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Constraints to Rootstocks for Growing Low-chill Peaches in Florida's Changing Climate

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Florida's peninsular shape and close proximity to the equator creates a humid, subtropical environment, with more than half of the year characterized by warm temperatures (> 32.2°C) and high relative humidity (> 50% RH) (Black, 1993). Over two-thirds of the state is surrounded by the Gulf of Mexico or the Atlantic Ocean, which absorb the sun's rays and radiate heat into the atmosphere facilitating the warm air temperatures for which Florida is known. These warm, tropical waters also bring about heavy rain fall and extreme seasonal weather events that impact both coastal and inland areas.

From 1988 to the present day, statewide precipitation in Florida has shown a steady increase [National Oceanic and Atmospheric Administration (NOAA), undated). The Conservation Biology Institute asserts that Florida has latitudinal variation in precipitation trends with southern Florida predicted to experience a decrease, the northern portion of the state an increase, and the central region experiencing virtually no change in precipitation (Ward, 2008). Conversely, Martinez et al. (2012) found that precipitation is increasing in all regions of the state; however, the northern region of Florida was predicted to experience a greater increase in precipitation. These latitudinal differences in precipitation may coincide with variations in air temperatures throughout the state. When looking at air temperature trends in Florida, Martinez et al. (2012) found that temperatures in the northern panhandle and central region tended to decrease over time, whereas in the southern region temperatures tended to increase. Statewide air temperatures in Florida have been increasing since about 1977 (NOAA, undated).

This range allows growers to produce a variety of crops, ranging from tropical to temperate. Nevertheless, Florida faces global competition for many of its exports including berries, citrus, and sugar cane. This has motivated efforts to diversify crops grown in Florida to allow growers the opportunity to stake claim to a variety of markets. One of these markets is low-chill peaches. Compared to national leaders in peach production, Florida has a short winter season which quickly becomes an early spring season. This allows growers to provide fresh peaches to consumers while other states do not have ripe fruit. Despite this market advantage, biotic and abiotic obstacles such as pest and pathogen pressure, flooding, high temperatures, and salinity stress pose risks to successful cultivation of peaches in Florida.

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Available Rootstocks for Florida Peach Production

Beginning in the 1950s, the University of Florida, IFAS (UF/IFAS) in collaboration with the USDA-Agricultural Research Station (USDA-ARS) Peach Rootstock Breeding Program in Byron, GA, has made efforts to establish peach as a viable crop for Florida. Through careful breeding and appropriate cultural practices, the UF/IFAS Stone Fruit Breeding program, currently led by Dr. José X. Chaparro, has sought to develop cultivars that exhibit disease resistance, low chilling requirements, and large, high-quality yields (Sarkhosh, 2019b). In commercial production of many fruit crops, grafting of scion cultivars onto rootstock cultivars is a recommended practice to increase tree resistance to biotic and abiotic stresses. *Prunus* rootstock cultivars, 'Sharpe', 'Flordaguard', and 'MP-29'; have been released for commercial production and at-home gardening in Florida (Table 1).

Despite the plum rootstock 'Sharpe' having resistance to the biotic stressors listed in Table 1, it has decreased yield and fruit size compared to 'Flordaguard' rendering it impractical for commercial use (Beckman et al., 2008; Sarkhosh, 2019a). Currently, 'Flordaguard' is the recommended rootstock cultivar for peach production in Florida because of its low-chilling requirement and resistance to *Meloidogyne incognita*, *M. javanica* , *M. floridensis,* three damaging root-knot nematodes. The plum × peach rootstock cultivar 'MP-29' has similar resistance to pathogens as 'Sharpe' with even greater resistance to *Armillaria* root rot (Beckman et al., 2012) (Fig. 1). 'MP-29' has reduced vigor compared to 'Flordaguard', and can be used as a semi-dwarfing rootstock to increase planting density (Beckman et al., 2012). These adaptations have aided in optimizing peaches for production in Florida, but there are still environmental obstacles facing the economic viability of peach as a crop in Florida.

Table 1. Available rootstock cultivars for cultivation in Florida[z].

Cultivar	Date Released	Chilling Units	Genetic Components	*Meloidogyne incognita*	*Meloidogyne javanica*	*Meloidogyne floridensis*	*Armillaria* Root rot	Peach Tree Short Life
'Sharpe'	2007	500	*Prunus* angustifolia (Marsh.) 'Chickasaw' plum × unknown plum species	Resistant	Unknown	Resistant	Resistant	Resistant
'Flordaguard'	1991	300	Six generations from Chico 11 × *P. davidiana* (Carr.) Franch, C26712	Resistant	Resistant	Resistant	Susceptible	Susceptible
'MP-29'	2012	750	'Edible Sloe' plum × SL0014 (*P. persica*)	Resistant	Resistant	Resistant	Resistant	Resistant

[z]Data from Sherman et al., 1991; Beckman et al., 2008; Beckman et al., 2012; Horticultural Sciences Department (HOS), 2012; Sarkhosh et al., 2019a; Sarkhosh et al., 2019b; and Sarkhosh et al., 2020.

Fig. 1. Effects of *Armillaria* root rot in a Florida peach orchard. Photo credit T. Beckman.

Where Do We Go from Here?

In addition to appropriate rootstock selection, it is critical to understand potential environmental stressors. Florida's long rainy season, coupled with warm soil temperatures, provides a breeding ground for pathogens to thrive. Developing disease resistant rootstocks is imperative to combatting Florida's moist soils. While 'Flordaguard' is the only recommended rootstock for Florida peach production, it is susceptible to *Armillaria* brown rot, peach tree short life, and *Botryosphaeria dothidea* (peach gummosis) (Sarkhosh, 2019a). These pathogens wreak havoc on established and newly planted orchards alike, causing dieback and reducing tree longevity and fruit quality. Peach tree short life (PTSL) is defined as the unexpected death of young peach trees, typically during the spring season (Beckman and Nyczepir, 2004). Researchers conclude PTSL is the result of an interaction of several factors, including susceptibility to *Macroposthonia xenoplax* (ring nematode), cold damage, bacterial canker, and variation in late winter and early spring temperatures (Ritchie and Clayton, 1981; Nyczepir et al., 1983; Beckman and Nyczepir, 2004). The proliferation of these pathogens can be facilitated by extreme environmental conditions, such as waterlogged soils after heavy rainfall.

Regardless of the location, flooding is regarded as a persistent threat to the state of Florida. The state's low elevation puts agricultural operations at risk of wind and flood damage following severe weather events such as tropical storms and hurricanes. Researchers believe the observed increase in the frequency and magnitude of tropical storms is likely caused by climate change (Mann and Emanuel, 2006; Kossin et al., 2007). Since this trend is likely to continue, it is vital that *Prunus* rootstocks selected for Florida peach production be tolerant to the increased risk of flooding.

Florida's hurricane (June-Nov.) and rainy seasons (June-Oct.) occur mostly during the warmest months of the year (May-Sept) (Martinez et al., 2012; Zhang et al., 2017; NOAA, 2021). The overlap between high temperatures and heavy rain creates the potential for the simultaneous exposure of crops to flooding and heat stress. Reighard et al. (2001) hypothesized that the shallow nature of *Prunus* root systems led to greater damage to roots than scions, following a hurricane . The close proximity of *Prunus* root systems to the soil surface increases their risk of damage from high soil temperatures and/or flooding. Increased precipitation in soils having a hardpan, can cause a perched water table, effectively waterlogging the soils (Fig. 2). Excess rainwater in the rootzone can displace soil oxygen, resulting in low soil oxygen concentrations, or hypoxia. Hypoxia decreases the plant's ability to absorb CO_2 through stomata in the leaves, and subsequently photosynthesize (Len et al., 2020; Salvatierra et al., 2020). The overall growth and development of the plant is affected, which can stunt or even kill the plant entirely (Fig. 2).

Hypoxia also inhibits root respiration resulting in insufficient energy production that can hinder the plant's ability to recover from possible mechanical injuries leaving wounds susceptible to pathogens and high light intensity (Crane et al., 1999). In the likely event of severe weather occurring during a period of high temperatures in Florida, plant rootzones may be subjected to greater stress. High temperatures in the rootzone can lead to

Fig. 2. Post-flooded Florida peach orchard following Hurricane Irma (2017). Photo credit: A.Sarkhosh.

decreased photosynthetic activity, oxidative stress, and cellular damage and death (Kotak et al., 2007; Fahad et al., 2017). Data from the Florida Automatic Weather Network (http://fawn.ifas.ufl.edu) indicates that several cities from south to north central Florida have experienced soil temperatures ranging from 32 to 49 °C in the past 20 years. The potential for these stresses to occur simultaneously provides justification for further development of a hypoxia and high temperature tolerant rootstock.

While peach is considered intolerant of flooding, wide variation within the *Prunus* genus has revealed other species that exhibit tolerance to flooding (Ranney et al., 1994; Pimentel et al.,2014; Ranney et al., 2016; Pérez-Jiménez et al., 2017; Rubio -Cabetas et al., 2018; Toro et al., 2018; Klumb et al., 2020). Recently, researchers have determined that the medium-chill plum rootstock,'MP-29', has increased tolerance to flooding compared to the low-chill peach rootstock, 'Flordaguard' (McGee et al., 2021) (Fig. 3). This wide variation has led researchers to investigate tolerance to rootzone temperatures that exceed averages in specific production areas (Bonomelli, et al., 2009; Hao et al., 2011; Bonomelli et al., 2012; Gainza et al., 2015). Further research is needed to determine if low-chill *Prunus* rootstocks exhibit tolerance to high soil temperatures occurring in Florida.

Salinity stress in the rootzone of glycophytes (plants intolerant to salinity stress) can result in a reduction in photosynthetic activity, disrupting plant development as well as cell death prompted by the accumulation of harmful reactive oxygen species (Massai et al., 2004; Ranjbarfordoei et al., 2006; Aazami et al., 2012; Papadakis et al., 2018; Shahid et al., 2020). Generally, plums exhibit lower mortality and fewer acute symptoms when exposed to salinity stress in the rootzone compared to peaches (Nasr et al., 1977; El-Motaium et al., 1994). The risk of salinity stress for crops in Florida is exacerbated by heavy precipitation, rising sea levels, and storm surge (Papacek et al., 2020; Wdowinski et al., 2020). These events can lead to a rise in the water table, which can prevent the downward flow of salts in the soil, leaving them in the rhizosphere (Boman and Stover, 2018).

A study involving salinity stress in citrus trees found that even root-knot nematode resistant rootstocks became susceptible to the nematodes when irrigated with highly saline water (Syvertsen and Levy, 2005). Operations located in coastal areas will need to mitigate the risk of high salinity with careful attention to production factors such as proper irrigation, drainage, and nutrient supply and balance. Operations located inland are not exempt from the risk of salinity stress as periods of high temperatures without adequate irrigation or precipitation can lead to increased evaporation leaving behind excess salts in plant rootzones. While there is limited research concerning tolerance to high salt levels in irrigation water used for low-chill *Prunus* rootstocks, the increased risk of flooding in Florida due to severe weather events and heavy rainfall may motivate future researchers to investigate this.

Fig. 3. Rootstock cultivar, 'Flordaguard', response to waterlogged soil. Photo credit: T. McGee.

Conclusion

As climate conditions continue to deteriorate, researchers race to predict and understand the impact of our changing climate on agricultural crops, including peaches. The diverse nature of the *Prunus* genus has facilitated global efforts to optimize peach production to various environments. Florida's short winter season is abruptly met with an early spring season allowing growers to provide fresh peaches to the consumer, while other domestic competitors do not have ripe fruit. Despite the progress made to perfect peach production in Florida's environment, there is still much work to be done to ensure the economic viability of commercial peach production in Florida. Environmental constraints to peach production such as pathogen pressure, salinity stress, flooding, and heat stress complicate the successful cultivation peaches in Florida. The UF/IFAS Stone Fruit Program is considering these obstacles and working towards expanding our knowledge of how low-chill *Prunus* spp. respond to these stresses, with the ultimate goal of developing low-chill peach rootstocks that are tolerant to one or a combination of the aforementioned biotic and environmental stresses.

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