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Evaluation of the effect of foliar application of kaolin clay and calcium carbonate on populations of *Diaphorina citri* (Hemiptera: Liviidae) in Tahiti lime

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ABSTRACT

Diaphorina citri Kuwuyama is one of the main concerns of citrus growers in the tropics because it is the pest responsible for transmitting citrus greening. The use of biorational insecticides has gained importance as an alternative for the control of arthropod populations in horticultural crops. The objective of the present study was to evaluate the foliar application of kaolin clay and calcium carbonate particle films on populations of *D. citri* as well as to estimate the effect of kaolin on physiological variables, such as photosynthesis, leaf temperature, relative chlorophyll content and PSII efficiency, in *Citrus latifolia* Tanaka trees. One set of experiments (two separate experiments) was conducted in two different municipalities (Apulo and Jerusalen, Cundinamarca, Colombia) to evaluate the effect of foliar kaolin clay sprays. Also, two repeat experiments were carried in two different farms in the municipality of Jerusalen to assess the efficacy of foliar calcium carbonate application. In all cases, a statistical design in series of experiments with analysis in different localities arranged in randomized blocks (four blocks) was used. In the kaolin clay experiment, population levels of Asian citrus psyllid were assessed in citrus trees treated with insecticide (imidacloprid) or kaolin clay and compared to population levels in control trees (no treatment). In the calcium carbonate experiment, populations of psyllid were assessed in citrus treated with calcium carbonate and compared to populations in control trees (no treatment). Foliar kaolin clay sprays showed lower population levels of adults (0.4 vs 1.1 individuals per flush), nymphs (0.5 vs 1.1 individuals per flush) and eggs (1.3 vs 4.3 individuals per flush) in comparison to control trees over the eight-week study. The calcium carbonate sprays also diminished the number of adults (0.5 vs 1.0), nymphs (5.0 vs 10) and eggs (4.0 vs 7.5) per flush at the end of experiment. Foliar applications of kaolin clay were as effective as imidacloprid for reducing populations of psyllid eggs. The use of kaolin reduced the photosynthetic rate of citrus trees by 25% compared to the other control and imidacloprid treatments (4.0 vs. 5.2 $\mu mol\ m^{-2}\ s^{-1}$, respectively). Leaf temperature was reduced by approximately 5 °C in trees treated with kaolin clay. Significant differences in relative chlorophyll content (SPAD readings) and PSII efficiency (F_v/F_m ratio) were not observed. In conclusion, the use of inert particles based on kaolin clay and calcium carbonate can be considered a control strategy within an integrated management program of *D. citri* because they showed repellent characteristics, primarily against oviposition. The use of kaolin can also help regulate leaf temperature, especially when episodes of heat stress are expected.

1. Introduction

World citrus production was estimated at approximately 1.2 billion tons in 2014, with the United States as one of the world's leading producers (FAO, 2015). In Colombia, citrus plantations occupied an area of 75,000 ha, with a production of 1,750,000 tons in 2014 (Agronet, 2017). The production of acid limes and lemons is growing in Colombia, obtaining a production of 360,836 tons in 2014 (Dane, 2015).

Citrus greening, or huanglongbing (HLB), is one of the most influential diseases in world citriculture (Bove, 2006; Batool et al., 2007). *Diaphorina citri* Kuwayama (Hemiptera: Liviidae) is the vector responsible for *Candidatus* Liberibacter asiaticus and americanus, causing HLB in the Americas (Canales et al., 2016). *D. citri* was officially reported in Colombia in 2007 (Santivanez et al., 2013). However, a state of phytosanitary emergency was declared in the national territory in 2015 by the Colombian Agricultural Institute (ICA) due to the presence of *D. citri* adults infected with the HLB disease bacterium, and this same

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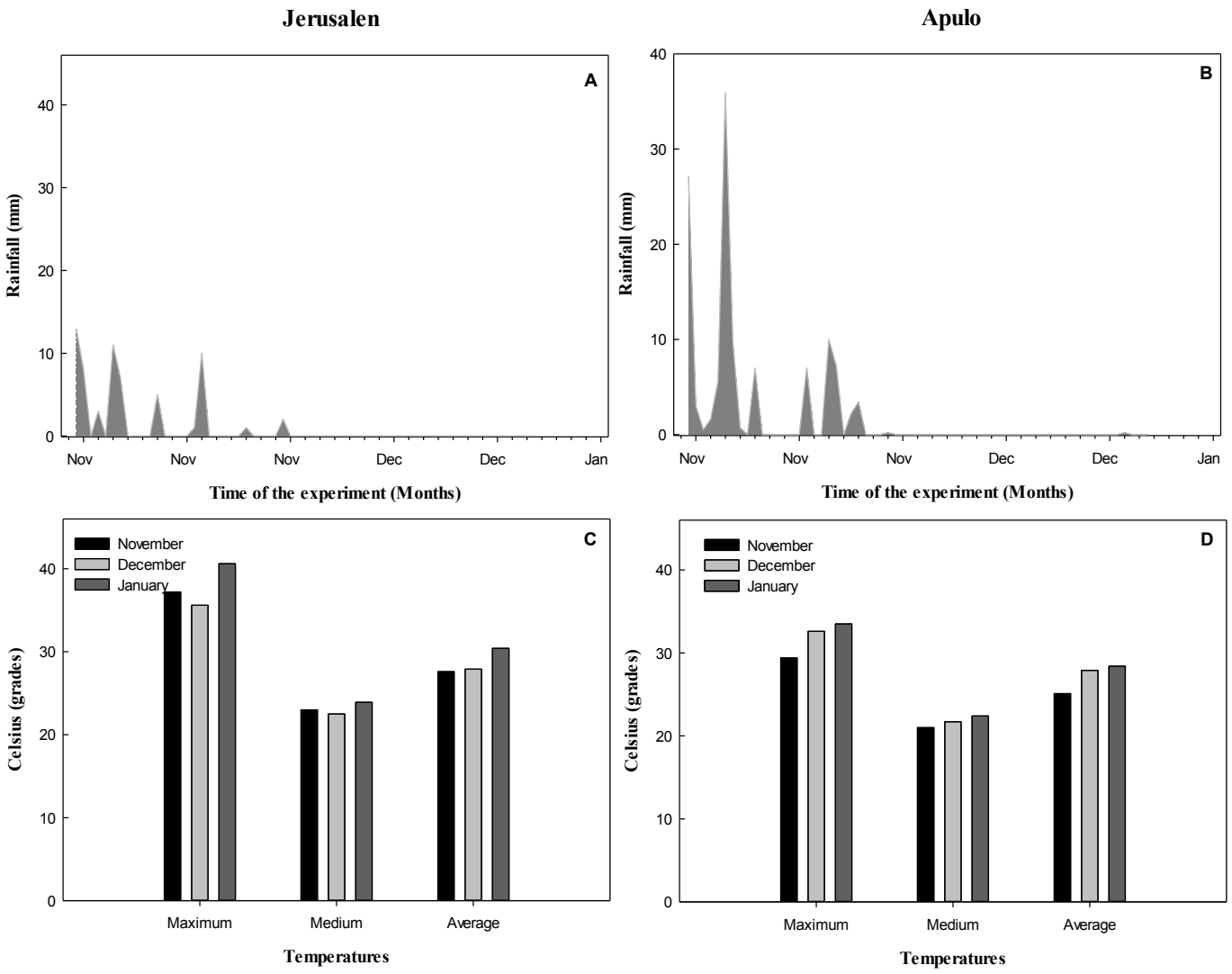

Fig. 1. Rainfall records and maximum, minimum and average temperatures for the kaolin clay experiments placed in Jerusalen (A and C) and Apulo (B and D) municipalities, respectively. Data were obtained from two nearby weather stations (Jerusalen (Latitude: 4°56′18'.06″ N, Longitude: 74°70′23.99″, altitude: 297) and Las Mercedes (Latitude: 4°58′18.89″ N, Longitude: 74°52′66.11″, altitude: 810) stations) of the Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM).

institute declared another national phytosanitary emergency due to the disease during 2017 (ICA, 2015, 2017).

One of the strategies for HLB management in commercial areas has been intensive chemical use against Asian citrus psyllid (ACP) (Hall et al., 2013). However, the frequent use of insecticides raises environmental concerns such as the negative effects on beneficial arthropods or the increase of resistance to insecticides (Hall et al., 2013). In the latter respect, populations of *D. citri* have shown resistance to insecticides in Florida in recent years (Tiwari et al., 2011).

The use of kaolin-based particle films has been reported as a tool for arthropod pest management (Glenn et al., 1999). Kaolin is a small, non-abrasive, white, aluminosilicate mineral that readily dissolves in water and creates a mineral barrier when sprayed onto plants (Glenn and Puterka, 2005). The use of this particle through foliar application has been studied for the control of Hemiptera, such as *Cacopsylla pyri* (L.) (Saour et al., 2010), *Bactericera cockerelli* (Sulc) (Peng et al., 2011), and *Trialeurodes vaporariorum* (Westwood) (Núñez-López et al., 2015). Kaolin clay application also produced reductions in ACP populations (Hall et al., 2007; Kim, 2013). In addition, the use of this particle may be more compatible with biological control programs since it does not affect the natural enemies of *D. citri* (Hall and Nguyen, 2010).

The use of particle film technology has gained importance over the past two decades because these substances cover organs, such as leaves, to reduce insect damage, disease, and abiotic stress and improve yields, helping to reduce the use of toxic chemicals (Sharma et al., 2015). In this regard, Prager et al. (2013) also noted that the development of calcium carbonate particle films is an alternative for insect repellency due to a tactile response. Foliar calcium carbonate sprays reduced the oviposition of *Rhagoletis indifferens* Curran in cherries (Yee, 2012) and repelled *B. cockerelli* in potatoes (Prager et al., 2013).

The use of particle films based on clay or calcium carbonate also benefits plant physiology (Sharma et al., 2015). Kaolin clay improved the water-use efficiency under water stress conditions in cape gooseberries (Segura-Monroy et al., 2015), reduced transpiration and increased chlorophyll content in bean leaves, and decreased canopy temperature in apples (Núñez-López et al., 2015; Glenn et al., 2003). Calcium carbonate particle films are also used to reduce light stress and modify the photosynthetic rate (Glenn and Puterka, 2010).

The recent appearance of citrus HLB in Colombia has caused great concern among growers, who have called for proposals to control the psyllid vector in commercial crops and nurseries. Consequently, one of the strategies proposed to reduce the spread of the disease is the use of particle film barriers (Hall et al., 2007). For this reason, the present study was developed to evaluate the effects of clay- and calcium carbonate-based films on the behavior of populations of *D. citri* as well as to study the effect of kaolin clay on the physiology of mature citrus trees