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The Use of Plant Extracts Against Straw Cereals Diseases

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Abstract: Straw cereals plants are constantly exposed and threatened to many pathogens throughout the growing season that affect their development, yield capacity and quality. The most used method of controlling cereal pathogens is the application of fungicides. However, pathogens have been observed to develop resistance to active substances contained in plant protection products. To reduce the use of conventional crop protection products and improve food and feed safety, there is increasing interest in the use of natural, more environmentally friendly plant-based compounds (i.e. botanicals) to control fungal diseases. Those are derived from plants belonging to different families and are either used as plant extracts, essential oils or both. Plant extracts are effective bioagents against a wide range of plant pathogens, i.e. fungal, bacterial and viral pathogens. Oils obtained from plant seeds have also been used to control plant pathogens. Globally, there are approximately 2500 species from 235 plant families that are effective in controlling diseases and pests. Botanicals based on preparations from medicinal and aromatic plants have high potential for the control of various fungal pathogens. Frequent examples include garlic (*Allium sativum*), caraway (*Carum carvi*), fern tree (*Jacaranda mimosifolia*), rosemary (*Rosmarinus officinalis*), sage (*Salvia fruticosa*), thyme (*Thymus vulgaris*), neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globolus*), bojho (*Acorus calamus*) and asuro (*Justicia adhatoda*) against fungal pathogens from the genera *Aspergillus*, *Alternaria*, *Cladosporium*, *Fusarium*, *Bipolaris*, *Penicillium* and *Puccinia*.

Keywords: barley, botanicals pesticide, diseases, plant extract, wheat.

Introduction

Cereal diseases are an important yield limiting factor in cereals, with average yield losses estimated at 15–20% (Figueroa et al., 2018). High losses are due to plant mortality or the reduction of the assimilation leaves and spikes area, resulting in poor grain formation and a decrease in the number of grains per spike (Różewicz et al., 2021). They also contribute to the deterioration of grain quality by contaminating it with mycotoxins dangerous to health. Cereal plants are constantly exposed and threatened to many pathogens throughout the growing season that affect their development, yield capacity and quality (Lengai et al., 2020). The most important from an economic point of view are: *Blumeria graminis*, *Blumeria graminis* f. sp. *hordei*, *Puccina recondita*, *Puccinia graminis*, *Puccina striiformis*, *Zymoseptoria tritici* and *Parastagnospora nodorum*, *Pyrenophora tritici – repentis*, *Puccinia hordei, Pyrenophora teres, Bipolaris sorokiniana, Ustilago nuda* as well as *Fusarium spp.*, *Cladosporium herbarum* and *Alternaria* spp.

The most used method of controlling cereal pathogens is the application of fungicides. However, pathogens have been observed to develop resistance to active substances contained in plant protection products (Fisher et al., 2018). The indiscriminate use of plant protection chemicals has caused unwanted effects as it contaminates the environment by leaving residues of active substances in soil and grain that contaminate food and feed (Spence et al., 2020), injury to non-target organisms, disease re-emergence, genetic variation of plants and the negative impact on biodiversity (Ngegba et al., 2022). Synthetic pesticides also have toxic effects on human lives due to the bioaccumulation of contaminants in food chains, which are widely distributed in terrestrial and aquatic environments (Lushchak et al., 2018).

The negative consequences related to the excessive and inappropriate use of chemical pesticides have necessitated the need for alternative means of disease and pest management (Mahmood et al., 2016). Therefore, there is a need to apply these methods to control pathogens.

In an attempt to reduce the use of chemical pesticides for the control of the main plant pathogens, a safer alternative has been developed that does not have negative consequences for the environment, humans and animals, and this is part of the sustainable concept of agriculture, which involves the rational and integrated control of plant diseases (Puia et al., 2017).

An alternative solution to synthetic fungicides is the use of plant extracts, i.e. botanicals biopesticide (Tian et al., 2016).

Botanical pesticides were widely used for millennia in both subsistence and commercial agriculture before the advent and development of synthetic pesticides. Botanical pesticide ingredients are chemical derivatives found naturally in plants, and act as repellents, attractants, anti-feedants and growth inhibitors (Mahmood et al., 2016; Hikal et al., 2017)

By extracting these plant compounds with suitable solvents and/or mixing with the necessary adjuvants, they become botanical pesticides. Due to the effectiveness of chemical pesticides on crop diseases, the application of botanical pesticides declined slightly until recently, when the intensive use of synthetic pesticides began to be restricted because they pose a threat to the environment and human health (Raja, 2014; Ngegba et al., 2022).

Botanical pesticides have gained popularity in organic farming due to the lack of toxicity and crop residues, and consumers are willing to pay a higher price for organic products (Misra, 2014).

Sources of botanical pesticides

Botanical pesticides are derived from plants belonging to different families and are either used as plant extracts, essential oils or both (Mizubuti et al., 2007). For the manufacture of botanical pesticides, different parts of plants are used: barks, leaves, roots, stems, flowers, fruits, seeds and rhizomes. The choice of plant part to use for extracting botanical pesticides is based on the target bioactive compounds and their concentration in that plant part.

Plant families reported to have plants containing bioactive compounds with activity against important crop diseases include *Rutaceae, Compositae, Meliaceae, Leguminosae, Araceae, Platycodoniaceae, Solanaceae, Chenopodiaceae, Zingiberaceae, Labiatae, Loniceraceae, Umbelliferae, Polygonaceae*, and *Euphorbiaceae* (Vidyasagar and Tabassum, 2013; Gakuubi et al., 2016; Ahmad et al., 2017). Globally, there are approximately 2500 species from 235 plant families that are effective in controlling diseases and pests (Stevenson et al., 2017; Das 2014). Plants with pesticidal properties include neem (*Azadirachta indica*), garlic

(*Allium sativum*), turmeric (*Curcuma longa*), rosemary (*Rosmarinus officin*alis), ginger (*Zingiber officinale*) and thyme (*Thymus vulgaris*) (Sharafzadeh, 2011; Joseph and Sujatha, 2012; Castillo-Sánchez et al., 2015). For extraction the harvested plant parts are dried and ground into fine powder and extracted with organic solvents that will maximize the extraction of the target compounds (Chougule and Andoji, 2016). The extracts are then concentrated, formulated and tested for efficacy under controlled laboratory and field conditions (table 1).

Phytochemical composition of botanical pesticides

Bioactive compounds in botanical pesticides are secondary metabolites such as steroids, alkaloids, tannins, terpenes, phenols, flavonoids and resins that have antifungal, antibacterial, antioxidant or insecticidal properties (Ahmad et al., 2017). For example, *Jatropha carcus* seeds contain high amounts of phenolics, esters and flavonoids (Oskoueian et al., 2011), and *Mentha piperita* leaves contain tannins and flavonoids as major bioactive compounds (Pramila et al., 2012). The bioactive compounds found in plants make them effective against a given category of pests and also dictate their mode of action on the target pest (Lengai et al., 2020).

Limitations of botanicals for plant disease management

Gurjar et al., (2012) shows that botanical pesticides have the following limitations:

- Extraction methods are not standardized;
- Rapid degradation;
- Most studies have in vitro efficacy;
- Need the development of formulations;
- Some chemical compounds are harmful to humans and plants;
- Less effective;
- Less available formulations.

Applying of plant extracts and essentials oils

Numerous researches have been performed to control plant diseases using plant extracts (Rahber-Bhatti, 1988; Chakraborty and Chakraborty, 2010; Singh et al., 2010; Dey et al., 2013). They showed that plant extracts are effective bioagents against a wide range of plant pathogens, i.e. fungal, bacterial and viral pathogens. Oils obtained from plant seeds have also been used to control plant pathogens (Kulkarni and Byadagi, 2004). In laboratory experiments, plant extracts such as neem have been reported to exhibit antibacterial, antifungal and insecticidal properties (Satish et al., 1999).

Natural products extracted from plants have become one of the main resources for the discovery of new compounds with distinct biological functions, resulting in a remarkable number of new substances that control phytopathogens (Agarwal et al., 2020; Lorsbach et al., 2019; Umetsu and Shirai, 2020). Several natural plant products have been shown to reduce foliar pathogen populations and limit disease development, implying that these plant extracts could be used as alternatives and ecological components in integrated disease management approaches (Draz et al., 2019). Research has found that plants belonging to several species contain natural substances that are either toxic to several wheat pathogens or can induce systemic plant resistance against them (Draz et al., 2019; Han et al., 2018).

Benefits from the use of environmentally friendly approaches in the control of wheat diseases are presented in Figure 1.

Conclusions

- Uncontrolled use of agrochemicals has caused significant damage to resource-poor ecosystems with low biodiversity.
- It is essential to use environmentally safe alternatives to achieve ecological pest management in agriculture in order to restore and repair damaged ecosystems.
- The effectiveness of botanical pesticides to manage agriculturally economic pests is vital due to their renewable tendency, significant environmental safety, and human welfare.

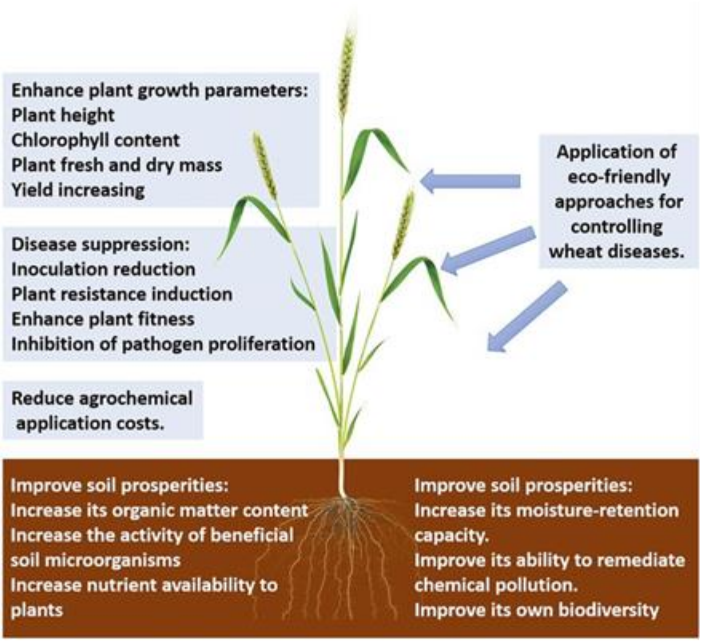

Figure 1. The anticipated advantages of using eco-friendly alternatives for the safe management of wheat diseases
(Source: Almoneafy et al., 2022)

Table 1.
Examples of plants with antimicrobial activity used to safely manage cereal diseases

Type of controlling approach	**Pathogen**	**Disease's name**	**Resulted effect**	**Reference**
Plant extracts of garlic (*Allium sativum*) summer savory, (*Satureja hortensis*) and essential oils of tea tree (*Malaleuca alternifolia*), summer savory (*Satureja hortensis*), true cinnamon tree (*Cinnamomum zeylanicum*)	*Fusarium* spp., *Alternaria* spp., *Helmintosporium* spp., *Cladosporium* spp., *Septoria* spp	seed-borne fungi	It had reduced the attack of *Septoria* spp., *Fusarium* spp. and *Helminthosporium* spp	Puia et al., (2017)
Biofumigation (white mustard - *Sinapis alba* meal)	*Fusarium culmorum*	common root rot	In a green house trial, treatment reduced pathogen infection by 38% and improved wheat growth and grain quality parameters in a field trial	Kowalska et al. (2021)

Type of controlling approach	Pathogen	Disease's name	Resulted effect	Reference
Biofumigation (mulch layerand botanical extracts of white mustard *Sinapis alba* , indian mustard - *Brassica juncea*, berseem - *Trifolium alexandrinum*)	*Fusarium graminearum*	fusarium head blight	Treatment resulted in consistent suppression of fusarium head blight and asignificant reduction of mycotoxins in wheat grains	Drakopoulos et al.(2020)
Leaf extracts of blue gum (*Eucalyptus globulus*), rubber tree (*Calotropis Procera*), chinaberry tree (*Melia azedarach*), thorn apple (*Datura stramonium*), indian scalypha (*Acalypha indica*)	*Alternaria alternata*	barley seed-borne fungi	Treatment resulted in reducing seed-borne incidence and improved germination	Ahmad et al. (2016)
Plant extracts of henna (*Lawsonia inermis*), acalypha (*Acalypha wilkesiana*), chinaberry (*Melia azedarach*), pomegranate (*Punica granatum*), lantana (*Lantana camara*)	*Puccinia triticina*	wheat leaf rusts	Treatment resulted in a significant decrease in the coefficient of infection of wheat leaf rust as well as an increase in wheat yield	Draz et al. (2019)
Plant extracts (white turmeric - *Curcuma zedoaria* rhizomes or its substance)	*Puccinia triticina*	wheat leaf rusts	In vivo, the treatment significantly suppressed wheat leaf rust	Han et al. (2018)
Plant extracts of neem (*Azadirachta indica*), clove (*Syzygium aromaticum*), and garden quinine (*Clerodendrum inerme*)	*Puccinia triticina*	wheat leaf rusts	Treatment completely prevented the development of leaf rust in treated plants	Shabana et al. (2017)
Plant extracts of african lily (*Agapanthus africanus*)	*Puccinia triticina*	wheat leaf rusts	The treatment increased the activities of-1,3-glucanase, chitinase, and peroxidase in both susceptible and resistant wheat cultivars	Cawood et al. (2010)
Plant extracts (aqueous leaf extracts of jacaranda - *Jacaranda mimosifolia*)	*Puccinia triticina*	wheat leaf rusts	Plant extract treatment alone or in combination with 0.05% Amistar Xtra increased PR protein expression in treated plants	Naz et al. (2014)

Type of controlling approach	Pathogen	Disease's name	Resulted effect	Reference
Plant extract of neem (*Azadirachta indica*), garlic (*Allium sativum*), eucalyptus (*Eucalyptus globolus*), bojho (*Acorus calamus*) and asuro (*Justicia adhatoda*)	*Bipolaris sorokiniana*	spot blotch	The tested botanicals exhibited fungicidal action and significantly inhibited mycelial growth	Magar et al., (2020)

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