Journal of Ethnopharmacology xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jep

Review

The use of *Clausena anisata* in insect pest control in Africa: A review

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A R T I C L E I N F O

Keywords:
Pest management
Botanical pesticide
Clausena anisata
Rutaceae

A B S T R A C T

Ethnopharmacological relevance: *Clausena anisata* is used traditionally by various communities across Africa against pests such as mosquitoes, flies and weevils among others. Pests are a major cause of disease and production losses in various crop and livestock production systems in Africa. This review discusses the available information on the occurrence, chemistry, biological activity and possible commercialization of *Clausena anisata* with a view to see the plant species being integrated in pest management.

Materials and methods: Information on the ethnomedical use, chemistry and biological activity of *C. anisata* published between 1980 and 2016 was accessed from various databases namely Science Direct, Springer Link and Wiley Online Library. In addition various relevant books were also consulted.

Results: The crude extracts as well as different fractions of *C. anisata* have been evaluated for activity against various insect pests and have been shown to be active. Furthermore, close to 50 compounds have been isolated and identified from *C. anisata,* which include coumarins, carbazole alkaloids, limonoids and essential oils (monoterpenes). Some of these compounds have been proven to exhibit pesticidal properties in both laboratory and field studies against various pests including mosquitoes, flies and weevils. The possible mechanisms of action of these compounds have been explored in this review.

Conclusion: The results of pesticidal and phytochemical screening of *C. anisata* strongly indicate that the species is endowed with pesticidal properties that can be harnessed into commercial products. However, one glaring challenge in the evaluation of this plant species for pesticidal activity has been the non-availability of standard testing systems. Researchers have used various methods which they developed based on their own circumstances and resources. Formulation, standard appropriate testing systems and agronomic research are key in unlocking the potential of this important African species.

1. Introduction

A pest is any living organism which is invasive or prolific, troublesome, noxious, destructive and detrimental to animals, humans or human activities such as crop or livestock production (Oerke, 2006). Pests often occur in large numbers, making the damage they cause even more detrimental (Maxmen, 2013). The most economically important pests are insects, mites, nematodes and gastropods. Pests are a major cause of disease and production losses in various crop and livestock production systems, frequently causing significant economic losses (McDermott and Coleman, 2001; Oerke, 2006; Smith, 2015).

Globally, arthropods (which include insects) destroy an estimated 18–26% of annual crop production, at a value of more than $470 billion (Culliney, 2014). Previously, Pimentel (2009) estimated crop loss from insect pests to be around $280 billion, contributing 14% to total crop losses. Thus, the losses to insect pests seem to be on the increase. Losses in the livestock production sector resulting from diseases transmitted by pests are equally huge. For example, trypanosomosis which is transmitted by the tsetse fly accounts for an annual loss of close to US $5 billion in Sub-Saharan Africa alone, resulting from livestock mortality, reduced fertility, decreased milk yields, an inability of traction animals to work and the expenditure on controlling the disease (Shaw et al., 2014). Another major disease is rift valley fever (RVF), a mosquito-borne zoonotic viral disease that is characterized by the onset of abortions in 80–100% of pregnant animals, high neonatal mortality (up to 90% in new-born lambs and kids), and mortalities of 15–30% or higher in adult sheep and goats (Kusiluka and Kambarage, 1996). The disease has a serious negative impact on rural food security and household nutrition, as well as direct and indirect losses to livestock producers in affected countries. In a RVF outbreak in Kenya in 2007 the estimated losses to the economy was more than US $24.5 million, from a combination of direct losses in the agriculture sector and subsequent losses in downstream industries (Rich and Wanyioke, 2010).

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http://dx.doi.org/10.1016/j.jep.2016.11.002
Received 25 August 2016; Received in revised form 2 November 2016; Accepted 3 November 2016
Available online xxxx

Insect pests also affect humans directly by transmitting diseases. Examples of diseases transmitted by pests that cause mortality in humans are malaria, yellow fever and more recently zika virus. Malaria has the largest impact on human health, with an on-going transmission in 106 countries and half of the world's population at risk of contracting the infection (WHO, 2015). According to WHO estimates, there were 214 million new cases of malaria worldwide in 2015 and an estimated 438 000 deaths. The greatest burden of malaria occurs across Africa with 90% of all malaria deaths occurring therein with the main victims being children under five years of age (WHO, 2015). Malaria is also a cause of poverty due to loss of ability to work and a major hindrance to economic development due to increased costs of health care, lost working days due to sickness, days lost in education, decreased productivity due to brain damage from cerebral malaria, and loss of investment and tourism (Gollin and Zimmermann, 2007; Worrall et al., 2005).

Control measures for pests are costly and often time-consuming and involve extensive use of chemical pesticides (Pimentel et al., 2005; Zalucki et al., 2012). While pesticides are in common use, most of them are toxic to the environment and pests are known to quickly acquire resistance to them, making them obsolete. The development of resistance frequently results in the need for several additional applications of the pesticides or the use of more expensive alternatives to control diseases and maintain crop yields, all at additional costs. In the US alone, the additional cost in pest control due to resistance is US$1.5 billion per year (Pimentel, 2009). Thus, there is a continuing need for the development of new products to address pest control problems but with better safety and ecotoxicity profiles.

The natural compounds found in plants offer one avenue for the discovery of safe novel pesticides since these compounds are typically biodegradable (Isman, 2005; Tripathi et al., 2009). Not surprisingly, there has been growing impetus worldwide to explore natural products particularly plants as a source of lead compounds for the development of new pest control agents. Natural products have long been used as pesticides and have broadly served as templates for some commercial synthetic pesticides that are on the market today (Gerwick and Sparks, 2014). For example, the pyrethroids, which constitute the majority of commercial household insecticides, are originally derived from pyrethrins isolated from flowers of *Tanacetum cinerariifolium (Trevir.) Sch. Bip. (Chrysanthemum cinerariifolium (Trevir.) Vis., Fl. Dalmat.* and *Tanacetum coccineum (Willd.) Grierson* (Casida, 1980). Examples of older botanical pesticides include nicotine which is derived from tobacco (Nicotiana spp.), rotenone an isoflavanoid obtained from the roots of tropical legumes in the genera *Derris, Lonchocarpus* and *Tephrosia* and ryanodine an alkaloid obtained from *Ryania speciosa* Vahl (Mann and Kaufman, 2012). This review focuses on *Clausena anisata* (Willd.) Hook.f. ex Benth., Rutaceae, a plant species that is widely used traditionally against various pests in Africa.

2. Materials and methods

Information on the ethnomedical use, chemistry and pesticidal biological activity of *C. anisata* published between 1980 and 2016 was accessed from various databases namely Science Direct, Springer Link and Wiley Online Library. The species names "*Clausena anisata*" and other synonyms including "*Clausena dentata*", "*Clausena inaequalis*" and "*Amyris anisata"* were used as the keywords in searching the title, abstract and keywords of articles in the databases. In addition various relevant books were also consulted.

3. Results and discussion

The search for '*Clausena anisata*" yielded 28 journal articles from ScienceDirect, 72 from Wiley Online Library and 82 from SpringerLink, while "*Clausena dendata"* yielded, 1, 0 and 20 from ScienceDirect, Wiley Online Library and SpringerLink respctively The articles from these databases were largely focused on the biological activity and/or chemical composition of *C. anisata* extracts and formed the basis of this discussion. Some of the articles obtained from this search were on the ecology of *C. anisata*.

3.1. Occurrence and taxonomy

Clausena anisata belongs to the genus *Clausena* in the Rutaceae (or Citrus) family. The Medicinal Plant Names Services (MPNS) gives 34 scientific synonyms for this plant species (http://mpns.kew.org/mpns-portal/), which include *Clausena dentata* (Willd.) M.Roem., *Clausena inaequalis* (DC.) Benth. and *Amyris anisata* Willd. The *Clausena* genus comprises 15 species, and is distributed in Africa, southern Asia, Australia, and the Pacific Islands (Tchinda, 2011). The most distinctive morphological character of the genus that separates it from the species of other related genera is the gynophore, which is a large, well-developed, hourglass-shaped structure supporting the ovary (Swingle and Reece, 1967). *Clausena anisata* is the only representative of the *Clausena* genus in tropical Africa (Schmelzer, 2001). It is widespread across the continent occurring in forests and forest margins, riverine thickets and bushveld from Guinea and Sierra Leone eastwards to Ethiopia and the Sudan and southward down to the Cape in South Africa, only avoiding the driest regions. *Clausena anisata* is also found in tropical and Southeast Asia, growing in India, Nepal and Sri Lanka and extending as far as Queensland in north-eastern Australia and some Pacific islands. It is cultivated for its oil in Malaysia, Indonesia and the Philippines (Axtell and Fairman, 1992; Tchinda, 2011). The oil is used as a medicinal flavour and in the Philippino local brandy "Anisdos" (Axtell and Fairman, 1992). *Clausena anisata* is a deciduous shrub or small tree with pinnate compound leaves which are densely dotted with glands and have a strong aniseed – like scent, when crushed. The flowers are small and white with orange-yellow stamens. The inflorescence forms a branched axillary spray (Hyde and Wursten, 2011).

3.2. Ethnomedical use

Clausena anisata is widely used against various pests and parasites in many parts of Africa. In Zimbabwe, the leaves are crushed and packed onto the wounds of animals to expel maggots (Chavunduka, 1976). It is used as a mosquito repellent in some parts of South Africa (Okunade and Olaifa, 1987; Mavundza et al., 2011). In Benin and Cameroon, *C. anisata* is used as an insecticide against stored-grain pests (Tapondjou et al., 2000; Boeke et al., 2004a). In Kenya and Ethiopia, the leaves of *C. anisata* are used against intestinal worms in animals or humans (Muthee et al., 2011; Firaol et al., 2013). The roots and leaf infusion are effective remedies against internal parasites especially flatworms infestations, such as schistosomiasis and taeniasis (Bryant, 1966).

The use of *C. anisata* in human traditional medicine is equally widespread throughout tropical Africa. Various parts of the plant are used to treat numerous disorders and infections which include diabetes, haemorrhoids, hypotension, hypertension, heart failure, indigestion, fever, pneumonia, headache, whooping cough, malaria, venereal diseases, sinusitis, wounds, and mouth infections (Hutchings et al., 1996) bilharzia (Adesina and Adewunmi, 1985), convulsions (Adesina and Ette, 1982; Makanju, 1983), mental disease and schizophrenia (Pujol, 1990; Watt and Breyer-Brandwijk, 1962). Leaf and root decoctions are also taken as an aphrodisiac, as a tonic by pregnant women, to facilitate child birth and cleanse the uterus and as an antidote for snake-bites (Watt and Breyer-Brandwijk, 1962; Hutchings et al., 1996; Tchinda, 2011).

3.3. Chemistry of C. anisata

There have been extensive studies on the chemical composition of