Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online
DOI: https://doi.org/10.18188/sap.v21i1.29120

SPATIAL ARRANGEMENTS BETWEEN ROWS x RADISH PLANTS

Mauro Porto Colli[1*]

SAP 29120 Received: 08/09/2021 Accepted: 20/03/2022
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 21, n. 1, jan./mar., p. 52-57, 2022

ABSTRACT - Given the importance of this crop and the need for phytotechnical knowledge about the plant spatial arrangement. The objective of this study was to evaluate the productive parameters of the radish culture when submitted to different spatial arrangements between plants and rows. To achieve this aim, the hybrid cultivar Red Pearl was used as a test in a randomized block experimental design, in a 4 x 6 factorial scheme, with four replications. The factors comprise the combination of crop spacing between “rows” and “plants”. The factor levels correspond to the distances between rows: 8, 16, 24, and 32 cm; and between plants: 4, 6, 8, 10, 12, and 14 cm. Root yield, average root mass, longitudinal and transverse diameters, and non-commercial roots were determined. The data obtained were tabulated to obtain the averages, which were submitted to the Shapiro-Wilk residual normality test, at 5% significance, followed by the analysis of variance. When the residual was normal and the response variable was significant, the data was analyzed using linear regression and the appropriate polynomial model was adjusted to present the results. Statistical analyzes were carried out using the R Software. The results show that there was no interaction between the spacing factors for the analyzed parameters, and the spacing between rows and plants influenced the attributes evaluated independently. The spatial arrangements with lower plant densities provided greater root mass and diameter. The importance of new studies involving fixing the spacing between rows and varying the spacing between plants is suggested to better understand the effect of new spatial arrangements on the productive parameters of the radish crop.
Keywords: *Raphanus sativus* L., density, yield.

ARRANJOS ESPACIAIS ENTRE FILEIRAS x PLANTAS DE RABANETE

RESUMO - Dada a importância da cultura e a necessidade de conhecimentos fitotécnicos acerca do arranjo espacial de plantas, o objetivo do presente trabalho foi avaliar os parâmetros produtivos da cultura do rabanete quando submetido a arranjos espaciais entre fileiras e plantas de rabanete. Para tanto, foi utilizada a cultivar híbrida Red Pearl como teste em delineamento experimental de blocos casualizados, arranjado em esquema fatorial de 4 x 6, contendo quatro repetições. Os fatores compreendem à combinação dos espaçamentos de cultivo entre fileiras e plantas, onde, os níveis dos fatores correspondem as distâncias entre fileiras de 8, 16, 24 e 32 cm e plantas de: 4, 6, 8, 10, 12 e 14 cm. Foram determinados o rendimento de raízes, a biomassa média de raízes, diâmetros longitudinais e transversais e raízes não comerciais. Os dados obtidos foram tabulados para posterior obtenção das médias, que foram submetidas ao teste de normalidade dos resíduos de Shapiro-Wilk, a 5% de significância e posteriormente à análise de variância. Quando normal o resíduo e significativa a variável resposta, era analisada por meio de regressão linear e ajustado o modelo polinomial apropriado para a apresentação dos resultados. As análises estatísticas foram realizadas com o auxílio do Software R. Os resultados evidenciam que não há interação entre os fatores de espaçamento para os parâmetros analisados, sendo que o espaçamento entre filas e plantas influenciam os atributos avaliados de forma independente. Os arranjos espaciais, com menores densidades de plantas, proporcionaram maior massa e diâmetros de raízes. Considera-se a importância de novos estudos que envolvam a fixação do espaçamento entre filas e variem o espaçamento entre plantas para melhor compreensão do efeito de novos arranjos espaciais sobre os parâmetros produtivos da cultura do rabanete.
Palavras-chave: *Raphanus sativus* L., densidade, rendimento.

INTRODUCTION

Radish (*Raphanus sativus* L.) belongs to the Brassicaceae Family. It is a tuberous root originated in the Mediterranean region. The roots might be reddish or white and globular or cylindrical shaped. This plant does not tolerate transplanting; therefore, it is sowed directly on the production site, and can be cultivated throughout the year. Despite not presenting great commercial importance, growing radish is an alternative for small producers since the crop shows a fast cycle of around 30 days. The most accepted cultivars for consumption are those that produce globular reddish roots with white pulp and pungent taste (FILGUEIRA, 2007).

To optimize and improve the quality of the crop, radish must be planted in suitable spatial arrangements, which enables good root development and, consequently, increased yield. However, increasing the number of plants might not necessarily increase its productivity since an increase in the populational density results in increased competition between plants, which might cause reduction in yield and root quality (ARRUDA JÚNIOR et al., 2015).

[1]Universidade do Oeste de Santa Catarina (UNOESC). Campus de Xanxerê. E-mail: mauro.colli@unoesc.edu.br. *Corresponding author.

Thus, to improve the use of the crop area, some knowledge is required about the crop and its yield capacity when subjected to different spatial arrangements (HACHMANN et al., 2017). The radish plant spacing is a relevant technical definition that has not been fully investigated, mainly when related to the crop yield aspects. Such knowledge would provide researchers and producers with a clear and scientifically grounded definition of the most efficient spacing and plant density per hole (NETO et al., 2018). One of the advantages of growing radish is the possibility of several crop cycles, due to its relatively fast production. In addition, radish represents a fast and considerable investment return, becoming a viable alternative for small farmers who seek an alternative crop (TORRES et al., 2003).

According to Costa et al. (2020), there is lack of technical-scientific information about the radish crop, and studies are still required focusing on the radish agronomic performance in different plant density conditions. Nascimento et al. (2017) pointed out that studies must be developed aiming to improve the yield and quality of tubers, aiming to meet the requirements of this food growing demand. Setting a suitable plant population to better use the crop area is an important measure that allows greater yield efficiency (TAVARES et al., 2016).

Taking all that into consideration, this study aimed to evaluate the productive parameters of the radish crop when subjected to different spatial arrangements between rows and plants.

MATERIAL AND METHODS

This study was carried out in field conditions in the municipality of Xanxerê (SC), in the Horticulture Sector of the La Salle Agricultural School. The area is located at 26°48'15,02" S latitude, 52°23'58,60" O longitude, and 731 m altitude. The soil in the area is classified as RED LATOSOL (EMBRAPA, 2006), and the physicochemical characteristics are: 40 clay (%); 6.7 SMP index; 153.4 phosphorus [P (mg dm^{-3})]; 328,0 potassium [K (mg dm^{-3})]; 3.7 organic matter (%); 0.0 aluminum [Al (cmolc dm^{-3})]; 10.0 calcium [Ca (cmolc dm^{-3})]; 2.8 magnesium [Mg (cmolc dm^{-3})]; 15.53[CTC (cmolc dm^{-3})]; and 87.82 [V (%)]. The climate is classified as *Cfb*, according to Köppen (temperate climate, with mean temperature in the coldest month below 18ºC, and mean temperature in the hottest month below 22°C) (WREGE et al., 2012). Temperature and rainfall values in the experimental period are shown below (Figure 1).

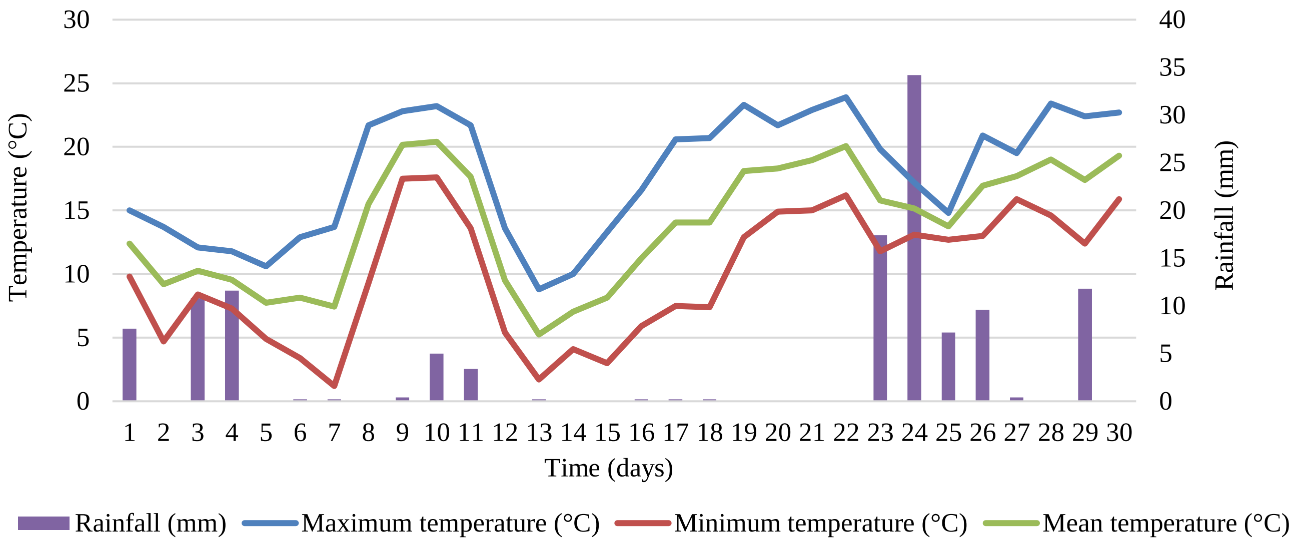

FIGURE 1 – Monthly average of maximum, minimum, and medium temperatures, and accumulated rainfall during the experimental period between the radish sowing and harvesting. Source: INMET, 2020 (station: A858).

Sowing was carried out on 9th April 2018 and harvesting on 7th May 2018. The study was developed using radish (*R. sativus* L.) seeds of the Red Pearl hybrid cultivar (deep red peel, white pulp, and a 25-30-day cycle), with 85% germination. Due to its reduced germination power, two seeds were placed in each hole and after emergence, excess seedlings were removed, leaving a single seedling per hole.

The experimental design used was randomized complete blocks, in a 4 x 6 factorial scheme, with four replications. The factors comprised a combination of crop spacing between radish rows and plants. The factor levels corresponded to the distance between rows, set at 8, 16, 24, and 32 cm, and between plants, set at 4, 6, 8, 10, 12, and 14 cm. Twenty-four treatment combinations were generated and placed in 96 experimental units, in a total area of 1.5 m², and 1 m^2 evaluation useful area. The experiment was carried out in field conditions in a conventional cultivation system.

Before planting, the soil was prepared using rotary hoes, resulting in 0.25m high and 1m wide beds. Next, pre-planting fertilization was carried out using: 67 kg ha^{-1} urea, triple superphosphate (146 kg ha^{-1}), and potassium chloride (104 kg ha^{-1}), according to the soil chemical analysis results and determination of the radish crop nutritional requirements (CQFS, 2016). Irrigation was provided using a conventional sprinkle system and followed the crop hydric requirements. During the crop development period, phytosanitary management was required to control caruru (*Amaranthus viridis*) through weeding, and beetle (*Diabrotica speciosa*) by using insecticide [Lambda-Cialotrina, 26.5 g active ingredient ha^{-1} and Thiamethoxam, 35.25 g active ingredient ha^{-1}] 15 days after sowing.

The response variables analyzed corresponded to the radish culture production components, that is, 25 days after emergence we evaluated root yield (kg m^{-2}), obtained from the radish harvested in the useful area of the experimental units; root mean biomass (g), obtained from weighing ten roots harvested from each experimental unit; longitudinal and transverse diameter (mm), obtained by the mean measure of two sides of the roots using a digital caliper (0.01 mm precision), and non-commercial roots (%), referring to the number of roots that presented symptoms or signs of disease, plague injury, and physiological problems (cracks) that would prevent their commercialization.

After harvested, the roots were selected, evaluated, and the data obtained were tabulated to obtain the averages, which were submitted to the Shapiro-Wilk residual normality test at 5% significance followed by variance analysis. When the residual was normal and the response variable significant, the data was analyzed using linear regression and the proper polynomial model was adjusted to present the results. The statistical analyses were carried out using the R Software (R CORE TEAM, 2018).

RESULTS AND DISCUSSION

The data were submitted to the Shapiro-Wilk residual normality test at 5% normality. We could observe that all response variables obtained a p-value over 5%, evidencing that the residuals were normal, and therefore, the variance analysis could be employed. The radish culture production components evidenced that the spacing between rows and plants did not present significant interaction (Table 1). Thus, when studying the yield variables such as the root mean biomass, longitudinal and transverse diameters, and non-commercial roots, we observed that the change in distances between rows and plants acted independently, that is, there was no interaction between them. The block significant effect revealed the need to block the experimental area for the variables listed above, due to the probable heterogeneity of the experimental environment.

Regardless of the factors, some effect of the spacing between rows and plants on the variables ($p<0.05$) was observed, except for the non-commercial roots, not presenting significance for the cultivation spacing. This fact suggests that the spacing between rows and plants did not result in the production of non-commercial roots, which was probably a consequence of the local agroecological conditions, since rainfall accumulation was observed between the 23rd and 26th days after sowing (Figure 1).

TABLE 1 - Variance analysis of the radish culture production components, showing different spatial arrangements.

VS	DF	RY	RMB	LD	TD	NCR
		F Values				
Block	3	10.14^{*}	11.50^{*}	4.37^{*}	9.27^{*}	4.51^{*}
SR	3	54.96^{*}	18.79^{*}	23.82^{*}	16.77^{*}	0.83^{ns}
SP	5	3.58^{*}	16.87^{*}	21.94^{*}	8.70^{*}	0.35^{ns}
EF x EP	15	1.03^{ns}	0.96^{ns}	0.86^{ns}	1.49^{ns}	0.86^{ns}
Mean	-	2.10	40.12	42.72	37.80	22.19
CV(%)	-	29.20	16.53	5.29	7.16	26.80

*Significant in the F test, 5% error probability. ^{ns} = not significant, VS = variation source, DF = degree of freedom, RY = root yield (kg m^{-2}), RMB = root mean biomass (g), LD = longitudinal diameter (mm), TD = transverse diameter (mm), NCR = non-commercial roots (%), SR = spacing between rows, SP = spacing between plants.

Non-commercial root yield is an undesired characteristic since cracks, mechanical damage, symptoms, signs, and plague injuries result in root discharge or commercial value reduction. The probable cause of the production of 22.19% non-commercial roots was the variation in the climate, temperature, and rainfall during the period since the phytosanitary condition of the crop was under control. Filgueira (2007) stated that fluctuations in the soil moisture content favor the appearance of cracks on the radish roots. This data confirms the report put forward by Costa et al. (2006) since oscillations in soil moist content and temperature throughout the crop cycle affect the yield and quality of the radish roots.

Regarding root yield, when submitted to spacing between rows and plants, significant effect and quadratic behavior was observed in relation to the spacing change (Figure 2A and Figure 3A). We could observe that the root minimum yield was 1.33 kg m^{-2}, with 31.75 cm spacing between rows, and 1.89 kg m^{-2}, with 12.05 cm spacing between plants. Such behavior usually results from the intraspecific competition between plants, mainly caused by the limitation of resources such as water, space, sunlight, nutrients, and O_2 and CO_2 in the environment, when the crop becomes denser. Spacing influences the yield and final quality of the crop and might provoke higher or lower competition between plants for water, sunlight, and nutrients, depending on the vegetable community where they are found (AMORIM et al., 2014). The competition effect results in reduction in the vegetative development and brassica yield and is a consequence of unsuitable populational arrangements/densities. Bezerra et al. (2014) pointed out that a suitable spatial arrangement favors more efficient use of water, sunlight, and nutrients, which is only possible when the plants are uniformly distributed in the production area. A report by Lavanya et al. (2017) discussed the same competition effect when studying radish root yield in relation to specific dates and spacing of sowing and observed biomass reduction with the plant density increase.

The spacing effect on the root mean biomass was significant, presenting a quadratic behavior for the spacing between rows, while the spacing between plants resulted in a linear behavior (Figure 2B, Figure 3B). When observing the spacing between rows, the maximum value obtained was 45.04 g root^{-1}, with 31.89 cm. As for the spacing between plants, an increase of 1.77 g cm^{-1} was observed with the increase in the spacing between plants, that is, when the spacing between plants increased, the commercial value of the roots improved with biomass gain. According to Costa et al. (2020, radish plants with larger space between rows (one plant per hole) produced roots with higher fresh mass values. Luz et al. (2017) studied the radish agronomic features as a function of the spacing between plants and rows and found similar results to the ones obtained in this study, with 46.76 g root biomass value.

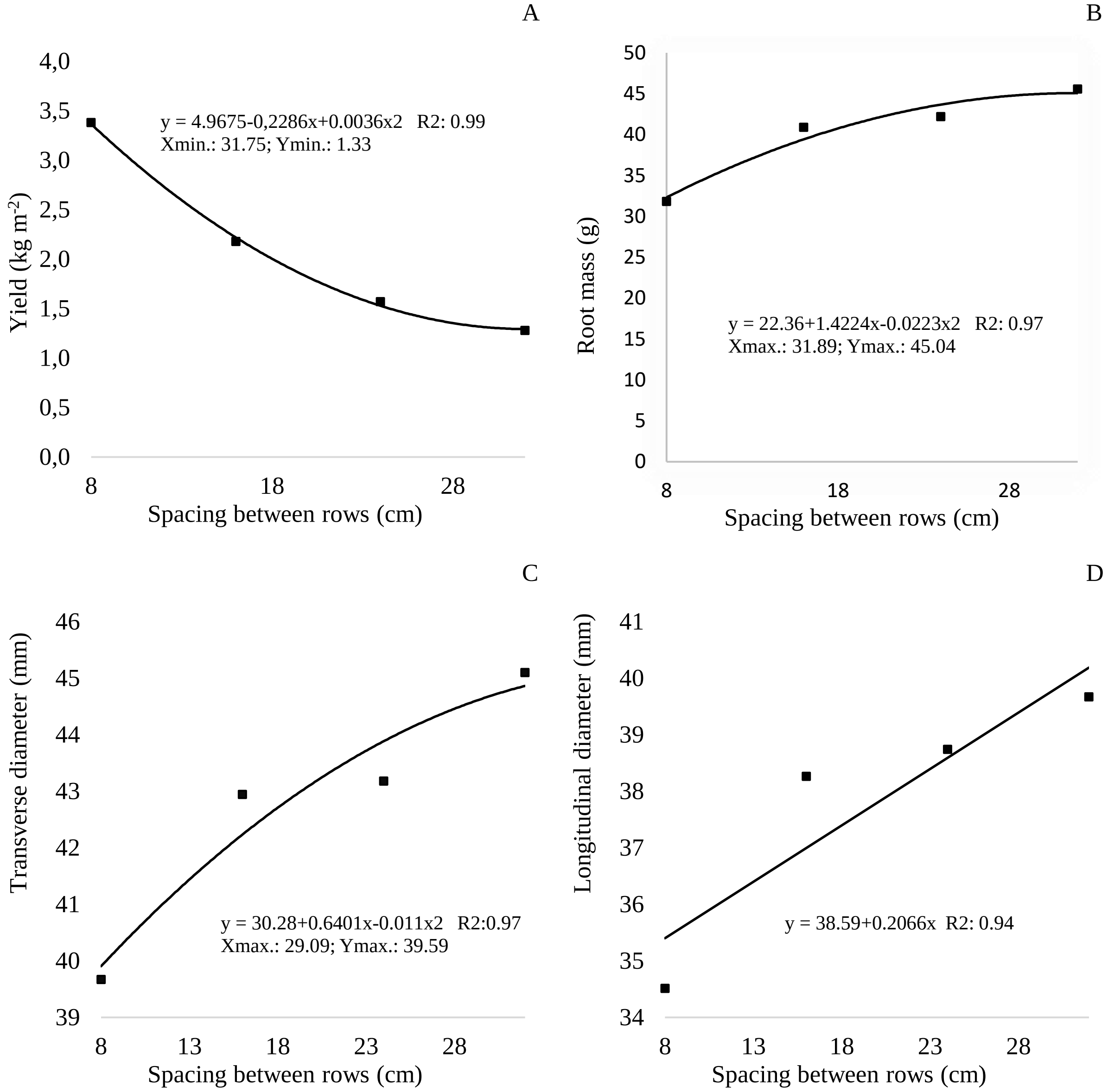

FIGURE 2 - Root yield (A), root biomass (B), transverse diameter (C) and longitudinal diameter (D) of radish as a function of spatial arrangements during cultivation.

Regarding the transverse diameter, it presented a quadratic behavior, and a maximum value of 29.09 mm, with 39.59 cm spacing between rows (Figure 2C). As for the spacing between plants, the transverse diameter showed a linear behavior, with a 0.51 mm increase for each centimeter increased between plants (Figure 3C). When the longitudinal diameter was analyzed, the spacing between rows was seen to present a growing linear behavior, with a 0.20 mm increase (Figure 2D). For the spacing between plants, the maximum longitudinal diameter was observed at 45.17 mm, with 14 cm between plants (Figure 3D).

The transverse and longitudinal diameters are an important feature of commercial interest, since they are determining factors for the definition of the root shape, categorization, and valuation of the product, and increased spacing might improve their values in the roots (LINHARES et al., 2010). Therefore, we could observe that the spatial arrangement influences root biomass and diameter, and its indication must be aligned to the crop commercial objective with an eye to the desired production. The spacing resulted in intraspecific competition, which promoted the regulation of all the parameters investigated in this study. According to Nunes et al. (2021), intra and interspecific competition is established by the position of plants and spacing between and within the crop rows. Therefore, before choosing the spacing, it is advisable to define the crop biological and commercial value for later establishment of the crop. Costa et al. (2020) pointed out that both the spacing and the number of plants per hole are production factors that might define the quality and size of the final product.

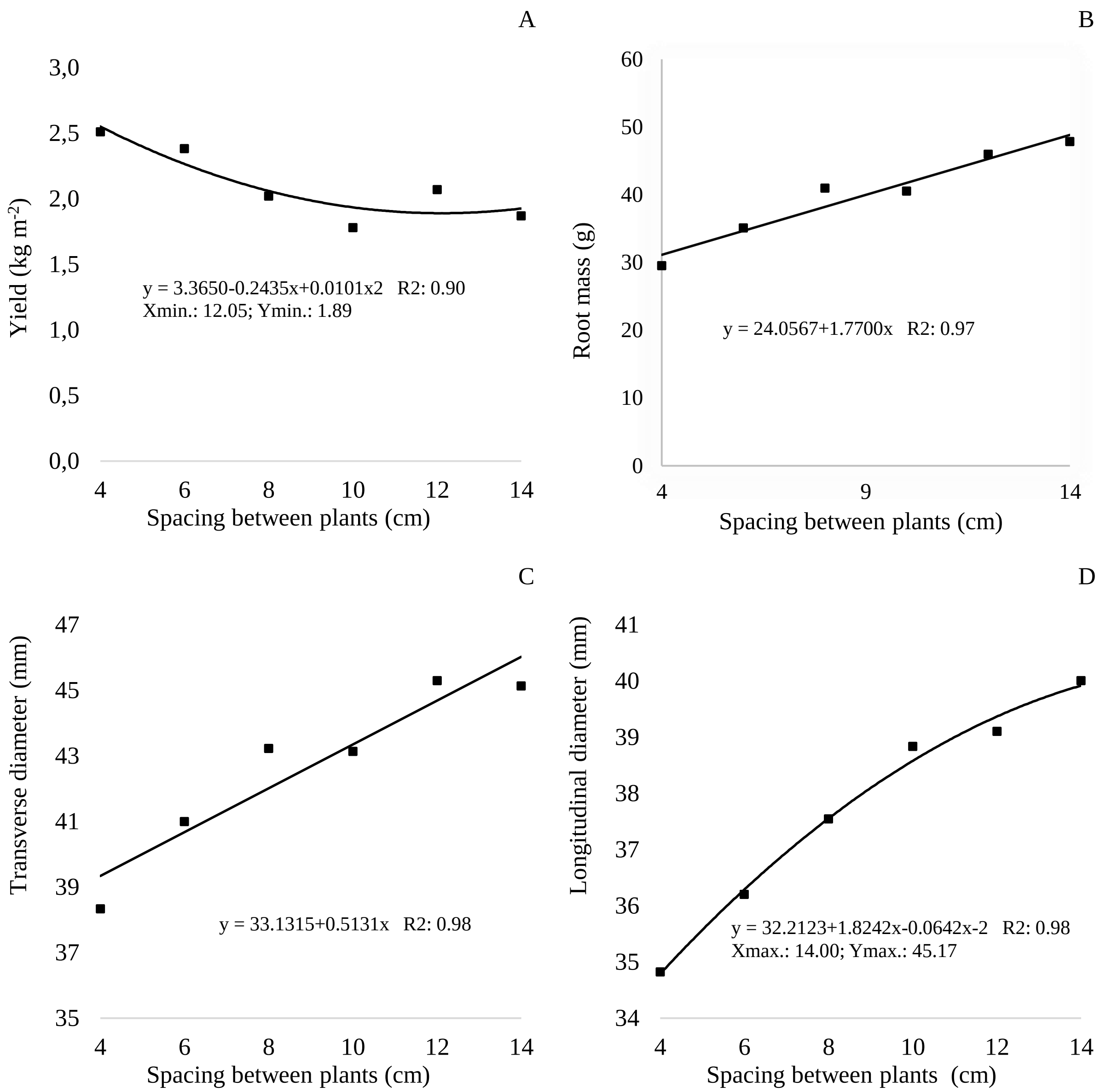

FIGURE 3 - Yield (A), root mass (B), transverse (C) and longitudinal diameter (D) of the radish culture as a function of spacing between plants.

CONCLUSIONS

No interaction was observed between the spacing factors for the parameters analyzed, and the spacing between rows and plants influenced the attributes evaluated independently.

Spatial arrangements with lower plant densities resulted in higher biomass and root diameter results.

New studies involving the fixation of spacing between rows and variation of the spacing between plants are still needed to better understand the effect of new spatial arrangements on the productive parameters of the radish crop.

REFERENCES

AMORIM, M.S.; ALMEIDA, D.J.S.; SILVA, M.A.M.; SILVA, B.S.; FREITAS, A.F.J. Qual é o espaçamento ideal para maximizar a produção de rabanete? **Enciclopédia Biosfera**, v.10, n.19, p.1573-1579, 2014.

ARRUDA, J.G.; VARGAS, P.F.; FERRARI, S.; PAVARINI, R. Desempenho de híbridos de brócolis de cabeça única em função de densidade e arranjo espacial. **Nucleus**, v.12, n.1, [s.p.], 2015.

BEZERRA, F.T.C.; DUTRA, A.S.; BEZERRA, M.A.F.; OLIVEIRA FILHO, A.F.; BARROS, G.L. Comportamento vegetativo e produtividade de girassol em função do arranjo espacial das plantas. **Revista Ciência Agronômica**, v.45, n.2, p.335-343, 2014.

COSTA, C.C.; OLIVEIRA, C.D.; SILVA, C.J.; TIMOSSI, P.C.; LEITE, I.C. Crescimento, produtividade e qualidade de raízes de rabanete cultivadas sob diferentes fontes e doses de adubos orgânicos. **Horticultura Brasileira**, v.24, [s.n.], p.118-122, 2006.

COSTA, M.R.; GUIMARÃES, M.A.; NETO, H.S.L.; RABELO, J.S.; HENDGES, A.R.A.A.; VIANA, C.S.; SAMPAIO, I.M.G. Desempenho agronômico do rabanete em diferentes densidades populacionais. **Brazilian Journal of Development**, v.6, n.6, p.35679-35689, 2020.

CQFS. COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO. **Manual de calagem e adubação para os Estados do Rio Grande do Sul e Santa Catarina de Química e Fertilidade do Solo.** 2016. p.376.

EMBRAPA. EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Sistema brasileiro de classificação de solos.** 2ª. ed. – Rio de Janeiro: EMBRAPA-SPI, Brasília, p.195-199, 2006.

FILGUEIRA, F.A.R. **Novo manual de olericultura:** agrotecnologia moderna na produção e comercialização de hortaliças. 3ª ed. Viçosa. Editora UFV, 2007. 421p.

HACHMANN, T.L.; DALASTRA, G.M.; ECHER, M.M. Características produtivas da chicória da catalogna, cultivada em diferentes espaçamentos sob telas de sombreamento. **Caderno de Ciências Agrárias**, v.9, n.2, p.48-55, 2017.

INMET. INSTITUTO NACIONAL DE METEOROLOGIA. **Dados meteorológicos: estações automáticas.** 2020. Estação: A858 - Xanxerê (SC). Available in: <http://www.inmet.gov.br/portal/index.php?r=estacoes/estacoesAutomaticas>. Access in: 10 mai. 2021.

LAVANYA, A.V.N.; VANI, V.X.; REDDY, P.S.S.; SHASHIKALA, P. Root yield of radish as affected by sowing dates and spacing. **International Journal of Pure & Applied Bioscience**, v.5, n.4, p.1780-1784, 2017.

LINHARES, P.C.F.; PEREIRA, M.F.S.; OLIVEIRA, B.S.; HENRIQUES, G.P.S.A.; MARACAJÁ, P. B. Produtividade de rabanete em sistema orgânico de produção. **Revista Verde**, v.5, n.5, p.94-101, 2010.

LUZ, S.R.O.T.; MARTINS, J.K.D.; FERREIRA, A.G.; SILVA, C.A. Características agronômicas do rabanete em função do espaçamento entre plantas e entre linhas. **Agrarian Academy**, v.4, n.8, p.76-82, 2017.

NASCIMENTO, M.V.; SILVA JÚNIOR, R.L.; FERNANDES, L.R.; XAVIER, R.C.; BENETT, K.S.S.; SELEGUINI, A.; BENETT, C.G.S. Manejo da adubação nitrogenada nas culturas de alface, repolho e salsa. **Journal of Neotropical Agriculture**, v.4, n.1, p.65-71, 2017.

NETO, H.S.L.; MAIA, C.L.; COSTA, M.R.; RABELO, J.S.; HENDGES, A.R.A.A.; GUIMARÃES, M.A. Fisiologia do rabaneteiro em diferentes arranjos espaciais. **Revista de Ciências Agrarias**, v.61, [s.n.], p.1-6, 2018.

NUNES, R.L.C.; NETO, F.B.; BARROS JÚNIOR, A.P.; LIMA, J.S.S.; SILVA, J.N.; CHAVES, A.P.; SANTOS, E.C.; GUERRA, N.M.; LINO, V.A.S.; SÁ, J.M.; LINO, F.K.K.S. Biological and economic efficacy of cowpea-radish association fertilized with organic manure in diverse planting arrangements. **Research, Society and Development**, v. 10, e133101119298, 2021.

R Core Team (2018). **R:** a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from: <https://www.R-project.org/>. Accessed on: 20 set. 2021.

TAVARES, A.E.B.; CLAUDIO, M.T.R.; FREITAS, P.G.N.; CARDOSO, A. 2016. Densidade de plantio na produção de ervilha-de-vagem. **Horticultura Brasileira**, v.34, n.2, p.289-293, 2016.

TORRES, C.A.S.; REBOUÇAS, T.N.H.; SIQUEIRA, L.G; SILVA, J.C.G.; AMORIM, C.H.F.; CARDOSO, N.S. Avaliação da densidade de plantio sobre a produção e diâmetro de rabanete. **Horticultura Brasileira**, v.21, n.2, [s.p.], 2003.

WREGE M. S.; STEINMETZ, S.; REISSER JUNIOR, C.; ALMEIDA, I.R. **Atlas climático da região Sul do Brasil:** estados do Paraná, Santa Catarina e Rio Grande do Sul. Pelotas: Embrapa Clima Temperado; Colombo: Embrapa Florestas, 2012. 2ª ed. p.44-44.