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Essential Oils As Alternative Antifungal Agents For The Citrus Industry In South Africa -A Review

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Abstract
The South African citrus industry has been contributing greatly to the economy's Gross Domestic Product (GDP) for a very long time. Citrus plantations in the country have been growing since the 1600s and the industry has grown enormously over the years. The industry provides 125 000 employees annually and the numbers are expected to increase. Furthermore, most of the citrus fruits produced are exported to foreign countries such as the United States of America (USA) and European Union countries (EU) as it provides great income return. However, the recent widespread problems of the Citrus black spot (CBS) have resulted in serious concern. CBS is caused by the fungus *Phyllosticta citricarpa* which affects almost all commercial citrus species. These losses not only affect profit margins and initial input costs but also lower retailer and consumer confidence in the marketplace. Symptoms and yield losses caused by CBS infection are usually minimized by the application of synthetic fungicides during the fruit susceptibility period. Synthetic fungicides are the primary means of controlling fungal pathogens. However, fungal pathogens have shown a concerning trend against these fungicides. Additionally, they are known to remain on the plant or within its tissues following treatment resulting in potentially toxic and carcinogenic effects on humans. To reduce the use of synthetic fungicides in the food chain, alternative methods to synthetic fungicides are needed. Hence, natural plant products such as essential oils and hydrosol are gaining attention from researchers globally due to their antimicrobial, biodegradable, eco-friendly, economical and safe properties.

Keywords: Essential oils, hydrosol, Citrus black spot, *Phyllosticta citricarpa*, citrus industry

INTRODUCTION

The citrus industry in South Africa

The South African citrus industry is one of the most important agricultural industries that contribute economically to the country by increasing foreign currency earnings, thereby contributing considerably to the country's Gross Domestic Product (GDP) (Dlikilili, and van Rooyen, 2018; Venter, 2018). With the history dating back to the 1600s, when the first citrus fruit trees were planted in the Western Cape (Dlikilili, 2018), the citrus fruit industry has since grown and currently represents one of South Africa's most important agro-commodities by value and volume (Sinngu, 2014). Citrus fruits currently constitute one of the most important horticultural crops in South Africa. In terms of gross value, the industry is currently the third-largest horticultural industry behind the country's deciduous fruit and vegetable industries (Dlikilili and Van Rooyen, 2018; Sinngu, 2014). This industry is characterised by the diversity of growers, varying from large and highly profitable commercial producers to small-scale producers (Dlikilili and Van Rooyen, 2018). Furthermore, the citrus industry has continued to experience growth as citrus fruits are grown in fifteen regions across the

country, supplying numerous citrus varieties, such as soft citrus, lemons, limes, orange, and grapefruit (Dlikilili and Van Rooyen, 2019). The citrus sector in the country has always presented good employment opportunities, particularly for disadvantaged communities (De Villiers, 1996). Currently, estimates indicate that the citrus industry in South Africa employs over 125 000 people, or 14% of the agricultural job market, with large numbers of workers in the orchards and packing houses (Genis, 2018). However, these numbers could be more if an "unspecified number of people employed throughout the citrus supply chain services such as transport, port handling, and other related (Genis, 2018; Sinngu, 2014) are also included.

Major citrus fruit produced and production areas in South Africa

According to Genis, (2018), about 72 731 hectares (ha) of citrus trees were planted across South Africa in 2017. However, the number of hectares has slightly increased to 77 676 hectares of planted area of citrus trees in South Africa producing over 2.1 million tonnes (Philips, 2018). Furthermore, in 2019, a total of 86,808 ha of citrus trees were planted in South Africa. This growth trend has continued to increase as it was estimated to be around 95,200 ha in 2020. An estimated total of 98,700 ha was planted to citrus in South Africa in 2021 (Cramer and Chisoro-Dube, 2021). Although the covid 19 pandemic has disrupted many industries worldwide, the citrus industry has continued to grow despite the crisis, in particular, the demand for citrus fruits has increased during the pandemic because of the high vitamin C content in citrus fruits. furthermore, the growth trend is forecast to continue in 2022, based on the significant investments and aggressive new plantings of soft citrus, lemons, and new varieties of oranges (Cramer and Chisoro-Dube, 2021). Within the Southern African Development Community (SADC), countries such as Zimbabwe, Swaziland and Mozambique also produce citrus fruits, although in much smaller quantities (Figure 1) (Department of Agriculture and Fisheries, 2017). In South Africa, citrus cultivation for a commercial purpose is reported mainly in Limpopo, Western Cape, Mpumalanga, Eastern Cape, KwaZulu-Natal and Northern Cape with North West, Gauteng and Free State provinces being the provinces which do not produce citrus fruits (Morokolo, 2016). Figure 1 depicts the percentage of the major citrus producing provinces. The highest citrus fruit production takes place in the Limpopo Province (Figure 1). It contributes 42% of the total area planted to citrus in South Africa, followed by the Eastern Cape Province at 26%, Western Cape provinces account for 17%, while Mpumalanga stands at 7%. A lower percentage of (2%) is cultivated in the Northern Cape and KwaZulu-Natal, respectively (Figure 1). The industry is spread across a variety of climatic zones, from a warmer and sub-tropical climate in Mpumalanga, Limpopo, and KwaZulu-Natal provinces to Mediterranean climates in the Eastern and Western Cape provinces (Genis, 2018; Sinngu, 2014). This range of climatic conditions provides an ideal environment for growing a full range of citrus fruits. Mpumalanga, Limpopo, and KwaZulu-Natal climates are warmer and better suited to the cultivation of grapefruit and valencia oranges. The Western Cape and Eastern Cape provinces, on the other hand, are 'cooler' citrus growing areas and production is focused on navel oranges, lemons, and soft citrus fruits (Sinngu, 2014). The area planted per citrus variety or group during 2016 is shown in Figure 2. It can be observed from Figure 2 that the most planted citrus variety in 2016 was Valencia at 38%. Limpopo province contributed 60% of all Valencia oranges planted in 2016. Another citrus variety planted the most in 2016 was Navel oranges (22%) (Department of Agriculture and Fisheries, 2017). The Eastern Cape Province contributed 40% of all Navel oranges planted in 2016. The third-largest planted citrus category was soft citrus at 16% of the total area planted to citrus products in 2016. Lemons and limes accounted for 13% while grapefruit accounted for 11% during the same period (Department of Agriculture and Fisheries, 2017).

Figure 1. Citrus production areas in hectares, 2017, cited from (Department of Agriculture and Fisheries, 2017).

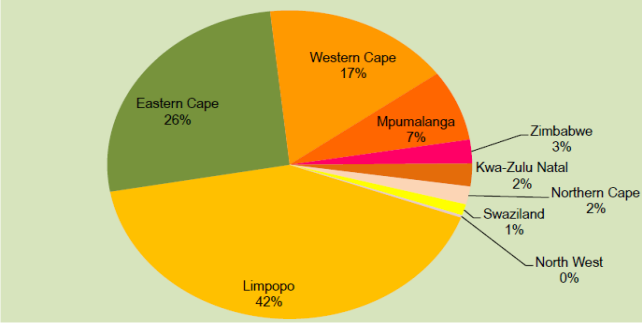
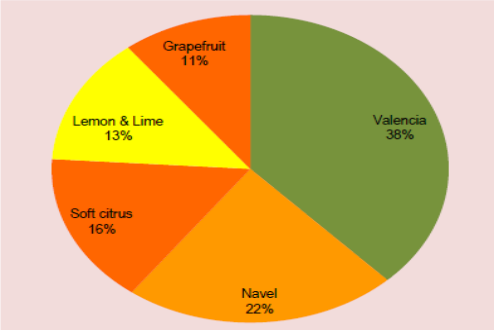


Figure 2. Area planted per variety group in hectares, 2017. Cited from Department of Agriculture and Fisheries, 2017.



Markets for the citrus industry

As South Africa produces more fruit than can be absorbed and consumed by the local market and the fruit is of high quality, these citrus fruits produced are then sold through different marketing channels such as national fresh produce markets, informal markets (street hawkers and bakkie traders), directly to processors for juice making and dried fruit production (Van Dyk, and Maspero, 2004). The fruits are also sold directly to wholesalers and retailers through signed contracts. A large percentage of fruit is exported to foreign countries through export agents (Kau *et al.,* 2018; Van Dyk, and Maspero, 2004). Most citrus growers export as much of their crop as possible because of the far greater returns obtained from the export market than from the domestic market (Genis, 2018; Urquhart, 1999). Furthermore, reports suggest that there is an establishment of emerging black farmers that export citrus fruits. It is recorded those 123 black farmers operate in the country, which is 10.7% of citrus orchards in South Africa and 42% of those farmers are exporting their products (Maspero, 2004; Kau *et al.,* 2018;). Furthermore, these initiatives assist in the South African context with the transformation progress of the industry to support the establishment and growth of sustainable and profitable black citrus growers with market linkage to ensure food security, job, and wealth creation (Kau *et al.,* 2018; Genis, 2018). For example, The Alice Kat Citrus Project in the Kat River area of the Eastern Cape was an agricultural development project initiated by the former Ciskei homeland. Several farms previously owned by white farmers were bought up by a parastatal and allocated to approximately 16 black farmers (Urquhart, 1999).

As already indicated in the preceding subsection, citrus production in South Africa is mainly destined for the export market. The biggest contributor to the total volume of South African citrus exports is oranges, it has contributed more than 63% (1,064,089 tons) to total citrus products exports since 2016 and the numbers have continued to increase as in 2019 as it was estimated to be around 1,186,426 (Table 1) (Department of Agriculture and Fisheries, 2017; United States Department of Agriculture, 2020). Lemon and lime were second in 2016 at 14% (237,131tons) and the number has also continued to increase from 2016 until recently, in 2019 it was about 350,245 tons, grapefruit and soft citrus at 12% (202,527 tons) and 11% (189,730 tons) respectively during the year 2016 (Department of Agriculture and Fisheries, 2017) and in 2019 it has increased to (258,423 tons) and (295,606 tons) respectively (Department of Agriculture and Fishery, 2017; United States Department of Agriculture, 2020). Volumes of citrus products sold to export and processing markets between 2016 and 2019 increased during the same period (Department of Agriculture and Fisheries, 2017; United States Department of Agriculture, 2020). Even though the South African citrus industry is very important in

Table 1. South Africa Citrus Exports to the World in Metric Tons, from 2016-2019. Cited from Department of Agriculture and Fisheries, 2017; United States Department of Agriculture, 2020

Description	2016	2017	2018	2019
Oranges	1,064,089	1,170,813	1,278,935	1,186,426
Lemons & Limes	237,131	299,323	315,197	350,245
Grapefruit	202,527	230,635	288,155	258,423
Soft Citrus*	189,730	209,754	260,850	295,606
All	**1,693,477**	**1,910,525**	**2,143,137**	**2,090,701**

*** Includes Mandarins (Including Tangerines And Satsumas), Clementines, and Walkings.**

boosting the economy of the country, the industry still faces huge obstacles, such as the rejection of citrus fruits by some markets, such as the United State of America (USA) and South Korea and the European Union (EU), citing safety problems resulting in stringent Sanitary and Phytosanitary (SPS) conditions, due to fungal disease Citrus Black Spot (CBS).

Problems affecting the citrus industry

South Africa's citrus industry has in the past received much media and policy attention due to concerns of increased fungal infection namely Citrus Black Spot (CBS) interceptions on the country's European Union-bound shipments, leading to fears of a possible ban on SA citrus exports (Olivier, 2017). CBS is a citrus disease caused by the fungus *Phyllosticta citricarpa* which affects almost all commercial citrus species externally but does not cause internal decay. CBS affects the agriculture industry negatively in terms of food production and security as well as trade. As such some trading partners were reluctant to import fresh fruit from production areas where CBS occurs, this has resulted in South Africa losing more than 45% of export revenue due to post-harvest infection of citrus fruit, which was (80-90% losses) intended for the European Union (EU) and Asian markets (Montesinos-Herrero *et al.,* 2009; Lesar, 2013; Christie, 2016). One of the main difficulties related to fungal pathogens is their progressive nature because they sometimes do not show during harvest or fruit grading in the packhouse; symptoms can develop during storage or weeks after harvesting (Erasmus *et al.,* 2015). In the case of export fruit, this window period matches the commercial shipping period and the fruit's arrival at the point of sale (Erasmus *et al.,* 2015). This results in customer complaints at best and huge financial losses at worst (Erasmus *et al.,* 2015).

These losses not only affect profit margins and initial input costs but also lower retailer and consumer confidence in the marketplace (Erasmus *et al.,* 2015). Symptoms and yield losses caused by CBS infection are usually minimized by the application of synthetic fungicides during the fruit susceptibility period; however, their use raises health and environmental pollution concerns including resistance to pathogens (Arraiza *et al.,* 2018). Moreover, the currently used treatment against this pathogen has also raised concerns among consumers on issues such as food safety (Du Plooy *et al.,* 2009). The food safety concerns aspects are due to the chemical residues left on food when synthetic fungicides are applied. Hence, research into the development of alternative agents for the replacement of synthetic fungicides for fungal disease control in the agriculture sector continues (Du Plooy *et al.,* 2009 Christie, 2016). An alternative antifungal need is to (a) overcome resistance problems observed against established commercial products, (b) have acceptable levels of persistence in the environment, and (c) have a market and technical advantages over synthetic fungicides (Arraiza *et al.,* 2018). Essential oils (EOs) and their hydrosol can represent a new class of Citrus Black Spot antifungal due to their antimicrobial effects (Arraiza *et al.,* 2018). In addition, the probabilities of creating new resistant strains by using essential oils as fungicidal agents are less likely since they have different chemical constituents that work in synergy simultaneously (Arraiza *et al.,* 2018).

CONCLUSION

The spread of the Citrus black spot (CBS) is a major concern in the citrus industry because the disease threatens fruit marketability and citrus tree health. In most countries, the disease is phytosanitary important because of its role in international trade. If the fruits contain CBS lesions, this can result in the rejection of the whole imported batch; moreover, the disease can spread readily in the natural environment resulting in an increased incidence of CBS. It is therefore of paramount importance to control and manage the disease; however, there is a great public concern about the safety and side effects of synthetic fungicides currently used to control citrus black spots. Synthetic fungicides are known to have carcinogenic effects on humans and are also toxic to the environment. Furthermore, microorganisms tend to develop resistance to most synthetic fungicides. This problem has prompted research into the identification of new ways with broad activity in the treatment of microbial disease in plants. Although alternative methods are being researched to control citrus fruits' diseases, natural plant products such as essential oils and their hydrosol are gaining popularity and drawing the attention of researchers. In nature, essential oils play an important role in the protection of plants. They contain a wide variety of secondary metabolites that can inhibit or slow the growth of bacteria, yeasts, fungi and even viruses. The oils and their components have activity against a variety of

microbial targets, particularly the membrane and cytoplasm, and in some cases, they completely change the morphology of the cells. Therefore, EOs can be ideal candidates for use as alternative antifungal compounds.

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CONFLICTS OF INTEREST

The author does not have conflicts of interest to declare.

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