TESTING RESISTANCE OF ROOTSTOCK MATERIALS FOR MANAGING ARMILLARIA ROOT DISEASE IN PEACH ORCHARDS OF MÉXICO

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Abstract

Armillaria mexicana and/or *A*. *mellea* cause Armillaria root disease that results in mortality of peach (*Prunus persica*) trees in orchards of the Mexican sub-tropics. Resistance/susceptibility reactions to *A*. *mexicana* and *A*. *mellea* were evaluated for three *Prunus* rootstocks under greenhouse and field conditions. For greenhouse tests, independent inoculations of *A*. *mexicana* and *A*. *mellea* were conducted on 14 trees for each of three rootstocks: *P*. *persica* × *P*. *davidiana* 'Nemaguard', *P*. *persica* landrace 'Criollos of La Goleta' genotypes, and *P*. *salicina* Japanese plum 'Mondragon', with four non-inoculated trees serving as controls for each rootstock. For greenhouse inoculations with *A*. *mexicana*, 'Criollos of La Goleta' and 'Nemaguard' rootstocks showed the highest incidence of infected roots (21.6% and 24.6%, respectively). In contrast, 'Mondragon' showed the lowest (2.5%) incidence of infected roots. Although 'Criollos of La Goleta' produced the highest root dry weights, root volumes, and plant dry weights, its root systems contained abundant mycelial infections. Under greenhouse conditions, an overall lower (17.5%) incidence of root infection was observed after inoculations with *A*. *mellea*. Inoculations with *A*. *mexicana* were performed in a commercial orchard that was naturally infested with *A*. *mexicana* using 21 plants of 'Mondragon' (cutting-derived), 'Criollos of La Goleta', and *P*. *mume* 'Japanese apricot'. The lowest susceptibility to *A*. *mexicana* was exhibited by 'Mondragon' rootstock. Management of Armillaria root disease in peach orchards of Mexico depends on identifying *A*. *mexicana*-resistant rootstock, such as 'Mondragon' (Elías-Román et al. 2019).

Introduction

Armillaria root disease causes wide-spread and severe damage/mortality within peach (*Prunus persica*) orchards in subtropical Central México (e.g., Morelos, Michoacán, and State of México), which is a primary region for peach production (Coria-Avalos et al. 2005, Alvarado-Rosales 2007, Fucikovsky 2009, Elías-Román et al. 2013, Rivas-Valencia et al. 2017, Elías-Román et al. 2018). In this region of México, Armillaria root disease of peach is caused by *A*. *mellea*, *A. gallica*, and *A*. *mexicana*, a recently described species (Elías-Román et al. 2018). Management strategies are critically needed to reduce *Armillaria*-caused mortality of peach trees to promote sustainability and production for commercial orchards within the prominent peach-production areas of México. The objective of this study was to evaluate the resistance/susceptibility of four *Prunus* rootstocks to infection by *A*. *mexicana* and/or *A*. *mellea* under greenhouse and/or field conditions.

Materials and Methods

Rootstock resistance to Amillaria root disease were evaluated under greenhouse and field conditions (Figures 1 and 2).

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Rootstocks – Four *Prunus* rootstocks for peach were tested:

1) *P. persica* x *P. davidiana* 'Nemaguard' (greenhouse test only);
2) *P. persica* landrace 'Criollos of La Goleta' genotypes;
3) *P. mume* seedlings, Japanese apricot (field test only); and
4) *P. salicina*, Japanese plum 'Mondragon'.

Inoculum – Seeds (acorns) of oak (*Quercus* sp.) were used to increase *Armillaria* inoculum, according to the procedure of Beckman & Pusey (2001) (Figure 1). *Armillaria mexicana* (isolate MEX85) and *A. mellea* (isolate MEX100) were used for greenhouse inoculations; whereas MEX85 isolate was used for field inoculations within a peach orchard that was heavily infested with *A. mexicana* (Figures 1 and 2).

Variables evaluated – Infected root incidence % (IRI), Dead root incidence % (DRI), Root dry weight (RDW), Root length of lateral roots (RL), Root volume (RV), Plant dry weight (PDW), Disease severity (0 – 4 scale, field test only, Figure 3), and Weighted average severity (WAS) in the field, according to the formula of Guzman-Plazola et al. (2004).

Experimental design and statistical analysis – In the greenhouse, a split plot with completely randomized design was used with a factorial arrangement. Incidence value percentages were transformed into their arcsin values using arcsin√x/100. The retransformed means to original units are shown in Table 1. The ANOVA was performed with the GLM procedure and the comparison of means with LSmeans (SAS®, 2011). In the field, trees were established in a randomized block design, with seven replications. The severity values of field experiment were analyzed using the Friedman test in InfoStat (2008).

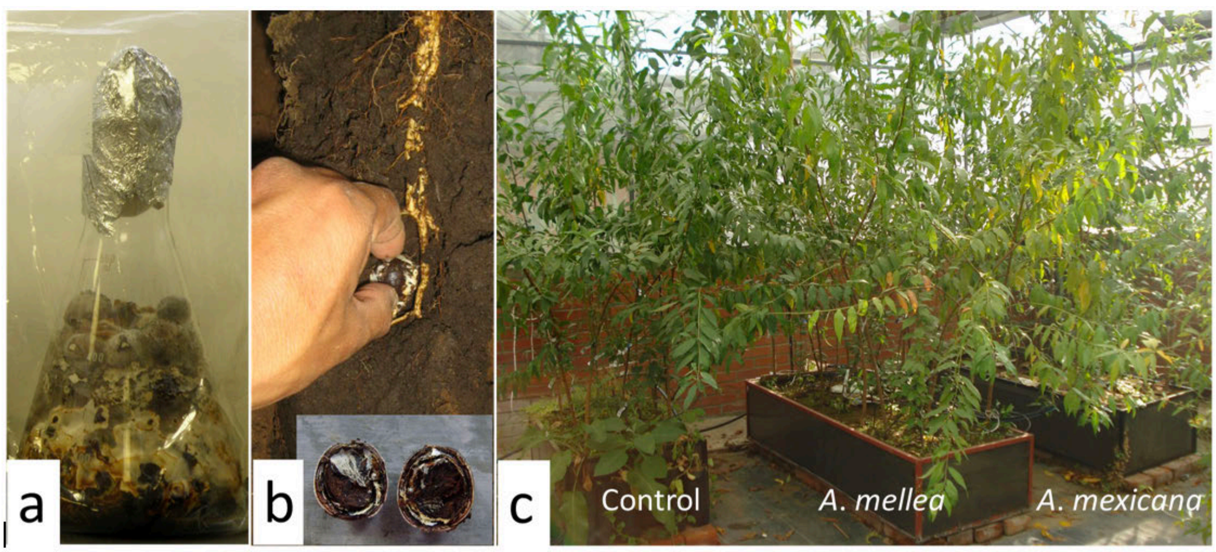

Figure 1: *Rootstock inoculation with* Armillaria *spp. a) Seeds (acorns) of oak (*Quercus *sp.) used to increase* Armillaria *inoculum; b) Inoculation in roots; c)* Prunus *rootstock trial in greenhouse.*

Results

In the greenhouse at 22 months post-inoculation, 'Mondragon' showed a high resistance to *A. mexicana* and *A. mellea*, evidenced by the lowest averages with 2.5% IRI and 0% DRI. 'Criollos of La Goleta' and 'Nemaguard' showed high susceptibility to *A. mexicana*, and *A. mellea*, with similar values (21.6 and 24.6

IRI; 7.2 and 9.2 DRI, respectively) (Table 1). The *Armillaria* species used for inoculation produced no detectable differences for RDW, RV, RL, and PDW, but significant differences were noted among the rootstocks. The highest growth was observed in 'Criollos of La Goleta', followed by 'Nemaguard'. 'Mondragon' had the lowest values of RDW, RV, RL and PDW (data not shown). In all field evaluations (2013–2015), 'Mondragon' showed the highest resistance against *A*. *mexicana* (40, 59, and 66 months post-inoculation), which was displayed as the lowest values on WAS and average ranks (Table 2).

Figure 2: Prunus *rootstocks test in field conditions. a) Inoculation of a tree with an acorn infected with* Armillaria*.*

Table 1: *Percentage of infected and dead roots in three rootstocks inoculated with two* Armillaria *species and their combinations at 22 months post-inoculation in the greenhouse (From: Elías-Román et al. 2019).*

Rootstock/ *Armillaria* sp. Inoculated		**n[1]**	**Infected root incidence (IRI) %[2]**	**Dead root incidence (DRI) %[2]**
'Nemaguard'[3]		18	24.6 a	9.2 a
'Criollos of La		18	21.6 a	7.2 a
'Mondragon'[5]		18	2.5 b	0.0 b
A. mexicana		21	31.2 a	13.1 a
A. mellea		21	17.5 b	3.3 b
Control		12	0.0 c	0.0 b
A. mexicana	'Nemaguard'	7	49.2 a	26.4 a
	'Criollos of La Goleta'	7	36.7 a	12.8 b
	'Mondragon'	7	7.6 b	0.0 c
A. mellea	'Nemaguard'	7	24.5 a	1.2 bc
	'Criollos of La Goleta'	7	27.9 a	8.7 bc
	'Mondragon'	7	0.0 b	0.0 c
Control	'Nemaguard'	4	0.0 b	0.0 c
	'Criollos of La Goleta'	4	0.0 b	0.0 c
	'Mondragon'	4	0.0 b	0.0 c

[1]Replications; [2]Means followed by the same letters in a column are not significantly different, based on LS-means ($P <$ 0.05); [3]*Prunus persica* × *P. davidiana* (Chinese wild peach); [4]Landrace of *P. persica* (peach); [5]*P. salicina* (Japanese plum)

Table 2: *Armillaria disease severity on three peach rootstocks evaluated 6 years after planting in an orchard naturally infested with* Armillaria mexicana *in Coatepec Harinas, State of México, México. August 2009 to May 2014 (From: Elías-Román et al. 2019).*

Rootstocks	**Disease severity[1]**					**Weighted average severity by rootstock**	**Average ranks[2]**
	0	**1**	**2**	**3**	**4**		
Disease severity 2013[3]							
'Japanese apricot'[4]		0	2	1	4	3.3	2.71 a
'Criollos of La Goleta'[6]	2	0	3	0	2	2.0	1.79 ab
'Mondragon'[7]	2	2	3	0	0	1.1	1.50 b
Disease severity 2014[8]							
'Japanese apricot'	0	0	1	0	6	3.7	2.57 a
'Criollos of La Goleta'	0	0	1	0	6	3.7	2.36 a
'Mondragon'	2	2	2	1	0	1.3	1.07 b
Disease severity 2015[9]							
'Japanese apricot'	0	0	0	0	7	4.0	2.5 a
'Criollos of La Goleta'	0	0	0	0	7	4.0	2.5 a
'Mondragon'	2	1	3	1	0	1.4	1.0 b

[1]Individual disease severity visually assigned to five (0-4) modified classes of disease severity similar that reported by Metaliaj et al. (2006); [2]Average ranks with different letters are significantly different (alpha=0.0.5); [3]Disease severity observed at 40 months post-inoculation (Source: Elías-Román, 2013); [4]*P. mume* (Japanese apricot); [5]Number of trees in each class of disease severity; [6]Landrace of *P. persica* (peach); [7]*P. salicina* (Japanese plum); [8]Disease severity observed at 59 months post-inoculation; [9]Disease severity observed at 66 months post-inoculation.

Discussion

Armillaria disease incidence/severity varied among the tested rootstocks, which could be attributed to differences in tolerance/resistance of *Prunus* host genotypes, differences in virulence of the *Armillaria* species/isolates used as inoculum, and/or other environmental interactions.

Under greenhouse conditions, *A. mexicana* was found to be more virulent than *A. mellea* across all rootstocks tested. *Armillaria mexicana* is a recently described species (Elías-Román et al. 2018); however, its distribution is already known to include important peach-producing regions, such as State of Mexico (Elías-Román et al. 2013) and Michoacan (Rivas-Valencia et al. 2017).

The full geographic and host range of *A. mexicana* is largely unknown and warrants further study. This study further confirms the role of *A. mexicana* as a primary root pathogen that causes extensive damage/mortality in peach trees in central Mexico, which is perhaps attributable to its higher virulence with respect to *A. mellea*, and its greater distribution (Elías-Román et al. 2013).

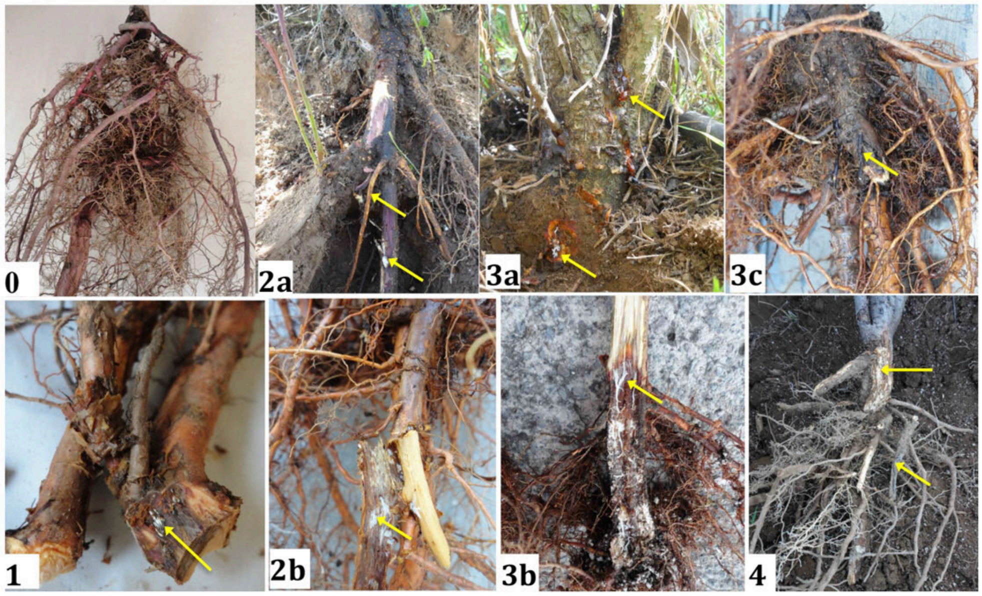

Figure 3: *Armillaria disease severity scale of five classes (0 to 4) in* Prunus *spp. exposed to* Armillaria *in the field, where: 0 = Healthy tree. 1 = Tree without disease symptoms or dead, but with one or more primary or lateral roots with initial colonization by a mycelial fan of* Armillaria*; 2 (a-b) = Tree without disease symptoms in the foliage, presence or absence of gummosis in root crown and/or stem, and living primary or secondary root, colonized with subcortical mycelial fan of* Armillaria*, and presence or absence of* Armillaria *rhizomorphs (2a), dead primary or secondary root, colonized with subcortical mycelial fan of* Armillaria*, and presence or absence of rhizomorphs (2b); 3 (a-c) = Tree with or without above-ground disease symptoms (gummosis, chlorotic leaves), subcortical colonization of* Armillaria *mycelial fans in the root crown and/or one or more roots (3a and 3b), one or more dead roots infected by* Armillaria*, presence or absence of rhizomorphs (3c); and 4 = Dead tree. Arrows show symptoms and signs of* Armillaria*. (From: Elías-Román et al. 2019).*

Conclusions

Work to develop *Armillaria*-resistant rootstock, such as 'Mondragon', is an integral part of management strategies for Armillaria root disease of peach in Mexico. Integrated disease management strategies, such as excavating root collars above ground level (Schnabel et al. 2012) and inoculum reduction measures (Cox et al. 2005b), can be used in conjunction with *Armillaria*-resistant rootstock to improve overall production.

For each production area, it is critical to determine which *Armillaria* spp. are present. The *Armillaria* genus displays considerable variation in virulence, and different *Armillaria* species represent different threats for different hosts and geographic areas. In peach orchards in central Mexico, *A*. *mexicana* appears to be the primary pathogen, which must be considered for disease management strategies. Furthermore, management strategies for Armillaria root disease should also consider other factors, such as climate, soil types, technology, economics, and other environmental factors.

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