



## Review article

A review on *Borreria verticillata*: A potential bionematicide, channeling its significant antimicrobial activity against root-knot nematodesNkechi B. Izuogu<sup>a</sup>, Oluwatoyin E. Bello<sup>a</sup>, Oluwasesan M. Bello<sup>b,\*</sup><sup>a</sup> Department of Crop Protection, University of Ilorin, Ilorin, Kwara State, Nigeria<sup>b</sup> Department of Applied Chemistry, Federal University Dutsin-Ma, Dutsin-Ma, Katsina State, Nigeria

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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 huge 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 antihelminthic effect. The review concludes on the need to extends 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 staple 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

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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 plant *Roh-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 emphasizes on its biological activity i.e. antimicrobial effects. The review asserts 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 these are the secondary metabolites responsible for the antimicrobial effects hence the proposed nematocidal ability. Its resistance ability attests 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 tetragynous. It is highly resistant hence can grow on a number of land 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 globularioides* Cham. & Schldtl, *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. & Schldtl, *Borreria oligodonta* Steyer.,

*Borreria thymocephala* Griseb, *Borreria podocephala* DC., *Borreria commutata* Spreng., *Spermacoce graminifolia* (M. Martens & Galeotti) Hemsl, *Spermacoce oligodonta* (Steyer.) Govaerts, *Spermacoce mucronata* Nees, *Spermacoce podocephala* (DC.) C. Wright, *Spermacoce polycephala* (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 rubbed topically on the skin for management of skin related ailments such as *Tinea versicolor* (eczema), *Tinea capitis* (ring worm),  *pityriasis versicolor*, skin itches, 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 leucorrhoeas and blenorreas (Peixoto 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 antidiarrheal, against hemorrhoids and erysipelas (Lorenzi and Matos, 2002). The decoction of the *B. verticillata* is prepared with *Cuscuta* and *Zebrina Schnizlein* employed in the treatment of amenorrhoea, also used against diabetes and dysmenorrhoea 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	<i>botón blanco; botoncito blanco; cardio de frade</i>	Spanish	Abdullahi-Gero et al. (2014); Andrioli et al. (2014)
France	<i>borrerie verticillée</i>	French	Andrioli et al. (2014); Campos et al. (2014)
Portugal	<i>éribun; poaia; vassourinha-de-botao</i>	Portuguese:	Burger and Taylor (1993)
Brazil	<i>coroa-de-frade; poaia miúda; poaia preta; vassourinha; poaia, coroa-defrade,</i>	Portuguese	Moreira et al. (2010); Conserva and Ferreira Júnior (2012)
Puerto Rico:	<i>juana la blanca</i>	Spanish	Chiquieri et al. (2004)
Saint Lucia:	<i>ti makonèt</i>	Creole	Andrioli et al. (2014);
Thailand:	<i>chat sam chan; ya khi kratai</i>	Thai	Campos et al. (2014)
Nigeria	<i>Karya garma</i>	Hausa	Biodiversity India, 2016; Ushie and Adamu (2010)
Nigeria	<i>Wantiyo kporou</i>	Tiv	Chiquieri et al. (2004); Ushie and Adamu (2010)
Nigeria	<i>Irawo-ile</i>	Yoruba	Ushie and Adamu (2010)
Nigeria	<i>Abia-ikana</i>	Ibibio	Chiquieri et al. (2004); Ushie and Adamu (2010);

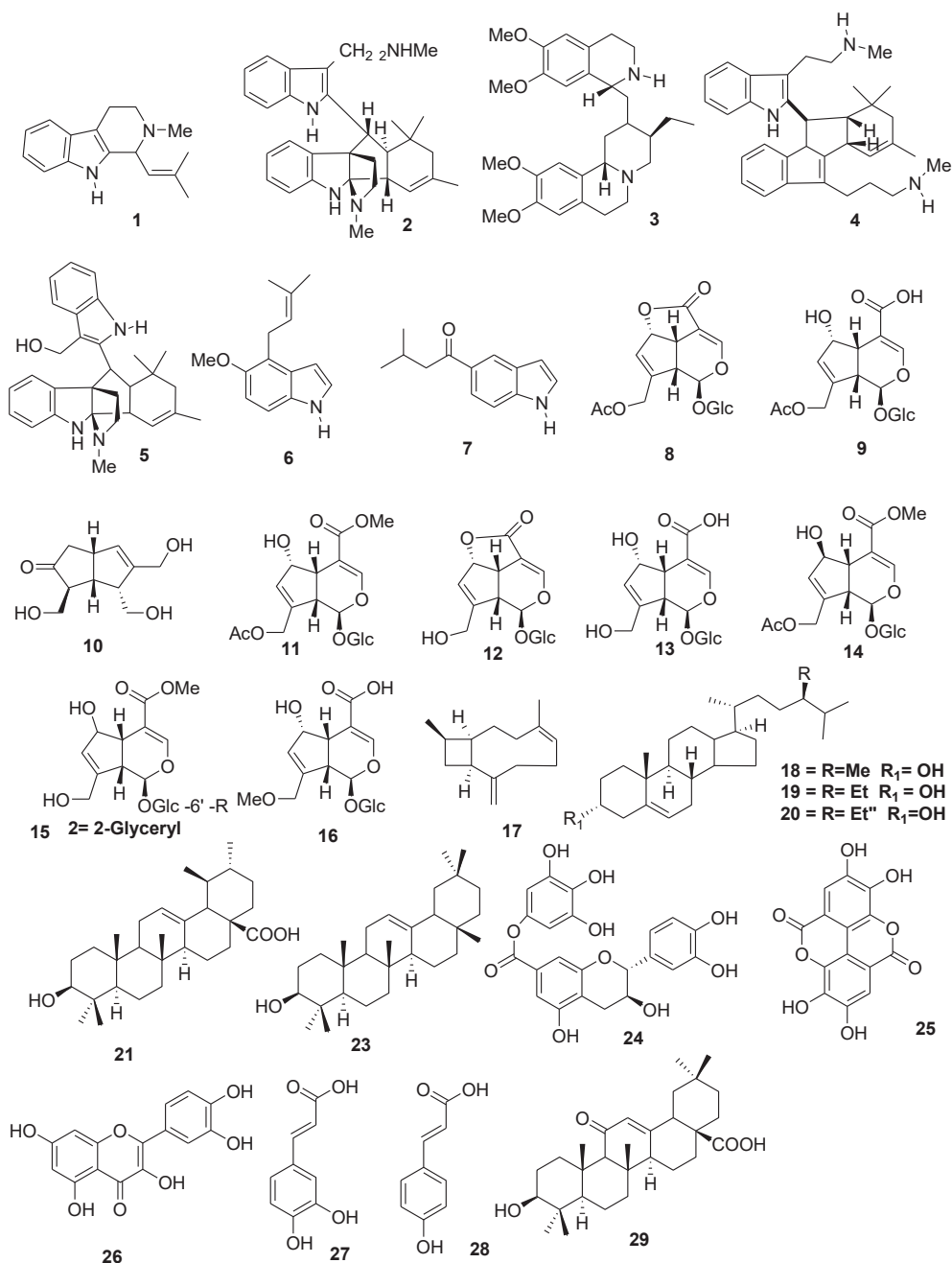


Figure 1. Isolated compounds from *B. verticillata*.

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, gonorrhoeal sores, leprosy, biharzia, furuncles, infantile hyperpnea 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 (Baldé 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- $\beta$ -carboline alkaloids, borrerine (1) and an apparent dimer, borreverine (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 borrieragenin (10), with two known iridoids asperuloside (8) and daphylloside (11). Baldé et al. (1991) isolated a new bis-indole alkaloid, spermacoceine (5) and other known three alkaloids from the aerial parts of *Borreria verticillata*. These indole alkaloids are borrerine (1), borreverine (2) and isoborreverine (4), these structures were established from spectroscopic data. Cadinene, caryophyllene (17) and guaiene (22),

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),  $\beta$ -sitosterol (19), Glycyrrhetic acid (29),  $\beta$ -amyryn (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) scandoside methyl ester (15), scandoside methyl ester (14) and asperuloside (8).

## 6. Biological activities

### 6.1. Hepatoprotective activity

The effect of aqueous leaf extracts of *B. verticillata* on CCl<sub>4</sub>-induced hepatotoxicity rats was studied. This investigation was carried out at different doses of the extract, the result showed that the test values were statistically lower compared to toxicity control at  $P < 0.05$ . The study concluded that the aqueous leaf extract of *B. verticillata* shows a significant hepatocurative properties of on CCl<sub>4</sub>-induced hepatotoxicity in rats (Murtala et al., 2015).

### 6.2. Antinociceptive activity

Both alcoholic and ethyl acetate fractions of *B. verticillata* were evaluated for antinociceptive activity employing *in silico* 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 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 (Moodie-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. Antilarvacidal activity

The antilarvacidal 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*, *Candidas albican*, *Streptococcus pneumoniae*, *Mycobacterium fortuitum*, *Gardnerella vaginalis* and weak against *Streptococcus viridans*. Furthermore, crude fraction of the alkaloids displayed the highest cytotoxicity (6–25  $\mu$ g/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 antidermatophytic and antitumor resistant pathogens by some authors. The extracts were tested 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*, *Microsporium 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 borrerine (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 cholera*.

## 8. Discussion

Phenolics and flavonoids are major secondary metabolites isolated from *B. verticillata*, many of these compounds have been associated with antineoplastic activity. Phenylpropanoids have assessed against broad spectrum of microorganism, 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. (2013) Aoudia et al. (2012) isolated phenolic compounds from *Melia azedarach*, these compounds are gallic acid (25), protocatechin, ferulic acid, epicatechin,

p-hydroxybenzoic acid and caffeic acid (27). The antinematic activities of these secondary metabolites were also assessed in *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 *Psidia punctulata* of the Compositae family. These compounds were found to exhibit significant nematocidal 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 Saeed, 2011). These compounds resulted in a significant significant nematocidal 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 nematocidal effect (Kahkeshani 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 hydroxylation 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; Borges 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 antinematic 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; Ntalli 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 Solacaneae, Rubiaceae and Fabaceae. Many authors have reported the nematocidal activity of alkaloids (Rao et al., 1996; Chitwood, 2002; Ntalli and Caboni, 2012; Kahkeshani et al., 2019). Four isoquinoline were isolated from the crude extracts of the aerial parts of *Macleaya cordata*, this plant has been a source for alkaloids. These compounds i.e. allocryptopine, chelerythrine, protopine and sanguinarine, were evaluated against nematodes i.e. *Bursaphelenchus xylophilus*, *Caenorhabditis elegans* and *M. incognita*. Three of these alkaloids (allocryptopine, chelerythrine and sanguinarine) exerts significant nematocidal activity with a median lethal concentration (LC50) values as 37.45, 28.52 and 34.50 µg/ml, respectively against *B. xylophilus*; 38.90, 22.78 and 40.25 µg/ml against *C. elegans* and 76.56, 67.52 and 61.00 µg/ml against *M. incognita* (Wang et al., 2012). Wen et al. (2013) reported a bioguided assay column chromatography was carried out to identify compounds in *Cephalotaxus fortune* twigs and leaves with nematocidal activity. The isolated compound called drupacine and the crude alkaloid extract suppress the plant-parasitic nematode hatch, activity of mixed life stages, and population numbers on plant roots. The roots of *Waltheria indica* exhibited strong nematocidal activity against *Meloidogyne incognita* hence study was carried out to characterized the constituents responsible for this significant activity (Jang et al., 2019). Three alkaloid compounds, they are 4-quinolone alkaloids i.e. waltherione A, waltherione C and 5'-methoxywaltherione A., were ecofriendly and exhibited good nematocidal activity. Alkaloids contained in plants have been noticed to affect the multiplication of plant-parasitic nematodes and the plants have been confirmed by many authors as nematocidal plants (Perrett and Whitfield, 1995; Kusano et al., 2000; Srivastava et al., 2000; Matsushashi et al., 2002; Sobkowiak et al., 2011). A common plant in West Africa countries *Tithonia diversifolia* (Hemsl.) A. Gray is very rich in alkaloids. Authors

have assessed its crude alkaloid fraction and they discovered that it suppresses egg hatching of *M. incognita* by 98 % from the second day after the necessary incubation and displayed 100 % inhibitory effect after 9 days. *Tithonia* extracts' treatment at the rate of 30 tons/ha on yam (*Dioscorea rotundata*) in the greenhouse experiments significantly curbed the growth of *M. incognita* (5,000 eggs/plant) reproduction, number of eggs, and juveniles, as well as root gall index (Odeyemi and Adewale, 2011). Hence, *B. verticillata* could display a significant antinematic activity since it is alkaloid containing plant.

Terpenes are structurally made when different isoprene units (5-carbon-base; C5) coupled together, they may have oxygen or not i.e. terpenoids and terpenes. The main classes of terpenoid are diterpenes (C20), hemiterpenes (C5), monoterpenes (C10), sesquiterpenes (C15), tetraterpenes (C40), triterpenes (C30). Essential oils are heterogenous mixtures of both terpenes and terpenoids in addition to other aromatic and straight chain constituents. They are mostly found in aromatic plants. Terpenes displayed several biological activities through synergistic and antagonistic ways (Aharoni et al., 2005; Ntalli and Caboni, 2012). Ursolic acid (24), cadinene, caryophyllene (17), Stigmasterol (20), guaiane (22) and β-amyrin (23) are terpenes isolated and identified from *B. verticillata*. Terpenes or aromatic plant species have been renowned to possess antinematic activity, many authors have reported that nematocidal activity is one of the activity displayed by this type of plant species beside antimicrobial effect (Ntalli et al., 2011). Begum et al. (2008) isolated some pentacyclic triterpenoids from the aerial parts of *Lantana camara*. They further confirmed that lantanolic acid, lantoic 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 nematocidal used "Furdan" (Begum et al., 2008). Some authors isolated three terpenoids from *Curtisia 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 groups, their antinematic activity is reported by numerous authors (Sultana et al., 2013). Sweroside, an iridoid was isolated from methanol extract of *Alstonia scholaris*, after the extract gave a significant antinematic activity against *M. incognita*. This compound exerts good nematocidal 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 (LD<sub>50</sub>) of ethanol leaf extract of *B. verticillata* was greater than 5,000 mg/kg body weight in mice and rats, while the intraperitoneal LD<sub>50</sub> 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, Columbia 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 impend 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 for *Apis mellifera*, *Melimpona subnitida*, and other bee species. *B. verticillata* is sold as an ornament 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 property. Phytopesticides are human-friendly beside been easily accessible and bio-degradable, are therefore environmentally friendly compared to the synthetic pesticides which huge 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 plant species is widely distributed globally, is mostly regarded as weed. Work is going on, on the extract of *B. verticillata* on the on egg hatching, mortality, the immobility of second-stage juveniles (J2s), root galling on the Root-Knot Nematode (*Meloidogyne incognita*). *B. verticillata*'s antimicrobial activity should be utilized for agricultural purposes. Innovative and knowledge is essential for the discovery of novel nematocidal 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 environmental friendly bio-pesticides.

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