

# AVAILABILITY OF SOIL WATER UNDER TILLAGE SYSTEMS, MULCH MANAGEMENT AND CITRUS ROOTSTOCKS<sup>(1)</sup>

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## SUMMARY

The increased availability of soil water is important for the management of non-irrigated orange orchards. The objective of this study was to evaluate the availability of soil water in a Haplorthox (Rhodic Ferralsol) under different tillage systems used for orchard plantation, mulch management and rootstocks in a “Pêra” orange orchard in northwest Paraná, Brazil. An experiment in a split-split-plot design was established in 2002, in an area cultivated with *Brachiaria brizantha* grass in which three tillage systems (no tillage, conventional tillage and strip-tillage) were used for orchard plantation. This grass was mowed twice a year between the rows, representing two mulch managements in the split plots (no mulching and mulching in the plant rows). The split-split-plots were represented by two rootstocks (“Rangpur” lime and “Cleopatra” mandarin). The soil water content in the plant rows was evaluated in the 0–20 cm layer in 2007 and at 0–20 and 20–40 cm in 2008–2009. The effect of soil tillage systems prior to implantation of orange orchards on soil water availability was less pronounced than mulching and the rootstocks. The soil water availability was lower when “Pêra” orange trees were grafted on “Cleopatra” mandarin than on “Rangpur” lime rootstocks. Mulching had a positive influence on soil water availability in the sandy surface layer (0–20 cm) and sandy clay loam subsurface (20–40 cm) of the soil in the spring. The production of *B. brizantha* between the rows and residue disposal in the plant rows as mulch increased water availability to the “Pêra” orange trees.

**Index terms:** *Brachiaria brizantha*, no tillage, soil management, soil texture, time domain reflectometry.

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**RESUMO:** *DISPONIBILIDADE DE ÁGUA NO SOLO EM SISTEMAS DE PREPARO, MANEJO DA COBERTURA MORTA E PORTA-ENXERTOS DE CITROS*

*O aumento da disponibilidade de água no solo é importante para o manejo de pomares de laranja não irrigados. O objetivo deste trabalho foi avaliar a água em um Latossolo Vermelho distrófico em sistemas de preparo utilizados para implantação do pomar, manejo da cobertura morta e porta-enxertos em pomar de laranjeira 'Pêra', no noroeste do Paraná. Um experimento no esquema de parcelas subdivididas foi implantado em 2002, em área com pastagem de braquiária-brizanta (*Brachiaria brizantha*), utilizando três sistemas de preparo do solo nas parcelas (sem revolvimento, com revolvimento e em faixas). A gramínea foi roçada duas vezes ao ano nas entrelinhas, constituindo dois tratamentos nas subparcelas (sem e com cobertura morta nas linhas das plantas). Nas subparcelas, foram avaliados dois porta-enxertos (limoeiro 'Cravo' e tangerineira 'Cleópatra'). Nas linhas das plantas, avaliou-se o conteúdo de água no solo nas camadas de 0–20 cm em 2007 e 0–20 e no de 20–40 cm em 2008-2009. O efeito do preparo do solo no conteúdo de água foi verificado somente em 2007, e o efeito da cobertura morta e dos porta-enxertos, em 2007-2009. O cultivo de laranjeira 'Pêra' enxertada sobre tangerineira 'Cleópatra' reduziu o conteúdo de água do solo em relação ao limoeiro "Cravo". A cobertura morta influenciou positivamente o conteúdo de água na superfície (0–20 cm; textura arenosa) e na subsuperfície do solo (20–40 cm; textura média) durante a primavera. A produção de braquiária-brizanta nas entrelinhas e seu manejo nas linhas das plantas como cobertura morta aumentaram a disponibilidade de água para as laranjeiras.*

*Termos de indexação:* braquiária brizanta, plantio direto, manejo do solo, textura do solo, reflectometria do domínio no tempo.

## INTRODUCTION

The availability of soil water in non-irrigated orange orchards can be increased by not disturbing the soil and mulching between plant rows to reduce evaporation. For the implantation of orange orchards, the soil is usually tilled and plants and residue are incorporated leaving the soil temporarily bare, which aggravates soil and water losses (Politano & Pissarra, 2005). Experimental results have shown the possibility of using reduced soil tillage for the implantation of orange orchards (Auler et al. 2008b; Fidalski et al., 2009), maintaining permanently vegetated rows without soil disturbance by tillage after the establishment of the orchard (Fidalski et al., 2007).

The large-scale external input of organic residues for mulch management in orchards would be economically unfeasible (Hogue & Neilsen, 1987). Alternatively, there is the possibility of producing grass biomass between the rows of orange orchards with mechanical mowing for mulch accumulation on the soil in plant rows (Beraldo et al. 2007; Bremer Neto et al., 2008; Fidalski et al., 2009). However, the effect of mulching in the plant rows has not been evaluated for the possible responses of rootstocks, which may differ in soil water uptake and consumption.

"Rangpur" lime is the most commonly used rootstock in Brazilian orange orchards; an alternative

rootstock option would be the mandarin "Cleopatra" (Pompeu Junior, 2005). Studies have shown that the canopy development of grafts on this rootstock is better than on "Rangpur" (Stenzel et al., 2005a; Auler et al., 2008a). However, "Cleopatra" mandarin rootstocks are more susceptible to water stress than "Rangpur" lime (Pompeu Junior, 2005), probably due to a higher transpiration rate (Cintra et al., 2000).

In the northwest of Paraná, water deficits in orange orchards occur during July and August, with probabilities of 76, 56 and 42 %, respectively, for periods of 5, 10 and 20 days (Calheiros et al., 1992). In this region, Stenzel et al. (2005b) found that water stress reduced the vegetative growth rate of "Folha Murcha" orange trees between March and April.

The objective of this study was to evaluate the soil water availability under different tillage systems prior to orange implantation as well as mulch management systems in plant rows of a "Pêra" orange orchard grafted on the rootstocks "Rangpur" lime and "Cleopatra" mandarin in a Haplorthox in northwest Paraná.

## MATERIAL AND METHODS

The study was carried out in an experimental area with "Pêra" orange trees, introduced in 2002, spaced

6.8 x 3.5 m, on the farm Ipiranga in Paranavaí, northwest of Paraná (23° 6' S, 52° 25' W, 450 m asl), slightly undulated relief with a maximum gradient of 6 cm m<sup>-1</sup>. Prior to orchard implantation the area had been cropped with long-term pasture (*Brachiaria brizantha*). The climate is subtropical (Cfa), with an average annual rainfall of 1,500 mm (Iapar, 2000). The soil is a Haplorthox (Rhodic Ferralsol) of sandy and sandy clay loam texture, respectively (Santos et al., 2006), in the surface and subsurface layers. The horizon (0–20 cm layer) is composed of 110 g kg<sup>-1</sup> clay, 15 g kg<sup>-1</sup> silt and 875 g kg<sup>-1</sup> sand; the Bw horizon (20–200 cm layer) consists of 170 g kg<sup>-1</sup> clay, 10 g kg<sup>-1</sup> silt and 820 g kg<sup>-1</sup> sand. Particle size was determined by the pipette method (Claessen, 1997).

The experiment was arranged in a randomized block design in split-split-plot with 12 treatments and four replications. Three soil tillage systems were considered as plots (no-tillage, conventional tillage and strip-tillage), two mulch managements (no mulching and mulching) in orange tree rows as split plots and two rootstocks as the split-split plots (“Rangpur” lime and “Cleopatra” mandarin rootstocks). In each plot, 15 plants were grown in three rows with five plants. No-tillage consisted of desiccation of *B. brizantha* in 2 m wide strips using glyphosate herbicide; conventional tillage consisted of plowing the entire area to a depth of 0–20 cm and two diskings in the 0–10 cm layer; and the strip tillage consisted of plowing and harrowing in narrow 2 m wide strips for soil preparation in the plant rows, without killing and incorporating *B. brizantha* growing between the rows (Auler et al., 2008b). Continuous 0–30 cm furrows spaced 6.8 m apart were then opened in all three systems, with holes spaced 3.5 m apart for the orange trees.

In the treatment no mulching in the plant rows, *B. brizantha* was cut and left between the orchard rows. In the treatment mulching in the plant rows, *B. brizantha* was cut with a mowing machine that threw the grass onto the plant rows, forming a mulch cover there (Figure 1). These practices were performed 2003, in the beginning and end of the rainy season, i.e., in November and March. The average dry mass production of *B. brizantha* was around 5 t ha<sup>-1</sup> (Beraldo et al., 2007). The weed in the plant rows without mulching was controlled by hand-weeding. To prevent the growth of *B. brizantha* in the tree rows, herbicide (glyphosate) was applied every year, to keep the grass development off the rows and at a distance of 50 cm from the projection of the canopy of the orange trees.

The first cycle of soil water availability evaluations was performed only in two tillage systems (conventional tillage and no-tillage), consisting of 17 measurements within 100 days (March 22 to June 29, 2007) using the time domain reflectometry technique (TDR). Probes with three steel rods (diameter 4 mm, length 20 cm), spaced 1 cm apart, were vertically installed



**Figure 1. Mulch management systems in a “Pêra” orange orchard cultivated with *Brachiaria brizantha* grass (Pedro Antonio Martins Auler - IAPAR).**

in the rows in the 0–20 cm layer and 75 cm away from the trunk of the orange trees. The soil dielectric constant was measured with a Tektronix 1502B cable tester and used to estimate the soil water content by equation (Topp et al., 1980). The second evaluation cycle of soil water was carried out in all three tillage systems (no-tillage, conventional tillage and strip-tillage), based on 12 disturbed soil samples collected in four drying periods: 1<sup>st</sup> (November 7, 14, 21, and 27, 2008), 2<sup>nd</sup> (March 10, 17 and 24, 2009), 3<sup>rd</sup> (May 18 and 25, 2009) and 4<sup>th</sup> (July 3, 8 and 21, 2009), respectively, in the Spring, Summer, Autumn, and Winter. On each date, a soil sample was collected in the plant row, between two orange trees, about 75 cm away from the orange tree trunk. Soil samples were collected with an auger probe (diameter 2.5 cm) from the layers 0–20 and 20–40 cm, filled in aluminum cans and stored in a polystyrene box followed by gravimetric determination of water according to Claessen (1997).

The rainfall during the two series of soil water evaluations was measured at the weather station of Iapar in Paranavaí, around 3 km away from the experimental area.

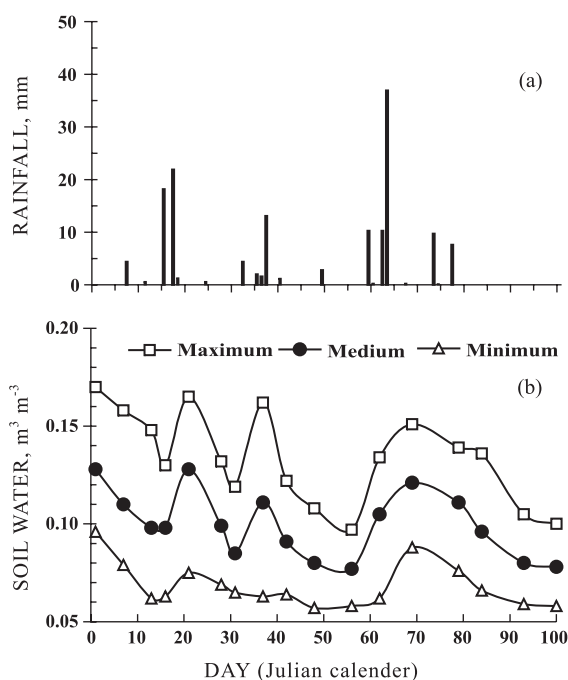
Soil water content data were subjected to analysis of variance for each measurement date using the mathematical model of randomized blocks in the scheme of split-split-plots and the means compared by the Tukey test (Banzatto & Kronka, 2006). Soil water content data in the 0–20 and 20–40 cm layers

of the soil tillage systems ( $n = 18$ ), mulching ( $n = 24$ ) and rootstocks ( $n = 24$ ) were compared by the t test.

## RESULTS AND DISCUSSION

During the first series of soil water content evaluations (2007) 19 rains of 0.2 to 36.9 mm (total amount of 147.7 mm) were observed (Figure 2a), and four periods of soil drying, beginning on the 81<sup>st</sup> day (March 22), 111<sup>st</sup> day (April 11), 117<sup>th</sup> day (April 27), and 149<sup>th</sup> day (May 29) (Figure 2b). The drying periods lasted, respectively, 20, 16, 32, and 31 days. The soil water content was highest on March 22 ( $0.138 \text{ m}^3 \text{ m}^{-3}$ ) and lowest on June 29 ( $0.075 \text{ m}^3 \text{ m}^{-3}$ ) (Figure 2b), corresponding to the water potentials, respectively, to field capacity (-8 kPa) and wilting point (-1,500 kPa) as found by Fidalski & Tormena (2007) in a similar soil study.

From March 22 to June 29, 2007, during the stages of high water demand of the trees (fruit development and maturation), two-factor interactions ( $p \leq 0.05$ ) were observed for the soil tillage systems and mulching; soil tillage systems and rootstocks, and mulching and rootstocks on April 18, and between the soil tillage systems and mulching on April 27 (Table 1). The soil water content in the 0–20 cm layer in the plant rows decreased on April 18 in the treatments no-tillage with mulching (Table 2), no-tillage with rootstock “Cleopatra” mandarin, and mulching with “Cleopatra” mandarin (Table 3). On April 27, the soil water in the same layer decreased again with the interaction between the treatments no-tillage with mulching and conventional tillage no mulching (Table 2). The reduction in soil water on



**Figure 2. Rainfall (a) and soil water in the 0–20 cm layer (b) in the assessment period of 100 days (March 22 to June 27, 2007).**

April 18 was observed under “Pêra” orange trees grafted onto “Cleopatra” mandarin (Table 3), which is a rootstock with a higher water demand than Rangpur” lime”(Cintra et al., 2000).

In the second series of evaluations of soil water, only individual effects of mulching and rootstocks were observed ( $p \leq 0.05$ ) in the layers 0–20 and 20–40 cm (Table 4). The evaluations were conducted after a total

**Table 1. Probabilities of influence of the factors F1 (soil tillage systems), F2 (mulching management) and F3 (rootstocks) for soil water volume in the 0–20 cm layer by the F test, in 17 assessments (March 22 to June 27, 2007), corresponding to 100 days, in the Julian calendar**

Date	Day	F1	F2	F3	F1xF2	F1xF3	F2xF3	F1xF2xF3
3/22/2007	81 <sup>st</sup>	0.61	0.26	0.28	0.14	0.36	0.56	0.71
3/28/2007	87 <sup>th</sup>	0.95	0.37	0.68	0.21	0.12	0.23	0.25
4/3/2007	93 <sup>th</sup>	0.96	0.71	0.73	0.30	0.31	0.49	0.45
4/6/2007	96 <sup>th</sup>	0.80	0.79	0.76	0.23	0.76	0.08	0.13
4/11/2007	101 <sup>st</sup>	0.89	0.37	0.71	0.82	0.50	0.33	0.87
4/18/2007	108 <sup>th</sup>	0.95	0.09	0.07	0.05	0.01	0.04	0.84
4/24/2007	111 <sup>st</sup>	0.55	0.68	0.70	0.24	0.40	0.36	0.61
4/27/2007	117 <sup>th</sup>	0.88	0.84	0.15	0.01	0.52	0.24	0.95
5/2/2007	122 <sup>nd</sup>	0.75	0.12	0.27	0.16	0.73	0.37	0.65
5/8/2007	128 <sup>th</sup>	0.42	0.11	0.31	0.31	0.66	0.40	0.90
5/16/2007	136 <sup>th</sup>	0.36	0.50	0.61	0.44	0.87	0.39	0.63
5/22/2007	142 <sup>nd</sup>	0.86	0.13	0.06	0.26	0.79	0.21	0.62
5/29/2007	149 <sup>th</sup>	0.91	0.34	0.21	0.16	0.55	0.08	0.60
6/8/2007	159 <sup>th</sup>	0.74	0.93	0.64	0.79	0.72	0.38	0.78
6/13/2007	164 <sup>th</sup>	0.74	0.86	0.61	0.73	0.55	0.48	0.59
6/22/2007	173 <sup>rd</sup>	0.60	0.81	0.72	0.27	0.63	0.36	0.61
6/29/2007	180 <sup>th</sup>	0.52	0.65	0.58	0.23	0.70	0.42	0.83

**Table 2. Soil water content in the 0–20 cm layer for soil tillage systems and mulch management in 2007<sup>(1)</sup>**

Soil tillage systems	Mulch management	
	No mulching	Mulching
m <sup>3</sup> m <sup>-3</sup>		
4/18/2007 (108 <sup>th</sup> day on the Julian calendar)		
No tillage	0.106 Aa	0.094 Ba
Conventional tillage	0.099 Aa	0.099 Aa
4/27/2007 (117 <sup>th</sup> day on the Julian calendar)		
No tillage	0.117 Aa	0.106 Ba
Conventional tillage	0.104 Ba	0.116 Aa

<sup>(1)</sup> Means followed by the same capital letter for soil tillage system (row) and lower-case letter for mulching (column) did not differ by the Tukey test (p < 0.05).

rainfall of 62.9 mm (November 6 and 7, 2008), 25.8 mm (March 8 and 10, 2009), 36.4 mm (May 14 and 15, 2009); and 18.1 mm (July 1 and 2, 2009). Four periods of soil drying were observed in the four seasons, with a range of soil water from 0.029 to 0.097 g g<sup>-1</sup> (Tables 5, 6 and 7), which corresponded, respectively, to soil water potentials below wilting point (-1,500 kPa) and near to field capacity (-8 kPa) which are close to the results of Fidalski et al. (2008) in a similar soil under orange.

Unlike in the first evaluation cycle, soil tillage systems did not affect the soil water content during the four drying periods (Table 5), possibly due to the long period after the last soil disturbance by tillage prior to orchard orange implantation (2002), because there was no change in the soil density in this experiment (Fidalski et al., 2009). Under mulching,

**Table 3. Soil water content in the 0–20 cm layer for soil tillage systems mulch management and rootstocks in 2007<sup>(1)</sup>**

Soil tillage systems and mulch manag.	Rootstocks	
	“Rangpur” lime	“Cleopatra” mandarin
m <sup>3</sup> m <sup>-3</sup>		
4/18/2007 (108 <sup>th</sup> day on the Julian calendar)		
No tillage	0.110 Aa	0.090 Ba
Conventional tillage	0.096 Aa	0.102 Aa
4/18/2007 (108 <sup>th</sup> day on the Julian calendar)		
No mulching	0.102 Aa	0.103 Aa
Mulching	0.104 Aa	0.089 Bb

<sup>(1)</sup> Means followed by the same capital letter for soil tillage system (row) and for mulching (row) and lower-case letter for rootstocks (column) did not differ by the Tukey test (p < 0.05).

**Table 4. Probabilities by the F test of the factors of variation F1 (soil tillage systems), F2 (mulch management) and F3 (rootstocks) for soil water content in the 0–20 cm and 20–40 cm layers, in 12 evaluations (November 7, 2008, to July 21, 2009)**

Date	F1	F2	F3	F1xF2	F1xF3	F2xF3	F1xF2xF3
0-20 cm							
11/7/2008	0.72	0.34	0.78	0.62	0.17	0.22	0.66
11/14/2008	0.30	<0.01	0.12	0.43	0.80	0.48	0.84
11/21/2008	0.92	<0.01	0.64	0.59	0.77	0.29	0.63
11/27/2008	0.33	0.07	0.95	0.21	0.87	0.14	0.29
3/10/2009	0.79	0.66	0.17	0.82	0.49	0.55	0.98
3/17/2009	0.38	0.93	0.02	0.06	0.93	0.63	0.19
3/24/2009	0.96	<0.01	0.33	0.34	0.99	0.22	0.54
5/18/2009	0.38	0.36	0.89	0.77	0.76	0.13	0.98
5/25/2009	0.88	0.81	0.04	0.38	0.65	0.94	0.26
7/3/2009	1.00	0.97	0.54	0.61	0.28	0.50	0.48
7/8/2009	0.62	0.01	0.27	0.55	0.96	0.75	0.93
7/21/2009	0.17	0.02	0.11	0.59	0.58	0.24	0.43
20-40 cm							
11/7/2008	0.26	0.72	0.89	0.78	0.59	0.10	0.44
11/14/2008	0.55	0.12	0.21	0.02	0.93	0.46	0.66
11/21/2008	0.65	<0.01	0.05	0.82	0.16	0.30	0.82
11/27/2008	0.76	0.01	0.83	0.21	0.31	0.17	0.52
3/10/2009	0.26	0.06	0.43	0.98	0.74	0.86	0.75
3/17/2009	0.79	0.09	0.36	0.07	0.92	0.80	0.81
3/24/2009	0.40	0.06	0.02	0.92	0.24	0.52	0.90
5/18/2009	0.41	0.21	0.42	0.75	0.52	0.40	0.79
5/25/2009	0.77	0.45	0.55	0.67	0.37	0.40	0.89
7/3/2009	0.78	0.16	0.21	0.30	0.62	0.48	0.96
7/8/2009	0.59	0.59	0.96	0.73	0.99	0.45	0.57
7/21/2009	0.27	0.17	0.77	0.59	0.91	0.93	0.41

the soil retained most water in the 0–20 cm surface layer (sandy texture) on November 14 and 21, 2008, March 24, 2009, and July 8 and 21, 2009, which was related to the soil water content in the 20–40 cm layer (sandy clay loam texture) on 21/11/2008 and 27/11/2008 (Table 6). The influence of clay content on soil water relationships were reported by Machado et al. (2008).

The soil water contents on March 17 and May 25, 2009 in the 0–20 cm layer and on November 21, 2008 and March 24, 2009 in the 20–40 cm layer were greater in the rows of orange tree grafted on “Rangpur” lime than on “Cleopatra” mandarin rootstock (Table 7). This finding confirm results of the first evaluation cycle indicating a higher transpiration rate of orange

**Table 5. Soil water content in four drying periods and four seasons between 2008 and 2009 under soil tillage systems<sup>(1)</sup>**

Drying period	Date	Season	0-20 cm			20-40 cm		
			No tillage	Strip tillage	Conventional tillage	No tillage	Strip tillage	Conventional tillage
g g <sup>-1</sup>								
1 <sup>st</sup>	11/7/2008	Spring	0.083 Ab	0.081 Ab	0.085 Aa	0.090 Aa	0.097 Aa	0.094 Aa
	11/14/2008	Spring	0.049 Ab	0.055 Ab	0.056 Ab	0.070 Aa	0.075 Aa	0.073 Aa
	11/21/2008	Spring	0.033 Ab	0.033 Ab	0.032 Ab	0.051 Aa	0.054 Aa	0.053 Aa
	11/27/2008	Spring	0.039 Ab	0.037 Ab	0.036 Ab	0.049 Aa	0.046 Aa	0.048 Aa
2 <sup>nd</sup>	3/10/2009	Summer	0.058 Aa	0.060 Aa	0.058 Aa	0.054 Aa	0.055 Aa	0.053 Aa
	3/17/2009	Summer	0.042 Ab	0.040 Ab	0.038 Ab	0.052 Aa	0.052 Aa	0.050 Aa
	3/24/2009	Autumn	0.032 Ab	0.032 Ab	0.033 Ab	0.043 Aa	0.045 Aa	0.046 Aa
3 <sup>rd</sup>	5/18/2009	Autumn	0.060 Ab	0.063 Ab	0.058 Ab	0.068 Aa	0.072 Aa	0.065 Aa
	5/25/2009	Autumn	0.040 Ab	0.041 Ab	0.041 Ab	0.053 Aa	0.052 Aa	0.054 Aa
4 <sup>th</sup>	7/3/2009	Winter	0.072 Aa	0.072 Aa	0.072 Aa	0.071 Aa	0.070 Aa	0.073 Aa
	7/8/2009	Winter	0.059 Ab	0.059 Ab	0.062 Ab	0.073 Aa	0.071 Aa	0.074 Aa
	7/21/2009	Winter	0.047 Ab	0.051 Ab	0.052 Ab	0.063 Aa	0.068 Aa	0.067 Aa

<sup>(1)</sup> Means of soil tillage systems followed by the same capital letter for the same date and depth did not differ by the Tukey test ( $p < 0.05$ ) and followed by the same lower-case letter on the same date did not differ by the t test ( $p < 0.05$ ).

**Table 6. Soil water content in the 0–20 and 20–40 cm layer under two mulch management systems, in four drying periods and four seasons between 2008 and 2009<sup>(1)</sup>**

Drying period	Date	Season	0-20 cm		20-40 cm	
			No Mulching	Mulching	No Mulching	Mulching
g g <sup>-1</sup>						
1 <sup>st</sup>	11/7/2008	Spring	0.085 Ab	0.081 Ab	0.094 Aa	0.093 Aa
	11/14/2008	Spring	0.049 Bb	0.057 Ab	0.072 Aa	0.074 Aa
	11/21/2008	Spring	0.031 Bb	0.035 Ab	0.048 Ba	0.057 Aa
	11/27/2008	Spring	0.035 Ab	0.039 Ab	0.045 Ba	0.051 Aa
2 <sup>nd</sup>	3/10/2009	Summer	0.058 Ab	0.059 Aa	0.051 Aa	0.057 Aa
	3/17/2009	Summer	0.040 Ab	0.040 Ab	0.050 Aa	0.053 Aa
	3/24/2009	Autumn	0.029 Bb	0.035 Ab	0.042 Aa	0.047 Aa
3 <sup>rd</sup>	5/18/2009	Autumn	0.062 Ab	0.059 Ab	0.070 Aa	0.067 Aa
	5/25/2009	Autumn	0.040 Ab	0.041 Ab	0.054 Aa	0.052 Aa
4 <sup>th</sup>	7/3/2009	Winter	0.072 Aa	0.072 Aa	0.073 Aa	0.070 Aa
	7/8/2009	Winter	0.058 Bb	0.062 Ab	0.072 Aa	0.073 Aa
	7/21/2009	Winter	0.047 Bb	0.053 Ab	0.065 Aa	0.067 Aa

<sup>(1)</sup> Means of the mulch managements followed by the same capital letter for the same date and depth did not differ by the Tukey test ( $p < 0.05$ ) and followed by the same lower-case letter on the same date did not differ by the t test ( $p < 0.05$ ).

trees grafted on “Cleopatra” mandarin rootstock (Cintra et al., 2000), corroborating the higher susceptibility to water stress of “Cleopatra” mandarin than of “Rangpur” lime (Pompeu Junior, 2005).

In the subsurface soil, a higher soil water content was measured at 20–40 cm depth (sandy clay loam texture) than in the 0–20 cm topsoil layer (sandy texture), regardless of soil tillage systems, mulching and rootstocks (Tables 5, 6 and 7), probably associated to the higher clay content (Fidalski et al., 2008, 2009, Machado et al., 2008) which reduce the drainage rate in this soil. In the spring, on November 21 and 27, 2008, mulching had a positive influence on the soil

7) related to the higher transpiration rates of the orange trees grafted on this rootstock (Cintra et al., 2000).

The results of both evaluation series for soil water availability under orange tree rows showed that the residual tillage effect was temporary (observed only in 2007). On the other hand, effects of mulching and rootstocks were observed in the entire experimental period (2007, 2008 and 2009). These facts highlight the importance of mulching for soil water availability to orange trees regardless of the rootstocks specific to the soil and climatic conditions of northwest Parana, in Southern Brazil.

**Table 7. Soil water content in the 0–20 and 20–40 cm layers, in four drying periods and four seasons between 2008 and 2009, under two rootstocks of “Pêra” orange<sup>(1)</sup>**

Drying period	Date	Season	0-20 cm		20-40 cm	
			“Rangpur” lime	“Cleopatra” mandarin	“Rangpur” lime	“Cleopatra” mandarin
			g g <sup>-1</sup>			
1 <sup>st</sup>	11/7/2008	Spring	0.083 Ab	0.083 Ab	0.094 Aa	0.093 Aa
	11/14/2008	Spring	0.055 Ab	0.052 Ab	0.074 Aa	0.071 Aa
	11/21/2008	Spring	0.033 Ab	0.033 Ab	0.055 Aa	0.051 Ba
	11/27/2008	Spring	0.037 Ab	0.037 Ab	0.047 Aa	0.048 Aa
2 <sup>nd</sup>	3/10/2009	Summer	0.057 Ab	0.060 Ab	0.053 Aa	0.055 Aa
	3/17/2009	Summer	0.042 Ab	0.038 Bb	0.052 Aa	0.051 Aa
	3/24/2009	Autumn	0.033 Ab	0.032 Ab	0.047 Aa	0.042 Ba
3 <sup>rd</sup>	5/18/2009	Autumn	0.061 Ab	0.060 Ab	0.069 Aa	0.067 Aa
	5/25/2009	Autumn	0.042 Ab	0.038 Bb	0.054 Aa	0.053 Aa
4 <sup>th</sup>	7/3/2009	Winter	0.071 Ab	0.072 Ab	0.073 Aa	0.070 Aa
	7/8/2009	Winter	0.059 Aa	0.061 Aa	0.073 Aa	0.073 Aa
	7/21/2009	Winter	0.051 Aa	0.049 Aa	0.066 Aa	0.066 Aa

<sup>(1)</sup> Means of rootstocks followed by the same capital letter for the same date and depth did not differ by the Tukey test ( $p < 0.05$ ), and by the same lower-case letter on the same date did not differ by the t test ( $p < 0.05$ ).

water content in the layers 0–20/20–40cm (Table 6). These results confirm the importance of the Bw horizon under the A horizon as a water reservoir for orange trees, regardless of the rootstock.

In this experiment, the soil organic carbon contents in the plant rows did not differ statistically between the mulch management systems (Beraldo et al. 2007; Fidalski et al., 2009). The high sand content of this soil reinforces that the soil water content and availability at 0–20 and 20–40 cm depth was influenced exclusively by mulching and by the different water consumption rates associated to rootstocks (Tables 6 and 7). The greater depletion of soil water in the soil under “Cleopatra” mandarin would indicate increased consumption (Tables 3, 4 and

## CONCLUSIONS

1. The effect of soil tillage systems prior to orchard orange implantation on the soil water availability was less pronounced than of mulching and rootstocks.

2. The soil water availability was lower under “Pêra” orange trees grafted on “Cleopatra” mandarin than on “Rangpur” lime rootstocks.

3. Mulching had a positive influence on the soil water availability in the sandy surface layer (0–20 cm) and sandy clay loam subsurface (20–40 cm) of the soil in the spring.

4. The production of *B. brizantha* between the rows and the residue disposal in the plant rows as mulch increased water availability to the “Pêra” orange trees.

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