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Article

Periods of Weed Interference on Orange Tree Crops

Períodos de Interferência de Plantas Daninhas na Cultura da Laranjeira

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ABSTRACT - Current orange tree cultivation practices in the Brazilian State of Amazonas present several production problems, being the inadequate weed management the most important one, and significantly affecting fruit productivity. However, if weeds are managed properly, their coexistence with orange cultivars does not affect the fruit yield of orange trees. Thus, the objective of this research was to identify the period of longer weed interference in orange production. The treatments were conducted during the 2013 and 2014 harvests as follows: one control treatment with no coexistence of weeds and crop throughout the growing season; and six periods of coexistence (October to January, February to May, June to September, October to May, October to January, June to September, and February to September). The coexistence of weeds from October to May with orange trees increased the fall of unripe fruits and reduced the yield and the number of oranges per plant. Therefore, this period was considered as the most critical one for the control of weeds in orange trees.

Keywords: *Citrus sinensis*, fruit yield, competition.

RESUMO - O cultivo da laranjeira, no Amazonas, apresenta diversos problemas de produção, destacando-se o manejo inadequado das plantas daninhas. A época do ano em que se realiza essa prática pode permitir o convívio dessas plantas com a cultura e reduzir a sua produtividade. Objetivou-se com esta pesquisa identificar o período de interferência de plantas daninhas na produtividade de laranjeiras no Estado. Os tratamentos foram: um controle, sem convivência de plantas daninhas com a cultura durante todo o ano agrícola; e seis períodos de convivência (outubro a janeiro, fevereiro a maio, junho a setembro, outubro a maio, outubro a janeiro e de junho a setembro, e fevereiro a setembro) conduzidos durante as safras 2013 e 2014. A convivência das plantas daninhas de outubro a maio com as laranjeiras aumentou a queda de frutos imaturos, reduziu o número de laranjas por planta e a produtividade. Esse período foi considerado crítico para o controle de plantas daninhas em laranjeiras.

Palavras-chave: *Citrus sinensis*, produtividade de frutos, competição

INTRODUCTION

In recent years, orange cultivation (*Citrus sinensis* (L.) Osbeck) in the State of Amazonas has had its growing area expanded to 4,000 ha (IBGE, 2016). In addition to favorable climatic conditions allowing a year-round production, the demand for orange fruits in the state is increasing, resulting in satisfactory

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gains by orange producers and in the generation of employment and income for the population of the region (Carvalho et al., 2015).

The abiotic factors that are favorable to the cultivation of this fruit may have little effect on the productivity of local orchards, due to the interference of weeds; the rainy season helps the growth of these plants and increases their competitive capacity, mainly for nutrients (Pitelli, 1985; Carvalho et al., 2015).

Interference is usually evaluated through productivity decreases or through plant growth reduction in response to the competition for environmentally available growth resources, such as CO_2, water, light and nutrients (Agostinetto et al., 2008). Weed interference causes economic damages to producers, by reducing the productivity and degrading the physical and chemical quality of the harvested product (Fialho et al., 2012; Costa et al., 2013).

The conventional control of weeds in the Amazonian citriculture is done with four applications of post-emergent herbicide in the plantation row, associated to four or five trimmings between the rows. In addition, a large number of producers still make at least two or three harrows a year in their orchards (Carvalho et al., 2015).

In the state of Amazonas, managing weeds only in the appropriate period is essential for the cultivation of orange trees, as it will reduce the exaggerated use of herbicides, labor, and, consequently, the production cost. Knowing this period will also reduce weed interference on fruit quality and maximize crop productivity.

In this context, considering that in the Amazon there is little information about weed management in citrus, and there is also a growing demand for technical information on this theme, the objective of this research was to identify the period of greater weed interference on the productivity of orange trees and on the quality of fruits.

MATERIAL AND METHODS

The experiment was conducted in a commercial production area of oranges cv. 'Pera', in a soil classified as Yellow Dystrophic Argisol (Embrapa, 2013). According to the classification of Köppen, the climate of the region is Af-type: hot humid, with a constantly high temperature, a minimum temperature of 23.5 ^oC and a maximum temperature of 31.2 ^oC, with rainfall around 2,200 mm year^{-1} (Alvares et al., 2013). The monthly distribution of rainfall and the water balance of the study region in the experimental period are described in Figure 1.

The analysis of soil fertility in the experimental area, in the 0 to 20 cm layer, indicated the following attributes: pH (H_2O) 4.45; 5.0 mg dm^{-3} of P; 36.0 mg dm^{-3} of K; 0.15 cmol$_c$ dm^{-3} of Al; 5.03 cmol$_c$ dm^{-3} of H + Al; 2.1 cmol$_c$ dm^{-3} of Ca; 0.8 cmol$_c$ dm^{-3} of Mg; 3.64 dag kg^{-1} of MO; 0.96 mg dm^{-3} of Zn; 184 mg dm^{-3} of Fe; 2.2 mg dm^{-3} of Mn; 0.3 mg dm^{-3} of Cu; and granulometry with the following composition: sand (214 g kg^{-1}); silt (136 g kg^{-1}) and clay (650 g kg^{-1}).

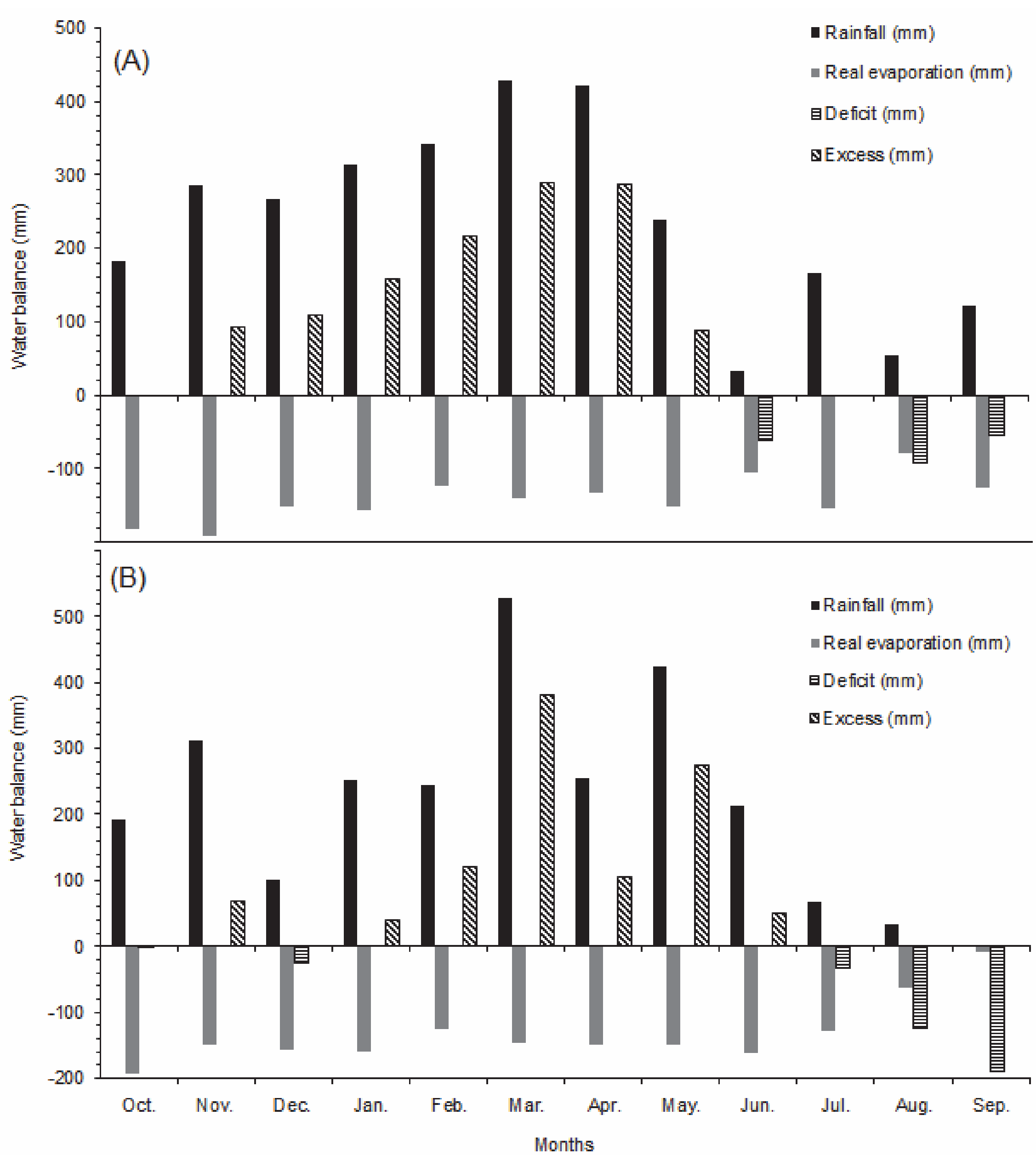
The orange orchard presented healthy plants, with a 6.0 m by 4.0 m spacing, aged approximately nine years. From the planting of seedlings until the installation of the experiment, weed control consisted of three applications of glyphosate at a dose of 1,720 g ha^{-1} of a.e. and two to three mechanized trimmings per year.

The experimental design was in randomized blocks, with seven weed interference treatments evaluated in two agricultural years (2012/2013 and 2013/2014), and four replications. The treatments were: one control treatment without weed coexistence with the crop during the whole agricultural year; and six coexistence periods (October to January, February to May, June to September, October to May, October to January, June to September, and February to September) (Table 1). These treatments were elaborated based on the water balance of the region (Figure 1). Weed control in coexistence-free treatments was made by applying glyphosate at a dose of 1,720 g ha^{-1} of a.e., plus Assist adjuvant at 0.5% v/v, sprayed on orange planting lines, in plots containing three rows of five plants. The two lateral rows, as well as one plant at each end of the plot, were considered as margins, and the three central rows were considered as plants of the usable area.

Table 1 - Periods of coexistence (black intervals) between weeds and orange crop and control periods (blank intervals). Manaus, 2014

Treat.	October 2012 to September 2013												October 2013 to September 2014											
	O.*	N.	D.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	J.	F.	M.	A.	M.	J.	J.	A.	S.
1																								
2	■	■	■	■									■	■	■	■								
3					■	■	■	■									■	■	■	■				
4									■	■	■	■									■	■	■	■
5	■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■				
6	■	■	■	■					■	■	■	■	■	■	■	■					■	■	■	■
7					■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■

* Months of the year.



Source: Data collected from the Inmet Network. Manaus, 2014.

Figure 1 - Water balance of the study region during the period from October 2012 to September 2013 (A) and from October 2013 to September 2014 (B).

The application of the herbicide was made with an electric backpack sprayer, equipped with a 80.02 fan-type spraying tip and a constant pressure of 2.81 bar. The pH of the spraying water was corrected to 4.0 by adding phosphonic acid. All herbicide applications occurred between 7 am and 10 am, and the wind speed did not exceed 2.1 km h^{-1}, measured with a digital anemometer. All proper care was taken to avoid drifting in the orange trees.

The evaluated characteristics were: number of unripe fallen fruits, number of harvested fruits per plant, fruit productivity, juice yield (JY), total soluble solids (SS), titratable acidity (TA), SS/TA ratio, and technological index (TI). Every 30 days, unripe fallen fruits were counted under the crown of useful plants, before the harvest, and then removed from the experimental area. Productivity (ton ha^{-1}) was estimated by the product of the average fruit weight per plant and the number of plants ha^{-1}.

For the analyses of juice yield and its chemical characteristics, 15 ripe fruits from the plants of the usable area were collected, and the juice was extracted. Juice yield (JY), as percentage, was estimated by the expression:

$$RS = \frac{VS}{PF} \times 100$$

where *VS* = juice volume of 15 fruits (mL) and *PF* = weight of 15 fruits (g).

The soluble solid content (SS) was determined by direct reading in an Instrutherm® dbr45 model refractometer. The titratable acidity (TA) of the juice of oranges from each treatment was obtained with a sodium hydroxide solution 0.1N in 10 mL of juice, by titration (Instituto Adolfo Lutz, 1976); the result was as percentage of citric acid. From soluble solid content and acidity results, the ratio (SS/TA ratio) was calculated. The technological index (TI) or quantity of soluble solids in the juice, in a 40.8 kg box (kg of SS box^{-1}) was calculated according to Di Giorgi et al. (1990):

$$IT = \frac{RS \times SS \times 40.8}{10,000}$$

where: *RS* = yield in juice and *SS* = soluble solids. The result was expressed in kilograms of total soluble solids per box.

Data were submitted to analysis of variance, and the F values were presented. Values of the characteristic means were obtained from the joint analysis of both research years, and were compared by Tukey's test ($p \leq 0.05$).

RESULTS AND DISCUSSION

For the characteristics of fallen unripe fruits, number of fruits per plant, productivity, total soluble solids, titratable acidity and SS/TA ratio, there was a significant effect ($p \leq 0.01$) of the isolated factors and the interaction (agricultural year vs. coexistence with weeds). However, as for number of fruits per plant and productivity, the interaction was not significant (Table 2).

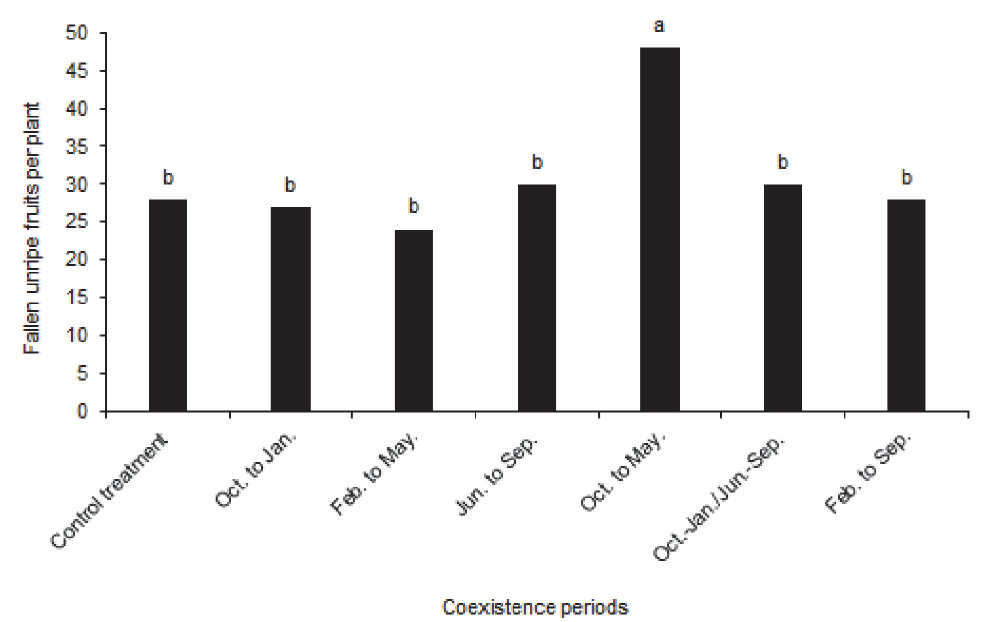
The water deficit may have been enough to promote significant changes in the evaluated characteristics (Figure 1). According to Cruz et al. (2007), when the water deficit is established in the soil, there is a reduction of the water potential in plant cells, with consequent modifications in the development of the plant, its flowering, fruiting and in the chemical composition of fruits. The evaporation of water in fruits causes a decrease in the water potential and a concurrent increase in the concentration of soluble solids. Other factors, such as temperature, luminosity and precipitation, as well as others such as cultivar, rootstock, altitude and cultural treatments may affect the composition of fruits (Detoni et al., 2009).

Weed coexistence treatments were significant for the fall of unripe fruits (Table 2). It was more pronounced when weed and citrus coexistence occurred from October to May of the following year (Figure 2).

Table 2 - Values of the F test of the analysis of variance for the evaluated characteristics of orange trees in different periods of coexistence with weeds. Manaus, 2014

Variation source	F values for the evaluated charcateristics							
	FF	FPP	PRO	JY	SS	TA	RA	TI
Year	45.67**	37.07**	73.82**	2.35 ns	19.59***	1647.51***	999.91***	5.21*
Treatment	29.02**	6.62**	9.00**	0.76 ns	19.08***	235.62***	208.29***	1.70 ns
Year *vs*. Treat.	12.11**	1.73 ns	1.55 ns	1.35 ns	25.58***	178.23***	162.93***	1.60 ns
VC (%)	13.25	13.48	16.39	6.52	1.57	1.99	2.08	6.79

FF - fallen unripe fruits; FPP - fruits per plant; PRO - productivity; JY - juice yield; SS - total soluble solids; TA - titratable acidity; RA - SS/TA ratio; TI - technological index. *** significant at 0.1%; ** significant at 1.0%; and * at 5% probability by F test by analysis of variance.

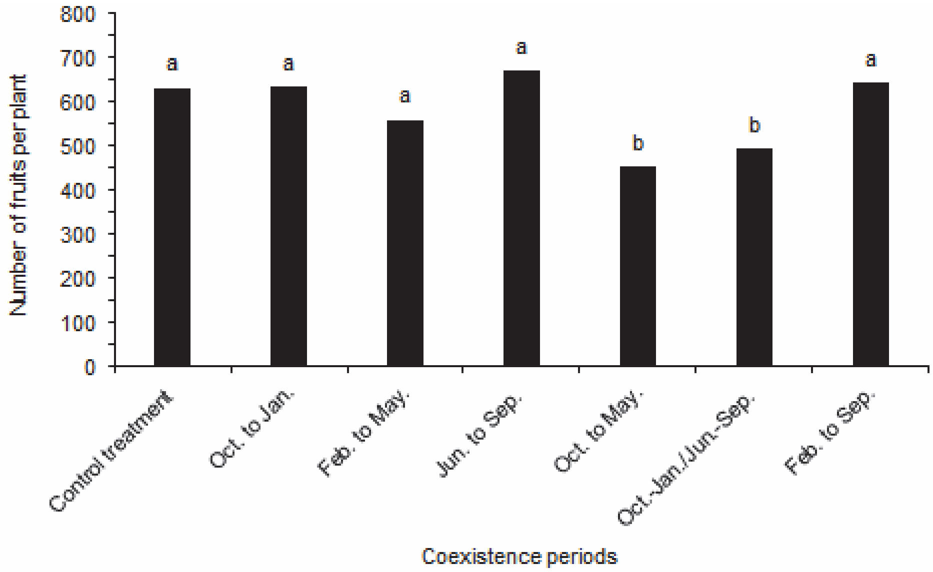


Columns with equal letters do not differ by Tukey's test ($p<0.05$). Manaus, 2014.

Figure 2 - Number of fallen fruits per Pera orange tree in different periods of coexistence with weeds.

The greater fall of unripe fruits observed during this period may be related to the longer period of coexistence (eight months in a row) and to a greater competition between weeds and crop for growth resources, such as water and nutrients, mainly P, K and B. According to Quaggio et al. (1996), the deficiency of P and B in citrus plants may accentuate the fall of young fruits, also reported by Freitas et al. (2011) in passion fruit plants, due to the deficiency of N and K. In this work, the fall of fruits in the treatment from October to May might have been accentuated because, besides the great weed competition period, the analysis of soil also indicated K deficiency. According to Jung et al. (2009), potassium deficiency can induce the production of H_2O_2, a toxic molecule for cell metabolism, and may increase the concentration of ethylene in plants - the hormone that is responsible for the falling of fruits. Potassium deficiency also reduces the export of photoassimilated compounds to the roots, inhibiting their growth and, consequently, the absorption of nutrients by plants (Gerardeaux et al., 2010).

As for the harvested fruits, the lowest amount was found in the treatment where coexistence occurred from October to May of the following year or from October to January and June to September of the same year. Weed coexistence from October to May reduced the amount of fruits per plant by 28% (Figure 3), compared to the control treatment (without interference); only in this period, the productivity of orange trees was significant. This reduction may be related to a greater fall of unripe fruits drop, that experienced a significant interference from weed competition.



Columns with equal letters do not differ by Tukey's test ($p<0.05$). Manaus, 2014.

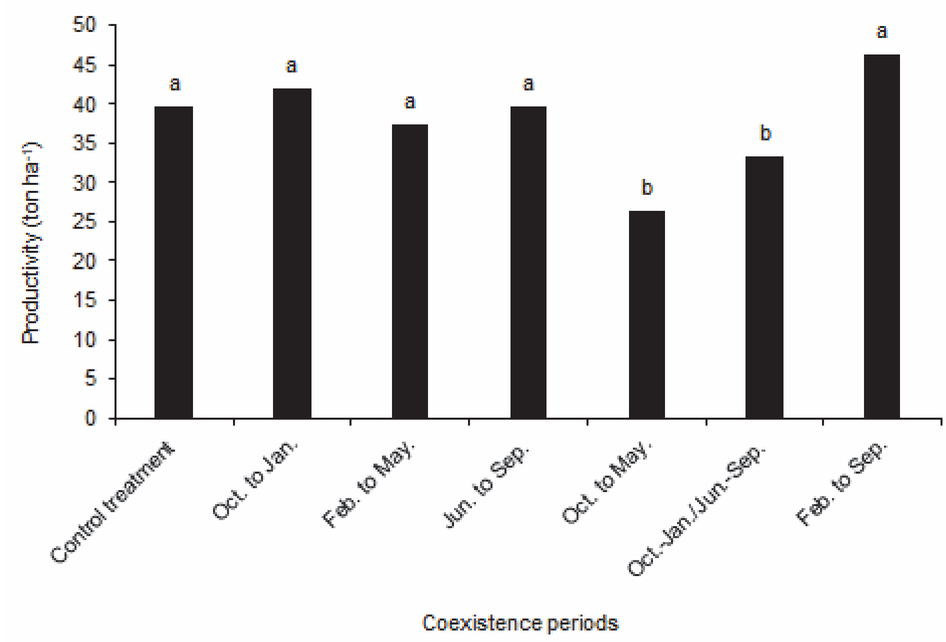
Figure 3 - Number of fruits per Pera orange tree in different periods of coexistence with weeds.

Productivity loss was 34% in relation to the control treatment (Figure 4). In a study conducted by Monteiro (2011), the weed coexistence with citrus plants in this period also reduced the productivity of orange trees in the same proportion. This may be related to the lower production of fruits per plant (Figure 3). According to Oliveira et al. (2009) and Morgado et al. (2010), under environmental conditions that are favorable for the crop and without weed interference, the number of fruits per plant is one of the main factors of citrus productivity variation, and these characteristics are positively correlated. However, some studies report that productivity depends on the number of fruits per plant, on the mean weight of fruits and on plant spacing (Matos et al., 2012; Cavichioli et al., 2014). These characteristics are strongly influenced by the coexistence period and by the interference with weeds. The longer the coexistence period, the more intense the interference and the lower the crop productivity (Alves et al., 2013; Fey et al., 2013).

In the Northeast region of Brazil, Carvalho et al. (2003) determined that the critical period of weed interference on citrus occurs from September/October to April/May of the following year. According to these authors, this period is considered dry and rainfall is not enough to meet the water requirements of the crop; this generates great competition for water and a reduction in the productivity of orange trees.

As opposed to the results obtained for the conditions of the Brazilian Northeast, the greatest productivity interference occurred in the period of greatest water availability in the soil (Figure 1). This may indicate that weed interference does not occur solely because of the competition for water in the soil, but also through other stresses caused by nutrient scarcity, high temperature, and so on. Under the conditions of Amazonas, with the arrival of the rainy season in October, weeds find optimal conditions for their growth and development (Monteiro, 2011), with a greater demand and competitive advantage of the resources in the environment, causing their scarcity in soil and their deficiency for the culture.

Weed coexistence treatments and agricultural year significantly influenced the amount of total soluble solids (SS), the titratable acidity (TA) and the SS/TA ratio of orange juice (Table 2). The highest SS value (9.62 °Brix) was observed in the coexistence treatment from June to September, indicating that the crop should remain weed-free from October to May, in order not to decrease the amount of sugar in the juice. The lowest SS value was 8.72 °Brix (Table 3) in the treatment with coexistence from October to January and from June to September, probably due to a greater interference of weeds, since this treatment remained weed-free for only four months throughout the year (Table 1).



Columns with equal letters are similar by Tukey's test ($p<0.05$). Manaus, 2014.

Figure 4 - Productivity of Pera orange in different periods of coexistence with weeds.

Table 3 - Chemical characteristics of the juice of ripe fruits of Pera orange trees submitted to different periods of coexistence with weeds. SS = total soluble solids; JY = juice yield; TA = titratable acidity; TI = technological index

Coexistence treatment	SS	JY	TA	SS/TA	TI
	(°Brix)	(%)			(kg box^{-1})
Control treatment	9.12 c	51.30 a	0.67 e	13.53 b	1.91 a
Ocrober to January	9.32 b	51.69 a	0.76 b	12.38 d	1.98 a
February to May	9.11 c	51.21 a	0.76 b	12.11 e	1.90 a
June to September	9.62 a	50.62 a	0.81 a	11.85 e	1.98 a
October to May	9.17 c	49.47 a	0.72 d	13.01 c	1.85 a
Oct.-Jan./Jun.-Sep.	8.96 c	50.56 a	0.74 c	12.54 d	1.84 a
February to September	9.11 c	52.78 a	0.57 f	13.92 a	1.96 a

Means followed by the same letter in the column do not differ by Tukey's test ($p<0.05$).

It is known that the accumulation of sugars in juice is influenced by the source-drain relation; thus, it was expected that plants with higher fruit load would accumulate less sugar in their fruits, but this was not observed in this study. According to Cruz et al. (2010) and Moreira et al. (2012), the SS content in the fruit increases as the number of fruits per plant decreases, since the availability and the contribution of photoassimilated compounds to the fruit increases. The opposite is observed with the increase in the number of fruits per plant, since it intensifies the competition for photoassimilated compounds, with a consequent reduction of the SS content. Another factor that can increase the SS content in fruits is the decrease of the water availability during ripening, with the increase of the internal concentration of sugars. These effects were observed on Tahiti limes (Miranda and Campelo Junior, 2010) and in Pera orange trees in northern Paraná (Tazima et al., 2010).

The SS contents indicate the amount of solids dissolved in the pulp. Generally speaking, high levels of SS are important both for fruit consumption *in natura* and for the industry, indicating the need to add less sugar to the final product (juices, ice cream, etc.) (Ramos et al. 2011). A high SS content is a very desirable characteristic for the industry and the fruit market, since it takes about 11 kg of fruits with SS between 11 and 12% to obtain 1 kg of concentrated juice at

50 °Brix. Thus, the higher the SS content, the lower the amount of fruit required for juice concentrate (Nascimento et al., 2003).

The highest juice acidity (0.81) in the weed coexistence treatment was from June to September (Table 3). The acidity decreased to 0.67 when the crop was kept clean, without the interference of weeds. Citrus fruits present a quantity of organic acids that, in balance with sugar contents, represents an important quality attribute; the higher the acidity, the lower the expense of the industry for the addition of organic acids. According to Chitarra and Chitarra (2005), fruit acidity tends to decrease with the use of organic acids in the respiratory activity, which is intense as the fruit grows and ripens.

Although SS and TA are separately evaluated characteristics, both must be analyzed together, since the fruit flavor is measured by the SS/TA ratio, and is due to acid and sugar balance (Chitarra and Chitarra, 2005), while sugar content and acidity may undergo variations due to environmental factors, cultivation practices, sunlight quality, temperature, fertilizer type and doses, with direct consequences on the SS/TA ratio (Nascimento et al., 2003). The lowest values of this relation (11.85 and 12.11) were recorded in treatments whose coexistence with weeds was from June to September and from February to May, respectively (Table 3), indicating the need to manage them in these periods. The lowest SS/TA values were due to the titratable acidity of the juice, which was also higher in the aforementioned control treatments. For the Pera orange cultivar, the SS SS/TA ratio is generally higher than 12, but may vary with the fruit harvest season (Mattos Junior et al., 1999).

In this study, the technological index (TI) of fruits did not exceed 2.0 kg of box^{-1} (Table 2). For the Pera cultivar, mean soluble solid values between 2.2 and 2.7 kg box^{-1} are expected (Di Giorgi et al., 1990). The low IT values can be explained by the reduced SS content of fruits, as they did not exceed 10 °Brix.

The coexistence from October to May between weeds and the orange crop indicated that this was the period causing the greatest reduction in the productivity of orange trees, and it was therefore considered the critical inetrference period.

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