

Single-head broccoli production under different spacing and conditions of Baixada Fluminense

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ABSTRACT

This study aimed to evaluate different spacings between rows on the development and yield of single-head broccoli under the soil and climate conditions of Seropédica, in the Baixada Fluminense region, the State of Rio de Janeiro (Brazil). Tests were carried out under field conditions using the Avenger hybrid. The experimental design adopted was randomized blocks with four treatments and four replications per treatment. Four spacings between rows were tested: 0.6 m, 0.7 m, 0.8 m, and 1.0 m. The spacing between plants in the rows was 0.6 m in all treatments. The number of leaves (NL), plant height (PHT), fresh leaf mass (FLM), stem fresh mass (SFM), inflorescence fresh mass (IFM), inflorescence longitudinal diameter (ILD), and estimated yield (YLD) were evaluated. Data were submitted to analysis of variance (ANOVA) and regression analysis ($p < 0.05$). Spacing variations did not influence PHT and SFM. There was a linear increase in NL and FLM according to the increase in the spacing between rows. A quadratic effect of spacing was observed on ILD, IFM, and YLD. The spacing between the rows of 0.85 m ensured greater yield (6.97 Mg ha^{-1}) and the production of inflorescences with characteristics compatible with those required by the consumer market (ILD = 9.83 cm; MFI = 347.15 g). It is concluded that the production of single-head broccoli under the conditions of Seropédica-RJ is possible, and the population density influences the development and yield of plants.

Keywords: *Brassica oleracea* var. *italica*, Brassicaceae, population density.

Produção de brócolis americano sob diferentes espaçamentos nas condições da Baixada Fluminense

RESUMO

O objetivo deste estudo foi avaliar diferentes espaçamentos entre as linhas de cultivo sobre o desenvolvimento e a produtividade de brócolis americano nas condições edafoclimáticas de Seropédica, na Baixada Fluminense do Estado do Rio de Janeiro (Brasil). Realizou-se ensaio em condições de campo utilizando-se o híbrido Avenger. O delineamento adotado foi de blocos casualizados com quatro tratamentos e quatro repetições por tratamento. Foram testados quatro espaçamentos entre as linhas de cultivo: 0,6 m; 0,7 m; 0,8 m e 1,0 m. O espaçamento entre as plantas, dentro das linhas, foi de 0,6 m em todos os tratamentos. Foram obtidos o número de folhas (NF), altura das plantas (ALT), massa fresca das folhas (MFF), massa fresca do caule (MFC), massa fresca da inflorescência (MFI), diâmetro longitudinal da inflorescência (DLI) e produtividade estimada (PE). Os dados foram submetidos a análise de variância (ANOVA) e à análise de regressão ($p < 0,05$). A ALT e a MFC não foram influenciadas pelas variações no espaçamento. Houve acréscimo linear do NF e MFF em função do aumento do espaçamento entre as linhas de cultivo. Observou-se efeito quadrático de espaçamento sobre DLI, MFI e PE. O espaçamento entre as linhas de 0,85 m garantiu uma maior produtividade ($6,97 \text{ Mg ha}^{-1}$) e a produção de inflorescências com características compatíveis às exigidas pelo mercado consumidor (DLI = 9,83 cm; MFI = 347,15 g). Conclui-se que a produção de brócolis americano nas condições de Seropédica-RJ é possível, sendo que a densidade populacional influencia no desenvolvimento e produtividade das plantas.

Palavras-chave: *Brassica oleracea* var. *italica*, Brassicaceae, densidade populacional.



1. Introduction

Broccoli (*Brassica oleracea* var. *italica*) is a vegetable belonging to the Brassicaceae family (=Cruciferae). Its consumption has increased in recent years in Brazil due to nutritional benefits such as low caloric value and high content of fiber, vitamins (A, C, and E), minerals such as calcium, magnesium, iron, and other associated substances to disease prevention (Kumar et al., 2014; Melo, 2015).

The production and commercialization of broccoli have high economic and social importance. Estimates indicate that the production of the species in Brazil annually moves around R\$ 1.2 billion in retail, with an average market growth between 4% and 5% per year (Santos et al., 2020a). As a vegetable widely cultivated on small farms, it assumes economic and social importance by generating income and direct and indirect jobs throughout its production and marketing cycle (Lima et al., 2018).

The production of broccoli in Brazil is carried out mainly in the states of the Southeast and South regions due to the need for mild temperatures for the species. The species, in general, requires average temperatures between 20 °C and 24 °C, and between 15 °C and 18 °C, before and after the emergence of the central inflorescence (Melo, 2015). Despite this, it is worth mentioning that plant breeding has allowed the development of cultivars adapted to higher temperatures, which contributes to the expansion of times and areas for the cultivation of this vegetable (Santos et al., 2020b).

Among the areas with good potential for growing broccoli is the Baixada Fluminense region in Rio de Janeiro. This region is close to a large consumer market, the Metropolitan Region of the City of Rio de Janeiro, and presents ease of logistics for the flow of production through the Metropolitan Arch (Goulart et al., 2018; Oliveira et al., 2018; Xavier et al., 2019). The climate of this region is classified as Aw according to the Köppen classification, characterized by annual average temperatures of 24°C. Despite this, records of absolute maximum temperatures above 42°C in summer are not uncommon (Fiorini et al., 2016; Oliveira et al., 2018). There are no reports of commercial and experimental broccoli production in the Baixada Fluminense, which reveals the need to develop basic studies to promote its cultivation on small farms in the region.

In the Brazilian market, there are two groups of broccoli, the “Ramoso”, with multiple harvests and aimed at the fresh trade in the form of bunches, and the single inflorescence (head), also known as American broccoli (Cecílio Filho et al., 2012; Melo, 2015). The market for single-head broccoli has grown significantly in recent years due to the greater ease of harvesting and handling, better post-harvest conservation, and the dual possibility

of destination – fresh trade and processing and/or freezing (Santos et al., 2020a; Oliveira et al., 2018).

To expand the production and quality of broccoli and its supply over the year, it is necessary to use superior cultivars that are more adapted to each condition and to adopt more efficient agronomic practices. In this context, it is worth highlighting the correct dimensioning of plant density in crops, as it influences the main factors that control plant development, such as the area available for water and nutrient absorption and light interception (Cecílio Filho et al., 2012; Porto et al., 2012; Turbin et al., 2014).

Broccoli seedlings can be planted in different spacings, ranging from 0.5 m to 1.0 m between rows and 0.5 to 0.8 m between plants (Filgueira, 2008; Melo, 2015; Melo et al., 2022), depending on factors such as cultivar characteristics, seasons, and production system. Studies point to a trend toward greater plant density in important areas of broccoli and cauliflower production in Brazil, with reports of populations of up to 30,000 plants per hectare (Bhering et al., 2017; Santos et al., 2021; Melo et al., 2022). Thus, determining the best spacing for growing broccoli, especially in regions with little or no tradition of broccoli cultivation, can contribute to greater success in the enterprise and guarantee better yield and quality of the harvested broccoli. Thus, greater profitability and economic return.

The present study aimed to evaluate the effect of different spacings between rows on the development and yield of single-head broccoli in the soil and climate conditions of Seropédica in the Baixada Fluminense region of the State of Rio de Janeiro (Brazil).

2. Material and Methods

An experiment was carried out in the field, from April 26 to July 27, 2018, in the Seropédica, the Baixada Fluminense, in Rio de Janeiro, at 22°45'50" S and 43°41'50" W. Meteorological data for the period of the experiment were collected from the National Institute of Meteorology (INMET, 2018).

The experiment was installed in an area with a history of growing various vegetables but without a history of growing broccoli. Soil preparation was carried out with a disc plow, followed by harrowing. The soil in the area was classified as Haplic Planosol and contained the following initial physical and chemical characteristics (0-20 cm): expedite texture = sandy; $\text{pH}_{(\text{water})} = 6.65$; $\text{Al} = 0.00 \text{ cmol}_c \text{ dm}^3$; $\text{H+Al} = 1.70 \text{ cmol}_c \text{ dm}^3$; $\text{Ca} = 2.51 \text{ cmol}_c \text{ dm}^3$; $\text{Mg} = 1.69 \text{ cmol}_c \text{ dm}^3$; $\text{SB} = 4.23 \text{ cmol}_c \text{ dm}^3$; $\text{CEC} = 5.93$; $\text{V} = 71.35\%$; $\text{P} = 283.0 \text{ mg dm}^3$ and $\text{K} = 10.60 \text{ mg dm}^3$.

A randomized block design was used with four replications and four treatments (spacing between rows): 0.6 m, 0.7 m, 0.8 m, and 1.0 m. The spacing

between plants in the rows was 0.6 m in all treatments. The spacings evaluated provided a population density of approximately 27,777; 23,809; 20,833; and 16,666 plants ha⁻¹, respectively. Broccoli seeds of Avenger hybrid (Sakata) were used. The seedlings were produced in a closed greenhouse using styrofoam trays with 128 cells containing commercial substrate (Multiplant® Hortaliças). The seedlings were irrigated daily in the morning using sprinklers.

The seedlings were transplanted to the field on April 26, 2018, 30 days after sowing, when the plants had about two definitive leaves. On this occasion, 400 grams per pit of bovine manure (20 × 20 × 15 cm) were applied and homogenized according to previously established spacings. Each experimental plot was 4.0 m long and 2.40 m wide, totaling an area of 9.6 m² per plot. As a useful plot, only the four central plants of each plot are considered. During the crop cycle, irrigation was carried out by sprinkling, in addition to the rains. At 30 and 60 days after transplanting (DAT), the topdressing fertilization was carried out with the application of 85 g plant⁻¹ of bokashi-type fermented organic compost. The compound had the following attributes: C = 51.9%, N = 4.2% and C:N = 12.3; Ca = 9.7, Mg = 6.7, K = 11.9, and P = 8.7 in g kg⁻¹). Weed control was done manually at 15 and 30 DAT.

Harvesting was performed at 76, 82, and 90 DAT, as the plants presented inflorescences (heads) at the point of commercial harvest (Melo, 2015). On these occasions, the plants were harvested by cutting at the base of the stem and transported in identified plastic bags for later evaluation in the laboratory. The number of leaves (units per plant), plant height (cm), longitudinal diameter of inflorescences (cm), the fresh mass of leaves, stem, and inflorescence (g), and the estimated yield (Mg ha⁻¹) were evaluated. The data obtained were submitted to analysis of variance (ANOVA) and linear or quadratic regression analysis according to the spacing between rows (p<0.05). The statistical software SISVAR (Ferreira, 2011) was used.

3. Results and Discussion

During the broccoli growing cycle in the field, an average temperature of 22°C was recorded in the region, with maximum values of 33.2°C and minimum values of 11.9°C. The mean relative humidity was 74.90%, with maximum and minimum values of 95% and 20%, respectively. Frequent precipitations were observed, amounting to 235 mm throughout the cycle and about 2.61 mm day⁻¹ (INMET, 2018).

These climatic conditions were sufficient for satisfactory vegetative growth and floral induction in most plants. In general, the plants of most broccoli cultivars need temperatures between 20 to 24°C for leaf development and 15 to 18°C for floral induction and inflorescence formation (Melo, 2015). The average cycle of single-head broccoli, Avenger hybrid, observed in the region was 90 days from transplanting to the end of harvest.

Statistically significant effects (p ≤ 0.05) of treatments (spacing between rows) were observed on the number of leaves, fresh mass of leaves, fresh mass and longitudinal diameter of the inflorescence, and estimated yield (Table 1). These results indicate that the broccoli genotype responded to the different spacings tested. However, there were no significant effects of treatments on plant height, ranging from 20.84 to 21.33 cm, and under stem fresh mass, which presented averages from 216.56 to 258.12 g plant⁻¹.

The number of leaves (NL) and fresh mass of leaves (FLM) showed significant increases (p ≤ 0.05) with increasing spacing between rows and better adjustments were obtained with linear equations (NL = 8.309 + 9.097x; R² = 0.98), (FLM = 73.87 + 558.78x; R² = 0.95). The average number of leaves varied from 13.57 to 17.33 units per plant as a function of the spacing between the crop rows. For the fresh mass of leaves, values from 400.22 to 619.76 g plant⁻¹ were obtained. However, these fresh leaf mass values are lower than the 1,134 g plant⁻¹ recorded by Seabra Júnior et al. (2014) when testing the same cultivar under the conditions of Cáceres-MT.

Table 1. Analysis of variance for plant height (PHT), the number of leaves (NL), fresh mass of leaves (FLM), stem (SFM) and inflorescence (IFM), inflorescence longitudinal diameter (ILD), and yield (YLD) obtained in an experiment carried out under field conditions.

Source of variation	DF	Mean squares						
		PHT	NL	Fresh mass			ILD	YLD
				FLM	SFM	IFM		
Treatments	3	6.94 ^{ns}	9.78*	38,022.1*	2,204.4 ^{ns}	26,581.6*	2.27*	1.69*
Block	3	3.84 ^{ns}	0.27 ^{ns}	1,067.0 ^{ns}	2,847.5 ^{ns}	975.4 ^{ns}	0.05 ^{ns}	0.47 ^{ns}
Error	9	4.29	1.08	2,069.8	1,628.3	642.88	0.16	0.27
CV (%)		10.07	6.77	8.97	17.1	8.73	4.41	8.47

* Significant at 5% probability by the F-test. DF – Degrees of Freedom. ns – Not significant.

Data on inflorescence growth and estimated yield in response to spacing were better fitted by quadratic equations (Figure 1). The longitudinal diameter of the inflorescences increased significantly until the spacing between the rows of 0.84 m (Diameter = 9.81 cm); however, with little expressive gains from this spacing. The increase in the spacing between the rows increases the diameter of the inflorescences of single-head broccoli. The same trend was observed in other botanical varieties of the species *B. oleracea*, such as Brussels sprouts (Turbin et al., 2014) and cauliflower (Pôrto et al., 2012).

The reduction in the size of the inflorescences with the reduction of spacing results from greater intraspecific competition for space and luminosity, given that the plants were fertilized and irrigated throughout the cycle. The fresh mass of broccoli inflorescences increased as the spacing between rows increased (Figure 1). The lowest value, 190.67 g, was recorded using the smallest spacing between the lines (0.6 m) (Figure 1), with increases in the averages when using larger spacings. That is, larger spacings resulted in inflorescences of larger size and diameter (Figure 1).

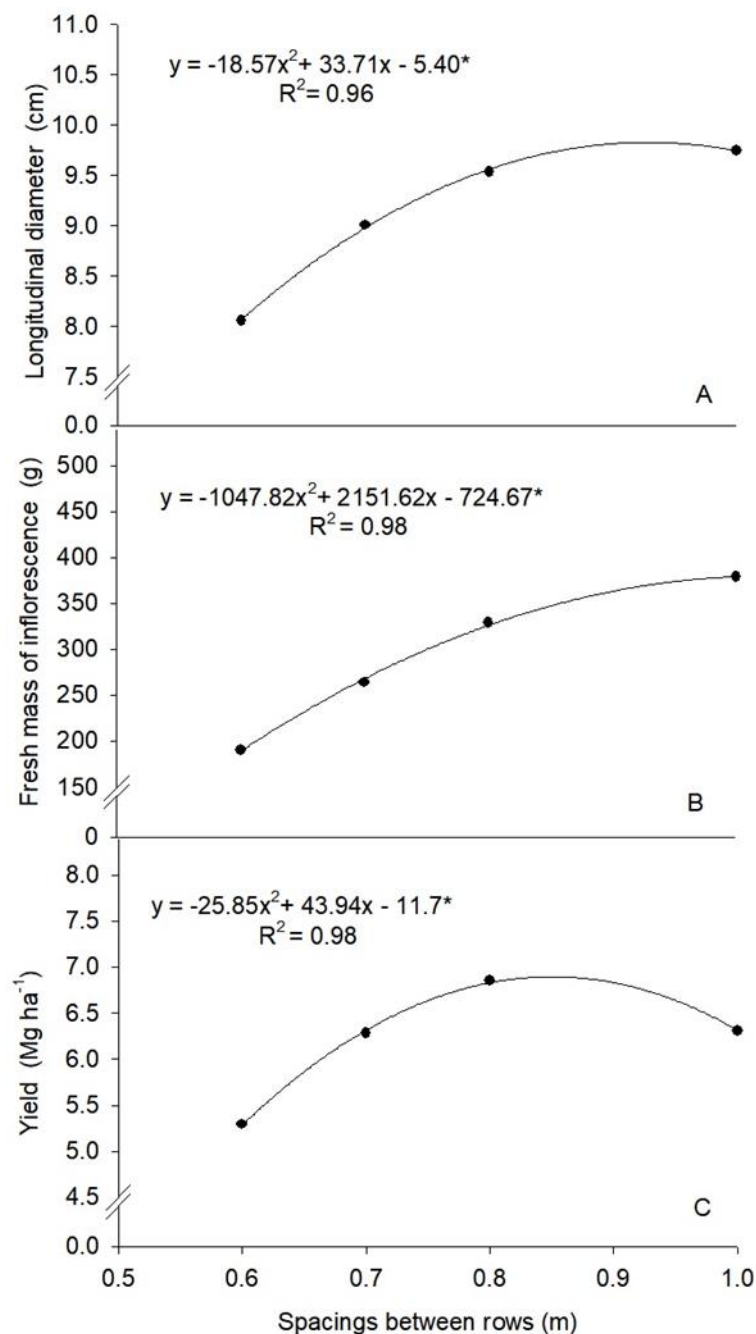


Figure 1. Longitudinal diameter (cm) (A), the fresh mass of inflorescence (g) (B), and estimated yield (Mg ha⁻¹) (C) of single-head broccoli, Avenger hybrid, according to the cultivation under different spacings between rows. Significant at 5% probability by the F-test.

The data relating to the yield (YLD) were better adjusted by a quadratic function, with an estimated maximum point for the spacing of 0.85 m (YLD = 6.97 Mg ha⁻¹). From the inflection point, there was a decrease as the spacing increased (Figure 1). According to the target market for commercialization, these results can guide the planning of future broccoli crops. It is known that single-head broccoli can be marketed fresh or destined for processing (Melo, 2015; Oliveira et al., 2018).

In the first case, sales are generally carried out per unit, and larger sizes have greater commercial value. In the segment focused on the frozen food industry, only the florets of the inflorescences are used, and the sale is carried out based on the crop yield (Cecílio Filho et al., 2012). The frozen segment has been a potential market for single-head broccoli today (Lima et al., 2018). However, this market is not yet a reality in the study region due to the non-production of brassicas and the absence of processing and freezing industries.

The production values found in this work are compatible with those described in the literature (Santos et al., 2020b; Santos et al., 2021). The results allow us to infer that, based on the evaluation of the diameter and fresh mass of the inflorescences, the adoption of lower population density with spacings of 0.8 to 1.0 m between the crop rows can result in inflorescences closer to the expected pattern by the fresh broccoli market. This market has given preference to single-type inflorescences, dark green, compact, with good granulometry, with an average size from 300 g to 400 g in weight and diameter between 12 cm and 15 cm (Melo, 2015).

Therefore, using larger spacings becomes an interesting option for producers seeking marketing aimed at this segment without significantly increasing fertilizer costs. Despite this, it must be considered that other conditions and management practices can interfere with plant responses and growth and yield in addition to population density. Among these variables are the genotype, which must be adapted to local conditions, adequate soil fertility management, adequate irrigation sizing, and phytosanitary management (Melo, 2015; Oliveira et al., 2018; Xavier et al., 2019; Santos et al., 2020b).

4. Conclusions

The cultivation of single-head broccoli, Avenger hybrid, allows a satisfactory production in the winter in Seropédica, the Baixada Fluminense, in Rio de Janeiro (RJ). The spacing of 0.85 m between the rows and 0.60 m between the plants in the rows is the most suitable for cultivating single-head broccoli (Avenger hybrid) in the winter in Baixada Fluminense, RJ. It allows good yield

(6.97 Mg ha⁻¹) and inflorescences with good commercial standards (347.15 g).

Authors' Contribution

Táisa Gonçalves Macedo: investigation; writing original draft; and formal analysis. Carlos Antônio dos Santos: conceptualization, investigation, writing, review and editing; and formal analysis. Antônio de Amorim Brandão: investigation. Evandro Silva Pereira Costa: investigation. Margarida Goréte Ferreira do Carmo: conceptualization, writing, review and editing; and supervision

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