

Seedling size and broiler litter composition affect Peruvian carrot productivity and profitability

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ABSTRACT: The commercial part of the Peruvian carrot plant is subterranean, requiring well-structured soils. Differences in seedling size and the use of organic residues may affect crop productivity and farmer income. This study aimed to assess the productivity and profitability of Peruvian carrot propagated using different seedling sizes (T1, T2, T3, and T4) and grown with broiler litter of different bedding materials (wood shavings and rice hull) as soil cover, arranged in a 4 × 2 factorial scheme in a randomized block design with five replicates. The highest production of fresh leaves (5.85 t ha⁻¹), shoots (7.55 t ha⁻¹), and commercial roots (6.30 t ha⁻¹) were obtained with propagation using T2 seedlings. Broiler litter with wood shavings bedding provided the highest commercial root productivity (5.00 t ha⁻¹). Costs per hectare varied by R\$ 3,093.42 between the lowest (R\$ 11,480.77) and highest (R\$ 14,574.19) costs. The highest gross (R\$ 41,940.00) and net (R\$ 28,881.50) incomes were obtained with broiler litter with rice hull bedding and T2-sized seedlings. Peruvian carrots should be grown in soil covered with broiler litter with rice hull or wood shavings bedding using T2-sized seedlings to obtain the highest productivity and net income.

Key words: agroecology; *Arracacia xanthorrhiza*; seedling weight

Tamanhos de mudas e composição da cama de frango influenciam a produtividade e rentabilidade de mandioquinha-salsa

RESUMO: A planta da mandioquinha-salsa tem sua parte comercializável subterrânea, exigindo solos bem estruturados. Diferenças de tamanhos nas mudas e a utilização ou não de resíduos orgânicos podem influenciar a produtividade e renda do agricultor. Objetivou-se conhecer a produtividade e rentabilidade da mandioquinha-salsa propagada com diferentes tamanhos de mudas (T1, T2, T3 e T4) e cultivadas com cama de frango de bases diferentes (maravalha e casca de arroz), arranjados em esquema fatorial 4 x 2 no delineamento experimental de blocos casualizados, com cinco repetições. A maior produção fresca de folhas (5,85 t ha⁻¹), rebentos (7,55 t ha⁻¹) e raiz comercializável (6,30 t ha⁻¹) foi com mudas T2. A cama de frango com resíduo base maravalha propiciou a maior produtividade de raiz comercializável (5,00 t ha⁻¹). Os custos por hectare variaram em R\$ 3.093,42 entre o menor (R\$ 11.480,77) e o maior (R\$ 14.574,19). A maior renda bruta (R\$ 41.940,00) e renda líquida (R\$ 28.881,50) foi com a utilização da cama de frango de base casca de arroz e mudas com tamanho T2. Para obter maiores produtividades e renda líquida o cultivo de mandioquinha-salsa deve ser feito em solo coberto com cama de frango e resíduo base de casca de arroz ou maravalha utilizando mudas de tamanho T2.

Palavras-chave: agroecologia; *Arracacia xanthorrhiza*; peso de mudas

Introduction

Peruvian carrot is considerably consumed throughout Brazil, although it is primarily grown in the South, Southeast, and Central West regions, where the species has great economic and social importance. According to a survey carried out at the VIII National Meeting of Peruvian carrot in Rio Negro, Paraná, in 2014, along with information from rural extension agencies in the main producing states, annual production ranges from 100 to 140 thousand tons in mountainous regions of Southeast and Southern Brazil, currently occupying between 10 and 12 thousand hectares, being the main producing states of Minas Gerais (35% to 40% of the area), Paraná (35% to 40%), Santa Catarina (8% to 10%) and Espírito Santo (8% to 10%) (Madeira et al., 2017). Average root production is approximately 250 thousand tons per year, and approximately 95% of this production volume is intended for the fresh root market (Granate et al. 2007). The root centesimal composition is approximately 74% water, 101 kcal, protein (1 g), carbohydrates (24 g), dietary fiber (2.1 g), ashes (1.1 g), Ca (17 g), Mg (12 mg), Mn (0.1 g), P (45 mg), Fe (0.3 mg), K (50.5 mg), Cu (0.05 mg), Zn (0.2 mg), thiamine (0.05 mg), pyridoxine (0.12 mg), and beta-carotene (0.8 µg) (Kinupp & Lorenzi, 2014).

In Mato Grosso do Sul, the quantity available in local markets is small as the consumption of this crop is traditionally not popular in this state. Thus, this vegetable is sold at high prices, thereby preventing its inclusion in the diets of low-income people (Heredia Zárate et al., 2008).

The propagation material for Peruvian carrot is bulky, expensive, and difficult to obtain. Consequently, shortage of propagation material has been a major factor limiting its expansion. The seedlings should originate from selected mother plants that have completed the vegetative stage of the growth cycle (Filgueira, 2008). Multiplication for commercial purposes is performed using seedlings obtained from the shoots formed in the crown, which vary in length and diameter depending on the plant clone and age. Commercially, only the apical portion of shoots (2.5 to 3.0 cm), which are removed from mature plants at approximately 8-12 months of age depending on the growing site, is used in propagation (Leblanc et al., 2008). The quality of the planting material determines the difference in rooting speed, growth, production, and duration of the crop cycle (Heredia Zárate et al., 2009).

Organic agriculture is an alternative strategy that aims at the sustainable and safe production of food, while improving soil quality and promoting greater environmental protection, avoiding the use of synthetic chemicals (Suja et al., 2017). The addition of organic residues to the soil improves the biological and physical attributes, as well as being essential to maintain the water and nutrients content, as they increase the retention capacity and availability, thus reducing their consistency through the soil profile (Cardoso et al., 2013).

Several types of organic waste materials are applied to agricultural soils, with broiler litter being the mostly used, and wood shavings and rice hulls are increasingly used as

bedding materials. Wood shavings are widely used because they provide the optimal microbiological conditions, combined with high absorption capacity and easy handling. However, availability of wood shavings is currently decreasing due to significant reductions in timber production in Brazil. In contrast, rice hulls are abundant in regions where rice is grown, although rice hulls have reduced absorption capacity (Ávila et al., 2007).

Knowledge of the profitability and production costs is necessary for any economic activity, including agriculture. Such information plays a key role as a managerial tool, as it provides data enabling the planning, cost control, and decision making, that can help to convert farms into profitable companies. The current reality requires the rural producer to act efficiently on his productive system in order to obtain a lower cost that will allow a enough profit margin to guarantee the survival of his enterprise (Dethier & Effenbeger, 2011).

This study aimed to assess the productivity and profitability of Peruvian carrot propagated using seedlings of different sizes and grown in soil covered with broiler litter with different bedding materials.

Materials and Methods

The study was conducted in the Medicinal Plant Farm (Horto de Plantas Mediciniais – HPM), School of Agricultural Sciences (Faculdade de Ciências Agrárias – FCA), Federal University of Grande Dourados (Universidade Federal da Grande Dourados – UFGD), in Dourados – Mato Grosso do Sul (MS), from May 2014 to January 2015. The experimental area is located at the coordinates 22°11'44" South and 54°56'08" West at an altitude of 430 m. The climate of the region is classified as Am according to the Köppen-Geiger climate classification (Alvares et al. 2013), the annual average rainfall is higher than 1,500 mm, and the average monthly rainfall of the driest months is lower than 60 mm. The soil is dystroferric Red Latosol, with a clay texture (Embrapa, 2013).

The soil chemical properties in the experimental area before planting and at 250 days after planting (DAP), as a function of treatments, and the properties of bedding materials of the semi-decomposed broiler litter used in the experiment are presented in Table 1.

The study factors were four sizes of Peruvian carrot seedlings (Table 2) planted in a soil covered with broiler litter (10 t ha⁻¹) with different bedding materials (wood shavings and rice hulls).

The treatments were arranged in a 4 × 2 factorial scheme in a randomized block design with five replicates. Each plot had a total area of 3.0 m² (1.5 m width by 2.0 m length), and the effective bed width was 1.0 m, with three plant rows spaced at 33.3 cm and with 25 cm between plants, totaling a population of 79,200 plants ha⁻¹.

The land was prepared two weeks before planting, by plowing and harrowing and, subsequently, tilling the beds with a rototiller.

Table 1. Chemical properties of samples of broiler litter with different bedding materials and soil samples collected in the experimental area before planting (BP) and at 250 days after planting (DAP) 'Amarela de Carandaí' Peruvian carrot. Dourados – Mato Grosso do Sul (MS), Federal University of Grande Dourados (Universidade Federal da Grande Dourados – UFGD), 2014-2015.

Soil properties ¹	BP ³	HULLS ⁴	SHAVINGS ⁴	Bedding properties ²	HULLS ⁵	SHAVINGS ⁶
pH in CaCl ₂	5.57	5.58	5.45	Total moisture	21.75 ⁵	20.74 ⁶
pH in water	6.20	6.22	6.10	Zn (mg kg ⁻¹)	299.00	414.00
P (mg dm ⁻³)	13.99	16.53	16.09	Mn (mg kg ⁻¹)	422.00	871.00
K (cmol _c dm ⁻³)	0.31	0.30	0.26	Fe (g kg ⁻¹)	1.04	6.05
Al ³⁺ (cmol _c dm ⁻³)	0.12	0.12	0.12	Cu (mg kg ⁻¹)	53.10	33.70
Ca (cmol _c dm ⁻³)	2.90	3.01	3.12	Ca (g kg ⁻¹)	12.04	19.29
Mg (cmol _c dm ⁻³)	2.08	2.19	2.34	Mg (g kg ⁻¹)	5.90	8.50
H+Al (cmol _c dm ⁻³)	3.28	3.13	3.45	K (g kg ⁻¹)	24.63	16.80
SB (cmol _c dm ⁻³)	5.29	5.50	5.72	N (%)	1.61	1.58
CEC (cmol _c dm ⁻³)	8.57	8.62	9.18	P (g kg ⁻¹)	10.80	15.30
V (%)	61.73	63.66	62.36	C/N	10.02	8.75

¹Tests conducted in the Soil Laboratory, FCA/UFGD; ²Tests conducted in the Organic Matter and Waste Laboratory, UFV; ³Before planting; ⁴Soil properties after harvesting; ⁵Rice hulls; ⁶Wood shavings.

Table 2. Characteristics (mean size, weight, diameter, and length) of Peruvian carrot seedlings in Dourados - MS, UFGD, 2014-2015.

Seedling Size	Weight* (g uni ⁻¹)	Diameter		Length
		(mm)		
T1	24.13	22.02		56.19
T2	16.52	20.15		52.73
T3	13.23	18.40		51.83
T4	8.60	17.73		38.05

* Grams per seedling

Peruvian carrot plant shoots of the 'Amarela de Carandaí' clone, grown in the region of Manhuaçu - Minas Gerais (MG), were used for planting. The shoots of crowns were collected one day ahead of planting, and they were visually classified and separated into four size groups (Table 2) at the same time. On the day of planting, the shoots were prepared by cutting the aerial part, leaving approximately 2.0 cm of petiole, and cross sectioning the basal part. Planting was performed manually, maintaining the shoot apices uncovered (Heredia Zárate et al., 2009) and broadcasting the broiler litter onto the soil in plots corresponding to each bedding material treatment immediately after planting.

Irrigation was performed using the sprinkler system, with irrigation shifts every two days during the initial phase, when the plant height ranged from 15 to 20 cm, which occurred at approximately 60 DAP, and every three days until 180 DAP. Subsequently, the irrigation was performed once a week until harvest. Weeding was performed using a hoe, between the beds, and manually inside the beds. The experimental area was infested with honeysuckle aphid (*Hyadaphis foeniculi* sp.) and pest control was performed using Neem oil.

Sample collection was conducted when approximately 70% plant leaf senescence was observed, which occurred at 250 DAP, to assess fresh and dry masses (mass obtained after drying the material in a convection oven, until constant mass, at the temperature of 65 °C ± 2 °C) of leaves, shoots, crowns, and commercial (mass higher than 25 g) and non-commercial

(mass lower than 25 g and damaged) roots. The numbers of shoots and commercial and non-commercial roots were also tallied and the diameters and lengths of commercial and non-commercial roots were measured.

The Tukey test was applied to detect significant differences in harvest data, using the F test, at a 5% probability level.

The production cost of 'Amarela de Carandaí' Peruvian carrot plants reported by Heid et al. (2015) was used as the basis to assess production costs between the treatments in this study.

The cost of seedlings was calculated considering the number of seedlings necessary for a population of 79,200 plants ha⁻¹, plus the estimated number of seedlings (5%) necessary to replace losses in the field during the budding phase, multiplied by the average weight of the seedlings used for cultivation and then multiplied by the purchase value of the seedlings, which corresponded to R\$ 2.00 kg⁻¹ (Heid et al., 2015).

Labor costs were determined considering the number of men required to perform each activity per day, multiplied by the amount paid for temporary work in Dourados-MS at the time the experiment was conducted (R\$ 45.00 day⁻¹).

Costs of machinery (tractor and irrigation pump) were calculated by recording the number of hours used to perform each operation and converting into hours/machine per hectare and multiplying by the equivalent proportion of the value of each machine.

Fresh mass of commercial roots and the price of R\$ 6.00 kg⁻¹, corresponding to 60% of the mean trade value at the Supply Centre (Central de Abastecimento – CEASA) of Campo Grande – Mato Grosso do Sul (MS), from November to December 2014, whose market value was R\$ 10.00 kg⁻¹, were used to determine the gross income. Net income was calculated by subtracting the production costs per hectare planted from the gross income.

Results and Discussion

Plants propagated with T2 seedlings had the highest productions of fresh leaf, crown, and shoot masses, surpassing

those of plants propagated with T4 seedlings by 4.75, 1.04, and 3.67 t ha⁻¹, respectively, and plants propagated with T4 seedlings had the lowest productions (Table 3). These results corroborate Heredia Zárata et al. (2009), who observed that plants propagated with larger seedlings had higher leaf (22.10 t ha⁻¹), shoot (12.40 t ha⁻¹), and crown (8.20 t ha⁻¹) productivities when studying the productive response of Peruvian carrot propagated with four seedling sizes. This occurs because seedlings with larger reserves likely induce greater leaf growth and development, especially in the initial phases of the growth cycle, thereby favoring the growth of stem components.

T2-sized Seedlings provided the best productions of fresh commercial and non-commercial roots (Table 3). The productivity of commercial roots obtained with T2-sized seedlings surpassed the productivity obtained with T1-, T3-, and T4-sized seedlings by 17.8, 39.2, and 58.4%, respectively. Commercial root is a key parameter because roots, which are commonly sold fresh, are the most important commercial component. When comparing non-commercial roots, the productivity of T2 seedlings surpassed that of T4 seedlings by 54.6%. During the growth and development of Peruvian carrot plants, only the leaves grow initially and then the stem structures (shoots and crowns) grow until the transformation of the main roots into the main storage organs (Sediyama & Casali, 1997). Seedlings with larger reserves presumably induce increased shoot growth and development during the initial crop stages, thus favoring the growth of subterranean components, including roots in the case of Peruvian carrot (Heredia Zárata et al., 2003).

Torales et al., (2015) observed that the mean seedling mass of 7.76 g promoted the highest fresh mass productivity of commercial roots (14.70 t ha⁻¹), with 2.32 t ha⁻¹ and 5.33 t ha⁻¹ increases over the productivities obtained with seedlings of 2.73 and 5.58 g, respectively, when studying the agro-economic production of 'Amarela de Carandaí' Peruvian carrot plants grown using two spacings (20 and 25 cm) between plants on the beds with five mean seedling masses (12.26, 7.76, 5.58, 3.98, and 2.73 g) and harvested at 249 DAP.

The type of bedding material of broiler litter significantly affected the productivity of commercial roots, and plants

grown in soil covered with broiler litter with wood shavings surpassed the productivity obtained with plants grown in soil covered with broiler litter with rice hulls by 1.04 t ha⁻¹ (20.8%) (Table 3). These results may be related to differences in the nutrient contents of both bedding materials (Table 1), because broiler litter with wood shavings has higher levels of zinc (Zn), manganese (Mn), iron (Fe), calcium (Ca), magnesium (Mg), and phosphorus (P), which may have been further released into soil for plant uptake throughout the plant cycle.

The leaf, crown, and shoot dry masses followed the same trends as the fresh masses and were significantly affected by the seedling size, obtaining the highest values in plants propagated with T2 seedlings (Table 4).

The leaf, crown, and shoot productivities of plants propagated with T2 seedlings surpassed the productivities obtained in plants propagated with T4 seedlings (which showed the lowest values) by 69.8, 33.3, and 53.1%, respectively. Torales et al. (2015) obtained the highest leaf (0.79 t ha⁻¹), crown (0.86 t ha⁻¹), and shoot (1.26 t ha⁻¹) dry masses from plants propagated using seedlings with higher masses when studying the productivity of Peruvian carrot in response to different spacings between plants and seedling weights, similarly to the trend of the present study.

The types of bedding materials caused no significant differences in plant dry mass productivity. The highest values of crown and shoot productivities followed different trends from the fresh mass trend (Table 4). These results suggest that both materials (wood shavings and rice hulls) used as broiler litter bedding material most likely provided similar conditions to the soil, thereby affecting the components tested similarly.

The commercial root productivity obtained in the treatments with T2 seedlings surpassed the productivities of plants propagated with T1, T3, and T4 seedlings by 15.8 (0.19 t ha⁻¹), 40.0 (0.48 t ha⁻¹), and 60.0% (0.72 t ha⁻¹), respectively (Table 4).

Commercial root productivity of plants grown in soil covered with broiler litter with wood shavings bedding was 0.16 t ha⁻¹ (17.2 %) higher than that of plants grown in soil covered with broiler litter with rice hulls (Table 4). This result was likely due to the higher phosphorus (P) values (Table 1), which affects the photosynthesis, respiration, energy storage

Table 3. Fresh masses of leaves, crowns, shoots, and commercial and non-commercial roots of Peruvian carrot plants grown in soil covered with broiler litter with two bedding materials propagated using seedlings of different sizes in Dourados - MS, UFGD, 2014-2015.

Study factors	Fresh masses (t ha ⁻¹)				
	Leaf	Crown	Shoot	Commercial root	Non-commercial root
Bedding material					
Wood shavings	2.64 a	3.92 a	5.93 a	5.00 a	2.47 a
Rice hulls	3.04 a	3.85 a	5.67 a	3.96 b	2.31 a
Seedling size					
T1	2.52 b	4.08 b	6.43 b	5.18 b	2.69 ab
T2	5.85 a	4.71 a	7.55 a	6.30 a	3.15 a
T3	1.88 bc	3.08 d	5.35 b	3.83 c	2.29 b
T4	1.10 c	3.67 c	3.88 c	2.62 d	1.43 c
C.V. (%)	35.55	8.08	15.34	17.34	21.15

Means followed by the same letters in columns are not different from each other according to F test for the bedding material, and according to the Tukey test for seedling size, at 5% probability.

Table 4. Dry masses of leaves, crowns, and commercial and non-commercial roots of Peruvian carrot plants grown in soil covered with broiler litter with two bedding materials propagated using seedlings of different sizes in Dourados - MS, UFGD, 2014-2015.

Study factors	Dry mass (t ha ⁻¹)				
	Leaf	Crown	Shoot	Commercial root	Non-commercial root
Bedding material					
Wood shavings	0.62 a	0.76 a	0.89 a	0.93 a	0.50 a
Rice hulls	0.70 a	0.80 a	0.93 a	0.77 b	0.48 a
Seedling size					
T1	0.63 b	0.85 a	0.96 b	1.01 b	0.55 ab
T2	1.16 a	0.93 a	1.28 a	1.20 a	0.60 a
T3	0.51 bc	0.73 b	0.81 bc	0.72 c	0.48 b
T4	0.35 c	0.62 b	0.60 c	0.48 d	0.33 b
C.V. (%)	28.43	11.51	19.77	15.05	18.21

Means followed by the same letters in columns are not different from each other according to the F test for bedding material, and according to the Tukey test for seedling size, at 5% probability.

and transfer, and cell division and cell growth processes, and contributes to premature root growth (Taiz & Zeiger, 2017), thus enabling higher photosynthate accumulation.

The numbers of shoots and commercial and non-commercial roots were significantly affected by seedling size (Table 5), and plants propagated with T2 seedlings showed 14.6, 22.6, and 33.3% increases in the number of

Table 5. Numbers ($\times 1,000,000$) of shoots and commercial and non-commercial roots of Peruvian carrot plants grown in soil covered with broiler litter with two bedding materials and propagated using seedlings of different sizes in Dourados - MS, UFGD, 2014-2015.

Study factors	Numbers ($\times 1,000,000$)		
	Shoots	Commercial root	Non-commercial root
Bedding material			
Wood shavings	0.61 a	0.11 a	0.24 a
Rice hulls	0.62 a	0.09 b	0.24 a
Seedling size			
T1	0.64 b	0.12 a	0.26 b
T2	0.75 a	0.14 a	0.32 a
T3	0.58 bc	0.09 b	0.22 b
T4	0.50 c	0.06 c	0.16 c
C.V. (%)	11.73	19.78	17.07

Means followed by the same letters in columns are not different from each other according to the F test for bedding material, and according to the Tukey test for seedling size, at 5% probability.

Table 6. Commercial and non-commercial root length and diameter of Peruvian carrots grown in soil covered with broiler litter with two bedding materials propagated using seedlings of different sizes in Dourados - MS, UFGD, 2014-2015.

Study factors	Length (cm)		Diameter (mm)	
	Commercial root	Non-commercial root	Commercial root	Non-commercial root
Bedding material				
Wood shavings	8.26 a	4.27 a	27.55 a	21.69 a
Rice hulls	8.34 a	4.52 a	26.63 a	20.90 a
Seedling size				
T1	8.64 b	4.58 b	28.55 ab	22.55 ab
T2	9.80 a	5.35 a	29.57 a	24.42 a
T3	8.08 b	4.13 b	26.59 b	20.87 b
T4	6.69 c	3.54 c	23.67 c	17.35 c
C.V. (%)	9.72	10.00	6.39	10.43

Means followed by the same letters in columns are not different from each according to the F test for bedding material, and according to the Tukey test for seedling size, at 5% probability.

shoots compared with plants propagated with T1, T3, and T4 seedlings, respectively.

The numbers of commercial roots (Table 5) showed no significant differences between plants propagated with T1 and T2 seedlings, albeit surpassing the values obtained with T4 seedlings by 57.1 and 50.0%, respectively. Plants propagated with T2 seedlings had the highest number of non-commercial roots (320,000), surpassing that obtained with T4 seedlings (160,000), which was the lowest, by 100%.

The bedding material affected the number of commercial roots of plants (Table 5), in addition to the fresh (Table 3) and dry (Table 4) masses. Wood shavings induced an increase of 2,000 roots in plants, when compared with the number of plants grown in soil covered with broiler litter with rice hulls as bedding material. Segundo Mangiori & Filho (2015), The addition of organic residues to the soil improves the biological and physical attributes, as well as being essential to maintain water and nutrient contents, as they increase retention capacity and availability, reducing their consistency through the soil profile (Hoshino et al., 2016). Thus, broiler litter with wood shavings, with has higher nutritional values and lower C/N ratio, may have provided higher quantities of those elements to plants throughout the growth cycle through decomposition than rice hulls.

The highest values of length (9.80 cm) and diameter (29.57 mm) (Table 6) of commercial roots were obtained in plants

propagated using T2 seedlings, surpassing the length and diameter of roots of plants propagated with T4 seedlings by 3.11 cm and 5.90 mm, respectively. These results corroborate Torales et al. (2015), who obtained greater lengths and diameters in plants propagated using seedlings with larger masses (12.26 g) when studying the weight of Peruvian carrot seedlings.

The estimated cost for 1.0 ha Peruvian carrot (Table 7) varied by R\$ 3,093.42 between the lowest cost (R\$ 11,480.77), which corresponded to the treatment with T4 mean seedling mass, and the highest cost (R\$ 14,574.19), obtained with T1 mean seedling mass. These results indicate that the higher the mean weight of the shoots used as seedlings is, the higher the value of the product cost component will be.

Of the total production costs, variable costs accounted for 73.21 (R\$ 10,669.40) for T1, 72.01 (R\$ 9,403.80) for T2, 71.40 (R\$ 8,856.40) for T3, and 70.43% (R\$ 8,086.40) for T4, with 10.03% variation resulting from the purchase of seedlings. Labor accounted for R\$ 4,455.00 spending, representing 30.57% of the highest and 38.80% of the lowest total production costs, indicating that growing Peruvian carrot plants is a key source of employment in the agricultural sector, requiring a considerable number of days/man to perform different operations, such as plant pest control treatment operations (Heid et al., 2015).

Inputs and machinery accounted for 36.12 (R\$ 5,264.40) and 6.52% (R\$ 950.00) of the costs for seedlings with T1 mean masses and 23.36 (R\$ 2,681.40) and 8.27% (R\$ 950.00) for seedlings with T4 mean masses, respectively. The other costs (contingency, administration, and interest) accounted for 14.96% (R\$ 2,179.79) of the total production costs for T1 seedlings and 14.54% (R\$ 1,669.37) of the total production costs for T4 seedlings. Differences in production costs demonstrate the need for studying the best ways of growing Peruvian carrot plants to reduce variable costs, and indicate that growing Peruvian carrot plants is a key source of employment in the agricultural sector due to its labor requirements for plant pest control.

Growing 'Amarela de Caranda' Peruvian carrot plants using T2-sized seedlings, regardless of the bedding material used, and harvesting at 250 DAP, noticeably provided higher values of commercial root production, with 6.69 and 6.99 t ha⁻¹ for wood shavings and rice hulls, respectively, considering the means of commercial root productivity assessed in each treatment and the estimates of gross income, production costs, and net income (Table 8).

The highest gross (R\$ 41,940.00) and net (R\$ 28,881.50) incomes were obtained from selling the commercial roots of plants propagated with T2 seedlings and grown in soil covered with broiler litter with rice hulls bedding, which surpassed

Table 7. Production costs per hectare of 'Amarela de Caranda' Peruvian carrots grown using two bedding materials of broiler litter and propagated using four seedling sizes in Dourados - MS, UFGD, 2014–2015.

Cost components	T1 (24.13 g)		T2 (16.52 g)		T3 (13.23 g)		T4 (8.60 g)	
	Quantity	Cost (R\$)	Quantity	Cost (R\$)	Quantity	Cost (R\$)	Quantity	Cost (R\$)
1. Variables Costs								
Inputs								
Seedlings ¹	2,006.7 kg	4,013.40	1,373.9 kg	2,747.80	1,100.2 kg	2,200.40	715.20	1,430.40
Price of Broiler litter	10 t ha ⁻¹	900.00	10 t ha ⁻¹	900.00	10 t ha ⁻¹	900.00	10 t ha ⁻¹	900.00
Neem oil ⁵	4.50 (liter)	351.00	4.50 (liter)	351.00	4.50 (liter)	351.00	4.50 (liter)	351.00
Labor								
Seedling preparation	8.00 H/D	360.00	8.00 H/D	360.00	8.00 H/D	360.00	8.00 H/D	360.00
Planting	16.00 H/D	720.00	16.00 H/D	720.00	16.00 H/D	720.00	16.00 H/D	720.00
CF Distribution	10.00 H/D	450.00	10.00 H/D	450.00	10.00 H/D	450.00	10.00 H/D	450.00
Irrigation	10.00 H/D	450.00	10.00 H/D	450.00	10.00 H/D	450.00	10.00 H/D	450.00
Neem application	5.00 H/D	225.00	5.00 H/D	225.00	5.00 H/D	225.00	5.00 H/D	225.00
Weeding	20.00 H/D	900.00	20.00 H/D	900.00	20.00 H/D	900.00	20.00 H/D	900.00
Harvesting	30.00 H/D	1,350.00	30.00 H/D	1,350.00	30.00 H/D	1,350.00	30.00 H/D	1,350.00
Machinery								
Irrigation pump	71.00 h	710.00	71.00 h	710.00	71.00 h	710.00	71.00 h	710.00
Tractor	4.00 h	240.00	4.00 h	240.00	4.00 h	240.00	4.00 h	240.00
Subtotal 1 (R\$)		10,669.40		9,403.80		8,856.40		8,086.40
2. Fixed Costs								
Improvement	250 days	375.00	250 days	375.00	250 days	375.00	250 days	375.00
Land lease ³	1.00 ha	1,350.00	1.00 ha	1,350.00	1.00 ha	1,350.00	1.00 ha	1,350.00
Subtotal 2(R\$)		1,725.00		1,725.00		1,725.00		1,725.00
3. Other Costs								
Contingency (10% ST1)	--	1,066.94	--	940.38	--	885.64	--	808.64
Administration (5% ST1)	--	533.47	--	470.19	--	442.82	--	404.32
Subtotal 3	--	1,600.41	--	1,410.57	--	1,328.46	--	1,212.96
TOTAL		13,994.81		12,539.37		11,909.86		11,024.36
Quarterly interest ⁴ (0.46%)	9 months	579.38		519.13		493.07		456.41
OVERALL TOTAL ha ⁻¹	--	14,574.19	--	13,058.50	--	12,402.93	--	11,480.77

¹Cost: Number of seedlings multiplied by the price of R\$ 2.00 kg⁻¹ paid to farmers. ²Cost of broiler litter = R\$ 90.00 t⁻¹. ³Cost: land lease = R\$ 150.00 ha⁻¹/month for 9 months. ⁴Interest/Smallholding farmer -Source: Bank of Brazil. Heid et al. (2015). ⁵MFRural 2015, available at: <http://www.mfrural.com.br/>. ST1: Subtotal 1.

Table 8. Commercial root productivity, gross income, production costs, and net income of 'Amarela de Carandaí' Peruvian carrot as a function of planting using two bedding materials of broiler litter and propagating using four seedling sizes in Dourados - MS, UFGD, 2014-2015.

Broiler litter (t ha ⁻¹)	Commercial production	Gross income ¹	Production costs ²	Net income
			(R\$ ha ⁻¹)	
Wood shavings				
T1	5.84	35,040.00	14,574.19	20,465.81
T2	6.69	40,140.00	13,058.50	27,081.50
T3	4.58	27,480.00	12,402.93	15,077.07
T4	3.70	22,200.00	11,480.77	10,719.23
Rice hulls				
T1	5.37	32,220.00	14,574.19	17,645.81
T2	6.99	41,940.00	13,058.50	28,881.50
T3	4.10	24,600.00	12,402.93	12,197.07
T4	3.22	19,320.00	11,480.77	7,839.23

¹R\$ 6.00 kg⁻¹; Price paid per kilogram of Peruvian carrot in the central market of Dourados-MS; ²Production costs per hectare of 'Amarela de Carandaí' Peruvian carrot.

the net income obtained from selling the commercial roots of plants propagated with T4 seedlings and grown in soil covered with broiler litter with rice hulls bedding by R\$ 21,042.27.

Commercial root production using broiler litter with rice hulls bedding was 0.3 t ha⁻¹ higher than commercial root production using broiler litter with wood shavings bedding, with the same seedling size (T2), which led to a net income of R\$ 27,081.50 and gains of R\$ 1,800.00 ha⁻¹.

These findings highlight the importance of studying the costs associated with applications of agricultural methods, and indicate that some economic indices should be determined to further understand the production structure of the activity and introduce the necessary changes to increase its efficiency (Perez Júnior et al., 2006).

Conclusions

Peruvian carrot plants propagated using T2 seedlings and grown in soil covered with rice hulls broiler litter produced an increased fresh mass of commercial roots and, therefore, increased gross and net incomes.

Peruvian carrot plants propagated using seedlings with weight of 16.52 g, diameter of 20.15 mm and length of 52.73 mm (T2) and grown in soil covered with rice hulls broiler litter produced more an increased fresh mass of commercial roots and, therefore, increased gross and net incomes. The plants propagated with seedlings with mass 8.60 g, diameter 17.73 mm and length 38.05 mm (T4) obtained lower fresh mass of commercial roots lower net income.

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Literature Cited

- Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Gonçalves J. L. M.; Sparovek, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, Germany, v. 22, n. 6, p. 711-728, 2013. <https://dx.doi.org/10.1127/0941-2948/2013/0507>.
- Ávila, V. S.; Bellaver, C.; Paiva, D. P. de; Jaenisch, F. R. F.; Mazzuco, H.; Trevisol, I. M.; Palhares, J. C. P.; Abreu, P. G. de; Rosa, P. S. Boas práticas de produção de frangos de corte. Concórdia: Embrapa Suínos e Aves, 2007. 28p. (Embrapa Suínos e Aves. Circular Técnica, 51). <https://www.embrapa.br/en/suinos-e-aves/busca-de-publicacoes/-/publicacao/433206/boas-praticas-de-producao-de-frangos-de-corte>. 17 Jun. 2018.
- Bueno, S. C. S. Produção de Peruvian carrot (*Arracacia xanthorrhiza* Bancroft) utilizando diferentes tipos de propágulos. Piracicaba: Universidade de São Paulo, 2004. 93p. Thesis PhD. <http://www.teses.usp.br/teses/disponiveis/11/11136/tde-23082004-160429/publico/silvana.pdf>. 22 Jun. 2018.
- Cardoso, E. J. B. N.; Vasconcellos, R. L. F.; Bini, D.; Miyauchi, M. Y. H.; Santos, C. A.; Alves, P. R. L.; Paula, A. M.; Nakatani, A. S.; Pereira, J. M.; Nogueira, M. A. Soil health: looking for suitable indicators. What should be considered to assess the effects of use and management on soil health? *Scientia Agricola*, v.70, n. 4, p. 274-289, 2013. <https://doi.org/10.1590/S0103-90162013000400009>.
- Dethier, J. J.; Effenberger, A. Agriculture and development: A briefreview of the literature. *Economic Systems*, v. 36, n. 2, p. 175-205, 2011 <https://doi.org/10.1016/j.ecosys.2011.09.003>.
- Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Sistema brasileiro de classificação de solos. 3. ed. Rio de Janeiro: Embrapa Solos, 2013. 306 p.
- Filgueira, F. A. R. Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças. Viçosa: Universidade Federal de Viçosa, 2008. 421p.
- Granate, M. J.; Sediya, M. A. N.; Puiatt, M. Batata - Baroa ou Mandioquinha - salsa (*Arracacia xanthorrhiza* Banc.). In.: Paula Júnior, T. J.; Venzon, M. (Eds.). 101 culturas: manual de tecnologias agrícolas, Minas Gerais: Viçosa: EPAMIG, 2007. p. 137-142.
- Heid, D. M.; Heredia Zárate, N. A.; Vieira, M. C.; Torales, E. P.; Carnevali, T. O.; Marafiga, B. G. Produtividade agroeconômica de Peruvian carrot em resposta à adição de cama-de-frango no solo. *Semina: Ciências Agrárias*, v. 36, n. 3, p. 1835-1850, 2015. <https://doi.org/10.5433/1679-0359.2015v36n3Supl1p1835>.
- Heredia Zárate, N. A.; Vieira, M. C.; Graciano, J. D.; Figueiredo, P. G.; Blans, N. B.; Curioni, B. M. Produtividade de Peruvian carrot sob diferentes densidades de plantio e tamanho de mudas. *Ciência e Agrotecnologia*, v. 33, n. 1, p. 139-143, 2009. <https://doi.org/10.1590/S1413-70542009000100020>.
- Heredia Zárate, N. A.; Vieira, M. C.; Rech, J.; Quast, A.; Pontim, B. C. A.; Gassi, R. P. Yield and gross income of arracacha in monocrop and intercropping with the Japanese bunching onion and parsley. *Horticultura Brasileira*, v. 26, n. 2, p. 287-291, 2008. <https://doi.org/10.1590/S0102-05362008000200032>.

- Heredia Zárate, N. A.; Vieira, M. C.; Facco, R. C. Produção de clones de inhame em função do tamanho das mudas. *Acta Scientiarum. Agronomy*, v.25, n.1, p.183-186, 2003. <https://doi.org/10.4025/actasciagron.v25i1.2649>.
- Hoshino, R. T.; Alves, G. A. C.; Melo, T. R.; Barzan, R. R.; Fregonezi, G. A. F.; Faria, R. T. Adubação mineral e orgânica no desenvolvimento de orquídea *Cattlianthe* 'Chocolate drop'. *Horticultura Brasileira*, v. 34, n. 4, p.475-482, 2016. <https://doi.org/10.1590/s0102-053620160405>.
- Kinupp, V. F.; Lorenzi, H. Plantas alimentícias não convencionais (PNAC) no Brasil. São Paulo: Instituto Plantarum, 2014. 768p.
- Leblanc, R. E. G.; Ramón, E.; Puiatti, M.; Sediya, M. A. N.; Finger, F. L.; Miranda, G. V. Influência do pré-enraizamento e de tipos de mudas sobre a população, crescimento e produção da Peruvian carrot "Roxa de Viçosa". *Revista Ceres*, v.55, n. 1, p.74-82, 2008. <http://www.redalyc.org/articulo.oa?id=305226830005>. 02 Ago. 2018.
- Madeira, N. R.; Carvalho, A. D. F.; Silva, G. O.; Pinheiro, J. B.; Pereira, R. B.; Filho, M. M.; Feldberg, N. P.; Moreira, S. O.; Silveira, G. S. R.; Cassia, R. M. Proposição de um sistema de produção de mudas de mandioquinha-salsa. Brasília: Embrapa Hortaliças, 2017. 24p. (Embrapa Hortaliças. Circular Técnica, 161). <https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1082627/proposicao-de-um-sistema-de-producao-de-mudas-de-mandioquinha-salsa>. 28 Jul. 2018.
- Mangiori, V. R. L.; Filho, J. T. Disposição de resíduos sólidos no solo: efeitos nos atributos físicos, químicos e na matéria orgânica. *Semina: Ciências Agrárias*, v. 36, n. 2, p. 747-764, 2015. <https://doi.org/10.5433/1679-0359.2015v36n2p747>.
- Perez Junior, J. H.; Oliveira, L. M.; Costa, R. G. Gestão estratégica de custos. 5.ed. São Paulo: Atlas, 2006. 378 p.
- Sediya, M. A. N.; Casali, V. W. D. Propagação vegetativa da Peruvian carrot. *Informe Agropecuário*, v. 19, n. 190, p. 24-27, 1997. http://www.epamig.br/publicacoes/informe-agropecuario/?cp_informe=8#. 22 Jun. 2018.
- Suja, G.; Byju, G.; A.N. Jyothi A. N.; Veena, S. S.; Sreekumar, J. Yield, quality and soil health under organic vs conventional farming in taro. *Scientia Horticulturae*, v.218, p. 334–343, 2017. <https://doi.org/10.1016/j.scienta.2017.02.006>.
- Taiz, L., Zeiger, E. *Fisiologia Vegetal*. 6.ed. Porto Alegre: Artmed, 2017. 858p.
- Torales, E.P.; Heredia Zárate, N. A.; Vieira, M. C.; Heid, D. M.; Bassi, M. L.; Grando, V. R. Produtividade de mandioquinha-salsa em resposta ao espaçamento entre plantas e peso de mudas. *Bioscience Journal*, v. 31, n. 2, p. 433-444, 2015. <https://doi.org/10.14393/BJ-v31n2a2015-22364>.