CARROT CULTIVARS UNDER ORGANIC SYSTEMS IN THE ANGOLAN SEMI-ARID REGION: AGRONOMIC PERFORMANCE AND IMPLICATIONS FOR FAMILY FARMING

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ABSTRACT

This study aimed to evaluate the agronomic and economic performance of the carrot cultivars Kuroda and Dante under organic management in a semi-arid region of Angola. The experiment was carried out from March to July 2023 in a randomized complete block design with three replications, assessing yield, root morphological traits, germination rate, pest and disease incidence, soil parameters, and economic return. Kuroda showed higher productivity and profitability but greater susceptibility to carrot fly and leaf blight, whereas Dante exhibited lower yield yet superior resistance to pathogens and greater phytosanitary stability. It is concluded that organic carrot production is technically feasible in the Angolan semi-arid region when associated with agroecological practices and appropriate cultivar selection, contributing to the improvement of varietal selection and sustainable management in organic systems.

Keywords: *Daucus carota L.*; organic agriculture; semi-arid.

INTRODUCTION

Organic agriculture has gained global prominence as a sustainable alternative to conventional systems, driven by the growing demand for healthy food and the need to mitigate negative environmental impacts (SALVADOR-ADRIANO et al., 2024). Among the vegetables cultivated under this system, carrot (*Daucus carota* L.) holds a prominent position as an important source of vitamins, fiber, and antioxidants (SIMON, LORIA & FREEMAN, 2008).

In the commune of Arimba, located in the Huíla-Lubango province, Angola, where 85% of smallholder farmers report annual yield losses exceeding 30% due to water stress (INSTITUTO NACIONAL DE ESTATÍSTICA, 2023 - Angola), the adoption of practices adapted to organic cultivation represents a strategic factor for mitigating production risks. This scenario is further aggravated by challenging edaphoclimatic conditions and the progression of climate change, which threaten the sustainability of production systems.

At the global scale, meta-analyses from FAO et al. (2023) indicate that carrot cultivars grown under organic management in semi-arid regions show average yields of 18–22 t/ha, while conventional systems can reach up to 25 t/ha. The lower productivity observed in organic systems reinforces the need for research aimed at narrowing this gap. Studies such as those by KIZILDENIZ, TURHAN & KAYA (2018) demonstrate that, in semi-arid environments, the success of vegetable production depends on the selection of cultivars with higher water-use efficiency. In the Angolan context, this need becomes even more urgent,

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since family farming accounts for about 80% of the country's agricultural production (FAO, 2022).

Moreover, few studies have been conducted specifically under African edaphoclimatic conditions, particularly in the semi-arid regions of Angola, creating a significant scientific gap. While cultivars such as BRS Paranoá have been successfully adapted to Brazilian conditions (VILELA, CAMPOS & ANDRADE JÚNIOR, 2020), data on the performance of genotypes in low-fertility soils, under high water restriction, and managed organically in Southern Africa remain scarce.

Given this context, the present study aimed to evaluate the agronomic and economic performance of the carrot cultivars Kuroda and Dante under organic management in the commune of Arimba, Angola, considering variables such as yield, root morphological quality, germination rate, pest incidence, and economic return, in order to identify the cultivar best adapted and most profitable under local edaphoclimatic conditions.

In this scenario, the research seeks to answer the following question: which carrot cultivar, between Kuroda and Dante, shows better agronomic performance under organic cultivation in the commune of Arimba, considering yield, root quality, and pest resistance?

The lack of reliable local data on cultivar performance under semi-arid and organic management conditions limits technological advancement in Angolan family farming. Scientifically based technical evaluations are necessary to guide production decisions, inform public policies, and strengthen breeding programs. Such studies contribute to local food security and enhance the resilience of agricultural systems in the face of climate change.

MATERIAL AND METHODS

The experiment was conducted between March and July 2023 in the commune of Arimba, Huíla-Lubango province, Angola (12°15'S, 15°30'E, altitude 1,700 m), a period that corresponded to the complete phenological cycle of the evaluated carrot cultivars. The region has a tropical highland climate (Cwb according to Köppen), with an average temperature of 22.4 °C, relative humidity of 68%, and total rainfall of 284 mm during the experimental period, according to records from the local agrometeorological station. Considering the typical edaphoclimatic conditions of the central Angolan plateau, a sprinkler irrigation system was implemented, providing a daily water depth of 6 mm, divided into two shifts (morning and afternoon), ensuring adequate soil moisture for plant development.

The experimental design was a randomized complete block design (RCBD) with three replications, totaling six experimental plots of 3.6 m² (3.0 × 1.2 m) each, as illustrated in Figure 1, which shows the schematic layout of the plots. The planting density was established at 12 plants per linear meter, with spacing of 0.25 m between rows and 0.10 m between plants, resulting in a final population of 48 plants per useful plot (2.88 m²).

Two carrot cultivars commonly used in organic systems were evaluated: Kuroda (Dante group) and Dante (Brasília group), both from certified seed lots supplied by AgroSeed Ltda., with purity levels of 98% and 97%, respectively, and germination vigor of 92% and 89%, according to ISTA (2023) standard tests. The Kuroda cultivar is characterized by a shorter vegetative cycle (95–105 days), tolerance to temperatures up to 35 °C, and high water-use efficiency, whereas the Dante cultivar has a longer cycle (105–115 days), genetic resistance to *Alternaria dauci*, and lower attractiveness to foliar pests.

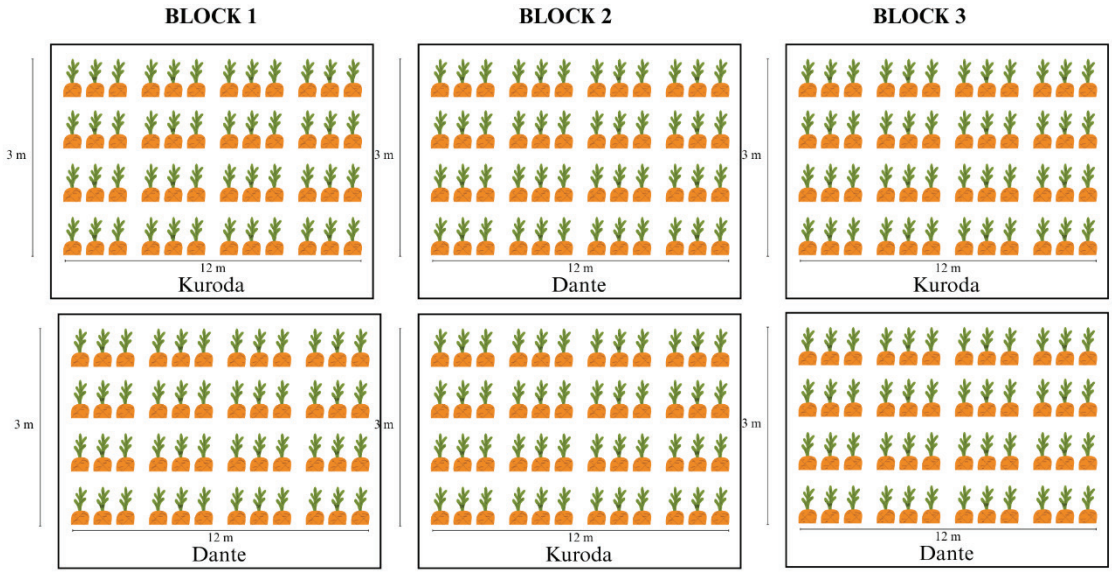

Figure 1. Schematic layout of the randomized complete block design with three replications and two carrot cultivars (Kuroda and Dante) in the commune of Arimba, Angola. Each block contains two plots of 3.0 × 1.2 m, with randomized treatment order.

Source: Prepared by the authors (2025).

Agronomic evaluations were conducted throughout the entire crop cycle, following internationally standardized protocols adapted to semi-arid conditions. For the determination of marketable yield, all harvested roots were individually evaluated for length and the presence of defects (cracks, bifurcations, or pest damage). Only roots with a diameter ≥ 2.5 cm and length ≥ 15 cm, without visible deformities, were classified as marketable, according to the Codex Alimentarius standards for organic carrots.

The germination rate was calculated by daily counts of the number of emerged seedlings up to the 14th day after sowing, expressed as a percentage of the total viable seeds per plot. For morphological analyses, a representative sample of 20 roots per plot (totaling 120 units per treatment) was randomly selected at harvest, and both length and diameter were measured with a precision of 0.1 cm. Measurements were performed by two independent technicians, and any differences greater than 5% were re-measured for verification.

The incidence of pests and diseases was quantified through weekly evaluations of 10 randomly marked plants per plot (60 plants per treatment), recording the presence or absence of symptoms of Alternaria leaf blight (necrotic foliar lesions), carrot fly attack (Psila rosae; galleries in the roots), and nematode infestation (root nodules). Each symptom was classified according to a diagrammatic severity scale adapted from BLANCARD, LOT & COMMENIL (2012), where 0 = absence of symptoms and 4 = more than 50% of the affected area.

Soil preparation (Table 1) was carried out according to practices recommended for organic systems, aiming to improve soil physical structure, fertility, and biological activity. The initial physico-chemical analysis indicated a pH of 6.2, organic matter of 2.1%, and low available phosphorus content (12.4 mg dm^{-3}). Based on these results, 25 t ha^{-1} of well-composted cattle manure were incorporated into the soil 30 days before planting at a depth of 20 cm, using a rotary tiller, followed by two light harrowings. The manure was composted for 60 days following the methodology of EMBRAPA (2017), achieving suitable stability for agronomic use.

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Table 1. Physico-chemical characterization of the soil, parameters of cattle manure composting, and soil preparation conditions adopted for organic carrot cultivation in the commune of Arimba, Angola.

Source: Prepared by the authors (2025).

Stage	Parameter	Value	Unit	Observation
Soil analysis (initial)	pH	6.2	—	—
	Organic matter	2.1	%	—
	Available phosphorus	12.4	mg/dm³	—
Organic correction	Cattle manure	25	t/ha	Well-composted, incorporated at 20 cm depth
	Depth	20	cm	Incorporated using rotary tiller
Manure composting	Duration	60	days	According to EMBRAPA (2017) methodology
	Maximum temperature	55	°C	During composting
	Final C/N ratio	18:01	—	—
Stability test	Cucumber germination	90	%	Emergence confirmed
Pre-planting interval	After incorporation	30	days	Before planting

The raised beds were established with a width of 1.2 m, height of 0.3 m, and spacing of 0.5 m between them, facilitating both crop management and irrigation. Initial irrigation was applied to ensure adequate moisture for germination, with the irrigation depth calculated based on the reference evapotranspiration (ET_0) and the crop coefficient (Kc) for carrot. Seven days before planting, a superficial manual weeding was carried out to eliminate weeds and reduce competition for nutrients.

A fermented liquid biofertilizer was applied through fertigation at 30 and 60 days after emergence. For phytosanitary control, practices compatible with organic management were adopted, including biweekly sprays with aqueous neem (*Azadirachta indica*) extract at 5% (obtained by macerating fresh leaves in water for 48 h), as well as preventive applications of sulfur–lime solution at 2% along the borders. All seeds were previously treated with 5% garlic extract as a biostimulant to enhance germination and initial seedling vigor.

The evaluated variables included marketable yield (t ha^{-1}), root length and diameter (cm), germination rate (%), and incidence of pests and diseases (%).

Statistical analysis of the data was performed using a two-factor ANOVA (cultivars × blocks) in the R software (version 4.3.1) with the packages agricolae, ExpDes.pt, and ggplot2. The normality of residuals and the homogeneity of variances were verified using the Shapiro–Wilk and Bartlett tests, respectively, adopting $p > 0.05$ as the criterion. Means were compared using Tukey's test at a 5% significance level ($p < 0.05$).

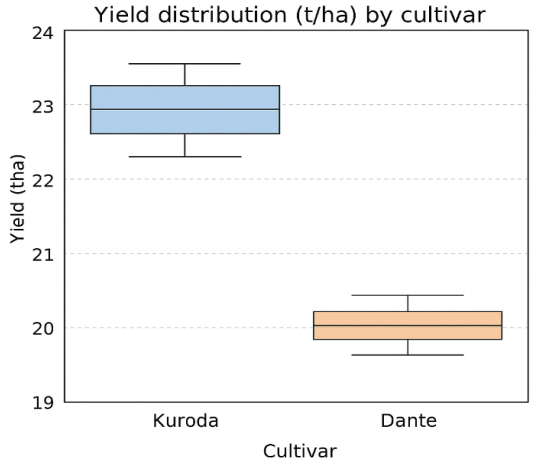
Additionally, Pearson's correlation analysis was performed among agronomic variables (e.g., yield × root length). The collected agronomic data, including (a) marketable yield based on 234 roots within the commercial standard (≥ 2.5 cm diameter), (b) morphometric measurements of 120 randomly selected samples, and (c) pest incidence indices from 60 monitored plants, were analyzed considering the randomized complete block design with three replications, ensuring statistical consistency throughout the experimental process.

RESULTS AND DISCUSSION

The statistical analysis revealed significant differences between the cultivars in terms of

agronomic and phytosanitary performance. Kuroda exhibited higher yield and greater production uniformity, demonstrating its stability under semi-arid conditions and confirming its physiological adaptation to water stress (Figure 2). This response suggests greater efficiency in the allocation of photoassimilates to the main root, a typical behavior of genotypes with higher expression of genes associated with cell expansion and carbohydrate transport (GHONEEM et al., 2023).

Figure 2. Distribution of yield (t/ha) for the carrot cultivars Kuroda and Dante under organic management.



Source: Prepared by the authors (2025).

In contrast, Dante showed lower yield performance (Figure 2) but greater resistance to pathogens and insect pests, confirming the trade-off between yield and defense commonly observed in organic systems (Table 2). The expression of the *AdR1* gene, reported in tropical cultivars resistant to *Alternaria dauci* (WANG et al., 2022), explains the lower incidence of this disease and of the carrot fly, as observed in the present study. This pattern confirms the model described by SHARMA, MINA & KUMAR (2022), according to which the prioritization of defense-related metabolic pathways reduces the allocation of resources to underground biomass production.

Variable	Kuroda	Dante	p-value
Yield (t/ha)	23.5 a	18.7 b	< 0.01
Root length (cm)	18.5 a	15.3 b	0.003
Root diameter (cm)	3.2 a	2.8 b	0.012
Germination (%)	92 a	85 b	0.021

Means followed by different letters in the same row differ significantly according to Tukey's test ($p < 0.05$).

Table 2. Comparison of agronomic performance between the carrot cultivars Kuroda and Dante.

Source: Prepared by the authors (2025).

The contrasting behavior of the cultivars highlights distinct adaptive strategies under organic cultivation in semi-arid conditions. Kuroda tends to maximize yield when subjected to fertigation and the use of bioinputs, benefiting from its high nutrient assimilation capacity and vigorous growth under technically assisted management. In contrast, Dante shows greater phytosanitary stability in systems with lower technological investment, being more suitable for smallholder farmers and environments with higher biotic pressure, where pathogen resistance is a determining factor for maintaining productivity.

These differences have direct implications for planning organic production in semi-arid regions. Kuroda requires more intensive management but offers higher economic returns, whereas Dante achieves lower yields yet provides greater production security and lower operational costs (Table 3).

Pest/Disease	Kuroda (%)	Dante (%)	p-value
Carrot fly	12.3 a	4.7 b	0.008
Alternaria dauci	8.5 a	3.1 b	0.011
Nematodes	6.2	5.8	0.421

Means followed by different letters in the same row differ significantly according to Tukey's test ($p < 0.05$).

Table 3. Incidence of pests and diseases in the Kuroda and Dante carrot cultivars.

Source: Prepared by the authors (2025).

The Dante cultivar exhibited greater resistance to the most common diseases and pests affecting carrot crops under organic systems, particularly due to its low incidence of *Alternaria dauci* and carrot fly (Psila rosae). Kuroda, despite its superior agronomic performance, proved more vulnerable to these biotic

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agents, requiring more intensive phytosanitary management. No statistical difference was observed in nematode occurrence, indicating similar susceptibility between the two cultivars in this regard.

The phytosanitary performance of Dante provides greater crop stability in environments with limited technical support, representing a reliable option especially for smallholder farmers. Conversely, the higher productivity levels achieved by Kuroda were only possible through the adoption of specific agroecological practices such as the use of bioinputs, chromatic traps, biological control, and botanical extracts.

This performance is also directly related to local edaphoclimatic conditions and to soil quality prior to the implementation of the experiment. Table 4 presents the physico-chemical parameters of the soil.

Table 4. Physico-chemical characteristics of the soil before the implementation of the experiment.

Source: Prepared by the authors (2025).

Parameter	Value	Method
pH (H_2O)	6.2	Electrometric (1:2.5)
Organic matter (%)	2.1	Walkley–Black
Available P (mg/dm³)	12.4	Mehlich–1

The soil exhibited low levels of available phosphorus, a typical limiting factor in organic systems. The use of organic amendments and biofertilizers contributed to balancing soil fertility and microbiota, as reported by SULIEMAN & MÜHLING (2021), allowing both cultivars to perform well even under restrictive edaphoclimatic conditions.

From an economic standpoint, Kuroda presented a higher net return per hectare, despite greater production costs associated with biological control and nutritional supplementation. This difference reflects not only its higher yield but also its more desirable morphological pattern for the fresh market. Dante, although more rustic and stable, generated a lower financial return, illustrating the classical dilemma in organic agriculture between productivity and sustainability.

In practical terms, the choice between the two cultivars should consider the farmer's profile and the available management conditions. Kuroda is better suited to systems with greater technical support, aimed at maximizing profitability and implementing intensive agroecological practices. Dante, on the other hand, is more appropriate for low-input contexts, where the priority is to ensure production stability, reduce external input dependency, and maintain system resilience under adverse conditions.

In summary, the study demonstrates that the two cultivars are complementary. Kuroda stands out for its agronomic and economic efficiency, whereas Dante excels in sanitary resilience and adaptability. Breeding programs that integrate traits from both cultivars may help reduce the trade-off between resistance and productivity, thereby expanding opportunities for organic horticulture in semi-arid regions.

CONCLUSION

The study confirms the technical and agronomic feasibility of organic carrot cultivation in semi-arid regions, provided it is associated with appropriate agroecological practices and careful cultivar selection. Kuroda stood out for its higher yield and economic return, whereas Dante exhibited greater phytosanitary resilience, highlighting the trade-off between productivity and resistance.

From a scientific perspective, the results expand the understanding of genotype × environment interactions in organic systems and suggest new directions for breeding programs aimed at integrating productivity and defense traits. The adaptation of both cultivars demonstrates that

organic agriculture can represent a sustainable and economically viable alternative for the Angolan semi-arid region, particularly when supported by integrated soil management and biological control practices.

Future research should include new genotypes and eco-physiological variables to consolidate resilient organic production models adapted to the water and nutrient limitations typical of these environments.

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