboline alkaloids, borrerine (1) and an apparent dimer, boreverine (2). The structures of these compounds were discovered by combined spectroscopic techniques. Vieira et al. (1999) isolated three iridoidal compounds from *Borreria verticillata*. A new iridoid aglycone borreriagenin (10), with two known iridoids asperuloside (8) and daphylloside (11). Baldé et al. (1991) isolated a new bis-indole alkaloid, spermacoene (5) and other known three alkaloids from the aerial parts of *Borreria verticillata*. These indole alkaloids are borrerine (1), boreverine (2) and isoborreverine (4), these structures were established from spectroscopic data. Cadinene, caryophyllene (17) and guaiene (22),

![Figure 1. Isolated compounds from *B. verticillata*.](image-url)
these compounds were identified by the comparison of its IR spectrum from the oil extracted from *B. verticillata* (Benjamin, 1979). Andre et al. (1976) identified a compound from the leaves of *B. verticillata*, when all the spectroscopic data were compared with an existing one, the compound was Stigmasterol (20). Silva et al. (2017) identified some secondary metabolites from the hydroalcoholic extract and ethyl acetate fraction from *B. verticillata* using High-performance liquid chromatography (HPLC-UV) analysis. Some of the compounds discovered are Gallic acid (25), β-sitosterol (19), Glycyrrhetinic acid (29), β-amyrin (23), Caffeic acid (27), Coumaric Acid (28), Quercetin (26), Ursolic acid (21), Ellagic acid (24). Moreira et al. (2010) reportedly isolate three new and two known compounds from *Borreria verticillata*. These were two novel simple indole alkaloids called verticillatine B (17) and verticillatine A (6), one new iridoid called 6-O-(2-glyceryl) scadsoside methyl ester (15), scadsoside methyl ester (14) and asperuloside (8).

6. Biological activities

6.1. Hepatoprotective activity

The effect of aqueous leaf extracts of *B. vesticillata* on CCl4-induced hepatotoxicity rats was studied. This investigation was carried out at different phases of formalin induced pain in rats. The extract showed significant hepatoprotective properties of on CCl4-induced hepatotoxicity in rats (Murtala et al., 2015).

6.2. Anti-inflammatory and analgesic activity

Both alcoholic and ethyl acetate fractions of *B. verticillata* were evaluated for antinociceptive activity employing in *silo* and *in vivo* studies. The in-vivo studies includes the paw edema test, tail flick test, writhing test, formalin test. The in *vitro* assessment were carried out on Wistar rats and Swiss mice. Ursolic acid (21) was the compound with best effect among the nine compounds identified. The study concluded that the antinociceptive effect of *B. verticillata* might be because of the secondary actions which include the contribution of anti-inflammatory constituents. Ursolic acid (21) is the major bioactive constituent and may be the favourable basis of COX-2 inhibitors and NMDA receptor antagonists (Silva et al., 2017).

6.3. Lowers blood pressure

Alkaloidal extracts of *B. verticillata* was separated into two different fraction as primary and secondary alkaloid fraction and quaternary alkaloid fraction. Both were assessed for their pharmacological activities on cardiovascular, uterine and gastrointestinal system. The study concluded that these fractions employed possess these biological activities and validates its traditional use to lower blood pressure and as an abortifacient (Moodle-Henry, 2007).

6.4. Anti-inflammatory and analgesic activity

The anti-inflammatory and analgesic effect of ethanol leaf extract of *B. verticillata* was investigated for in mice and rats. Significant (p < 0.05) analgesic activity was noticed at 1,000 and 500 mg/kg orally in both phases of formalin induced pain in rats. The extract showed significant anti-inflammatory activity (p < 0.001, p < 0.05) at doses of 200 to 1,000 mg/kg p.o./i.p in the rats and in all models employed (Abdullahi-Gero et al., 2014).

6.5. Antilarvalcidial activity

The antilarvalcidial effect of solvent-derived extracts of *Borreria verticillata* (Linnaeus) on *Culex quinquefasciatus* (Say) was investigated. The bioassay of the extracts on late third larval instars of *Culex quinquefasciatus* was investigated in the laboratory employing 2, 4, 6 and 8 (mg/l) concentrations. The study recommended that *Borreria verticillata* may be employed in the management of noxious mosquito species i.e. larvae and function as option in replacement of harmful synthetic insecticides (Kontagora, 2017).

7. Antimicrobial activity

7.1. Antimicrobial activity of extracts of *B. verticillata*

Peixoto Neto et al. (2002) reported the antimicrobial activity of methanol extract of the roots of *B. verticillata*. The extract displayed high antimicrobial activity against six different strains of *P. aeruginosa* displaying inhibition areas between 10 and 18 mm even against resistant strains. Different solvent extracts and alkaloid fraction of different parts of *B. verticillata* were evaluated for their antimicrobial activity by Baldé et al. (2015). Crude alkaloidal fraction was significant against *Staphylococcus aureus*, moderate against *Candida tropicalis*, *Neisseria gonorrhoeae*, *Candida albican*, *Streptococcus pneumoniae*, *Myobacterium fortuitum*, *Gardnerella vaginalis* and weak against *Streptococcus viridans*. Furthermore, crude fraction of the alkaloids displayed the highest cytotoxicity (6–25 μg/ml) among the tested extracts against *herpes*, *poliomyelitis* and *semliki* forest viruses (Baldé et al., 2015). Different solvent extracts of *B. verticillata* leaves were assessed for their antioxidant and antitub drug resistant pathogens by some authors. The extracts were identified to identify various secondary metabolites present and were evaluated against some gram-positive organisms (*B. subtilis*, *S. aureus*), gram-negative organisms (*Escherichia. coli*, *Pseudomonas aeruginosa*, *Streptococcus typhi*, *Klebsiella pneumoniae*) and dermatophytic infections are caused by some fungi i.e. *Epidermophyton floccosum*, *Microsporum canis*, *Trichophyton rubrum*, *T. mentagrophytes*. The study shows that the plant possesses activity against dermatophytic and drug resistant pathogens and also significant antimicrobial activity (Aremu et al., 2016).

Ushie and Adamu (2010) reported the antimicrobial effect of ethyl acetate fraction of leaf extract of *B. verticillata*. The authors noticed that ethyl acetate extracts had the most inhibitory action on pathogenic organisms such as *C. albican*, *E. coli*, *P. aeruginosa* and *S. aureus* (Ushie and Adamu, 2010). Anti-eczematic nature of the essential oil extracted from the leaves of *B. verticillata* was investigated by Benjamin (1979). The oil displayed good inhibitory activity against the growth of both gram-positive and gram-negative bacteria.

7.2. Antimicrobial activity of the isolated compounds from *B. verticillata*

Isoborreverine (4) displayed a significant and broad antimicrobial effect against both gram-positive, gram-negative bacterial and fungal i.e. *C. albicans*, *C. tropicalis*, *Gardnella*, *S. aureus*, *M. fortuitum*, *Pneumococcus*, *S. viridans* and *N. gonorrhoeae* but borreverine (2) exhibits a moderate and narrow antimicrobial activity (Baldé et al., 1989). Pousset et al. (1977) beside isolating these compounds borreverine (1), isoborreverine (4), and borreverine (2) from *B. verticillata*, also reported their antimicrobial activity against *S. aureus* and several *Enterobacteriaceae* including *Pseudomonas aeruginosa* and *Vibrio cholerae*.

8. Discussion

Phenolics and flavonoids are major secondary metabolites isolated from *B. verticillata*, many of these compounds have been associated with antinemic activity. Phenylpropanoids have assessed against broad spectrum of microorganisms, their behavior towards was repelling and they were inhibitor of *M. incognita*’s motility especially the simple phenolic compounds i.e. Gallic acid (25), Caffeic acid (27), Coumaric Acid (28), Ellagic acid (24) (Qamar et al., 2005), Nguyen et al. (2015) Aoudia et al. (2012) isolated phenolic compounds from *Melia azedarach*, these compounds are gallic acid (25), protocatechun, ferulic acid, epicatechin,
p-hydroxybenzoic acid and caffeic acid (27). The antimicrobial activities of these secondary metabolites were also assessed in vitro and in vivo tests on normal and cancer cells. Some authors investigated various fractions of *Viola betonicifolia* against *M. incognita* and *M. javanica*. A novel methylated flavonoid was isolated with same other compounds i.e. Kaurene and trachyloban diterpenes from Psidium punctulata of the Compositae family. These compounds were found to exhibit significant nematicidal activities (Simmonds, 2003). The ethyl acetate fraction that is rich in flavonoids and phenolics contents, was discovered to inhibit the growth, mobility and life of *M. incognita* and *M. javanica* (Muhammad and Saed, 2011). These compounds resulted in a significant nematicidal activity (Aoudia et al., 2012). Structure-activity relationship (SAR) studies of phenolic compounds reveal that some factors such as the main chemical moiety, the arrangement and position of substituents, and the number of hydroxyl groups in addition to other substituents on the phenolic moiety ring and the esterification of the carboxyl group, all these can affect the antimicrobial activity vis-à-vis the nematicidal effect (Kakheshani et al., 2019; Dubey et al., 2013). Phenolic compounds like gallic acid (25) and ellagic acid (24) possess more free hydroxyl groups on the phenolic moiety. They have a high measure of hydroxylatation in phenol ring and highly methoxylated phenol groups with increased oxidized phenol groups. These helps the compounds to be able prevent motility, adherence and biofilm growth of gram-positive, gram-negative bacteria, fungi and protozoa i.e. Chromobacterium violaceum, Pseudomonas aeruginosa, Listeria monocytogenes, S. aureus, Streptococcus mutans (Kang et al., 2008; Borge et al., 2012; Shao et al., 2015). These compounds can mimic and simulate the antimicrobial effects of known antibiotics i.e. ampicillin, ciprofloxacin, erythromycin, gentamicin, norfloxacin, oxacillin, penicillin via synergism. The antimicrobial effect of phenolics has been copiously reported by several authors (Simmonds and Stevenson, 2001; Wu et al., 2001; Simmonds, 2003; Carlsen and Fomsgaard, 2008; Popa et al., 2008; Ntalii et al., 2009). The presence of flavonoids i.e. Quercetin (26), Ellagic acid (24) and phenolics i.e. caffeic acid (27) and coumaric acid (28) makes *B. verticillata* an effective and alternative candidate as bio-nematicides.

Alkaloids are plants secondary metabolites containing nitrogen atoms and are isolated from some plant families, amongst which these families are Solanaceae, Rubiaceae and Fabaceae. Many authors have reported and are isolated from some plant families, amongst which these families are treated against nematodes i.e. allocryptopine, chelerythrine, protopine and sanguinarine, were evaluated against nematodes *M. incognita* and *H. contortus* (Ntalii et al., 2011). Ursolic acid (24), cadinene, carophyllene (17), Stigmasterol (20), guaiene (22) and *j*-amyrin (23) are terpenes isolated and identified from *B. verticillata*. Terpenes or aromatic plant species have been renowned to possess antinemic activity, many authors have reported that nematicidal activity is one of the activity displayed by this type of plant species beside antmiocrobial effect (Ntalii et al., 2011). *Begum et al.* (2008) isolated some pentacyclic triterpenoid from the aerial parts of *Lantana camara*. They further confirmed that lantanolacnic acid, lantonic acid and pomolic acid displayed 100% mortality at 1 mg/ml concentration after a day of application and camarin, camarinin, ursolic (24) and lantacin acid exhibited 100% mortality at 1 mg/ml concentration after two days of application. The result was as the discovery of the conventional nematicide used “Furadan” (*Begum et al.*, 2008). Some authors isolated three terpenoids from *Curcisia dentata* extracts, betulinic acid Lupeol and ursolic acid (24). These compounds were evaluated on *Haemonchus contortus*, *Trichostrongylus colubriformis* and *C. elegans*. Betulinic acid and Lupeol were active only on *Trichostrongylus colubriformis* and *Haemonchus contortus* but at high concentrations (200 and 1,000 μg/mL). All three compounds were active against *C. elegans* with an LC50 of 2, 12 and 79 μg/mL, respectively (Shai et al., 2009). Iridoids are classes of organic compounds that belongs to terpenes group, their antinemic activity is reported by numerous authors (Sultana et al., 2013). Sweroside, an iridoid that is isolated from methanol extract of *Alstonia scholaris*, after the extract gave a significant antinemic activity against *M. incognito*. This compound exerts good nematicidal activity as reported by the authors (Sultana et al., 2013). This plant is interesting for further research.

8.1. Toxicity and economic impact

Abdullahi-Gero et al. (2014) showed that the oral median lethal dose (LD50) of ethanol leaf extract of *B. verticillata* was greater than 5,000 mg/kg body weight in mice and rats, while the intraperitoneal LD50 in mice was 3,807.88 mg/kg and greater than 5,000 mg/kg in rats. This means that *B. verticillata* has very low toxicity and well tolerated to rats and mice (Abdullahi-Gero et al., 2014). *B. verticillata* has a harmful effect on agricultural yield, it greatly reduces the yield. It is an important weed for major crop such root crops, sugarcane and vegetables. *B. verticillata* is a popular weed in Brazil, Trinidad, Panama, Colombia and most of the West Africa countries. This plant species affect cassava, cocoa, cowpea, rice, maize and beans (Cherigo et al., 2012; Marques et al., 2011). Mixed cropping system, cultivation, frequent grazing and mowing are effective in checking *B. verticillata*’s growth and progress in an area especially beyond the herbaceous stage and creating thick stumps which can impede the growth of other vegetation (ISSG, 2016). Many authors demonstrated the relative resistant nature of *B. verticillata* to many synthetic herbicides commonly sold. They reported that this weed show great selectivity in its response to these herbicides (Sellers and Ferrell, 2014; FLEPPC, 2016).
Some parts of B. verticillata i.e. flower, draw hence entice Larra bicolor and L. americana, these wasps are employed in Puerto Rico as a biological control tool against crickets (Scapteriscus didactylus) which are responsible for great loss of some crops i.e. turf, coffee, vegetable seedlings, sugarcane and pastures. In Brazil, studies on honey have shown that B. verticillata is the main basis of pollen forApis mellifera, Melipona subnitida, and other bee species. B. verticillata is sold as an ornamental plant (Souza et al., 2015; de Novais and Absy, 2015; Pinto et al., 2014). Campos et al. (2014) discovered that this plant species has a great tolerance for arsenic polluted land hence proposing that this plant can be useful in detoxifying land mass and areas affected by arsenic.

8.2. Future consideration and conclusion

Alkaloids, terpenes, iridoids, phenolics and flavonoids which are some of the secondary metabolites isolated from B. verticillata, have been reported to possess antinemic activity. Phytopesticides are human-friendly beside been easily accessible and bio-degradable, are therefore environmentally friendly compared to the synthetic pesticides which have adverse effects on human, animals and the ecosystem. Multiple factors have renewed interest in the source of natural products as pesticides for the pesticide industry and the market. Application of these plant extracts to nematodes will be easy because of its accessibility and easy to use, not as the chemical pesticides, costly and dangerous to health. This work is going on, on the extract of B. verticillata the on egg hatching, mortality, the immobility of second-stage juveniles (J2), root galling on the Root-Knot Nematode (Meloidogyne incognita). B. verticillata s anti-microbial activity should be utilized for agricultural purposes. Innovative and knowledge is essential for the discovery of novel nematicidal compounds, and constituents isolated from plants could play a foremost role in the discovery of leading constituents for chemical synthesis. Grasping and knowing the biochemical interaction between metabolites and compounds of B. verticillata and root-knot nematodes is vital in developing novel and environmentally friendly bio-pesticides.

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