PESTICIDAL PROPERTIES OF ESSENTIAL OILS OF *LANTANA CAMARA* L.

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Abstract

***Lantana camara* Linn. (Verbenaceae) is an aromatic herb, commonly known as lantana or wild sage. It is expansively found in tropical Africa growing in the wild and planted around compounds as fences for demarcation due to its low herbivore pressure. *L. camara* is known in folkloric medicine and used as a remedy against many ailments. Therefore, its medicinal properties are studied widely. However, its biopesticidal properties neglected. Though, lately, *L. camara* essential oils (EOs) have gained much interest from a multidisciplinary assembly of researchers, looking into their secondary metabolites, biological activities and potential application in agriculture. The high interest in EOs as biopesticides has gained much acceptance globally due to its natural base compared to synthetic pesticides. This review aims to highlight some insights into the existing evidence-based applications of *L. camara* as validated by modern research. Several researchers have evaluated the chemical composition of *L. camara* EOs (leaves, flowers, and berries). The major constituents identified are monoterpenes and sesquiterpenes. The biological properties attributed to *L. camara* are insecticidal, antibacterial, antifungal, nematicidal, acaricidal, and fumigant activity against a wide range of agricultural and domestic pests and diseases. Evidence suggests that it is comparable to synthetic pesticide, and it is economically viable. This weed demonstrates the ability to become a cheaply harnessed biopesticide for pest management. Thereby improving agricultural productivity and as a source of revenue for resource-poor farmers. Applications of *L. camara* EOs through in-depth scientific studies to authenticate its properties are required to position L. camara plant as a new generation crop, for the development of value-added biopesticides.**

Keywords: *bio-insecticide, new generation crop; potential; secondary metabolites; Value addition.*

Introduction

Historically, plants continue with the selection for the development of biopesticides and are utilized in plant pests and disease management. A good number of pesticidal plants are undergoing research (Stevenson *et al*., 2017; Tembo *et al*., 2018) as neem, pyrethrum, tephrosia and others. Numerous plants possess interesting biological properties (Isman, 2017). The occurrence of different phytochemicals in different plant parts validates the ability of the plant to provide a source of natural biopesticide. Understanding of the plants offers the potential of developing effective broad-spectrum biopesticides, representing an alternative to synthetic pesticides. Therefore, there is a great need to continually search for plants with pesticidal potentials, especially among the lesser-known plants, among which is *L. camara.*

Lantana camara (Verbenaceae) is one plant with great potential as a biopesticide due to the many biological properties attributed to its essential oil (EO). Though *L. camara* has been on the limelight as an invasive weed; it has a lot of hidden potentials. The control of *L. camara* has been the focus of many scientists for centuries, and it is still problematic. For example, Bhagwat *et al*. (2012) reviewed the effectiveness of controlling *L. camara* and pointed out a complete lack of success. For that reason, Willis (2017) suggested that the control of *L. camara* needs thinking out to make it possible. Hence, the need to adopt a different adaptive management model such as weed management by utilization. One new strategy to optimize its usefulness is by exploring its pesticidal potential.

The excessive use of synthetic pesticides has increased the risk of pesticide resistance, pest resurgence and resistance development, environmental pollution and toxicological implications to human and animal health. Therefore, efforts geared toward replacing synthetic pesticides with environmentally benign alternatives. Moreover, using natural plant products, including the essential oils, holds a good promise in the control of pests and diseases. Among essential oils, Lantana oil, in particular, is useful because it possesses a broad spectrum of desirable properties worth exploiting for pest and disease management (Kaur *et al*., 2017; Murugesan *et al*., 2016; Singh and Srivastava, 2012).

The essential oils of *L. camara* contain active compounds (Javier *et al*., 2017; Murugesan *et al*., 2016; Yuan and Hu, 2012), which are promising sources for a new biopesticide. It contains many secondary metabolites (SMs) including monoterpenoids, sesquiterpenoids, triterpenes, iridoid glycoside, flavonoids, alkaloids and phenolic compounds (Adjou *et al*., 2012; Yadav *et al*., 2014). Recent studies have established that *L. camara* oils have the potential for use as an insecticidal (Murugesan *et al*., 2016), antibacterial (Anjum *et al*., 2017; Md. Firose *et al*., 2018), antifungal (Sarpong, 2016; Sreeramulu *et al*., 2017), acaricidal (Kaur *et al*., 2017), nematicidal (Ghimire, 2015) among other properties as an alternative to synthetic pesticide.

Despite being a plant of potential medicinal interest, there are very few reports that document the biological properties of this plant scientifically. Also, no significant biotechnological advances have been made in this genus to exploit or enhance its utility at subsistence and commercial levels. Therefore, our objective in the present context is to review its use as a natural biopesticide and its potential to encourage research in the development of new affordable oil-based biopesticide for pest management.

Taxonomy of *Lantana camara*

Lantana camara Linn. species (Figure 1: Lantana camara Plant) belongs to the family Verbenaceae within the order *Lamiales* and genus *Lantana* (Gisin, 2019). Historically, the taxonomy of the genus *Lantana* has been very complicated, and this hinders their identification in the field (Passos *et al*., 2009; Urban *et al*., 2011). Innumerable taxonomic problems reported and frequently classified incorrectly (Passos *et al*., 2009). Based on floral and carpological features, *Lantana* genus has four sections: *Camara, Calliorheas, Rhytocamara* and *Sarcolippia* (Sousa *et al*., 2018). The *Lantana* complex in Camara section includes the weedy lantana referred to as *L. camara* Linn. (*Sensu lato*). *Lantana* sect. *Calliorheas* is often confused with *L. camara,* though *Calliorheas* have ovate to reniform imbricate floral bracts and purplish corollas (Sanders, 2006), sometimes fruits are needed to ensure correct sectional placement.

Lantana camara is a highly variable species, with high genetic diversity (Goyal & Sharma, 2015; Maschinski *et al*., 2010; Sanders, 2006; Scott *et al*., 1997). The widespread hybridization, the changes in the shape of the inflorescence with age, and the colour variation of the flowers with age and maturity complicate the taxonomic identification of the species in the complex (Ghisalberti, 2000; Goyal & Sharma, 2015; Sanders, 2006; Sousa *et al*., 2018). Sanders, (2006) acknowledge that lantana that grows in the wild differ morphologically, karyologically, physiologically and ecologically from those prized for their horticultural value, multicoloured flowers. Therefore, weedy, naturalized and invasive complex constituents, broadly referred to as *L. camara* L. (sensu lato) merit a deliberate taxonomic delineation (Sanders, 2006).

Lantana complex constituents can be distinguished morphologically (flower size, shape and colour; leaf size, hairiness and colour; stem thorniness; height and branch architecture), physiologically (growth rates, toxicity to livestock) and by their chromosome number and DNA content (Scott *et al*., 1997). Leaf anatomical characteristics (Passos *et al*., 2009) and detailed chemical profiling of foliar chemical constituents (Sena Filho *et al*., 2012) used as valuable markers for supporting species identification. However, natural variation and the disputed limits of *L. camara* complicate identification, classification and disentanglement of the complex constituents (Goyal & Sharma, 2015). A detailed study of the complex constituents will offer opportunities to answer critical questions about plant invasions.

Figure 1: *Lantana camara Plant*

Ecology and morphology of *Lantana camara*

Lantana, as is commonly known in Africa, is native to tropical and subtropical America and has been dispersed throughout the world. The genus *Lantana camara* L. is a widely distributed aromatic plant throughout the world because of its different tolerance to different soil types and ecological zones (Aruna & Balasubramanian, 2015).

Lantana in Kenya is naturalized, and the distribution is still increasing, with it infesting most parts of the country apart from the north and north-east parts of Kenya, which are unsuitable areas for their growth due to low rainfall (Shackleton *et al.*, 2017). Human activities, such as logging facilitate the spread of lantana, and other forms of habitat disturbances and climate change exacerbate the invasion (Mungi *et al.*, 2018; Niinemets, 2015; Zhang *et al.*, 2014). Lantana has many traits that make it a good invader, including all-year flowering and fruit production, under adequate moisture and light; adaptation to long-range dispersal by birds and other mammals; high establishment rates; the ability to coppice; poisonous leaves; high phenotypic plasticity; the ability to hybridise; vegetative reproduction; and allelopathy (Priyanka & Joshi, 2013; Shackleton *et al*., 2017). It occurs in diverse habitats ranging from wastelands, rainforest edges, and disturbed forests (Day *et al*., 2003), roadsides, urban and rural homesteads, and other disturbed sites (Enloe *et al*., 2018).

The plant grows luxuriantly at altitudes from the sea level to 1800 m.a.s.l and thrive very well under precipitation ranging from 750 to 5000 mm per annum. It has a unique ability to adapt to different kinds of soils (rich as well as poor soils, gravel and laterite). It does well under optimal temperatures but very susceptible to low temperatures and frosts. It is drought-resistant and light-loving but cannot tolerate shades; therefore, it does not survive in dense forests (Negi *et al*., 2019). This broad adaptation ability to different kinds of conditions (climate and soils) has made the plant to disperse widely and adapt differently to their environment.

The morphology of lantana is very distinct in different regions of its naturalized range compared to the native range (Goyal & Sharma, 2015; Sanders, 2006). However, *Lantana camara* is a perennial, multi-stemmed, deciduous, thorny shrub growing to an average height of about 2m. The leaves are ovate and oppositely arranged. They are bright green on the upper surface and hairy and pale green below, and leaf blades are serrated (Figure 2a). It feels like fine sandpaper (Sankaran, 2013). Flower heads have many smaller flowers. Each flower is tubular-shaped and has four spreading lobes (petals), changing colour with age (Figure 2b). The colours would be of various combinations of white, yellow, orange, red or pink. A robust aromatic smell characterizes the leaves and flowers. The fruit is tiny, one-seeded berry about 6–8 mm. It looks green when young and unripe and shiny black or purple when fully ripe (Figure 2c). The stems have bristly hairs when green (Rana *et al*., 2019), and often armed with small prickles (Enloe *et al*., 2018) (Figure 2d). The root system is shallow with a short taproot and lateral roots branching out to form a mat (Sankaran, 2013) (Figure 2e).

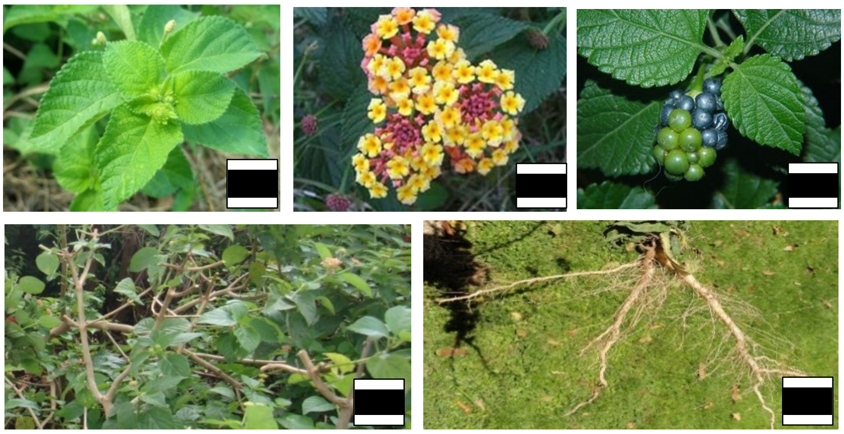

Figure 2*: Morphology of L. camara Linn. a) Leaves, b) Flowers, c) Berries (Ripe and unripe), d) Stem, e) Root system*

Chemical composition of the essential oils of *Lantana camara*

Essential oils are extracted from aromatic plants and are complex mixtures of natural organic compounds which are predominantly composed of terpenes (hydrocarbons), terpenoids (oxygen-containing hydrocarbons), aromatic phenols, monocyclic ketones and esters among others (Koul *et al.*, 2008). *Lantana camara* plant synthesizes biologically active compounds making it an essential resource for the production of essential oils. Non-woody parts of the lantana plant produce the oils, particularly the leaves, through steam or hydro-distillation. The oil gives a pale yellow colour and a viscous consistency. It comprises some metabolites in high quantities but varies with geographical location, seasons and the developmental stage of the plant (Javier *et al.*, 2017; Murugesan *et al.*, 2016; Zoubiri & Baaliouamer, 2012).

Due to the medicinal properties exhibited by these species, a large number of studies have had the goal to identify and isolate their volatile and non-volatile chemical constituents. It is an excellent source of several classes of bioactive compounds, the principle components being terpenes (monoterpenes and sesquiterpenes) and their oxygenated derivatives (Anjum *et al*., 2017; Patil *et al*., 2017; Begum *et al*., 2015; Patil *et al*., 2015). Cited among the common major constituents identified are the sesquiterpenes, α and ß-caryophyllene, isocaryophillene, germacrene D, bicyclogermacrene, caryophyllene oxide and caryophyllene epoxide, (Sena Filho *et al*. 2010). These oils reveal the high complexity of the plant and may explain most of its properties. For example, Lantadenes that are present in Lantana essential oils are believed to be responsible for almost all the biological activities, such as antipyretic, antimicrobial, antimutagenic, antimicrobial, fungicidal, insecticidal, nematicidal among others (Barre *et al*., 1997; Negi *et al*., 2019). Secondary metabolites such as alkaloids, terpenoids, phenolics, iridoid glycosides, flavonoids, glycosides and miscellaneous compounds are also responsible for some of the biological activities (Barre *et al*., 1997). Besides, Lantanoside, linaroside and camarinic acid isolated from Lantana are potential nematocides (Day *et al*., 2003). Still, constituents like 1, 8-cineole, sabinene, and caryophyllene and other minor constituents including E-nerolidol, bicyclogermacrene, and pinene are also believed to be responsible for the biological activities of Lantana (Chowdhury *et al.*, 2007). Further, Murugesan *et al*., (2016) isolated Caryophyllene II oxide and Aromadendrene II oxide from lantana oil and found out that they have insecticidal activity, while (Chegini *et al*., 2018) confirmed that pure α-pinene had moderated toxicity effect on pests.

The presence of numerous toxic compounds in Lantana makes it an important species to study its phytochemistry. Several researchers have worked with the lantana oil for control of pests and diseases with positive results. However, scanty information is available on the isolation of individual components found in lantana oil, although many researchers believe that these compounds work in a synergistic effect rather than as an individual. In this sense, major biological activities of isolated constituents from lantana essential oil can be established through advanced research.

***Lantana camara* essential oils as a pesticide**

Lantana camara consists of volatile oil with desirable properties making it an excellent source of commercially essential oil that can find extensive use in agrochemical (Kaur *et al*., 2017; Murugesan *et al*., 2016) and pharmaceutical industry (Delgado-Altamirano *et al., 2019)*. The essential oil from *L.* camara can be among the world's top traded oils because of its abundance in a wide range of climatic regions (Day *et al*., 2003). Moreover, it has the advantage of having multipurpose usage in both agriculture and pharmaceutical industries. It also has the potential of being rated as superior in quality if the extraction process and propagation are standardized.

In recent history, the essential oils of *L. camara* were extensively undergoing research and reported to have insecticidal, antibacterial, antifungal, nematicidal, acaricidal and fumigant activity (Figure 3) against a wide range of pests and diseases (Murugesan *et al*., 2016; Rajashekar *et al*., 2012).

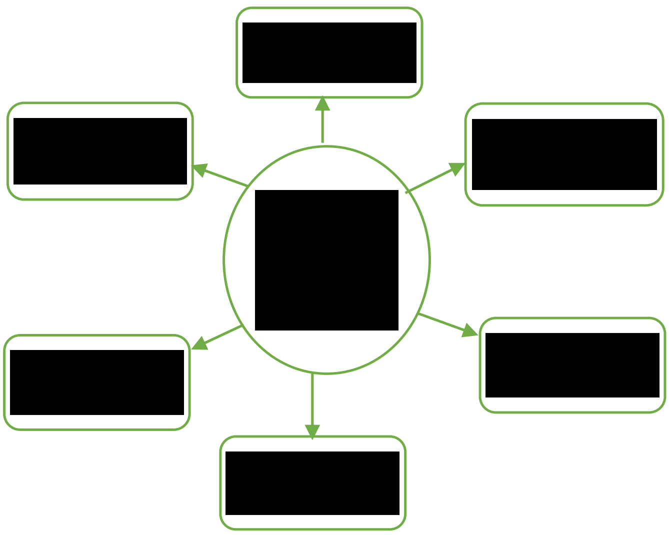

Figure 3: Pesticidal properties of *Lantana camara* Linn.

To date, there is a disproportion of research concerning the use of lantana oil as a biopesticide. Many constituents have been found toxic to many agricultural pests. Interestingly no further work is undertaken beyond the laboratory. The toxic compounds derived from the essential oil can be an alternative approach to their synthetic pesticide with additional benefits; they are readily biodegradable, have minimal side effects on non-target organisms and are varying mixtures of biosynthetically different compounds, efficient in preventing the evolution of resistance (Pavela & Benelli, 2017).

As a biopesticide, lantana oil can provide sustained control of pests and diseases with a broader effect in mesocosms and temporary pool, if only the advantages stated are taken seriously and new biopesticides produced from the oil.

Insecticidal activity of *Lantana camara*

The insecticidal activities of *L. camara* essential oils have been evaluated and reported. The oil exhibited significant insecticidal activity against several pests such as *Hyblaea puera* and *Ahevidae fabriciella* (Murugesan *et al*., 2016). In other studies, the EO of *Lantana camara* showed insecticidal properties against third instar larvae of *Helicoverpa armigera*, causing 56% inhibition. Kathuria and Kaushik (2006) and Kasmara *et al*. (2018) also found out that lantana can be used effectively in the control of *Spodoptera litura*. Although a lot has been done on the laboratory bioassay with promising results, so far only one product has been isolated and patented as a modern biopesticide "Tree PAL^{H}" (Murugesan *et al*., 2016) for the control of the nursery forest tree defoliators in India.

The essential oils comprise rapid neurotoxicity in insect pests due to the interference with the neuromodulator octopamine, acetylcholinesterase, GABA-gated chloride channels, and inner cell membranes (Noutcha, Edwin-Wosu, Ogali, & Okiwelu, 2016; Ntalli, Koliopoulos, Giatropoulos, & Menkissoglu-Spiroudi, 2019). Additionally, they may disrupt the cell wall and cytoplasmic membrane leading to lysis and leakage of intracellular compounds or uptake of inorganic phosphate and leakage of K^+ (Pavela & Benelli, 2017).

Through the documented evidence of the effectiveness of this weed, we consider preferentially this plant might have some useful influences in the field of agriculture in terms of the development of novel bioinsecticides. However, further toxicity studies are needed to validate this plant as a new generation crop for the development of new bioinsecticides for pest management.

Antibacterial activity of *Lantana camara*

The antibacterial activity of *Lantana camara* against human and plant pathogens has been on the forefront. Research has shown that it can be used on several pathogens such as gram-positive and gram-negative bacteria (Anjum *et al*., 2017), *P. vulgaris* and *V. cholera* (Passos *et al*., 2012). Drawing from this inspiration Alemu *et al*., (2014) tested the extracts of lantana and concluded that, it can be used for the control of bacterial wilt (*Ralstonia solanaceanum*) as an antibacterial. Additionally, a significant result was found for methanol and ethanol extract of *Lantana camara* regarding the growth inhibition of *Pseudomonas caricapapayae* causing the Bacterial leaf spot of papaya (Md. Firose *et al*., 2018). Such findings are helpful to biologically control the bacterial plant pathogens.

Information regarding the use of *Lantana camara* as an antibacterial on the control of plant diseases is scanty. However, no research has been done using the essential oils from *L. camara* in the control of plant bacterial diseases. Furthermore, isolation of individual compounds that are attributed to the antifungal properties is not definite. This information opens new avenues for future research and serves as a source of hypotheses for further research on *Lantana camara* essential oil as a potential antibacterial biopesticide for the control of bacterial diseases in plants.

Antifungal activity of *Lantana camara*

The essential oils of *Lantana camara* have been used in folkloric to treat several antifungal pathogens, particularly for human. Though Passos *et al*. (2012) tested the oil in his study and demonstrated that the oils have some fungicidal properties against *Corynespora cassiicola*, he suggested that more research work be undertaken to investigate the significant components of the oil against plant pathogenic fungi. Singh and Srivastava (2012) found the antifungal activities of ethanolic and acetonic extract of *Lantana camara* to be significantly active against phytopathogenic *Alternaria alternata* that was isolated from potato (*Solanum tuberosum*) and tomato (*Lycopersicon esculentum*). Likewise, Sarpong, (2016) tested the crude extracts of *Lantana camara* against *phytophthora nocotianae* and found out that it exhibited high inhibition of the mycelial growth and therefore, it can be utilized as a fungicide in the control of phytophthora rot in pineapples. Recently, Sreeramulu *et al*. (2017) tested the leaf extracts against the pathogenic *Colletotrichum falcatum* and concluded that the extracts can be utilized as a fungicide for the control of red rot disease.

The shreds of evidence presented by researchers' are indicative that *Lantana camara* essential oil has antifungal properties. Therefore, the oil can be utilized as a sustainable alternative to synthetic fungicides, although more work is needed to understand the significant compounds responsible for the fungicidal activity.

Nematicidal activity of *Lantana camara*

The nematicidal and nematostatic activities of *L. camara* against various species of root-knot nematodes have been evaluated *in vitro* and *in vivo* experiments (Ahmad *et al*., 2010; Ghimire, 2015). Studies have shown that the use of lantana extracts inhibit plant-parasitic nematodes. Ahmad *et al*. (2010) found out that, *L. camara* extracts have nematicidal properties against root-knot nematode (*Solanum melongena).* Recently, Ghimire, (2015), in his research, using aqueous extracts of *L. camara,* reported that the extract was very effective in immobilizing the *Meloidogyne* juveniles.

So far, all the work undertaken has focussed on the use of crude extracts. Therefore, experiential research is needed using the essential oil, since it presents itself as a potentially sustainable solution for the control of nematodes.

Acaricidal activity of *Lantana camara*

Control of tick (*Rhipicephalus Microplus*) infestations has primarily been through the application of different synthetic acaricides. Plant oils and extracts represent an affordable and easily accessible alternative method for controlling ticks. *L. camara* is such one plant that has been used traditionally in the control of ticks. Although to date, no product has been released from this plant, it continues to be used traditionally. Several researchers have conducted studies on the efficacy of *Lantana camara* plant extracts and essential oil against ticks. For instance, Adehan *et al*. (2016) tested both the extract and the oil for their acaricidal activity and found that both have the same effect. Likewise, Kaur *et al*. (2017) recently tested the leaf extracts of *L. camara* and demonstrated that it possesses anti-tick activity with a higher concentration of extracts proving more effective. Therefore, the oil can be utilized in small quantities as an anti-tick agent. Providing a new approach to the development of natural acaricides to be used both in biological and integrated pest management strategies as an alternative to synthetic acaricides for controlling ticks.

Fumigant activity of *Lantana camara*

Biofumigants is a potential alternative to chemical fumigants against stored grain insect pests (Rajashekar *et al*., 2014).

Essential oils and their constituents in relation to fumigant actions demonstrated very well against stored product pests. For example, The EO of *L. camara* showed fumigant toxicity to *C. maculatus* adults (Nooshin *et al*., 2012). At the lowest concentration, the EO caused 63.2% and 55.4% mortality after 24 h in males and females, respectively. These results corroborate to those of Zoubiri and Baaliouamer (2012), who showed mortality of *Sitophilus granarius* adults on exposure to the *L. camara* essential oils for 96 hours for oils obtained in different months of the year.

Recently, Gotyal *et al*. (2016) tested the essential oil of *L. camara* against Almond Moth (*Cadra cautella*). They reported that the larval stage was more susceptible as compared to eggs and adult stage. This study revealed that the use of *L. camara* essential oil could be utilized for sustainable management of *C. cautella.* Coumaran has been reported to be a potent biofumigant isolated from leaves of *L. camara* (Rajashekar *et al*., 2014).

L. camara essential oil can be utilized as a biofumigant for the control of storage pests presented by many researchers'. Therefore, more research is called for to validate this claim and product development be encouraged.

Toxicological and commercialization concerns of Lantana biopesticide

Although substantial progress has been made in biopesticide research for integrated pest and disease management, as mentioned in this review, many technical and scientific challenges that prevent the application of these technologies in crop protection programs remain. First, the horticultural industry pays more significant consideration to improved safety of products and environmental protection. To achieve these goals and remain competitive, strict regulations involved in the introduction/commercialization of a product needs the introduction of new legislation and guidelines that facilitate the registration of biopesticides (Czaja *et al*., 2015; Damalas & Koutroubas, 2018). Including toxicological evaluations against non-target organisms, product quality variation and regulatory approvals (Isman, 2017; Pavela and Benelli, 2017; Stevenson *et al*., 2017)

Concerning the toxicity of *L. camara* oils, not much is known. Though *L. camara* oils possess a wide-ranging biological activity, efforts to commercialize it as insecticides/repellent products are meagre. For example, only one product of agricultural importance from *L. camara* essential oil has so far produced, the Tree PAL. Tree PAL contains a mixture of neem oil, pungam oil, and the isolated Caryophyllene II Oxide, and Aromadendrene II Oxide (0.1mg) from *Lantana camara* essential oil (Murugesan *et al*., 2016) as the active ingredients.

The lesser number of commercialized products based on Lantana oil is not different from other plant-based oil biopesticides despite the enormous scope and market for natural pesticides. This is mainly due to the strict regulations involved in the introduction/commercialization of a product (Pavela & Benelli, 2017; Stevenson et al., 2017). Further, the issues of quality is a significant problem and limits the potential of essential oil-based biopesticides because the quality of the essential oils varies with season, climate, age, geographical region, genetic makeup of the plant (Moustafa *et al*., 2016; Ncube and Van Staden, 2015; Swagatika and Smaranika., 2017), method of extraction and formulation. This also applies to *L. camara* plants as a raw material. Furthermore, the essential oils volatilize quickly and have shorter persistence in the environment, unlike synthetic pesticides (Isman, 2017; Pavela and Benelli, 2017; Stevenson *et al*., 2017). Therefore, it needs regular reapplication for the desired results to be achieved. Additionally, awareness about efficacy, mode of action and cost is lacking about biopesticides to many farmers.

Nonetheless, the use of essential oil as a biopesticide is vital to reduce insect pest resistance and resurgence development against synthetic pesticides. Therefore, they can be used for pest and disease management. More so, resource-poor farmers will benefit a lot from these natural pesticides by reducing the production cost, as shown by (Tembo *et al*., 2018) in their research work which highlights the use of pesticidal plants at field level reduced input costs. The use of the pesticidal plant is of beneficial for smallholder farmers in the sense that it is environmentally friendly and reduced the risks of health problems associated with synthetic pesticides. Furthermore, this can be a source of additional income through lantana cultivation for the production of raw material for the processing of the essential oils.

Conclusion

L. camara is a multi-purpose shrub with the vast number of uses. It is clear that *Lantana camara* essential oils possess a broad spectrum of biological activity against fungi, bacteria, insects, ticks, and nematodes and provides simple, affordable management alternative. Moreover, it is an environment-friendly alternative pest control. Quite a lot has been done on the exploration of its chemistry. However, the effects on non-target organisms including natural predators/enemies, pollinators, and honeybees, have not been evaluated. Further experiments are therefore needed to evaluate its economic, health and environmental benefits under field conditions.

This review paper has revealed a wide variety of biological properties of *L. camara* and attempted to elucidate why *L. camara* tick as a pesticidal plant. *L. camara* is, therefore, a good starting point for a search for phytomedicines of pesticidal and veterinary nature. Scientific reports about the medicinal properties of *L. camara* represent it as a valuable plant to be established as a candidate for the future bio-pesticide development with a broad-spectrum activity. Most of the scientific knowledge on pesticidal properties of *L. camara* has not been translated into practice. Therefore, providing an avenue for additional research and serving as a source of hypotheses for further research work on bioprospecting of *L. camara* essential oils as a prospective biopesticide in the agricultural field and beyond.

Thus, we consider that preferentially this plant might have some useful influences in two fields; medicine and agriculture. However, further toxicity studies are needed for dose adjustment, isolation and structure clarification of bioactive compounds responsible for the observed toxicity in order to establish the scientific validity of these significant properties to ascertain with confidence if *L. camara* is a marvel plant for modern science.

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Conflict of Interest

We, authors, declare that we have no conflict of interest.

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