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THE APPLICATION OF PLANT BASED PESTICIDES IN SUSTAINABLE AGRICULTURE

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The persistence of synthetic pesticides in the environment has caused considerable changes in legislation regarding the use of them. This, coupled with the consumer trend for natural alternatives has brought increasing attention to the application of plant derivatives (essential oils, plant extracts and components) as environmentally sustainable pesticides against microorganisms, insects and nematodes. Furthermore, natural products can be found in developing countries where medicinal and aromatic plants grow in abundance. The unique and complex structure of essential oils makes it difficult for pests to develop resistance to them. Additionally, the volatile nature of the essential oil components due to their low molecular weights makes them less likely to persist in the soil.

Essential oil research in South Africa (SA) has focussed mainly on optimising biomass production and essential oil yield of commercial and emerging farmers to allow them to become role players in the essential oil market worldwide. The majority of the research into essential oils as fungicides has been limited to laboratory assays and very few, if any, of these fungicides have been registered in SA. However, in the context of integrated pest management, products based on plant extracts to control diseases are well suited and may play a role in the production and protection of food, in both industrialised and developing countries. These products, with particular attention to essential oils against pathogenic fungi will be discussed here. Vegetable crops are valuable commodities worldwide due to the good source of fibre and nutrients which are important in the human diet. Their protection from pests is crucial to ensure good production and quality of vegetable crops. Therefore, many pest management researchers have focussed their efforts on developing fungicides based on some essential oils which are exempt from registration as already commonly used in processed foods and beverages. For example, in Egypt, most production occurs in insulated greenhouses were conditions are favourable to the fungi that affect them. The impact of plant diseases on growers is direct and significant. Thyme essential oil in combination with plant resistance inducers and biological control agents (*Trichoderma* spp.) have been successfully used as a soil drench against root rot pathogens on tomato, pepper, cucumber and cantaloupe under protected agriculture conditions.

The need for alternatives to chemical fumigants namely, methyl bromide and metham sodium in Australia has led to growers wanting more integrated methods of production. This had led to the investigation of many biocides and natural soil fumigants which include both crude plant extracts and essential oils. Table 1 provides a list of products and their active ingredients which are available in Australia but might not be registered as pesticides. These products have been applied mainly in organic agriculture, and to a lesser extent in conventional agriculture, to a host of damaging soil borne diseases of vegetable crops. Timorex 66EC and Timorex Gold® (Stockton Chemical Corporation, Israel) are tea tree extracts (*Melaleuca alternifolia*) which have recently received registration from the Environmental

Protection Agency (EPA) in the United States. These products are used as adjuvants to chemicals to reduce the amount of agrochemicals in spray disease control programs. The strategy is to decrease the rate at which fungi develop resistance to chemical sprays by replacing one or two of the chemical sprays with the essential oil formulation. These formulations are approved for use in both conventional and organic farming systems and registered in over 25 countries, however no information was found to show their registration and distribution in SA. Timorex, originally formulated to control Black sigatoka a leaf-spot disease of banana plants (Figure 1), is also effective against a broad spectrum of, diseases affecting vegetables, vineyards and fruit trees. Timorex 66 EC 0,5%-1,0%, Timorex Gold 0,75% (plant extract from tea tree), has proven to be effective against late (*Phytophthora infestans*) and early blight (*Alternaria solani*) on tomato and can be included in integrated pest management thus reducing agro-chemical use and delaying fungicide resistance build up (Masheva *et.al.*, 2012).

TABLE 1: Essential oil and plant extract based pesticides used against fungal pathogens of most vegetable crops in Australia

Trade name	Active ingredient	Target pests
Dazitol	mustard oil, capsacanoids unknown % allyl- isothiocyantes	*Fusarium, Pythium, Rhizoctonia, Phytophthora,* Pyrenochaeta*, Sclerotium,Armillaria* & clubroot organism,*Plasmodiophora*
PhytaGuard EC	rosemary and clove oil	Powdery Mildew & bacterial spot
Proud 3^{OG}, ProMax^{OG}	thyme oil	*Pythium, Phytophthora* species, *Rhizoctonia,* Club root & *Sclerotium*
Sporatec^{OG}	rosemary, thyme & clove oil	*Anthracnose, Botrytis*, downy mildew powdery mildew, leaf spots & rusts
Timorex 66EC	tea tree extract	Grey mould & powdery mildew
Vigour	mustard oil & chillie extracts	Downy mildew
Voom®	mustard and other essential oils 15-20% allyl-isothiocyanates	*Sclerotium*

FIGURE 1: *Control of Black sigatoka on Banana using Timorex Gold, left- control, right- treatment with Timorex Gold (image by Harsh Saxena) (http://banana-disease.blogspot.com/)*

The vapour phase of essential oils presents viable options for post-harvest disease control as it can be applied at lower concentrations than the liquid phase counterpart which does not affect the taste and smell of produce. Applying these oils via the vapour phase makes their use more cost effective than conventional dipping procedures. Anthracnose is a major postharvest disease in avocados that causes significant losses during transportation and storage. A Post-Harvest Innovation Programme at the Tshwane University of Technology recommended the use of thyme oil, in combination with a modified packaging method which would make the vapour phase of the essential oil most effective, as an acceptable post-harvest treatment to control anthracnose in avocados (Sellamuthu *et al*., 2013). Moreover, thyme oil is cost effective over fungicides containing prochloraz due to the affordability of its active ingredient thymol which is already used in food preservation making it feasible for use by emerging farmers.

Essential oils have shown their ability to protect against post-harvest fungi causing mycotoxin accumulation in stored food crops resulting in substantial economic losses worldwide. Mycotoxins are produced as secondary metabolites by, predominantly, *Fusarium* species which are hazardous to human and animal health. Lemongrass and basil essential oils (both at 4.8µL/g) proved to be highly effective against *F.verticillioides* and were recommended to small scale farmers in South Africa for maize stored in closed conditions (Fandohan *et al*., 2004).

Essential oils have also been investigated for their use in controlling *Fusarium* that infect maize stalks by initially invading and then colonising root systems. This compromises the health of the root system and directly affects yields.

The strategy is to use essential oils as seed treatments to protect the plants, at the earliest growth stage, from yield reducing diseases, ensuring that good crop development is achieved. Lemongrass, thyme and basil essential oils were found to control the seed borne inoculum of the pathogen, *Fusarium verticillioides*, by 90 to a 100% *in vitro*. Field trials in the Cameroon showed that these oils were able to highly increase the plant densities in treated plots (Tagne et al., 2008). Research conducted in the Biochemistry unit of the KZN Department of Agriculture and Rural Development has shown that of 32 essential oils tested, clove, thyme, cinnamon and origanum oil showed the strongest fungicidal activity against eight *Fusarium* species associated with maize crown and root rot. The minimum fungicidal concentrations of clove oil (1 µl/ml), cinnamon oil (1 µl/ml), thyme oil (1.56 µl/ml) and origanum oil (3.13 µl/ml) where sustained over a 21 day incubation period of the assay. The oils at these concentrations were found to be non-toxic to the maize plant and their relatively low effective concentrations show potential to utilise them in small quantities. These results obtained *in vitro* were used to conduct *in vivo* studies applying essential oils at effective doses as seed and soil treatments against *Fusarium* stalk and root rot pathogens.

It is plausible that natural products in combination with other methods could provide higher levels of crop protection and therefore greater productivity with fewer environmental problems. Plant based products, at present, may be more suited for use in organic food production in industrialised countries and enclosed production systems. However, it could play a much greater role in crop and food protection once sufficient formulations which maintain their concentration over a long period of time are developed

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