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Economic impact of the avocado (cv. Hass) wilt disease complex in Antioquia, Colombia, crops under different technological management levels

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A B S T R A C T

The avocado wilt disease complex is the most important pathology in avocado crops worldwide. Despite its importance, research about its economic losses is limited. In this work, the objective was to determine the economic impact of the wilt disease in three regions located in Antioquia, Colombia, and its relationship with the technological level of farm management. Six nurseries and 20 fruit production lots were tested for economic losses due to the wilt disease, including all crops stages of development. Results showed an average incidence and mortality of 28.2 and 60.8%, respectively, at the nursery level. Economic losses due to the disease were 356, 340 and 325 USD per nursery per production cycle. Cost over-run for the nursery stage was 64.5, 75.4 and 50.9 USD for the northern, eastern and southwestern regions, respectively. In the field crops, an incidence of 33.83 and mortality of 25.06 were observed, economic losses were 2340, 1702 and 2103 USD ha^{-1}, with a cost over-run of 225, 372 and 287.9 USD ha^{-1} for the same regions, respectively, during a 8-year period. As expected, the highest yields, lowest incidence of the wilt disease and best cost/benefit relationship, were registered for high technological grade of farm management. In this work, the economic impact of the avocado wilt disease during the different stages of crop development were determined as a direct effect of plant deaths and reduction of plant production, in addition to the cost over-run due to replanting and disease management.

1. Introduction

Currently, avocado is cultivated in 59 countries, both in subtropical and tropical regions. The Americas are home to 60% of the plantations of this fruit crop in the world, and Mexico is the top producer, with 34.5% of the global avocado production (FAO, 2013; http://www.fao.org/faostat/en/#data/QC/visualize (accessed 11.07.17)). In Colombia, the avocado production system has grown greatly in recent years because of both the excellent opportunities that it presents in foreign markets and the existence of an unsatisfied domestic demand (http://www.agronet.gov.co/estadistica/Paginas/default.aspx Agronet, 2017; http://www.agronet.gov.co/estadistica/Paginas/default.aspx (accessed 11.07.17)). The cultivar Hass of avocado is the variety with the greatest planted area in moderately cold climate zones and is primarily grown for exportation (Bernal and Díaz, 2014). For most crops, as the planted area expands, the problems limiting production also increase, the most notable being those of phytosanitary nature (Agrios, 2005; Mitchell and Power, 2003). In the case of avocado in Colombia, the wilt disease complex is the most important problem, in both the area affected and economic losses (Ramírez-Gil et al., 2014; Tamayo, 2007).

The avocado wilt disease complex is associated with a number of causal agents that affect the roots and vascular systems of the trees; these agents induce similar symptoms in the plants, making it difficult to correctly diagnosis and manage them. Of the biotic agents, the oomycete *Phytophthora cinnamomi* Rands is considered to be the most important pathogen (Ramírez-Gil et al., 2014; Vitale et al., 2012; Pérez, 2008; Zentmyer, 1980). Wilt can also be caused by abiotic agents, such as episodes of hypoxia and anoxia (Stolzy et al., 1967; Wager, 1942).

Studies regarding the incidence and economic importance of avocado wilt complex at a global level are scarce, and in many cases very basic, and are usually focused on *P. cinnamomi*, with reported

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losses ranging from 45% to 90% (Pérez, 2008; Tamayo, 2007; Zentmyer, 1980). In Colombia, the economic impact of pathogens associated with wilt complex on avocado crops is practically unknown (Ramírez-Gil et al., 2014; Tamayo, 2007). On the basis of field work, Ramirez-Gil et al. (2017) reported that during crop production, losses in diseased plants were 89.5% with respect to healthy plants. However, under suitable conditions of management, it is possible to improve the production, with a positive cost/benefit relationship. On the other hand, it has also been identified that this disease is very limiting in production systems with low technological level and in areas not suitable for sowing this fruit (Ramírez-Gil et al., 2014).

Despite the different studies on avocado, detailed and precise information on the economic impact of avocado wilt complex is lacking, in addition to the fact that the existing evaluations have been focused on the production stage, resulting in a limited knowledge of the impact in other stages of development such as nursery and initial establishment. This situation generates the need to know the effect of this pathology and to determine the existing relationships with aspects such as the producing region and the existing technological level. This information will serve as a basis to improve management practices and focus research needs on this fruit.

The objective of this study was to determine the economic losses associated with the avocado (cv. Hass) wilt complex in crops located in cultivated areas in Antioquia, Colombia. In this work, we quantified the economic effects of avocado wilt complex by conducting a study for 8 years covering all stages of development in different production systems. The relationship between the disease and the technological level of the crops' farm management and the cost/benefit ratio was determined. In addition, a statistical model was developed to predict production and incidence in accordance with the presence or absence of this disease.

2. Materials and methods

2.1. Location and data acquisition

The evaluated zones were located between 1800 and 2500 m above sea level, with temperatures, precipitation and relative humidity of 14–20 °C, 1800–2600 mm and 75–99%, respectively, corresponding to the tropical lower montane humid forest and tropical lower montane very humid forest life zones (Holdridge, 1967). The trees sampled were all of the Hass variety grafted on West Indian rootstock; age 5 years or older; and sowing distances of 5 × 6, 5 × 7, 6 × 6 and 6 × 7 m. These lots were selected because there were fields dedicated to the production of fruit for export and national market in each of the regions (Fig. 1). Laboratory analyses were carried out in the Laboratory of "Fitotecnia Tropical" at Universidad Nacional de Colombia sede Medellín.

The economic impacts of wilt complex were calculated from data obtained from nurseries and commercial lots over a 8-year period, from 2009 to 2016. All data were collected from crops of avocado cv. Hass during the production phases given in Table 1. The evaluation of the nursery stage was determined using data collected from six commercial production systems of avocado seedlings located in the northern, eastern and southwestern regions of the department of Antioquia, Colombia. In addition, data related to the field stage were collected in 20 avocado lots in the department of Antioquia, six in the north highlands (Donmatías, Entrerríos and San Pedro), 10 in the east (San Vicente, El Peñol, El Retiro, Marinilla, La Ceja and Sonsón) and four in the southwest (Amagá, Jardín and Salgar) (Fig. 1).

2.2. Diagnosis of the pathogens associated with avocado wilt complex

Plants diagnosed as having avocado wilt complex showed, at any developmental stage, symptomatology of generalized wilt; stagnation of growth; loss of vigour, colour or brightness; yellowing of the leaves; dieback; root rot; chancres at the base of the stem; or hemilateral wilt. Additionally, microbial isolates were obtained from avocado root tissues samples following the method described by Ramírez-Gil et al. (2014). Morphological identification of isolates at the genus and species level was performed using the keys given by Barnett and Hunter (1972) and Seifert et al. (2011) for fungi and Erwin and Ribeiro (1996) for *Phytophthora* spp. For each isolate, a corresponding pathogenicity test was conducted. Isolates that induced symptoms of the wilt disease complex were further confirmed through molecular identification by sequencing the genomic ITS regions by polymerase chain reaction (PCR) using the primers pairs ITS5-ITS4 and ITS1-ITS4 (White et al., 1990; Ramírez-Gil et al. manuscript in preparation).

2.3. Selected variables

To perform a detailed analysis of the health status of the avocado production system, four crop stages were defined in the 8 years of evaluation, including the nursery stage (Table 1). For the nursery stage, the incidence and mortality were determined. These were evaluated as the number of diseased plants of the total number of plants and the number of plants that died of the total number of diseased plants, respectively. For field conditions, these variables were determined in stages 2, 3 and 4 (Table 1) using Equations (1) and (2). Additionally, 30 healthy trees and 30 diseased trees were selected in each plot to assess accumulated fruit production and fruit quality (based on weight), according to the following parameters: extra (fruit >250 g), first-class (fruit of 150–250 g) and other (second-class + industrial) (fruit <150 g) (Ramírez-Gil et al., 2017; Bernal and Díaz, 2014; Smith et al., 2011). Additionally, crop management practices associated with the wilt disease were characterized in each production system, according with the procedures reported by Ramírez-Gil et al. (2014).

$$I = \sum_i^n \left(\frac{DP}{TP} * 100\right) + \left(I(n-1) - M(n-1)\right) \tag{1}$$

Where

I = incidence in %.
DP/TP = incidence during the period (diseased plants/total plants).
M = mortality (Equation (2)).
n = stage of evaluation.
i = initial stage of evaluation.

$$M = \sum_i^n \left(\frac{PD}{I+c} * 100\right) + M(n-1) \tag{2}$$

Where,

M = mortality as %.
PD = plant deaths during the period.
I = incidence (Equation (1)).
c = constant (0 when the incidence is ≥ 1 or 1 when incidence is 0).
n = stage of evaluation.
i = initial stage of evaluation (1).

In each of the stages described in Table 1, the fixed and variable