Permanent wilt point from two methods for different combinations of citrus rootstock

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ABSTRACT: *Considering that water is extremely important in agricultural production, but with restricted availability in some Brazilian regions, this research sought to identify the water limit for the rootstocks: Cleóptra tangerine (Citrus reshni hort. Ex Tan), Volkamer lime (Citrus Volkameriano Pasquale), Citrandarin 'indio' (TSK X TRENG 256), Santa Cruz Rangur lime (Citrus × limonia) and Sunki Tropical tangerine (Citrus sunki HORT. EX TAN) grafted orange 'Pera' (Citrus sinensis), obtained by two methods: the traditional method of determining the permanent wilting point described by SHANTZ & BRIGGS (1912) recovery of plants with saturated environment and by irrigating recovery method. The experimental design used was in a completely randomized design with four replications totaling 20 experimental plots. It was verified that the rootstocks Cravo Santa Cruz lemon and Volkamerian lemon were the most resistant in initial conditions of water restriction, evaluated by the method of BRIGGS & SHANTZ (1912), with recording of humidity of 0.0488 and 0.0489 respectively. Under more severe conditions of water restriction, determined by the irrigation method, Volkamerian lemon presented the highest resistance, with a humidity of 0.0371.*
Key words: *permanent wilting point, water déficit, hydrical stress.*

Ponto de murcha permanete a partir de dois métodos para diferentes combinações copa porta-enxerto de citros

RESUMO: *Considerando que a água é extremamente importante na produção agrícola, mas com restrita disponibilidade em algumas regiões brasileiras, é que esse trabalho buscou identificar o limite hídrico inferior para os porta-enxertos: tangerina Cleóptra (Citrus reshni hort. Ex Tan), limão Volkameriano (Citrus Volkameriano Pasquale), citrandarin 'Indio'-TSK X TRENG 256, limão Cravo Santa Cruz (Citrus × limonia) e tangerina Sunki Tropical (Citrus sunki HORT. EX TAN) enxertadas em laranja 'Pêra' (Citrus sinensis), obtidos por dois métodos: o método tradicional de determinação do ponto de murchamento permanente descrito por BRIGGS & SHANTZ (1912) com recuperação das plantas em ambiente saturado e o método de recuperação por rega. O delineamento experimental utilizado foi o inteiramente casualizado, com quatro repetições, totalizando 20 parcelas experimentais. Verificou-se que os porta-enxertos limão Cravo Santa Cruz e o limão Volkameriano foram os mais resistentes em condições iniciais de restrição hídrica, avaliado pelo método de BRIGGS & SHANTZ (1912), com registro das umidades de 0,0488 e 0,0489, respectivamente. Em condições mais severas de restrição hídrica, determinado pelo método de rega, o limão Volkameriano foi o que apresentou maior resistência, com a umidade de 0,0371.*
Palavras-chave: *ponto de murchamento permanente, déficit hídrico, estresse hídrico.*

INTRODUCTION

Water is the most important factor limiting agricultural productivity, since water deficit can influence metabolism (CRUZ et al., 2005), the structure and transport in plants (BIANCHI et al., 2016), promoting morphophysiological disorders crops (FERRAZ et al., 2011). Also, the shortage of water is a phenomenon occurring registered in large acreages (NOGUEIRA et al., 2001).

It is considered as water available to plants, that present between the field capacity (FC) and permanent wilting point (PWP) (SOUZA et al., 2002). The field capacity is the amount of water held by the soil after the excess is drained movement with marked decrease (VEIHMEYER & HENDRICKSON, 1949). The PWP is the minimum limit of Soil Water Content which the plants to lose turgor and wilted not recover to be transferred to the dark environment and saturated with water (BRIGGS & SHANTZ, 1912).

These limits are influenced by soil physical properties, and may differ between crops in response to existing adaptation mechanisms in each species (SALVESTRO et al., 2013). From several studies it was established tension of 1.5 MPa as water available limit the PWP (COELHO et al., 2014).

However, the physiological wilting point of the crops does not always correspond to this value, since each species respond differently to such

a situation (ALVES, 2010), being the most suitable to define the specific point of physiological wilting for each crop (BRIGGS & SHANTZ, 1912), thus ensuring greater efficiency in the management of irrigation projects, as well as in choosing the most efficient species in water use (KLEIN et al., 2010).

The choice of species more resistant and efficient use of water is the most suitable alternative for agriculture in arid and semi-arid environments, as the great periods of drought facing, reaching extreme scarcity at some time of the year (SILVA et al., 2009).

In situations of water scarcity, plants can be affected by that describes how stress conceptualized phenomenon while a deviation from the ideal conditions for life, capable of causing changes and responses at different levels in the body, which may be a reversible principle or become permanent depending on the intensity or duration of the phenomenon (LARCHER, 2000).

According BIANCHI et al. (2016), stress has four phases: initial phase, known as the alarm reaction; resistance or restitution phase, wherein the plant uses mechanisms to cope with the situation to the maximum; final phase or stage of exhaustion when the resistance mechanism are no longer able to respond and may lead to plant collapse; and the regeneration phase, when stress is suspended and the plant may or may not recover fully or partially.

Thus, it is likely that the PWP not always represent the final stage of stress exhaustion, but the regeneration phase, when access to water again. The citrus industry is one of the agricultural activities with great importance in the Brazilian economy, bequeathing to Brazil the title of world's largest producer of this crop (SOARES et al., 2015). However, one of the deficiencies in this activity is the use of few combinations of canopy cover and rootstock, a factor that exposes them to pests attack and the occurrence of abiotic stresses, among these, water stress (SCHINOR et al., 2006).

Thus, it is believed that when reaching PWP by the traditional method proposed by Briggs & Shantz, the plants are still able to recover when access to water in the soil, being this the condition similar to that experienced by the plants in the field, in periods of drought, when they are submitted to the water deficit extending until the new rainy season Thus, it was sought to identify the moisture limit in the soil at the physiological wilt point by the conventional method, as well as the moisture limit for the physiological PWP obtained by irrigation, for combinations of 'Pêra' orange with five citrus rootstock.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse in the experimental unit belonging to the Universidade Estadual de Feira de Santana, Bahia, Latitude: 12 16 '00 "S and Longitude: 38 58' 00" W, starting in January 2017 and ending in June of the same year.

Were analyzed the rootstocks: Cleóptra tangerine (*Citrus reshni hort. Ex Tan*), Volkamer lime (*Citrus Volkameriano Pasquale*), citrandarin 'Indio' (TSK X TRENG 256), Santa Cruz Rangpur lime (*Citrus × limonia*) and Sunki Tropical tangerine (*Citrus sunki HORT. EX TAN*) grafted orange 'Pera' (*Citrus sinensis*) in a completely randomized design with four replications totaling 20 experimental plots.

The seedlings were produced and grafting by Embrapa Mandioca e Fruticultura growing, located in Cruz das Almas -BA city. After grafting the plants were transplanted to pots with 50 cm tall and 20 cm diameter, it was filled with 14 kg of substrate, produced on the experimental unit, having the following chemical characteristics: pH 6.5; P 9.73 mg/ dm³; K 15.64 mg / dm³; Na 23.0 mg / dm³; Ca^{2+} 7.0 cmol (c) / dm³; Mg^{2+} 1.8 cmol (c) / dm³; Al^{3+} 0.0 cmol (c) / dm³; H + Al 0.7 cmol (c) / dm³; MO 1.82%.

The experiment started one month after the transplant, in which the plants were watered with 900 mL of water, the containers were sealed with aluminum foil, covered with film paper. From that moment the plants were not watered until reaching the permanent wilting point.

As the plants showed wilting signal, the pots were moved to the end of the day a dark room with relative humidity close to 100% for 48 hours, it is seen plants already developed.

When completing the period, we observed the return or not of turgidity of each plant, adopting the criteria that if at least one sheet to recover, the vessel then returned to the greenhouse, remaining without irrigation. This succession was not until the final return of turgidity, assuming then as a traditional physiological permanent wilting point (TPPWP). Soil samples were collected (without roots), weighed on a precision scale and taken to the drying oven at 105 °C for 48 hours and weighed again to determine moisture in the sample gravimetric basis. From the gravimetric water content in the soil samples for each evaluated plant, the moisture corresponding to the physiological permanent wilting point (TPPWP) of the crop was determined.

After reaching the traditional method (TPPWP) by BRIGGS & SHANTZ (1912) initiated

to check that wilt point from the access Soil Water Content. Thus, the same plants were watered again with 900 mL suspending access to water again, and awaiting the physiological permanent wilting point by watering (PPWPW). At that time a new soil sample was collected to obtain the water content at the physiological permanent wilting point by watering. The criterion used for the return was the recovery of the plants or even the emission of new leaves within a period of three days.

Plants that were recovering were held without access water to reach the water limit and no definitive return. Before being watered again, new soil sample was collected up to obtain the water content in point of permanent wilting of reference - PWPr.

To determine the vase capacity, it was built a water retention curve in the soil, using Richards system, depending on the moisture content in saturated samples obtained and subjected to pressures of -1, -33, -100, -500, -1500 kPa. For this we used a soil sample collected in rings, saturated capillary, for a period of 24 hours and placed in the extractor apparatus porous plates Richards.

After equilibration, the samples were weighed and oven dried at 105 ° C, to obtain the corresponding moisture at each pressure. The data were fitted to the mathematical model proposed by VAN GENUCHTEN (1980):

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (|\alpha\phi_m|)^n]^m} \quad (1)$$

On what, θ is the volumetric moisture, ϕ is the potential; θ_s and θ_r respectively, residual moisture and gravimetric saturation, and n, m, α are tuning parameters.

From the water retention curve (Figure 1) and using the equation 2, it was possible to find the matric potential for each combination canopy rootstock in both water limits analyzed:

$$\phi_m = \frac{\left[\left(\frac{\theta_s - \theta_r}{\theta - \theta_r} - 1\right)^{\frac{1}{m}}\right]^{\frac{1}{n}}}{\alpha} \quad (2)$$

The variables analyzed were: moisture at the permanent wilting point by the classical and irrigation method and the days until reaching the permanent wilting point. Results were subjected to ANOVA and means were compared by SCOTT-KNOTT TEST (1974) at 5% probability, using the statistical program Sisvar.
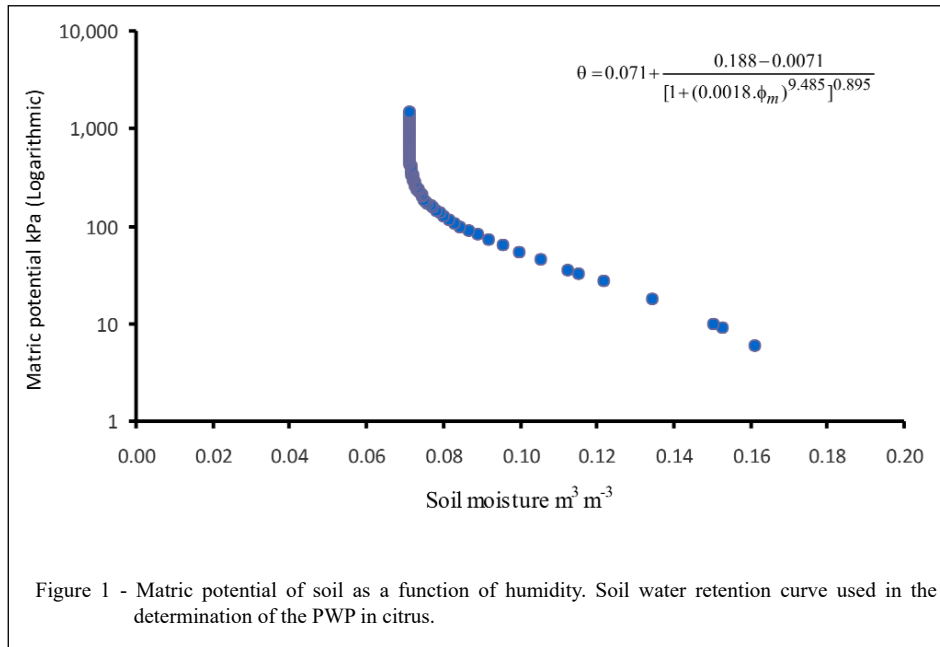
RESULTS AND DISCUSSION

Results for the water boundary at the traditional physiological permanent wilting point (Table 1) showed that the rootstocks Volkamer lime (VL) and Santa Cruz Rangpur lime (SCRL) were not statistically different from each other, with the lower water content in this condition, followed by rootstock Cleopatra tangerine (CT) with intermediate values. The higher humidity values that permanent wilting point were observed in citrandarin Indian (TSK X TRENG 256) (CI) and tropical sunki tangerine (TSM), which did not statistically differ from each other. These results show a higher capacity of the LV and LCSC rootstocks to absorb the water more strongly retained in the soil in relation to the other rootstocks analyzed.

The transformation of these water content values in matric potential indicated that in the

Table 1 - Average humidity values and days to the traditional permanent wilting point and watering on different rootstocks of citrus in orange canopy 'Pera'.

Variables	Humidity values				
	CT	VL	CI	SCRL	TST
MPWP (m³m³)	0.0571 b	0.0489 c	0.0878 a	0.0488 c	0.0888 a
H.Irrigation (m³m³)	0.0529 b	0.0371 d	0.0632 a	0.0426 c	0.0666 a
	Days				
TPPWP	50 bA	57 aA	37 cA	56 aA	33 cA
PPWPI	81 cB	101 aB	87 bB	90 bB	86 bB

Lowercase letters in the same line and capital letters in the same column do not differ statistically from each other by Skott-Knott test (P <0.05). CT - Cleopatra tangerine; LV - Volkamer lime; CI - citrandarin 'Indio' -TSK X TRENG 256; SCRL - Santa Cruz Rangpur lime; TST - tropical Sunki tangerine; - TPPWP - Humidity in the traditional physiological permanent wilting poin; PPWPI - humidity in the physiological permanent wilting point by irrigation.

$$\theta = 0.071 + \frac{0.188 - 0.0071}{[1 + (0.0018 \cdot \phi_m)^{9.485}]^{0.895}}$$

Figure 1 - Matric potential of soil as a function of humidity. Soil water retention curve used in the determination of the PWP in citrus.

exception of Indian rootstocks and tropical sunki tangerine, the other rootstocks found with lower potential to -1.5 MPa, potential conventionally used for PWP, that is, they had withstood a soil water potential lower than established for crops. SOUZA & PAIVA (2001), when analyzing the matric potential of soils of the Coastal Board in the city of Sapeaçu-BA, verified that the citrus plants cultivated in these soils could survive to potentials less than -1.5 MPa, concluding that this crop presents PWP at potentials lower than -1.5 MPa, soon, that the PWP reference value does not apply to that crop and is actually lower (more negative) to that limit.

Results of TPPWP indicated that the rootstock Volkamer lime (VL) and Santa Cruz rangpur lime (SCRL) are more resilient in water deficit conditions. FERNANDES et al. (2011) reported similar results when analyzing different rootstocks subjected to salt stress by checking the rootstock Volkamer lime was the least sensitive to such a situation.
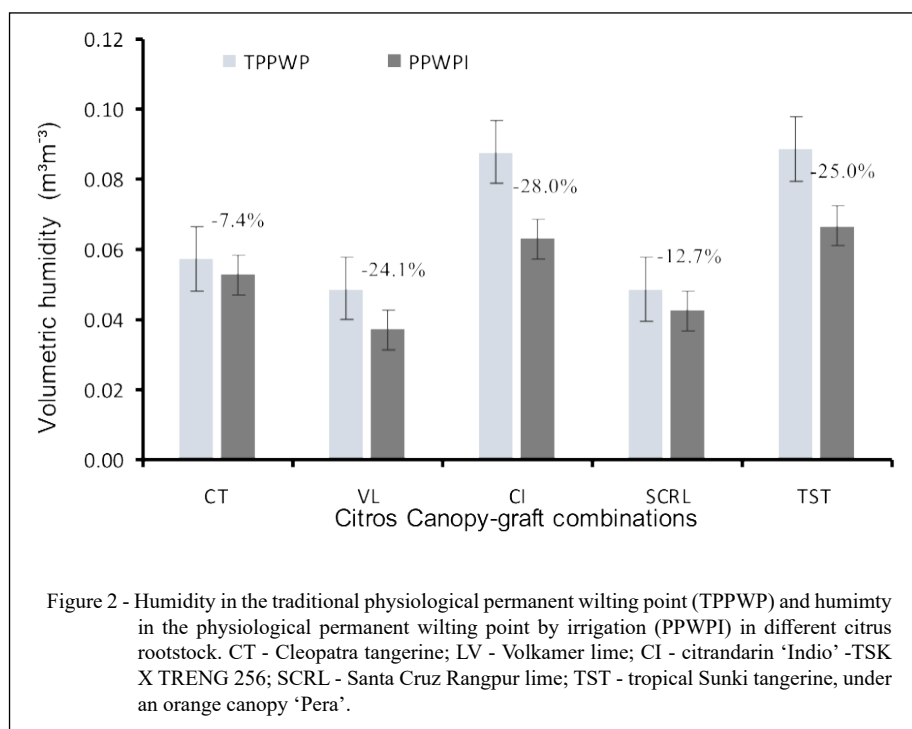
CINTRA et al. (2000), to perform the water balance of a citrus area, also noted that the rootstock Santa Cruz rangpur lime had the lowest amount of evapotranspiration from the others present in the area, indicating that it is one of the mechanisms of its adaptation to tolerate water deficit.

Results for the moisture limit at the point of permanent physiological wilting by irrigation (Table 1) indicated that the rootstock Volkamer lime was that resisted the lowest humidity value on the ground, this being the point where the Soil Water Content, the plant has not recovered. The value for the rootstock Volkamer lime was statistically different from the others, suggesting that it was the more resistant rootstock in conditions of water deficit, among the evaluated.

When comparing the values for the two given water limits (Figure 2), it was reported that the Indian rootstocks and tropical sunki tangerine were those with the biggest difference between the moisture in the traditional PWP and PWP for irrigation, with percentages around 28% and 25%, respectively (Figure 2).

These results show that to achieve the traditional PWP, the plants are still able to recover when access to Soil Water Content and can correlate these situations with the different phases described by BIANCHI, et al. (2016) for conditions of stress.

Figure 2 - Humidity in the traditional physiological permanent wilting point (TPPWP) and humimty in the physiological permanent wilting point by irrigation (PPWPI) in different citrus rootstock. CT - Cleopatra tangerine; LV - Volkamer lime; CI - citrandarin 'Indio' -TSK X TRENG 256; SCRL - Santa Cruz Rangpur lime; TST - tropical Sunki tangerine, under an orange canopy 'Pera'.

In the first limit of permanent physiological wilt by the traditional method the plants are still able to regenerate, by suspending the stressor (drought), while at the second physiological permanent wilt limit determined by the irrigation method, even with the suspension of stress, plants are no longer able to recover, may coincide with the phase of exhaustion, that is, at the second limit established by the irrigation method, plants may have lost their regeneration capacity due to the prolonged water deficit to which they were submitted.

The time to reach the TPPWP (Table 1) followed soil humidity results (Table 1) and rootstocks which had the lower water content in this condition, leading them more days to reach such a situation. For the traditional method, the mean days until reaching TPPWP ranged from 33 to 57 days. However, for PPWPW moisture, the Cleopatra tangerine grafted seed was the first to reach this point; although, it did not present the highest soil moisture upon reaching TPPWP.

The graft holder Volkamer lime was what took more days to reach the PPWPI, differing from the other rootstocks. The result indicated that this rootstock is possibly more resistant to the conditions of prolonged water deficit, factor that may be associated to physiological mechanisms of greater efficiency in the use of water and greater capacity and

water absorption to very low potential potentials. By analyzing the soil water potential in Coastal board crops with citrus, SOUZA & PAIVA (2001) observed that the citrus plants were able to withstand more than four months with soil matric potential of less than -1.5 MPa.

COELHO et al. (2014) also values lower than -1.5 MPa for the PMP in cowpea bean and concluded that this would result in increased availability of water to the crop this could mean increased tolerance to drought species.

CONCLUSIONS

There was a difference between the values of humidity at the permanent wilting point established by the traditional method and the irrigation method, indicating that when reaching the first point of much, plants are still able to regenerate when accessing water. The lowest values of moisture were observed in the rootstocks Santa Cruz Rangpur lime and Volkamerian lemon, indicating that they are the most resistant to water deficit.

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DECLARATION OF CONFLICTI OF INTERESTS

The authors declare no conflict of interests.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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