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BRS Paranoá: carrot for organic production systems

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ABSTRACT

'BRS Paranoá' was obtained by the carrot breeding program of Embrapa Hortaliças, aiming to obtain a cultivar adapted to most carrot-producing regions in an organic system. It was developed through selection of half-sib progenies and validated in Brazil. 'BRS Paranoá' is indicated for sowing in the spring/summer seasons especially because it displays high resistance to leaf blight caused by the fungal and bacterial association (*Alternaria dauci*, *Cercospora carotae*, and *Xanthomonas hortorum* pv. *carotae*) with defoliation between 20 to 25% at 100 days after planting (DAP), eliminating the need to control this disease with chemical pesticides. In addition, it shows high production stability and an outstanding production exceeding 32 t ha^{-1}. 'BRS Paranoá' is an early maturity cultivar, and the harvest can be carried out from 85 DAP when the commercial roots range from 16 to 22 cm, 3 cm diameter, intense orange color, cylindrical shape, and no external or internal physiological defects. The postharvest quality was evaluated and the titratable acidity found was 0.20%, 6.9°Brix soluble solids, 78.40 µg g^{-1} total carotenoids, and 22.69 µg g^{-1} ß-carotene (provitamin A). 'BRS Paranoá' was registered and protected by the Ministry of Agriculture, Livestock and Food Supply and its seeds have been marketed by the main vegetable seeds companies in Brazil.

Keywords: *Daucus carota*, open pollinate cultivar, breeding.

RESUMO

BRS Paranoá: cenoura para sistemas orgânicos de produção

A 'BRS Paranoá' foi obtida pelo programa de melhoramento genético de cenoura da Embrapa Hortaliças, visando obter uma cultivar adaptada à maioria das regiões produtoras de cenoura em sistema orgânico. Essa cultivar foi desenvolvida através de seleção de progênies meias-irmãs e validada no Brasil. A 'BRS Paranoá' é indicada para semeadura nas estações primavera/verão. Essa cultivar apresenta elevada resistência à queima das folhas causada pela associação fungo e bactéria (*Alternaria dauci*, *Cercospora carotae* e *Xanthomonas hortorum* pv. *carotae*) com desfolhamento entre 20 a 25% aos 100 dias após o plantio (DAP). Além disso, apresenta elevada estabilidade de produção e elevado teto produtivo, superando 32 t ha^{-1}. A 'BRS Paranoá' possui ciclo precoce, com a colheita podendo ser realizada a partir dos 85 DAP. As raízes apresentam comprimento variando de 16 a 22 cm, diâmetro de 3 cm, coloração alaranjada intensa, formato cilíndrico e ausência de defeitos fisiológicos externos ou internos. A qualidade pós-colheita foi avaliada e a acidez titulável encontrada foi de 0,20%, sólidos solúveis de 6,9°Brix, carotenoides totais de 78,40 µg g^{-1} e ß-caroteno (pró-vitamina A) de 22,69 µg g^{-1}. A 'BRS Paranoá' foi registrada e protegida pelo Ministério da Agricultura, Pecuária e Abastecimento e suas sementes têm sido comercializadas pelas principais empresas de sementes de hortaliças no Brasil.

Palavras-chave: *Daucus carota*, cultivar de polinização aberta, melhoramento.

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Carrot growth in organic production systems

Carrot is one of the main vegetables grown and consumed in Brazil, with an annual production estimated at 480,000 t in a harvest area of 13,000 ha. Alto do Paranaíba-MG accounts for more than 60% of total Brazilian carrot production, followed by Marilândia do Sul-PR, Caxias do Sul-RS, Cristalina-GO, and Irecê-BA (IBGE, 2017).

Although most of this production is obtained from conventional systems, carrots are often grown in organic production systems. The organic production has been improved, establishing ecologically balanced and stable agricultural systems, economically productive, with high efficiency in the use of natural resources, resulting in healthy food produced in harmony with nature (Resende & Braga, 2014). However, currently, the major limitation for its expansion is the lack of cultivars adapted to this production system, especially in the summer, when the crop is subject to large losses induced by foliar diseases (Resende & Braga, 2014; Resende *et al*., 2016).

Leaf blight is the most common foliar disease of carrot. This disease is commonly found in any region where carrot is grown, especially in the

warmest and wettest season of the year. Leaf blight is caused by an etiological complex involving a fungal and bacterial (*Alternaria dauci*, *Cercospora carotae*, and *Xanthomonas hortorum* pv. *carotae*) association (Lopes & Reis, 2016). Resistant cultivars released in the 1980's by Embrapa (Carvalho *et al*., 2016) were essential for carrot cultivation in the summer season, although usually associated with the use of fungicides to achieve adequate disease control (Lopes & Reis, 2016; Marcuzzo & Teixeira, 2019).

Besides the foliar diseases, nematodes are a serious constraint for carrot production in warmer seasons, with an aggravation that nematicides are usually very toxic to humans and seldom recommended even for conventional carrot production (Lopes & Reis, 2016). It makes nematode resistance a trait of surmounting importance in carrot breeding, regardless of the production system.

In the organic production system, in which the use of chemicals for disease control is prohibited, the genetic resistance factor becomes highly desirable. In this context, Embrapa's carrot breeders have been working on developing cultivars more adapted to this cropping system, with good yield and root quality, but mainly higher levels of resistance or tolerance to this disease complex (Carvalho *et al*., 2013, 2017). As a result of the efforts in the last decade, the cultivar BRS Paranoá was released in 2020.

'BRS Paranoá', originated from population 081101, was developed after 20 cycles of recurrent selection based on the selection of half-sib progenies (Carvalho *et al*., 2016). In each selection cycle, at least 70 selected plants were crossbred, thus forming the next cycle population. Among progenies, genotypes with resistance to leaf blight superior to the cultivar Brasília (at 70 DAP) and absence of bolting plants were selected. Within the progenies, at 100 DAP, roots without green or purple shoulder, with cylindrical shape, length equal to or greater than 18 cm, diameter in the upper middle part of the roots greater than 2.5 cm and Nantes-type tip were selected.

The selected roots were maintained with a 3 cm petiole. Then, they were washed and vernalized in a cold room for 40 days at 5°C. After vernalization, the roots were bevel-cut and assessed for color uniformity and absence of internal defects.

In 2008, after attesting its phenotypic stability, the bred population was validated for four consecutive years in organic and conventional production systems in the main carrot-producing areas in Brazil. A randomized block design with three replications was used for the validation tests, with commercial varieties used as controls for comparison. Resistance to foliar and root diseases, as well as commercial root mass (CRM) were evaluated. The analysis of variance, the Scott-Knott mean grouping tests and the stability and adaptability tests, based on factor analysis, were performed using the software Genes V. 1990.2019.120 (Cruz, 2013).

In Brasília, in 2016 and 2017, experiments were carried out to obtain the phenotypic descriptors as recommended for protection by the Ministry of Agriculture, Livestock and Supply (Brasil, 1997).

Description

'BRS Paranoá' is an open-pollinated summer carrot cultivar, developed especially for organic production system. Its roots have an average diameter of 3 cm, length between 18 and 20 cm, and a straight shape with a smooth surface, which provides high yield compared to conventional carrot cultivars. In addition, it has high resistance to leaf blight and tolerance to root-knot nematode (*Meloidogyne* spp).

The roots of 'BRS Paranoá' have an intense and homogeneous orange color, displaying a good visual appearance. The postharvest quality was evaluated and the titratable acidity found was of 0.20%, 6.9°Brix soluble solids, 78.40 µg g^{-1} total carotenoids, and 22.69 µg g^{-1} ß-carotene. These contents found for 'BRS Paranoá', although slightly lower than those found for cultivar Alvorada (Pilon *et al*., 2022), consist of rich sources of provitamin A.

Seed avaliability

Embrapa released the cultivar BRS Paranoá in 2020 and four seed companies are currently producing commercial seeds.

General information and comparative data

The planting date for 'BRS Paranoá' in the South, Southeast and Midwest regions of Brazil is from October to March, and in other regions, all year round. Harvest is from 90 to 120 DAP. The high tolerance of this cultivar to leaf blight and moderate tolerance to

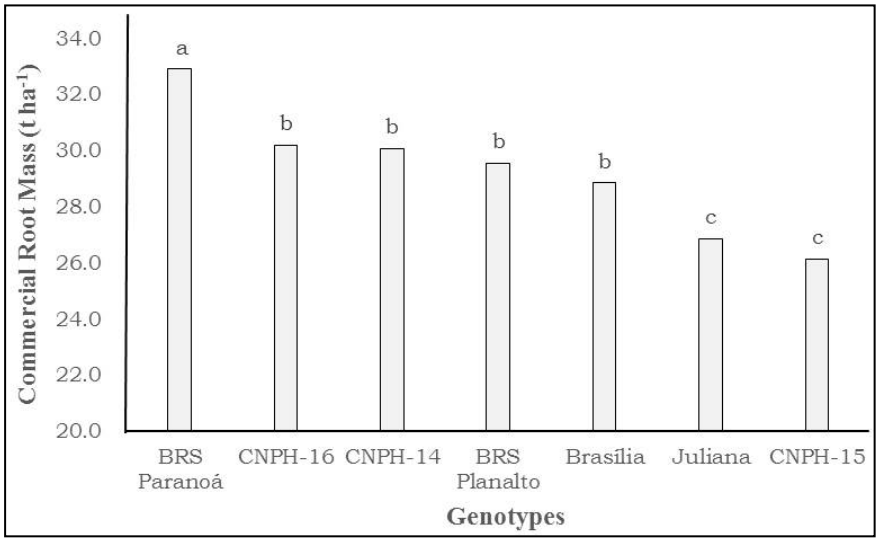

Figure 1. Commercial root mass (t ha^{-1}) of carrot genotypes evaluated in 16 environments, in organic production system. Brasília, Embrapa Hortaliças, 2020.

root-knot nematodes highly favor its adequacy to the organic production system. A population of 500,000 plants per hectare is recommended to allow the production of roots with a diameter and length suitable for commercialization. In competition trials, 'BRS Paranoá' showed higher commercial yield in organic system than other cultivars available on the market, exceeding 32 t ha^{-1} of marketable roots.

'BRS Paranoá' displays tolerance to root-knot nematodes and high-resistance to leaf blight, commonly with less than 20% defoliation, with no fungicide or bactericide application. Its plants are light green, erect, and 45-cm in height. Besides disease resistance, this cultivar stands out by the high root uniformity, representing an opportunity for participation in seed market to the organic production system.

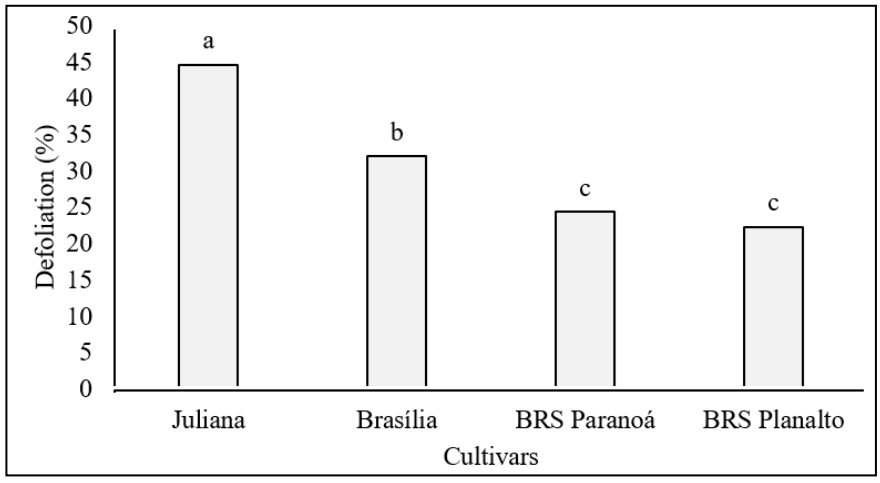

Figure 2. Mean leaf blight severity of carrot genotypes in organic production system. Brasília, Embrapa Hortaliças, 2020.

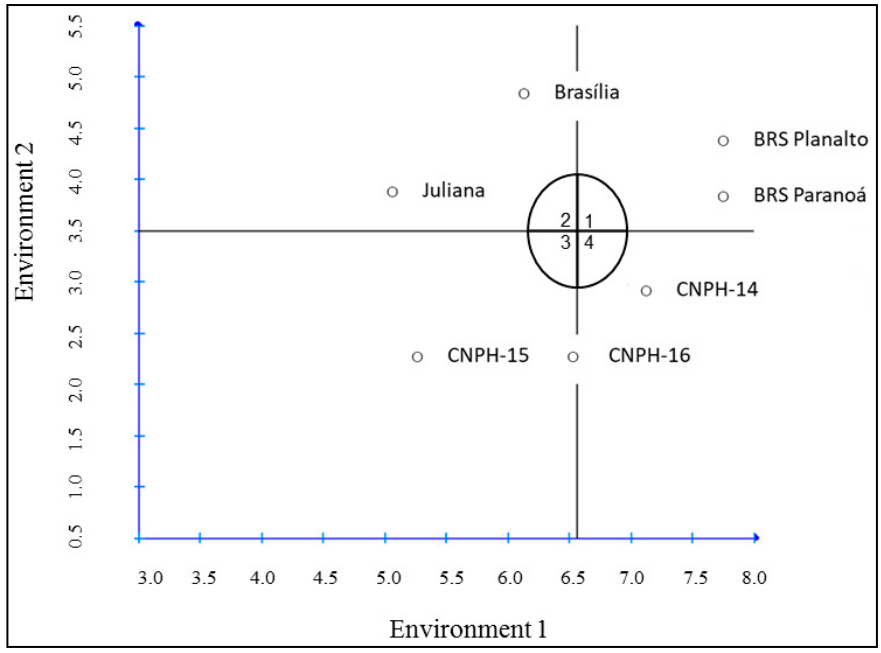

Figure 3. Factor analysis for carrot genotypes evaluated over four years in four environments. The quadrants: 1) genotypes adapted to favorable and unfavorable environments; 2) genotypes adapted to favorable environments; 3) genotypes adapted to unfavorable environments, and 4) genotypes without adaptability to the evaluated locations and years. Brasília, Embrapa Hortaliças, 2020.

The mean production of commercial roots for 'BRS Paranoá', considering 16 environments (4 years x 4 organic production systems), is shown in Figure 1. The Scott-Knott test ($P<0.05$) showed that 'BRS Paranoá' (32.9 t ha^{-1}) was the most productive genotype. This high productive potential was the main criterion adopted for the choice of 'BRS Paranoá' for release as a cultivar for the organic system.

Defoliation caused by leaf blight was evaluated at Embrapa Hortaliças, in 2012 (Figure 2). 'BRS Paranoá' showed defoliation of around 20% in the assessment at 100 DAP, without fungicide or bactericide to control this disease, significantly lower defoliation when compared to cultivars Brasília and Juliana.

In the stability analysis of the validated genotypes (Figure 3), 'BRS Paranoá' showed wide adaptability in any evaluated environment. Cultivar Juliana showed specific adaptation to favorable environments, whereas the genotypes CNPH-14 and CNPH-16 showed specific adaptability to unfavorable environments. CNPH-15 was not adapted to any environment.

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