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REVIEW ARTICLE
Plant Health

Application of propolis in agriculture

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ABSTRACT
This work carried out a literary review of the different aspects related to the use of propolis in the management of plant crops and their advances in agriculture. Propolis is a product widely known for its therapeutic capacity. Due to its antimicrobial and antioxidant properties, among other biological activities, its use has been studied in agriculture. Studies they show that the use of propolis via ethanolic propolis extract (EEP) provides beneficial effects on crops. These benefits are associated with the control of phytopathogens, postharvest preservation and conservation of fruits and vegetables and promotion of plant growth. There is evidence that benefits are the result of the propolis chemical composition that is especially rich in phenolic compounds and nutrients. In addition, the typical waxy property of propolis results in an efficient biofilm in plant tissues. There are still scarce reports showing that the use of EEP in crop management controls the presence of insects and reduces water stress in plants. Generally, studies are mainly focused on *in vivo* and greenhouse evaluations, requiring further research to elucidate the full potential of the use of propolis in crop management.

Keywords: disease control; ethanolic propolis extract (EEP); phytosanitary; promotion of growth; pests.

Propolis is a gummy and resinous substance naturally produced by plants, that is collected by *Apis mellifera* bees in flower buds, sap flow, trichomes and other vegetable structures (GHISALBERTI, 1979; BANKOVA et al., 2002; BONAMIGO et al., 2017). In the hive, bees incorporate salivary secretions, wax and pollen to obtain the final chemical complex product (OLDONI et al., 2011).

More than 300 substances have already been identified in different types of propolis, especially flavonoids, besides phenolic and fatty acids, terpenoids, vitamins, amino acids, sugars, proteins, and minerals (BURDOCK, 1998; BANKOVA et al., 2000; ALMEIDA; MENEZES, 2002; BANKOVA et al., 2002; TORETI et al., 2013).

The benefits of propolis have been known for centuries and ancient people used this product for therapeutic purposes (CASTALDO; CAPASSO, 2002; PEREIRA et al., 2015). The composition of propolis is strongly associated to its geographical origin and vegetation found close to the hives (PEREIRA et al., 2002; CASTRO et al., 2007).

Thus, there is a worldwide diversity of propolis with different textures, aroma and colors that can vary from yellowish, greenish, reddish-brown, dark-brown tones to a black color (MARCUCCI, 1996; BURDOCK, 1998; ALENCAR et al., 2005; LOUREIRO, 2008; TORETI et al., 2013).

Because of its great biodiversity, the propolis produced in Brazil is classified in 13 different groups according to their physical-chemical and biological characteristics (PARK et al., 2000; ALENCAR et al., 2005; HAYACIBARA et al., 2005; DAUGSCH et al., 2008; BELMIRO et al., 2011). Among these groups, the green and red propolis are known all over the world and have been extensively researched. There is also a type of propolis called geopropolis found in South America, which peculiar characteristic is the fact that stingless bees incorporate soil when producing it (BARTH, 2006; SILVA et al., 2016).

Currently, propolis is known for having antimicrobial, antiviral, anticariogenic, anti-inflammatory, antioxidant, immunomodulatory, healing, and anesthetic properties, among other biological activities (FALCÃO et al., 2010; RIGHI et al., 2013; VALENZUELA-BARRA et al., 2015; ARAÚJO et al., 2016; CORRÊA et al., 2017; KUSTIAWAN et al., 2017; SILVA et al., 2017; VEIGA et al., 2017).

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Besides its established use in Medicine and Pharmacology, studies have shown that propolis can be used in agriculture, especially in the control of crops phytopathogens, such as tomatoes (MORAES et al., 2011; PEREIRA et al., 2016), coffee (PEREIRA et al., 2013; 2016), beans (PEREIRA et al., 2014; 2016), cucumbers (PEREIRA et al., 2016), and grapes (MARINI et al., 2012; WUADEN et al., 2018). Its use in the agriculture is relatively recent and still requires further researches and the development of commercial products.

However, it is an alternative that can be applied in crop systems to avoid the indiscriminate use of pesticides that cause well-known damages to the environment and human beings. When considering natural products, sustainability and organic food, the use of propolis in agriculture becomes attractive, having the potential to be widely incorporated in the management of vegetable crops of economic importance in the near future (PEREIRA et al., 2008).

In agriculture, propolis is not used in its raw form, instead its compounds need to be extracted so that the final solution can be applied. Because of the complex chemical structure of propolis, some substances present in the raw form are soluble in water or alcohol or in both solvents (MELLO et al., 2010). At first, water was used to obtain the propolis extract. However, because it is practical and also due to the low solubility of some substances in water, currently the most used and effective solvent for the extraction process is the hydrous ethanol (KONISHI et al., 2004). The final product is the ethanolic extract of propolis.

Literature shows several different ways of preparing the ethanolic extract of propolis (EEP). In general, EEP is obtained by using 5-18% raw propolis in 70-90% hydrous ethanol. After resting for about five days, the solution is filtered through a paper filter and the final EEP is obtained. When used in agriculture, this extract is still diluted in distilled water in concentrations that vary from 0.1 to 10% EEP for later application. It is important to emphasize that each study employed different amounts of raw propolis and periods of time to obtain the EEP. This fact, along with different types of available propolis can cause variations on the effects observed in the studies. Therefore, future researches should be performed to investigate the full potential of using different types of propolis in crop management (PEREIRA et al., 2016).

Thus, this study carried out a literature review on the different aspects related to the use of propolis to manage agricultural crops and its advances in agriculture.

Investigations about propolis (EEP) and its benefits in the management of agricultural crops are recent. One of the most researched characteristics is its potential to control diseases of bacterial and fungal origin. There have been reports of the antagonistic effects of EEP on pathogens in some crops, such as eggplant (PASTANA et al., 2016), coffee (PEREIRA et al., 2013), beans (PEREIRA et al., 2014), mango (MACHADO et al., 2015), passion fruit (ZIBETTI et al., 2009), corn (SILVA et al., 2018), cucumber (PIVA, 2013), soybean (ZANATTO et al., 2018), and tomato (MORAES et al., 2011).

One of the pioneering studies in the control of bacteria investigated the use of a water-based extract of propolis in the in vitro control of *Agrobacterium tumefaciens*, *Clavibacter michiganensis* and *Xanthomonas axonopodis* pv. *phaseoli* (BIANCHINI; BEDENDO, 1998). The authors found an effective control of the bacteria using a 10% concentration of the extract. Although the researches related to propolis and its effect on bacteria and plant diseases are just in the initial stages, some of them have found in vitro the antagonistic effect of different propolis extracts in some Gram-positive and Gram-negative phytopathogenic bacteria, such as: *A. tumefaciens*, *C. michiganensis*, *Erwinia chrysanthemi*, *X. axonopodis* pv. *phaseoli* and *Xanthomonas gardneri* (BALDIN et al., 2014; LOUREIRO et al., 2014; PEREIRA et al., 2014; JASKI et al., 2015).

In these investigations, the main observed feature is the partial inhibition (bacteriostatic) of bacterial growth in the lab, showing that the EEP has the potential to be used as a tool to control some plant diseases. This activity is linked to the presence of flavonoids, aromatic acids and esters contained in propolis (BURDOCK, 1998). On the other hand, some bacteria in certain plants are apparently insensitive to commonly tested propolis extracts, such as the bacteria of the genus *Pseudomonas* (BIANCHINI; BEDENDO, 1998; HEIMBACH et al., 2016).

In addition to the bactericidal feature, there are some reports that evidenced the antagonistic action of EEP to phytopathogenic fungi. In the case of coffee crops, for instance, PEREIRA et al. (2001; 2008) carried out lab and greenhouse experiments with EEP in the control of coffee rust (*Hemileia vastatrix*) and cercosporiosis (*Cercospora coffeicolla*) diseases. These authors concluded that the use of 4% EEP (16% raw propolis) could stop the germination of the fungi *H. vastatrix*, decreasing the incidence of rust to about 65%. As for the cercosporiosis, its incidence decreased about 75% when applying the EEP. ANDROCIOLI et al. (2012) also observed a decrease in the incidence of coffee rust by using the EEP, finding out its efficacy was similar to the one obtained with commercial fungicides.

In bean crops, the use of EEP (10% raw propolis) resulted in beneficial effects against the anthracnose, causing a 63% decrease in the progress curve of the disease (PEREIRA et al., 2014). Corroborating with the other studies, VIEIRA et al. (2011) also observed that the use of EEP in bean seeds reduced the in vitro growth of the fungi *Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp. and *Colletotrichum* spp.

As for the cucumber and tomato crops, when the studies were performed in a greenhouse, it was possible to notice that the use of 8% EEP (30% raw propolis) resulted in a 53% reduction in the progress curve of powdery mildew disease (*Podosphaera fuliginea*) in cucumbers and drastically reduced the severity of powdery mildew disease (*Solanum lycopersicum*) in tomatoes (MORAES et al., 2011; PIVA, 2013). In addition to powdery mildew, there are reports showing that the EEP was effective in the control of the fungus *Alternaria solani*, that causes the early blight disease in tomatoes (RUBIRA, 2008; MEINERZ et al., 2010).

Although recent, the use of propolis in the management of agricultural crops has been studied by different research groups, finding the antifungal capacity of EEP in several fungi, such as: *Colletotrichum gloeosporioides*, *Corynespora cassiicola*, *Lasiodiplodia theobromae*, *Peronospora manshurica* and *Puccinia polysora* (MONZOTE et al., 2012; MAEKAWA et al., 2013; MACHADO et al., 2015; PASTANA et al., 2016; SILVA et al., 2018; ZANATTO et al., 2018).

The efficacy of propolis on the control of some fungi and phytopathogenic diseases is possibly related to the formation of a waxy layer resulting from the application of EEP, which coats the leaves preventing the fungi penetration. Another possible characteristic is the elicit capacity of the phenolic compounds contained in the propolis that can stimulate the resistance of the plant to pathogens (PEREIRA et al., 2008).

Another property of propolis that has also been investigated is the postharvest conservation capacity of fruits and vegetables through the formation of a biodegradable biofilm. It is known that fruits and vegetables have low shelf life and that the postharvest technologies used to keep these foods for longer are desirable strategies, especially those alternatives that replace the use of synthetic products. In this sense, the use of propolis has a great potential because of its waxy and antimicrobial characteristics, avoiding the loss of moisture from food, reducing plant metabolism, delaying senescence and avoiding the presence of harmful microorganisms (KAMEYAMA et al., 2008; DAIUTO et al., 2012; ALI et al., 2014).

In order to evaluate the conservation potential of propolis, CUNHA et al. (2017) carried out a study and found out that when using 2.5% EEP (11% raw propolis) to coat the yellow passion fruit, there was a lower mass loss because the EEP reduced the water loss by transpiration and, consequently, a decrease in wilting, production and sensitivity to ethylene and oxidation reactions. DAIUTO et al. (2012) verified that in avocados, the use of 2% EEP along with the vegetable wax provided a lower mass loss, lower CO_2 production and greater firmness compared to the fruits that were not coated with propolis. Furthermore, the authors evidenced that the use of propolis and wax in fruits makes their skin shine, providing a better visual aspect and increasing their commercialization. In another study that evaluated the papaya solo 'Golden' cultivar, PASSOS et al. (2016) found that 5% EEP (10% raw propolis) had a positive effect on fruit firmness and prevented mass loss, having a conservation effect similar to the refrigerated treatment for eight days. This fact is important, because it is known that although refrigeration is a good practice of preserving papaya, it can cause injuries to the fruit because of the constant cold.

Thus, the EEP can be a viable alternative to keep fruits and vegetables fresh. Similarly, the researches with strawberry (LOEBLER et al., 2018) and grapes (PASTOR et al., 2011) report the preservation of fruits when the EEP was used as a coating, especially the reduction of mass loss and turbidity since the water loss was avoided. The preservation of food was also verified in lettuces (ARAUJO et al., 2012) when using the EEP as coating. The authors believe that propolis stopped the presence of microorganisms in the food, resulting in its preservation and increasing the shelf life.

Another property related to propolis is the beneficial effect on the vegetative growth of plants. However, this aspect requires further studies to clarify its mechanism of action. Currently, only few groups have researched this topic. Phytopathogen control was also the object of a study by PEREIRA et al. (2013), who observed increases of up to 74.75 and 23.76% in the coffee leaf area and number of leaves, respectively, when using 2.5% EEP (4% raw propolis). The authors associated this vegetative growth with the presence of nutrients in the composition of propolis.

The same effect on growth promotion was observed by PEREIRA et al. (2014) in beans cultivated in greenhouses, where the use of 4% EEP (10% raw propolis) resulted in a 39% increase in productivity compared to the control. PEREIRA et al. (2018) verified an increase in magnesium and chlorophyll content in bean leaves and a 22% yield increase when 8% EEP (10% raw propolis) was applied.

Propolis is an option in terms of natural product that has an evidenced action in the control of some phytopathogens in certain crops. Besides that, positive effects have been observed in the postharvest conservation of fruits and also mineral nutrition of the plant. The decrease in plant water stress is also an aspect to be researched when evaluating the use of EEP.

All reports regarding the use of propolis in agriculture are associated with in vitro and greenhouse experiments. There are strong indications for the practical use of propolis in the field and it can bring several benefits to agricultural crops. However, the advances must continue and, to become a reality, optimization in the process of obtaining the EEP in an industrial scale and the development of commercial products based on propolis aiming its specific use in agriculture are required. Despite the challenge involving the market and the entire production chain, studies show that propolis is a product with great potential to be used in agriculture in an efficient and sustainable way.

As mentioned above, studies involving the use of propolis in agriculture are scarce. Therefore, further studies are necessary, adding a larger number of crops and observing the consequent effects on them. In addition, the extracts should be standardized and the registration of commercial products should be possible, having a positive effect and avoiding the increase in the price of the production process.

AUTHORS' CONTRIBUTIONS

Conceptualization: Carvalho, G.J.L.; Sodré, G.S.; **Formal analysis:** Carvalho, G.J.L.; **Literature search:** Carvalho, G.J.L.; Sodré, G.S.;**Supervision:** Sodré, G.S.; **Writing – original draft and Writing – review & editing:** Carvalho, G.J.L.; Sodré, G.S.

AVAILABILITY OF DATA AND MATERIAL

Data sharing not applicable to this article as no datasets were generated during the current study.

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CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

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