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Agronomic performance of *Raphanus sativus* L. cultivars grown under different spacings

Rendimiento agronómico de los cultivares de *Raphanus sativus* L. con diferentes espaciamientos

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ARTICLE DATA

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ABSTRACT

An ideal spacing between plants should be established for the optimization of radish (*Raphanus sativus* L.) crops since the plant spatial distribution of plants affects the crop yield. This study was conducted aiming to evaluate the agronomic performance of radish cultivars grown under different spacings. The experiment was conducted at the Experimental Field of the Federal Institute of Education, Science, and Technology of Maranhão, in Codó, MA, Brazil, from June to July 2017. The experiment was conducted in a randomized block design with five replications, using a 2×2 factorial arrangement. The factors consisted of 2 cultivars (Sparkler Ponta Branca and Saxa) and 2 spacings between plants (5 and 8cm), totaling 20 experimental plots. Data were collected in 6 plants from each experimental plot. The agronomic parameters: total fresh weight (TFW), root fresh weight (RFW), root mean diameter (RMD), root means length (RML), and root yield (RY) of the radish plants were evaluated. The factors (cultivars and spacing between plants) had no significant effect on TFW, RFW, RML, and RMD. The spacing between plants has a significant effect on the yield of radish crops of the cultivar Saxa, and higher yields are found when using the spacing of 5cm.

Keywords: Plant spatial arrangement; production components; horticulture; yield.

RESUMEN

Debe establecerse un espacio ideal entre las plantas para optimizar los cultivos de rábano (*Raphanus sativus* L.), ya que la distribución espacial de las plantas afecta al rendimiento de los cultivos. Este estudio se realizó con el objetivo de evaluar el rendimiento agronómico de los cultivos de rábano cultivados con diferentes espaciamientos. El experimento se llevó a cabo en el Campo Experimental del Instituto Federal de Educación, Ciencia y Tecnología de Maranhão, en Codó, MA (Brasil), de junio a julio de 2017.

El experimento se llevó a cabo en un diseño de bloques aleatorios con cinco réplicas, utilizando un arreglo factorial de 2×2. Los factores consistían en 2 cultivares (Sparkler Ponta Branca y Saxa) y 2 espaciamientos entre plantas (5 y 8cm), totalizando 20 parcelas experimentales. Se recogieron datos en 6 plantas de cada parcela experimental. Se evaluaron los parámetros agronómicos: peso fresco total (PFT), peso fresco de las raíces (PFR), diámetro medio de las raíces (DMR), longitud media de las raíces (LMR) y rendimiento de las raíces (RR) de las plantas de rábano. Los factores (cultivares y espaciamiento entre plantas) no tuvieron un efecto significativo en el PFR, PFR, LMR y DMR. El espaciamiento entre plantas tiene un efecto significativo en el rendimiento de los cultivos de rábano del cultivar Saxa, y se encuentran rendimientos más altos cuando se utiliza el espaciamiento de 5cm.

Palabras clave: disposición espacial de las plantas; componentes de la producción; horticultura; productividad.

INTRODUCTION

Radish (*Raphanus sativus* L.) is a vegetable native from the Mediterranean region (Rodrigues *et al*., 2013), belongs to the Brassicaceae family, the same family of cauliflower, oilseed radish, rocket, cabbage, and others. The plants usually have small sizes, tuberous roots, and green compound leaves with leaflets and lobes (Guimarães and Feitosa, 2014).

The consumption of vegetables has increased in the last years due to the search for healthier foods with nutraceutical properties (Cunha *et al*., 2017), considering that the population is aware of the benefits and properties of these foods. It increases the responsibility and challenges for rural producers who need to increase crop yields and search for tools to control and mitigate the occurrence of pests and diseases and, also, search for compatible sustainable production systems that ensure the availability of foods to consumers and, consequently, the growth of the food production sector (Montezano and Peil, 2006).

The world radish production is estimated at 7 million Mg year^{-1}. Japan is one of the largest radish producers (Linhares *et al*., 2010; Ito and Horie, 2008). In Brazil, radish is grown mainly in the South and Southwest regions, showing yields from 11 to 30Mg ha^{-1} and a production cost of BRL (R$) 10,000 to 14,000 per hectare (Melo, 2017). Despite present in several Brazilian recipes, radish crops have not been emphasized in Brazil regarding the crop area and production volume (Cecílio Filho and May, 2002).

Radish presents the lowest expressiveness in Brazil among marketed vegetables (Puliti *et al*., 2009). Therefore, it can be grown in small size properties along with green belts of large cities, enabling a faster financial return and higher income in periods between seasons of crops of longer cycles (Cardoso and Hiraki, 2001; Oliveira *et al*., 2010). Thus, radish is a good alternative crop, mainly for small farmers, since it can be grown throughout the year and between other crop seasons (Bonela *et al*., 2017).

The crop spacing between rows and between plants and the number of plants per pit are factors that define the plant population to be grown. Climate, soil, and plant chemical and physical characteristics, crop management, and cultural practices should be considered to determine these factors (Severino *et al.,* 2006). Studies on radish crops for the Cocais administrative region of the state of Maranhão, Brazil, are scarce. In this context, this study was conducted aiming to evaluate the agronomic performance of radish (*R. sativus* L.) cultivars grown under different spacings.

MATERIAL AND METHODS

The experiment was conducted with radish crops at the Experimental Field of the Federal Institute of Education, Science, and Technology of Maranhão, in Codó, in the mesoregion East of the state of Maranhão, Brazil (4°26'51''S, 43°52'57''W, and altitude of 48m) (Castro Júnior *et al*., 2015).

According to Köppen and Geiger (1928), the climate of the region is Aw; the mean air temperature is 27.4ºC; the mean annual rainfall depth is 1.526mm. August is the driest month, with a rainfall depth of 12mm, and March presents the highest mean rainfall depth (307mm). September is the hotter month with a mean temperature of 28.8°C. The soil of the area was classified as Typic Quartzipsamment (Santos *et al*., 2018).

Soil samples from the 0.0 - 0.20m layer were collected and sent to the Laboratory of Soil Analysis of the Federal University of Piauí (UFPI) for soil chemical characterization; the results are shown in Table 1.

Soil chemical analysis indicated that liming was not needed. A soil organic fertilizer (cured caprine manure) was used at 20L per plot of $1m^2$. A chemical fertilizer (N-P-K) was applied according to the soil analyses and recommendations of the Manual of Fertilization and Liming (Aquino *et al.,* 1993).

Urea (CH_4N_2O), simple superphosphate (P_2O_5), and potassium chloride (KCl) were applied to the radish beds. The soil chemical fertilizers were applied in two phases: soil fertilization at planting, using P and K; and a topdressing at 15 days after planting, using N and K.

The area was chosen and delimited, and a brush cutting and weeding were carried out through a harrowing of the area. The beds were then manually raised using a hoe. Cured caprine manure was applied to the beds and incorporated into the soil, and the area was leveled using a rake. The plots were then established by dividing beds of 2 × 1m into two plots.

The following cultural practices were carried out during the crop cycle: adding soil to the plants' base, removal of weeds, manual hoeing, and plant health protection. The plants were harvested at 30 days after sowing, on July 18, 2017. A localized irrigation method was used, with a micro-sprinkler system.

The evaluated variables were: total fresh weight (g $plant^{-1}$), using a digital balance; root fresh weight (g $plant^{-1}$), for which leaves were cut at their base to remove them from the roots, and the roots were weighed in a digital balance; root-mean diameter (mm), using a caliper to measure the transversal diameter; root mean length (mm), measuring the root length of each plant with a caliper, and dividing the result by the number of plants in the evaluation area; root yield (kg ha^{-1}), which is the weight of radish roots produced divided by the planted area.

Table 1. Chemical characteristics of the soil of the experimental area.

Layer	pH	P	K	Na	Ca	Mg	Al	H+Al
m	H_2O	mg dm^3		cmolc dm^3				
0.0-0.20	6.6	0.2	21.5	7.9	4.2	4.1	0	3.07

A randomized block experimental design was used, in a 2×2 factorial arrangement, with five replications. The treatments consisted of two cultivars (Sparkler Ponta Branca and Saxa) grown under different spacings between plants (5 and 8cm), totaling 20 experimental plots, with 6 evaluated plants per plot.

Thus, the treatments were: Sparkler Ponta Branca with a spacing of 5cm (T1); Sparkler Ponta Branca with a spacing of 8cm (T2); Saxa with a spacing of 5cm (T3); and Saxa with a spacing of 8cm (T4).

The data found were subjected to analysis of variance (ANOVA) by the F test. The means were evaluated through comparison by the Tukey's test at 5% probability, level using the Assistat® 7.7 beta program (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

According to the analysis of variance (Table 2), the factor cultivar (Sparkler Ponta and Saxa) had no significant effect ($P \geq 0.05$) on the total fresh weight (TFW), root fresh weight of (RFW), root mean diameter (RMD), root mean length (RML) and root yield (RY) of radish plants; and the factor spacing between plants (5 and 8cm) had no significant effect ($P \geq 0.05$) on the variables TFW, RFW, RML, and RMD. However, the spacing between plants (5 and 8cm) had a significant effect ($P < 0.01$) on RY, showing lower RY when using the spacing between plants of 8cm.

These results are explained by the effect of climate conditions since oscillations in soil moisture and temperature throughout the crop cycle affect the yield and quality of radish roots (Costa *et al.,* 2006).

Table 2. Analysis of variance for the total fresh weight (TFW), root fresh weight of (RFW), root mean diameter (RMD), root mean length (RML), and root yield (RY) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Treatments	TFW	RFW	RML	RMD	RY
Cultivar	1.7373 ^{ns}	0.0087 ^{ns}	0.5594 ^{ns}	0.4916 ^{ns}	0.0807 ^{ns}
Spacing	0.3436 ^{ns}	0.0780 ^{ns}	0.0601 ^{ns}	0.3673 ^{ns}	12.3411 **

** = significant at 1% probability level ($p<0.01$), and ns = not significant ($p>0.05$) by the F test.

The cultivar (Sparkler Ponta and Saxa) and spacing between plants (5 and 8cm) had no significant effect ($P \geq 0.05$) on TFW (Table 3). Caron *et al.* (2004) found similar results that corroborate those found in the present work; they explain that the shoot fresh weight of radish plants determines the leaf area and is directly correlated to the production and distribution of photoassimilates and allocation of biomass, mainly in leafy vegetables.

Table 3. Total fresh weight (TFW) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Cultivar	Spacing (20 × 5 cm)	Spacing (20 × 8 cm)
Sparkler Ponta	57.50 Aa	61.05 Aa
Saxa	55.40 Aa	42.80 Aa

Means followed by the same lowercase letter in the columns, or uppercase letter in the rows, are not different by Tukey's test at 5% probability.

The cultivar (Sparkler Ponta and Saxa) and spacing between plants (5 and 8cm) had no significant effect ($P \geq 0.05$) on RFW (Table 4). These are similar results to those found by El-Desuki *et al*. (2005), Rezende *et al*. (2006) and Bonela *et al*. (2017), who found no significant differences for RFW in radish plants of the cultivar Crimson Giant, Saxa, Sparkler Ponta Branca, Red Jewel F1, and No. 25.

Table 4. Root fresh weight (RFW) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Cultivar	Spacing (20 × 5 cm)	Spacing (20 × 8 cm)
Sparkler Ponta	21.55 Aa	23.20 Aa
Saxa	24.60 Aa	20.85 Aa

Means followed by the same lowercase letter in the columns, or uppercase letter in the rows, are not different by Tukey's test at 5% probability.

The cultivar (Sparkler Ponta and Saxa) and spacing between plants (5 and 8cm) had no significant effect ($p \geq 0.05$) on RMD (Table 5). Despite the lack of significance between the treatments, the presence of radish roots with problems, such as sponge-like texture, was not found. These problems result in radishes with a spongy texture, insipid taste, and cracks, thus compromising their quality (Filgueira, 2003).

Table 5. Root mean diameter (RMD) (mm) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Cultivar	Spacing (20 × 5 cm)	Spacing (20 × 8 cm)
Sparkler Ponta	31.35 Aa	31.40 Aa
Saxa	31.20 Aa	28.60 Aa

Means followed by the same lowercase letter in the columns, or uppercase letter in the rows, are not different by Tukey's test at 5% probability.

Caetano *et al*. (2015) evaluated radish crops and found RMD of 19.47 and 18.20mm, which were similar results to those found in the present study. However, Salgado *et al*. (2006) and Vitti *et al*. (2007) found RMD of 3.5cm for radish plants grown under organic soil fertilization.

The cultivar (Sparkler Ponta and Saxa) and spacing between plants (5 and 8cm) had no significant effect ($p \geq 0.05$) on RML (Table 6). Cortez *et al*. (2010) reported that tall plants are not a desirable characteristic to increase radish yields.

Table 6. Root mean length (mm) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Cultivar	Spacing (20 × 5 cm)	Spacing (20 × 8 cm)
Sparkler Ponta	47.20 Aa	50.30 Aa
Saxa	54.25 Aa	49.20 Aa

Means followed by the same lowercase letter in the columns, or uppercase letter in the rows, are not different by Tukey's test at 5% probability.

The cultivar (Sparkler Ponta and Saxa) had no significant effect ($p \geq 0.05$) on RY. However, the spacing between plants had a significant effect ($p < 0.01$) on RY, showing lower RY when using the spacing between plants of 8 cm (Table 7). According to Cecílio Filho *et al*. (1998), mineral nutrition for plants has a high effect on the crop, affecting root qualitative aspects and, mainly, the crop yield.

Table 7. Root yield (RY) of radish plants of different cultivars (Sparkler Ponta and Saxa) grown under different spacings between plants (5 and 8cm).

Cultivar	Spacing (20 × 5 cm)	Spacing (20 × 8 cm)
Sparkler Ponta	17.64 Aa	11.38 Aa
Saxa	20.11 Aa	10.22 Ab

Means followed by the same lowercase letter in the columns, or uppercase letter in the rows, are not different by Tukey's test at 5% probability.

Batista *et al*. (2013) found similar results for radish crop yield, with the highest total root yield of 11.81g plant^{-1}, which was found at 21 days after the incorporation of 15.6Mg ha^{-1} of *Calotropis procera* biomass.

CONCLUSION

The spacing between plants has no significant effect on the yield of Sparkler Ponta Branca radish cultivar but significantly affected the yield of the cultivar Saxa, where higher yields are recorded when the spacing between plants was of 5 cm.

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