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Potato cultivar BRS F63 Camila has higher yield at lower plant spacing

Vlandiney Eschemback[1]; Jackson Kawakami[1]; Aline M Genú[1]; Dioni Stroparo[1]

[1]Universidade Estadual do Centro-Oeste do Paraná (UNICENTRO), Guarapuava-PR, Brazil; veschemback@hotmail.com

ABSTRACT

The plant management used in potato crop is usually similar across the main producing regions in Brazil. Same plant spacing are commonly used, despite the differences in climate and soil of the various potato planting areas. The objective of this work was to evaluate the yield of potato cultivars in response to different plant spacing. Experiments were conducted in the field, and the treatments consisted of three cultivars (Agata, BRS Clara and BRS F63 Camila) and three plant spacing (20, 25 and 30 cm) in randomized blocks with three repetitions in two years. The total, marketable and non-marketable tuber yield, total and marketable number of tubers per area and size class, mean total and marketable tuber weight and percentage of tuber dry weight of the tubers were evaluated. Camila was the cultivar with highest yield when spaced 20 cm due to the greater number of tubers in the marketable class 100-200 g. In the 25 and 30 cm plant spacing, there was no difference in yield among cultivars. Depending on the cultivar and the destination of the harvested tubers, producers can choose the most appropriated plant spacing.

Keywords: *Solanum tuberosum*, Agata, BRS Clara, density, productivity, variety.

RESUMO

Cultivar de batata BRS F63 Camila tem maior produtividade em menor espaçamento de plantio

As práticas fitotécnicas utilizadas no cultivo da batata se assemelham nas principais regiões produtoras do Brasil. Em locais com clima e solo distintos, comumente utiliza-se as mesmas densidades de plantio. O objetivo deste trabalho foi avaliar a produtividade de cultivares de batata em resposta a diferentes espaçamentos de plantio. Foram conduzidos experimentos a campo, sendo os tratamentos constituídos de três cultivares (Ágata, BRS Clara e BRS F63 Camila) e três espaçamentos entre plantas (20, 25 e 30 cm), em blocos casualizados, com três repetições, em dois anos. Foram avaliados a produtividade de tubérculos total, comercial e não comercial, número total e comercial de tubérculos por área e por classe de tamanho, massa média de tubérculos total e comercial e a porcentagem de matéria seca dos tubérculos comerciais. Camila foi a cultivar mais produtiva quando espaçada em 20 cm, devido ao maior número de tubérculos na classe comercial 100-200 g. Nos espaçamentos de 25 e 30 cm não se observou diferença de produtividade entre as cultivares. Dependendo da cultivar, deve-se utilizar o espaçamento de plantio mais adequado à finalidade comercial para qual é destinada a produção.

Palavras-chave: *Solanum tuberosum*, Ágata, BRS Clara, densidade, rendimento, variedade.

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Spacing between plants is a fundamental element to obtain better results in potato crop yield. Considering the alternatives associated with crop management, an adequate plant distribution arrangement in the area is a start point for the crop to maximize its development, with better utilization of environmental factors and lower competition between plants for elements such as solar radiation, water and nutrients, by the canopy and the root system (Tarkalson *et al.*, 2012).

Results show that plant spacing does not influence plant emergence and that the increase in plant density increases the yield of tubers per area (Van der Zaag & Demagante, 1990). Usually, within certain limits, higher potato yield per area is achieved with greater population (Bussan *et al.*, 2007), that is, almost always dictated by smallest spacing among plants. Yield, mean size and number of tubers produced are affected by plant density (Tarkalson *et al.*, 2012). Results of studies indicate that potato yield, in response to different plant densities, is directly influenced by the environment and by the cultivar (Tarkalson *et al.*, 2012).

Tuber development and production with the variation of plant spacing has been different in distinct cultivars used by producers. The cultivars differ morphologically in its capacity to compensate for variations in plant spacing, and each cultivar has a plant density that results in maximum yield (Mauromicale *et al.*, 2003). Determining the yield response of tubers to different plant population is a recurrent study area (Rex, 1991; Rykbost & Maxwell, 1993; Zebarth *et al.*, 2006), because interactions among technical, genetic and commercial factors are in constant changes and adjustments.

The main genotype effect is wide adaptation, meanwhile the genotype and environment interaction refers to strict adaptation (Gauch, 2006). For producers, cultivars with stable and

high yield, that is, with a great genotype effect, result in greater competitiveness in the market. In the Brazilian market, new cultivars that have high yield potential, are currently available for use but are still often unknown by the producers (Souza *et al*., 2011).

There is little information on the response of these new cultivars to plant spacing variations. Therefore, adjusting the best plant density for a given cultivar can result in significant gain in tuber yield and quality.

The objective of this work was to evaluate the yield performance of potato cultivars in response to different plant spacing.

MATERIAL AND METHODS

The experiment was held at the experimental field of Midwestern State University, UNICENTRO, in Guarapuava-PR, whose soil is classified as Latossolo Bruno (very clayey Typic Hapludox) (Michalovicz *et al*., 2014). The necessary amount of limestone was calculated to achieve a base saturation of 60%, based on the initial data of soil chemical attributes analysis in the depth of 0-20 cm and applied three months before crop implantation.

Treatments consist of three plant spacing (20, 25 and 30 cm between plants) and three potato cultivars (Ágata, BRS Clara and BRS F63 Camila), conducted in two crop seasons (2014 and 2015). Experimental design was a completely randomized block, in a split-plot scheme, with the cultivars and crop seasons assigned to the main plots and the plant spacing to the subplots, with three replicates. Each subplot measured 4.8 x 4.5 m, composed by six rows, with 18 plants in each row, in a spacing of 80 cm between rows.

Type III (30 and 40 mm) seed tubers were used from cultivars Clara, Camila and Ágata. In the first crop season (2014) the seed tubers of Clara and Camila were obtained from Embrapa Produtos e Mercado (Canoinhas-SC) and Ágata was obtained from a regional seed tuber certified producer. In the second crop season (2015) seed tubers were harvested manually from the first crop season, standardized and kept stored in a cold chamber (4ºC) until approximately 40 days prior to tuber planting.

Yield quantification was held by collecting manually after physiological maturation, the tubers of 12 plants per plot, from the four central rows. The harvested tubers were divided into three categories: total tubers, commercial tubers (>45 mm transversal diameter) and non-commercial (<45 mm transversal diameter). The number of tubers (m^2) and tuber fresh weight (kg ha^{-1}) were quantified. Commercial tubers were divided into three classes: until 100 g, 100 to 200 g and greater than 200 g, number and fresh weight were recorded to calculate the percentage of tuber dry weight when the samples dried at 70°C reached constant weight.

Soil preparation begun a month prior to the crop implantation, with one subsoiling and two harrowings. Further, a light harrowing and furrowing of the area for planting were held. Planting of tubers was held on December 06 and 08, in 2014 and 2015, respectively. The NPK fertilizer 04-14-08, in the dose of 4 t ha^{-1}, was distributed in total dose in the furrow, immediately before manual planting of tubers. Hilling was done in both crop seasons, approximately 15 days after emergence (DAE). The phytosanitary management was done according to technical recommendation for the region (Pereira & Daniels, 2003).

Shapiro-Wilk's was used for data standardization and when necessary, Box-Cox transformation was done. Analysis of variance (ANOVA) and Tukey test (p<0,05) were performed. When there was significant interaction, the decomposition of the interaction was performed, and the results presented.

RESULTS AND DISCUSSION

The Shapiro-Wilk's test showed that non-commercial tuber yield and number of tubers in the 100-200 g class data had non-normal distribution and were transformed.

There was no difference in total and commercial yield between the crop season 2014 and 2015, but there was interaction between plant spacing and cultivar (Table 1). Cultivar Camila showed higher yield than the other cultivars in 20 cm plant spacing for both total yield (Figure 1a) and commercial yield (Figure 1b). In 25 and 30 cm plant spacing, the cultivars did not differ in total and commercial tuber yield.

There was a difference in non-commercial tuber yield only for plant spacing (Table 1). The plants cultivated in 20 cm spacing presented the highest yield (4.13 t ha^{-1}), and in 30 cm plant spacing had the lowest yield (3.05 t ha^{-1}), and those plants spaced 25 cm obtained a non-commercial tuber yield of 3.33 t ha^{-1}

There was no difference between the crop season for total and commercial number of tubers but there was interaction between plant spacing and cultivar (Table 1). In 20 and 30 cm plant spacing, no difference was observed for total number of tuber among the cultivars; however, Ágata produced higher number than cultivars Clara and Camila in 25 cm spacing (Figure 1c). Cultivar Camila produced higher number of commercial tubers in 20 cm plant spacing, compared to the other cultivars (Figure 1d). In the plant spacing 25 and 30 cm no difference was observed for number of commercial tubers among the studied cultivars. All cultivars produced the smallest number of commercial tuber under 30 cm spacing, and the lowest production was observed for cultivar Camila.

An effect was ovserved for cultivar and plant spacing in the commercial tuber class of <100 g and interaction between plant spacing and cultivars for classes 100-200 g and >200 g (Table 1). Ágata was the cultivar with highest number of tubers <100 g compared to the other cultivars (Figure 2a) and plant spacing of 30 cm resulted in a lower number of tubers for this commercial class (Figura 2b). In 20 cm plant spacing we observed that cultivar Camila produced higher number of tubers of the commercial class 100-200 g, compared to Ágata and Clara, and higher number of tuber of the >200 g class in relation to Ágata, and the production of Clara was intermediate in this tuber class (Figure 2c). In the 25 cm plant spacing, Clara

Table 1. *P*-value of the analysis of variance of the variables evaluated during the experiments in the crop season 2014 and 2015. Guarapuava, UNICENTRO, 2014-2015.

P-value	Crop Season (CS)	Cultivar (C)	CS x C	CV 1 (%)	Spacing (S)	S x CS	S x C	S x CS x C	CV 2 (%)
TY (kg ha^{-1})	0.068	0.144	0.973	25.05	<0.001	0.463	0.010	0.876	19.11
CY (kg ha^{-1})	0.082	0.091	0.967	29.25	<0.001	0.349	0.005	0.878	20.62
NCY (kg ha^{-1})	0.749	0.072	0.985	46.60	0.006	0.577	0.087	0.912	27.77
NTT (m^2)	0.205	0.045	0.968	16.92	<0.001	0.755	0.010	0.436	13.63
NCT (m^2)	0.124	0.398	0.833	15.24	<0.001	0.544	0.007	0.376	15.37
NT<100 g (m^2)	0.440	0.004	0.485	20.01	<0.001	0.416	0.072	0.872	22.92
NT 100-200 g (m^2)	0.517	0.059	0.692	42.17	<0.001	0.987	<0.001	0,460	28.94
NT>200 g (m^2)	0.205	0.027	0.953	25.12	<0.001	0.574	0.047	0.942	25.86
MTTW (g tub^{-1})	0.249	0.039	0.993	25.56	0.005	0.273	0,067	0.970	15.25
MCTW (g tub^{-1})	0.158	0.058	0.959	22.42	0.019	0.354	0.179	0.961	14.63
DWCT (%)	0.059	<0.001	0.120	2.93	0.057	0.926	0.333	0.919	8.78

[1]Total yield (TY), commercial yield (CY), non-commercial yield (NCY), number of total tubers (NTT), number of commercial tubers (NCT), number of tubers (NT), mean total tuber weight (MTTW), mean commercial tuber weight (MCTW) and percentage of dry weight of commercial tubers (DWCT).

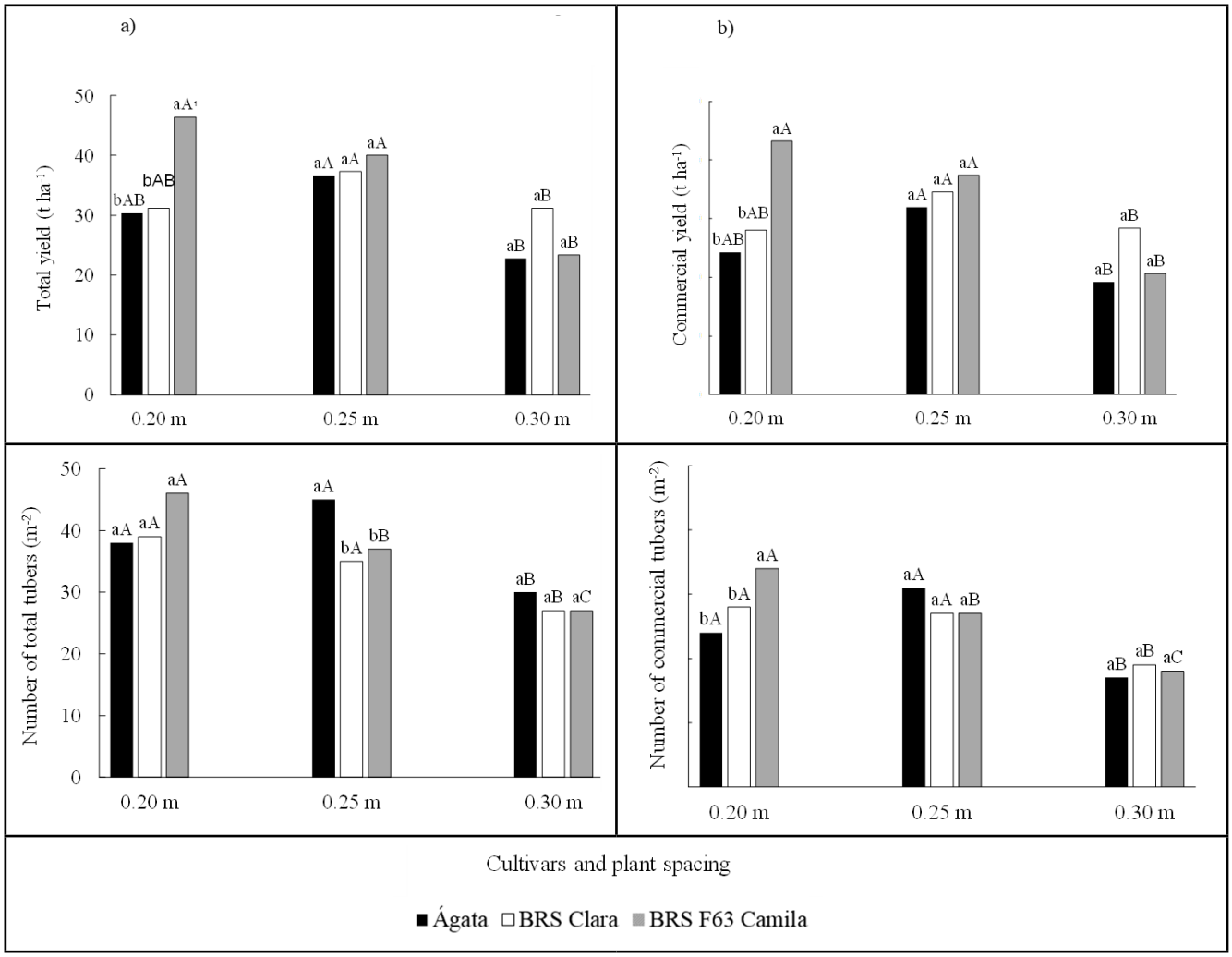

Figure 1. Total (a) and commercial yield (t ha^{-1}) (b), number of total (c) and commercial tubers (m^2) (d), of potato under different plant spacing, crop season 2014-2015. Means followed by same lowercase letter (among cultivars in the same spacing) and uppercase (among cultivars in the same spacing) did not differ significantly, Tukey test, p<0.05. Guarapuava, UNICENTRO, 2014-2015.

and Camila produced higher number of tubers than Ágata in class >200 g, not differing between themselves. In the same plant spacing no difference was observed among the cultivars for number of tubers between 100-200 g. When spaced 30 cm, no difference in tuber production of both commercial classes 100-200 g and >200 g was found among the studied cultivars.

No difference was found for total and commercial mean tuber weight between the crop seasons 2014 and 2015 (Table 1). For total mean weight, effect of cultivar and plant spacing was observed. Cultivar Camila produced tubers with higher mean weight and cultivar Ágata tubers with lower total mean weight, while the tubers from Clara showed an intermediate mean weight (Figure 3a). The spacing that results in total tubers with higher mean weight was 25 cm (Figure 1b). About mean commercial tubers weight, only spacing effect was observed (Table 1). The spacing which resulted in higher mean commercial tuber weight was 25 cm; 20 cm resulted in lowest mean commercial tuber weight and 30 cm in intermediate mean commercial tuber weight (Figure 3d).

Only cultivar effect was observed for tuber dry weight (%) (Table 1). Tubers from cultivar Clara presented higher dry weight, Ágata lowest and Camila, intermediate (Figure 3c).

The results of this study indicate that

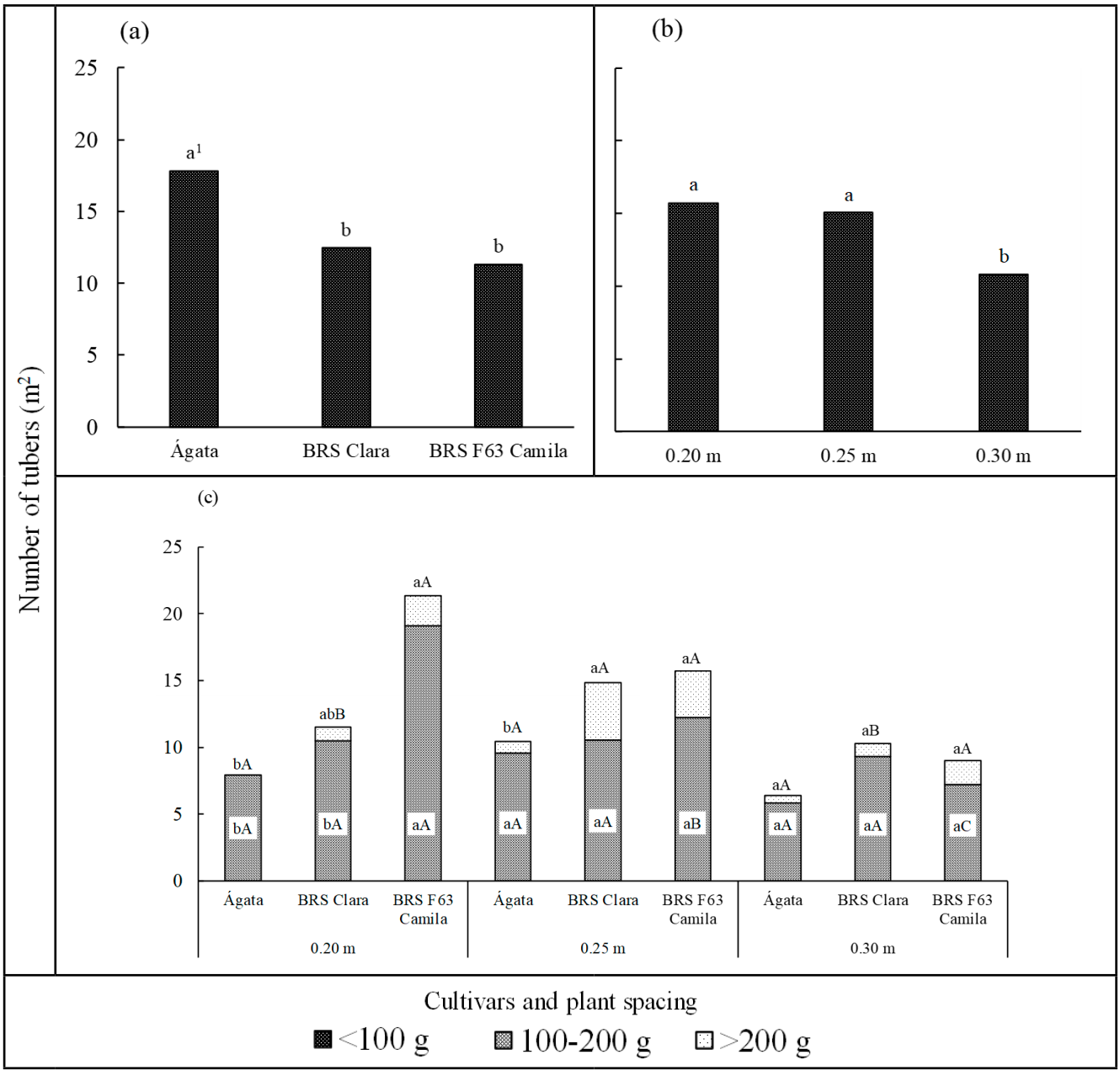

Figure 2. Number of commercial tubers (m^2) separated in classes <100 g among cultivar (a) and among plant spacing (b), 100-200 g and >200 g (c), of potato cultivars according to different plant spacing, crop season 2014-2015. Means followed by same lowercase letter (among cultivars in the same spacing) and uppercase letter (among spacing in the same cultivar) did not differ significantly by Tukey test, $p<0.05$. Guarapuava, UNICENTRO, 2014-2015.

the response of potato plants to different plant densities is directly influenced by environment and cultivars. The highest commercial yield from cultivar Camila observed in 20 cm spacing (Figure 1b) was due to the highest number of commercial tubers of class 100-200 g compared to cultivars Clara and Ágata (Figure 1d). This higher commercial yield of Camila resulted in greater total yield of this cultivar, since there was no difference in non-commercial yield among the studied cultivars (Table 1). The tuber production with highest mean weight of cultivar Camila, even in the smallest spacing tested (Figure 3a), probably influenced the higher yield of this cultivar, because in smaller plant spacing potato plants tend to produce tubers with lower mean weight as observed on the other cultivars (Queiroz *et al*., 2013; Tarkalson *et al.,* 2012).

Studies report that the productive capacity of potato cultivars may vary according to planting density, due to number, size and mean weight of the produced tubers, which may differ according to plant spacing and cultivar (Fontes *et al.*, 2012), a fact also observed on the cultivars of the present study, which presented variations of these characteristics depending on the density and cultivar used. Mauromicale *et al*. (2003) report that, because of the increase in plant density, despite the competition, there was an increase in yield, also observed in the present study for cultivar Camila in the highest density, both for total and commercial yield. There are results indicating the possibility of obtaining high tuber production regardless of plant spacing, such as in studies of Creamer *et al.* (1999), where cultivar Russet Burbank did not have the production affected, varying plant spacing from 15 to 30 cm. However, higher yield was obtained by Rykbost & Maxwell (1993) ranging plant spacing from 17 cm of cv. Century Russet and Atlantic, to 30 cm of cv. Russet Norkotah. These data show that not only plant density affects tuber yield but also the used cultivar.

Plants of the cultivar Ágata in the smallest spacing (20 cm) produced a greater number of tubers per area compared to the greater spacing (30 cm) (Queiroz *et al.*, 2013). These data corroborate the data of the present study that found a higher number of total and commercial tubers of plants spaced 20 cm, in comparison to the higher spacing tested (30 cm). In addition, our data show that an increase in the number of tubers per area, with reduction in planting space occurs not only on cultivar Ágata, but also on the other studied cultivars.

When the objective is production of seed tubers, the most important is the number of tubers produced. So, the smallest spacing should be used. According to Fontes *et al.* (2012), it is possible to use spacing reduction between plants as a management technique to increase the number of drains per unit area and, consequently, the number of tubers with lower weight

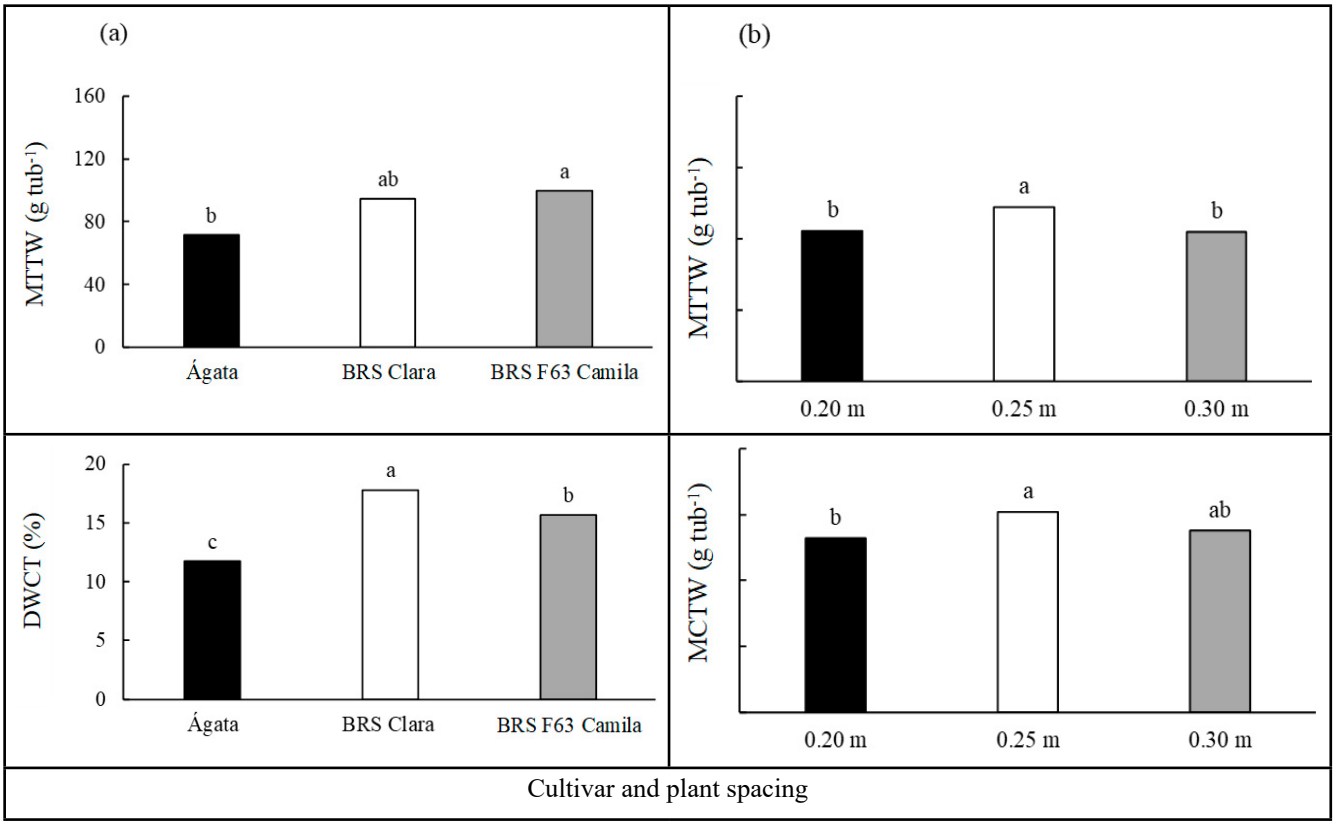

Figure 3. Mean total tuber weight (MTTW) among cultivars (a) and among spacing (b), dry weight (%) of commercial tuber (DWCT) among cultivars (c) and mean commercial tuber weight (MCTW) among plant spacing (d), crop season 2014-2015. Means followed by same letters did not differ significantly, Tukey test, $p < 0.05$. Guarapuava, UNICENTRO, 2014-2015.

and diameter, suitable to be used as seed tubers. Furthermore, it is speculated that, to produce seeds of cultivar Camila, spacing could be reduced even more than 20 cm between plants, due to the fact that the tubers of this cultivar had high mean weight, even in the smallest spacing.

The use of lower spacing between plants implies greater seed tuber expenditure by producers, a significant component in the crop production cost, contributing to about 20% of the total crop cost (Cepea, 2018). In addition to the higher seed tuber spending, there are costs with fertilizer and practices in the field, such as planting, pest and disease control and the harvest that needs to be considered in practical terms. In the present study, we used in the smallest spacing (20 cm) about 50% more seed tubers compared to the greater spacing (30 cm). Thus, the spacing between plants has an impact on the total and commercial yield of the cultivars as well as on the economic return of the crop, since the cost of the seed tuber varies depending on season and the cultivar.

The absence of effect of plant spacing on tuber dry weight results in no interference of this variable in tuber's frying quality, since greater percentage of dry weight of tubers is desired. Although these cultivars are not mainly destined to the industry, that is, to be fried, they can be fried by home consumers. Moreover, based on the results of the present study, it is presumed that the planting of type III seed tubers of cultivars destined to industry can benefit in spacings of 25 cm between plants and 80 cm between rows.

Plants of cultivar Camila spaced 20 cm were more productive, both for total and commercial tuber yield. This higher yield was due to the higher number of commercial tubers from class 100-200 g.

Our results show that the appropriate cultivar and plant spacing should be used depending on the destination of the production.

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