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Evaluation of summer carrot cultivars in bed and ridge systems

Agnaldo DF de Carvalho [1]*; Giovani Olegário da Silva [1]; Samuel F Guedes [2]; Ester de C Pereira [1]; Guilherme P Martins [2]; Caroline da C Magalhães [3]

[1]Embrapa Hortaliças, Brasília-DF, Brasil; agnaldo.carvalho@embrapa.br (author for correspondence); giovani.olegario@embrapa.br; estercarvalhopereira@gmail.com. [2]Centro Universitário ICESP, Brasília-DF, Brasil; agro.samuelguedes@gmail.com; guilherme.martins2303@gmail.com. [3]Centro Universitário de Desenvolvimento do Centro Oeste (UNIDESC), Valparaíso de Goiás-GO, Brasil; carolinecruz.m@hotmail.com

ABSTRACT

In Brazil, carrots are usually grown in beds 30 cm heigh and 1 to 1.8 width. Although widely used, these beds present problems regarding cultural practices and disease management, especially in spring/summer seeding. The aim of this study was to compare the agronomic performance of carrot cultivars in summer cultivation in bed and ridge. Ten carrot cultivars were evaluated in two experiments in strips (bed and ridge), in a randomized complete block design with three replications. Seeds were sown on November 23, 2021, in Brasília-DF. At 90 days, evaluation of foliar diseases was performed, and at 100 days, evaluation of characteristics related to root yield was carried out. Total production was higher in bed, but there was no difference for commercial production in the two cultivation methods. The ridge favored root development, providing a greater mean root mass. Cultivation in ridge did not reduce the incidence of foliar diseases in carrots, but proved to be an alternative for commercial production of summer carrots.

Keywords: *Daucus carota*, cultivation system, production, disease.

RESUMO

Avaliação de cultivares de cenoura de verão em sistemas de semeadura em canteiro e leira

No Brasil a cenoura geralmente é cultivada em canteiros com 30 cm de altura e largura variando entre 1 e 1,8 m. Esses canteiros apesar de amplamente utilizados, apresentam problemas em relação a tratos culturais e manejo de doenças, principalmente nas semeaduras de primavera/verão. O objetivo com este trabalho foi de comparar o desempenho agronômico de cultivares de cenouras em cultivo de verão em canteiro e em leira. Dez cultivares de cenoura foram cultivadas em dois experimentos em faixas (canteiro e leira), em delineamento em blocos casualizados com três repetições. A semeadura foi realizada em 23 de novembro de 2021 em Brasília-DF. Aos 90 dias foi realizada avaliação de doenças foliares e aos 100 dias foi realizada a avaliação de características relacionadas à produtividade de raízes. A produção total foi maior em canteiro, mas não houve diferença para a produção comercial nos dois tipos de cultivo. A leira favoreceu no desenvolvimento de raízes proporcionando maior massa média de raízes. O cultivo na leira não reduziu a incidência de doenças foliares em cenoura, mas se mostrou uma alternativa para produção comercial de cenoura de verão.

Palavras-chave: *Daucus carota*, sistema de cultivo, produção, doenças.

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Carrots are one of the main vegetables cultivated and consumed in Brazil and around the world due to their constant supply throughout the year, affordable prices for consumers, culinary versatility and nutritional attributes. According to IBGE (2017), carrots are the fifth most cultivated vegetable in Brazil with approximately 23,000 producers and a production of over 480,000 tons.

The agronomic performance of carrots is influenced by numerous factors that affect productivity. Soil type, land preparation, cultivar selection, seeding time, irrigation, fertilization, and disease control are examples of these factors. Many of these conditions are well studied in the literature, but other variables still require research (Lopes *et al*., 2008). The arrangement and density of seedlings are objects of study, as they influence crop management and productivity indices, since competition among carrot plants for resources such as water, light, and nutrients, interfere with productivity components (Lopes *et al*., 2008).

Carrots cultivated in Brazil, whether in conventional or organic systems, by small or large producers, are usually done through direct seeding, in beds prepared manually or mechanically with the use of a bed former machine (Magno Junior, 2012). This system promotes good root development, but in rainy periods, it increases the duration of leaf wetness, which, combined with reduced aeration, favors the occurrence of foliar diseases. Additionally, this system is less efficient in terms of drainage (Töfoli & Domingues, 2010; Marcuzzo & Tomasoni, 2020).

Alternately to the use of beds, seeding in the ridge has been performed.

This system provides better soil drainage and greater plant aeration, which is particularly important in summer seeding, when there is a possibility of higher rainfall levels (Evers *et al*., 1997). However, the reduction in useful area of this system, compared to beds, significantly reduces the number of plants per hectare if the same spacing between plants is used in both systems (D'hooghe *et al*., 2018; Tegen & Jembere, 2021), thus requiring studies to determine possible reduction in productivity.

In the evaluation of carrot experiments in direct seeding, narrow-top ridge and wide-top ridge, Evers *et al*. (1997) verified that in sandy soils, under reduced rainfall, ridges dry more quickly than direct seeding, however, there were no differences in commercial root production. In conditions of higher precipitation, the narrow-top ridge drained water more quickly and produced roots with a higher mean root mass.

The higher commercial root yield in carrot cultivation in ridges compared to flat surface seeding is reported by Zalatorius *et al*. (1998). On the other hand, in carrot cultivation under conditions of high soil moisture and low temperatures, a higher mean root mass was found in wider ridges (base 75 cm, top 29 cm) compared to narrower ridges (base 49 cm, top 23 cm) and beds (Taivalmaa & Talvitie, 1997).

Therefore, the aim of this study was to evaluate the productive performance of carrot cultivars in two cultivation systems (bed and ridge).

MATERIAL AND METHODS

The experiment was carried out in the spring/summer season (2021/22), with seeding on November 23, 2021 and harvesting on March 3, 2022 in an experimental field area of Embrapa Hortaliças (15º55'49"S; 48º28'49"W, altitude 1,000 m).

The precipitation and mean temperature for the period of the experiments are described in Figure 1. The maximum temperature recorded during the period was 31.7°C on January 24, 2022, the minimum temperature of 14°C was recorded on December 25, 2021, the maximum daily precipitation was 64.2 mm recorded on February 3, 2022, and the total precipitation during the experiment period was 954.14 mm.

The climate of the region is of the Aw type, a tropical climate with a dry season in winter and predominance of heavy precipitation in summer, according to Köppen-Geiger. The soil in the experimental area is dystrophic red latosol with a clayey texture. Chemical analysis of soil samples collected from the 0-20 cm layer showed the following results: pH = 5.8; organic matter = 4.3%; P = 14 mg/dm^3; K = 183 mg/dm^3; Ca = 2.0 cmolc/dm^3; Mg = 0.8 cmolc/dm^3 and H + Al = 4.0 cmolc/dm^3.

Liming (1.2 t/ha, 85% PRNT, dolomitic limestone) was applied two months before installing the experiment. Conventional soil preparation was performed with deep plowing to incorporate the limestone. Before seeding, light harrowing was performed followed by bed and ridge preparation.

The fertilization used a dosage of 2,100 kg/ha of the 04-14-08 fertilizer (NPK), following the recommendation for carrot crop (Trani & Raij, 1997). The application was manually carried out on top of the beds and ridges, with incorporation through the second operation of the bed former.

The experiment was conducted in randomized blocks design, in a 2 x 10 factorial scheme with three replications, the first factor being two cultivation systems (bed and ridge) and the second factor being ten carrot cultivars (Alvorada, cv. Brasília, Carandaí, Kuroda, Kuronan, Nantes, BRS Paranoá, BRS Planalto, Sugarsnax 54 and Tropical).

The experiment was allocated in a strip-plot scheme. The cultivars were evaluated in randomized blocks design with three repetitions The treatments were arranged in parallel in the bed and ridge, and to achieve equivalent plot areas, two parallel ridges were used next to the same treatment in the beds (Figure 2).

The bed was formed with a bed former measuring 1.3 m at the base, 1.1 m at the top, and height of 0.3 m (Figure 2a). To shape the ridge, the same bed former was used, but an original central furrower attachment was installed to form two ridges with 1.3 m base and 0.35 m width at the top (Figure 2b).

In the bed, the experimental plot consisted of an area of 1.1 m in width x 1.2 m in length. Seeding was carried out in double rows, with spacing of 0.2 m between double rows and 0.1 m between single rows, in a transversal direction, with manual sowing in 1 cm deep furrows.

In the ridge treatment, the experimental plot consisted of two parallel ridges (Figure 2b). The seeding was performed manually in 1 cm deep furrows, with spacing of 0.1 m between

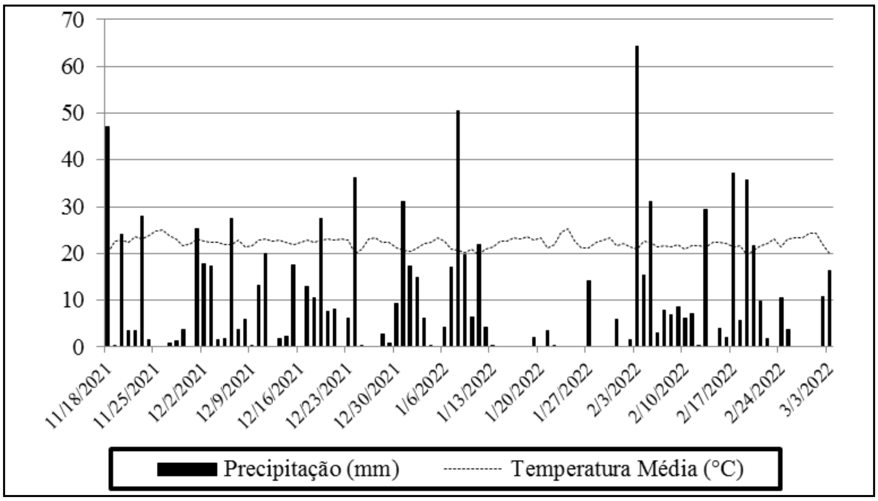

Figure 1. Precipitation (mm) and mean temperatures (ºC) during the carrot experiment conducted in the Federal District from November 2021 to February 2022. Source: INMET (2022).

rows, in the longitudinal direction, with three rows at the top of the ridge, with a useful plot area of 0.84 m^2 (2 ridges x 0.35 m width x 1.2 m length).

Topdressing fertilization was performed 25 days after seeding with 400 kg/ha of ammonium sulfate (N= 21%) (Trani & Raij, 1997).

The spacing between plants, after thinning, was 5 cm, both for bed and ridge. Thus, the number of plants per plot in the bed was 176 plants (916 thousand plants/ha) and 144 plants in the two ridges (750 thousand plants/ha).

Weeds were controlled with a dose of 2.2 L/ha of the commercial herbicide Linuron, four days after planting (Correia & Carvalho, 2017). During the development phase of carrot crop, weeds were controlled manually. No product was applied to control fungal or bacterial diseases, so that the different evaluated cultivars expressed maximum potential for resistance to leaf blight. The other cultural practices followed the recommendations for summer carrot crop under Brazilian Savanna conditions.

Irrigation, when necessary, was performed by sprinkling with a sufficient water depth to maintain soil at field capacity, as measured by a reading of 30 kPa using the Irrigas® irrigation system.

At 88 and 95 days after seeding (DAS), the incidence of leaf blight was evaluated using a rating scale adapted from Gaube *et al*. (2004), ranging from 1 to 5 for each plot, where 1 = more than 90.0% severity, 2 = 50.0 to 90.0% severity, 3 = 12.5 to 49.0% severity, 4 = 3.8 to 12.4% severity, and 5 = less than 3.8% severity. The scores assigned to the plots were converted to percentages, and for the analysis of variance, the mean of the two evaluations was taken.

The evaluation of root yield traits was conducted at 100 days after seeding (DAS), and the following variables were measured: total root mass (TRM, t/ha) by weighing all harvested roots in each plot; marketable roots mass (MRM, t/ha) by weighing roots without external defects, cylindrical in shape with a diameter between 2.5 to 3.5 cm and a length between 10 to 26 cm, according to CEAGESP classification (CEAGESP, 2015). The non-marketable roots mass (NRM, t/ha) was obtained by subtracting MRM from TRM. The relation between MRM and TRM was obtained dividing MRM over TRM. The total roots number (TRN) was determined by counting all the roots in the plot; the marketable roots number was determined by counting the roots meeting the commercial standard in the plot (MRN), and non-marketable root number (NRN) was obtained by subtracting MRN from TRN. The mean root mass ARM was calculated by dividing TRM by TRN.

After verifying the assumptions, analysis of variance was performed using SAS software (Muller & Fetterman, 2003). After estimating the adjusted means of the treatments, the Scott-Knott means grouping test ($P<0.05$) was performed using Genes software (Cruz, 2013).

RESULTS AND DISCUSSION

There were significant differences among cultivars for the leaf blight (LBL), non-marketable roots mass (NRM), non-marketable root number (NRN), and mean root mass (ARM) characteristics. Between cultivation systems, only ARM variables showed significant differences, with the ridge system resulting in roots with a mean mass 24% greater than the bed system (Table 1). Plant spacing is one of the factors that affects carrot root development (Lana *et al*., 2012). Thus, the development of carrot roots is directly influenced by nearby plants that compete for water, light, and nutrients (D'hooghe *et al*., 2018). In the present study, the greater spacing provided by the ridge system influenced root size but not on disease incidence or the mass and quantity of non-marketable roots. This is because the lower stand did not reduce the aboveground portion enough to create an unfavorable environment for the pathogen but provided conditions for greater root development.

Despite the greater useful space for planting, there was no significant

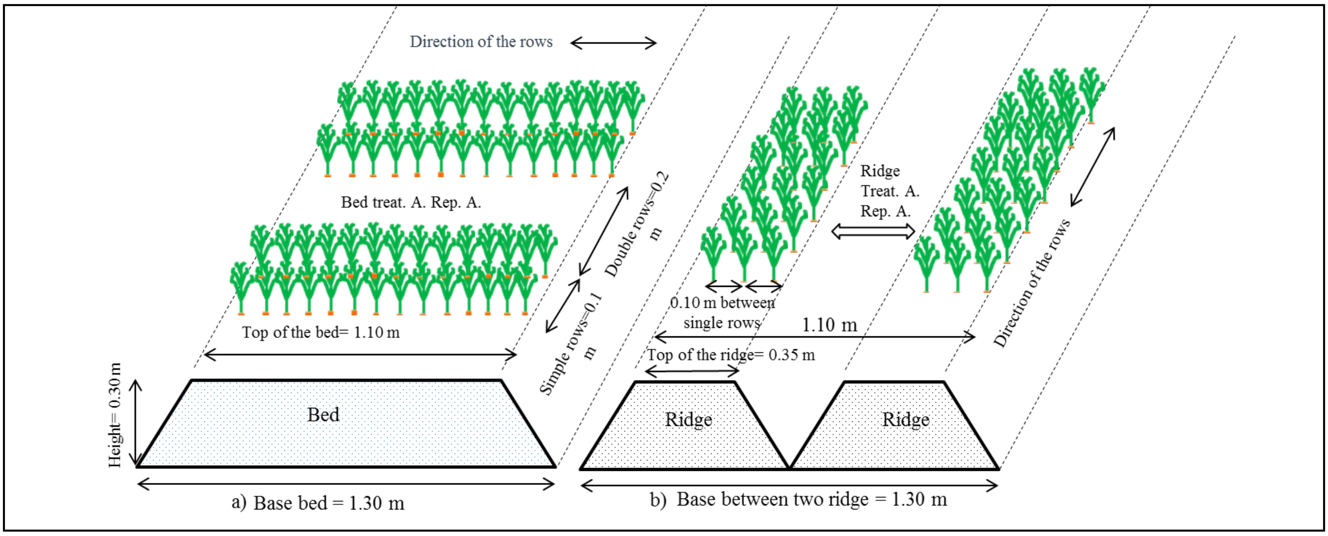

Figure 2. Systems used, bed on the left (a) and ridge on the right (b). The treatments were parallel in the bed and ridges. To ensure equivalent plot areas, two ridges were used parallel to the same treatment in the bed. Brasília, Embrapa Hortaliças, 2022.

statistical difference in the interaction between the cultivation systems factor (bed or ridge) and the cultivar factor for the characteristics of LBL, NRM, ARM, TNR, and NRN. For these, therefore, the analyses were performed on the mean of the two systems.

The grouping of means by the Scott-Knott test (P<0.05) for LBL revealed 3 groups of cultivars, with the group with greater tolerance formed by the cultivars Brasília, BRS Paranoá, and BRS Planalto. On the other hand, in the group with higher incidence, Nantes and Sugarsnax 54 appeared to be more susceptible (Table 1).

For NRN, five cultivars presented values above 12 t/ha (cv. Brasília, Kuroda, Kuronan, BRS Planalto, and Tropical) and belonged to the same group, while Sugarsnax 54 (3.11 t/ha) was in the group with the lowest mean. On the other hand, the cultivars that presented the highest values for NRN were Kuroda, Nantes, BRS Planalto, and Tropical.

The ARM comprised four groups of means, with the cultivar Brasília having the highest mean (81.97 g/root), and Nantes and Sugarsnax 54 having the lowest means, 17.25 and 13.86 g/root, respectively (Table 1).

Based on the results of the present study, it became clear that the choice of cultivars that are more adapted to different seeding periods is more important than the type of system used, since, regardless of the cultivation system, Nantes and Sugarsnax 54 (indicated for winter seeding) showed severe incidences of leaf blight, while cultivars developed for planting in warmer and more humid periods (Brasília, BRS Planalto and BRS Paranoá) showed high tolerance to leaf blight, regardless of whether in beds or ridges. These results are supported by studies on carrots conducted by Tegen & Jembere (2021). This statement suggests that in terms of the mass and quantity of non-commercial roots, the greater quantity of small, non-commercial roots produced by the bed system is compensated for by the greater number of non-commercial roots with green shoulders produced by the ridge system.

Table 1. Scott-Knott grouping test for carrot cultivars evaluated in bed and furrow systems for leaf blight (LBL, score of 1 to 5, where lower scores indicate lower severity), non-marketable root mass (NRM, t/ha), total root number (TRN, x 1000/ha), non-commercial root number (NRN, x 1000/ha), and mean root mass (ARM, g/root). Brasília, Embrapa Hortaliças, 2022.

Crop System	Characteristics				
	LBL	NRM	TRN	NRN	ARM
ridge	3.14 a*	8.11 a	418.27 a	271.60 a	48.13 a
bed	2.89 a	12.64 a	636.96 a	472.43 a	38.57 b
Cultivars					
Alvorada	3.04 b	9.42 b	395.85 a	266.35 b	50.39 b
Brasília	4.04 a	12.89 a	491.89 a	239.61 b	81.97 a
Carandaí	3.04 b	9.90 b	505.30 a	350.72 b	40.89 c
Kuroda	2.79 b	12.09 a	594.80 a	483.61 a	31.44 c
Kuronan	3.13 b	12.61 a	553.09 a	376.54 b	50.36 b
Nantes	1.46 c	6.90 b	547.44 a	486.51 a	17.25 d
BRS Paranoá	4.08 a	9.13 b	476.65 a	263.20 b	60.31 b
BRS Planalto	3.96 a	14.82 a	576.32 a	411.58 a	53.18 b
Sugarsnax 54	1.75 c	3.11 c	437.13 a	319.74 b	13.86 d
Tropical	2.88 b	12.91 a	697.69 a	522.29 a	33.82 c
Mean	3.02	10.38	527.61	372.02	43.35
CV (%)	6.39	21.86	24.90	28.15	14.02

*Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott test at a 5% probability level.

The results of the mean grouping test for the variables that showed a significant interaction between systems x cultivars are presented in Table 2. For TRM, the cultivars Brasília, Kuronan, and BRS Planalto showed higher mean values when evaluated in a bed compared to the ridge, while the other cultivars showed similar performance in both tested systems. The cultivar with the highest mean yield in the bed system was Brasília (46.56 t/ha), followed by BRS Planalto (36.16 t/ha), Kuronan (30.77 t/ha), and BRS Paranoá (27.86 t/ha). In the ridge system, the cultivars Brasília (36.16 t/ha) and BRS Paranoá (26.97 t/ha) were the most productive, while Nantes and Sugarsnax 54 comprised the group of less productive cultivars. The larger area available in the bed compared to the ridge allowed for greater utilization of space, which resulted in higher total root yield for some cultivars. This is because ridging reduces the useful area by approximately 40% compared to the bed, which affects production if the spacing between plants is equal in both systems.

For MRM, Brasília (30.25 t/ha) and BRS Planalto(18.59 t/ha) presented higher yield in the bed, compared to the ridge system (Brasília =23.85 t/ha and BRS Planalto= 8.84 t/ha). On the other hand, cv. Carandaí was more yielding in the ridge system (12.52 t/ha) in comparison to the bed system (6.91 t/ha). Among cultivars in the bed, Brasilia stood out in yield (30.25 t/ha). In the second group of the most yielding were BRS Paranoá (19.27 t/ha) and BRS Planalto (18.59 t/ha).

Zalatorius *et al*. (1998) found higher MRM in ridge cultivation compared to flat surface planting. Taivalmaa & Talvitie (1997), in carrot cultivation under high soil moisture but low temperatures, found higher root mass ratio in wider ridges (75 m base width, 29 cm height, 15 cm top width) compared to narrower ridges (49 cm base width, 23 cm height and 15 cm top width) and beds. Singh *et al*. (2017) evaluated three carrot planting methods: mechanized in beds, manual, in ridges, and broadcast on flat surfaces, and found higher root yield with bed seeding (69.3

Table 2. Scott-Knott clustering test for carrot cultivars evaluated in bed and furrow system for total root mass (TRM, t/ha), marketable root mass (MRM, t/ha) and marketable root number (MRN, x 1000/ha), Brasília, Embrapa Hortaliças, 2022.

Cultivars/Crop system	Characteristics					
	TRM		MRM		MRN	
	Bed	Ridge	Bed	Ridge	Bed	Ridge
Alvorada	20.59 Ac	19.09 Ab	8.03 Ac	11.43 Ab	106.17 Ab	135.80 Ab
Brasília	46.56 Aa	32.47 Ba	30.25 Aa	23.85 Ba	288.89 Aa	227.16 Aa
Carandaí	20.31 Ac	19.93 Ab	6.91 Bc	12.52 Ab	116.05 Ab	177.78 Aa
Kuroda	21.41 Ac	15.41 Ac	6.45 Ac	5.58 Ac	130.86 Ab	93.83 Ab
Kuronan	30.77 Ab	22.52 Bb	13.46 Ac	14.62 Ab	172.84 Ab	180.25 Aa
Nantes	9.59 Ad	8.77 Ad	0.66 Ac	3.43 Ac	14.88 Ac	79.01 Ab
BRS Paranoá	27.86 Ab	26.94 Aa	19.27 Ab	17.83 Aa	249.38 Aa	195.06 Aa
BRS Planalto	36.16 Ab	21.73 Bb	18.59 Ab	8.84 Bc	224.69 Aa	88.89 Bb
Sugarsnax 54	6.94 Ad	5.58 Ad	3.14 Ac	3.01 Ac	125.96 Ab	98.77 Ab
Tropical	24.96 Ac	21.63 Ab	7.87 Ac	11.80 Ab	148.15 Ab	190.12 Aa
Mean	24.52	19.40	11.46	11.29	157.79	146.67
CV (%)	16.77		25.35		29.85	

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ from each other according to Scott Knott test at a 5% level of probability.

t/ha) compared to 51.75 t/ha and 48.38 t/ha obtained by ridge seeding and broadcast on flat surfaces, respectively.

The marketable roots number (MRN) was higher only for the BRS Planalto variety when planted in beds (224.69 x 1000/ha) compared to planting in ridges (88.89 x 1000/ha). However, in general, the seeding systems did not show significant differences for the MRN.

The cultivation options that allow greater ventilation or facilitate carrot management are necessary to improve production systems. The ridge, aiming to improve aeration and reduce disease incidence, has been implemented in commercial crops in the Brazilian Savanna, especially in the hottest and rainiest periods of the year. This technique also favors management compared to the bed system, as it can eliminate the thinning process and facilitate the removal of weeds in the central portions of the ridge by tractor equipped with a cultivator. In the present study, the total production in the bed system was higher than in the ridge system. However, regarding the production of marketable roots, both systems were equivalent. It should be noted that no spraying was carried out to control diseases, which may have contributed to the similarity in the production of marketable roots. In this case, disease control could favor cultivation in beds, in agreement with the statements of Alam *et al*. (2020), where denser plantings allow for higher total and commercial yields. However, with the inconvenience of requiring more fungicide applications.

The effect of improved drainage in the ridge system compared to bed cultivation was also related to a decrease in problems with Pythium cavity spot (*Pythium* spp. Pringsheim) in a study conducted by Jacobsohn *et al*. (1984).

Therefore, it can be verified that ridge cultivation, despite resulting in lower TRM, enabled equivalent MRM and is a viable alternative method for cultivating carrots in the summer.

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