NUTRIENT DEMAND BY THE CARROT CROP IS INFLUENCED BY THE CULTIVAR

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ABSTRACT

Farmers must carefully choose the cultivar to be grown for a successful carrot crop. The yield potential of the cultivar may influence nutrient demand and should be known to plan for fertilization application. The aim of this study was to evaluate the cultivar effect on carrot yield and on the nutrient content and quantities allocated to leaves and roots. Three experiments were set up in two crop seasons in Rio Paranaíba, MG, Brazil. In the first season, typical summer, 10 summer cultivars were sown. In the second season, summer-winter (transition), two experiments were set up, one with summer cultivars and the other with winter cultivars. The treatments consisted of the carrot cultivars distributed in randomized blocks with four replications. Fresh and dry matter of the roots and leaves was quantified. Yield was calculated based on fresh matter of the roots. The nutrient content in leaves and roots was determined at the time of harvest. These contents and the dry matter production of roots and leaves were used to calculate nutrient uptake and export. The greatest average for total and commercial yield occurred in the crop under summer conditions. Extraction of N and K for most of the cultivars in the three experiments went beyond the amounts applied through fertilizers. Thus, there was contribution of nutrients from the soil to obtain the yields observed. However, the amount of P taken up was considerably less than that applied. This implies that soil P fertility will increase after cropping. The crop season and the cultivars influenced yield, nutrient content in the leaves and roots, and extraction and export of nutrients by the carrot crop.

Keywords: *Daucus carota* L., nutritional balance, extraction, nutrient export.

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RESUMO: *DEMANDA DE NUTRIENTES PELA CULTURA DA CENOURA É INFLUENCIADA PELA CULTIVAR*

A escolha da cultivar de cenoura deve ser planejada cuidadosamente pelo agricultor para o sucesso da exploração da cultura. O potencial produtivo da cultivar pode influenciar a demanda de nutrientes e deve ser conhecido para estabelecer o plano de fertilização. Objetivou-se, com este trabalho, avaliar o efeito de cultivares sobre a produtividade de cenoura, o teor e as quantidades alocadas de nutrientes em folhas e raízes. Foram implantados três experimentos em duas épocas de cultivo em Rio Paranaíba, MG. Na primeira época, caracterizada como verão típico, foram semeadas 10 cultivares de verão. Na segunda, evidenciada como verão-inverno (transição), instalaram-se dois experimentos, um com cultivares de verão; e outro, de inverno. Os tratamentos consistiram das cultivares de cenoura, distribuídos em blocos casualizados, com quatro repetições. Quantificaram-se a matéria fresca e a seca de raízes e folhas. Com base na matéria fresca de raízes, calculou-se a produtividade. Determinou-se o teor de nutrientes em folhas e raízes por ocasião da colheita. Calcularam-se, com bases nesses teores e na produção de matéria seca de raízes e folhas, a absorção e exportação de nutrientes. A maior média de produtividades total e comercial ocorreu no cultivo em condições de verão. A extração de N e K para a maioria das cultivares nos três experimentos superou as quantidades aplicadas via fertilizantes. Assim, houve contribuição dos nutrientes no solo para obter as produtividades alcançadas. Entretanto, para o P, a quantidade absorvida foi consideravelmente menor que a aplicada. Isso implicou que o solo teve sua fertilidade aumentada em P, após o cultivo. A época de cultivo e as cultivares influenciaram a produtividade, os teores de nutrientes nas folhas e raízes, a extração e a exportação de nutrientes pela cultura da cenoura.

Palavras-chave: Daucus carota L., balanço nutricional, extração, exportação de nutrientes.

INTRODUCTION

Worldwide production of carrot is more than 24 million tons (Singh et al., 2012), which may be consumed fresh or processed in forms such as mini carrots, grated carrots, baby food, and instant soups.

In Brazil, carrot is among the five main garden crops grown and 80 % of the total production supplies the Brazilian domestic market. The Southeast, Northeast, and South regions are the largest producers of this root crop. The State of Minas Gerais stands out in production of this vegetable crop and one of the main producing regions is São Gotardo, in the Alto Paranaíba region (Mesquita Filho et al., 2005).

Yield potential of the crop is from 100 to 120 t ha^{-1}; however, the Brazilian average is much lower, at 33 t ha^{-1} (Embrapa, 2010). Success in growing this crop for high yields involves the integration of various factors, such as soil tillage, the cultivar chosen, and climatic conditions, among others.

Various cultivars are on the market that differ in relation to size, color, shape, sugar content, resistance to pests and diseases, and early maturity (Luz et al., 2009a). The correct choice of the cultivar for a certain crop season may define crop yield (Oliveira et al., 2008).

The cultivar × environment interaction exhibits different responses according to each cultivar (Nicolle et al., 2004). Plant spacing, fertilization levels, irrigation, soil tillage, and other factors may interact in diverse manners, depending on the cultivar. One of the environmental factors that strongly influences yield is soil fertility. Therefore, it is necessary to know the nutritional requirements for a cultivar to achieve its maximum yield potential.

High fertilization rates are common in carrot growing. Fertilization represents around 45 % of the production costs of this crop (CEPEA, 2010) and influences yield, the quality of the root crop (Luz et al., 2009b), and, therefore, the profitability of the crop. Nevertheless, the use of high rates of fertilization, though having a positive effect on yield, may compromise the economic viability and environmental sustainability of growing this crop (Smolen and Sady, 2009; Zumbado and Soto, 2010).

Knowing the nutritional demands of the crop in an accumulated manner and the nutrient uptake rate is highly important to achieve high yields (Singh et al., 2012). For each yield level and cultivar there is the respective nutritional demand; knowing this may assist the producer in applying amounts of nutrients that are not excessive, thus achieving reduction in production costs.

The nutrient content in the plant may be used in estimation of the amount of nutrients taken up and exported by the crop. These amounts are essential in establishing an effective fertilization system (Sharma et al., 2012).

To establish a more efficient method of fertilizer recommendation, based on nutritional balance, it is necessary to obtain the nutrient requirements of the different cultivars in accordance with the desired yield, as has been developed for the soybean crop (Santos et al., 2008). The aim of this study was to evaluate the effect of cultivars on yield, and on the content, extraction, and export of nutrients by the carrot crop.

MATERIAL AND METHODS

Three experiments were set up in two crop seasons in the experimental area of the COOPADAP (Cooperativa Agropecuária do Alto Paranaíba) in the municipality of Rio Paranaíba, MG, in 2012. The geographic coordinates of the location are 19° 12' 21" S and 46° 10' 05" O, at an altitude of 1,140 m. The climate according to the Köppen international classification system is Aw, defined as tropical with a dry season. The soil was classified as a Latossolo Vermelho-Amarelo (Oxisol) with a very clayey texture.

Before planting, soil samples were taken from the crop areas and chemical characterization of the soils was carried out (Table 1). Planting density of the cultivars was 1.2 million seeds per hectare. For all the experiments, fertilization at planting was 1.0 t ha^{-1} of simple superphosphate and 1.5 t ha^{-1} of the fertilizer 04-30-16 (N-P_2O_5-K_2O) broadcast and incorporated to 15 cm depth with a rotary hoe bed former. The fertilizer 21-00-21 was used for topdressing fertilization. Two applications were made at the rate of 200 kg ha^{-1} each, the first at 30 days after sowing (DAS) and the second at 70 DAS. Immediately after distribution of the topdressing fertilizer, the crop was irrigated for fertilizer incorporation. The fertilizer application rates, formulations, and periods were based on those adopted by producers in the Alto Paranaiba region of MG for the carrot crop.

The treatments in the three experiments consisted of carrot cultivars. A randomized block experimental design was used with four replications. In the first experiment, considered to be typical summer sowing (hot and rainy), the following cultivars were sown: AF 2031, AF 2335, Amanda, Bruna, Carandaí, Juliana, Marli, Poliana, Suprema, and Verano. Sowing of this experiment occurred on January 24, 2012 and harvest was on May 18, 2012.

The second and third experiments were set up on March 1st, 2012, considered to be a transition crop period (summer-winter). In the second experiment, typical summer cultivars were sown: AF2031, Amanda, Bruna, Carandaí, Diana, Juliana, Marli, Nativa, Poliana, Sigma, Suprema, and Verano, which were harvested on June 21, 2012. In the third experiment, typical winter cultivars were sown: Baltimore, Belgrado, Concerto, Excelso, Forto, Hana, Invicta, Maestro, Nayarit, Romance, and Soprano, which were harvested on July 3, 2012.

Each plot consisted of a crop bed of 1.75 m width (distance between pathways), with 1.20 m width at the upper part and 6 m length. Four double rows were arranged in each crop bed. The useful part of the plots consisted of the four central meters of the bed.

Table 1. Chemical characterization of the soil in the carrot cropping areas

Property	1st experiment		2nd and 3rd experiments	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
pH($CaCl_2$)	5.5	5.6	5.1	5.4
P-res (mg L^{-1})	9.2	7.5	9.2	7.5
P (mg dm^{-3})	120	64	73	56
OM (g dm^{-3})	37	45	42	35
K^+ ($mmol_c$ dm^{-3})	3.7	2.9	3.4	3.5
Ca^{2+} ($mmol_c$ dm^{-3})	42	37	37	43
Mg^{2+} ($mmol_c$ dm^{-3})	9	9	10	10
Al^{3+} ($mmol_c$ dm^{-3})	0	0	0	0
H+Al ($mmol_c$ dm^{-3})	33	28	39	31
SB ($mmol_c$ dm^{-3})	54.7	48.9	50.4	56.5
CEC ($mmol_c$ dm^{-3})	88.7	77.5	100	88.5
V (%)	61.7	63.1	50.4	63.8
B (mg dm^{-3})	1.01	1.16	0.92	0.81
Cu (mg dm^{-3})	2.5	1.7	1.9	1.8
Fe (mg dm^{-3})	25	23	33	27
Mn (mg dm^{-3})	33	27	2.4	1.4
Zn (mg dm^{-3})	2.4	1.4	7.4	6.4

Extractors: P and K: Mehlich-1; Ca^{2+}, Mg^{2+}, and Al^{3+}: KCl 1 mol L^{-1}; H+Al: extracted by 0.5 mol L^{-1} calcium acetate at pH 7.0; B: hot water; Cu, Fe, Mn, and Zn: DTPA pH 7.3.

Crop treatments such as thinning, irrigation, and weed, pest, and disease management were carried out according to practices usually adopted by carrot producers in the Alto Paranaiba region of Minas Gerais.

Carrots were harvested when most of the roots had achieved the most acceptable commercial standard, class 22. This class includes roots from 22 to 26 cm length, with diameter variation of less than 1 cm, without attack from pests or disease or the occurrence of green shoulder or cracking.

The roots were separated into commercial and non-commercial produce based on the classification criteria in effect for the carrot market. Based on commercial root production and total root production (commercial + non-commercial), commercial and total yield was calculated. In addition to roots, leaves were collected from the useful area, which were subsequently washed, and leaf fresh matter was quantified. Then a subsample of roots and another of leaves were weighed and placed to dry in an air circulation laboratory oven at 70 °C for 72 h. Based on the weight of the subsamples after drying, the dry matter content in the roots and leaves was determined.

The dry matter yield was obtained by the product of the total yield and the dry matter content of each part harvested (roots or leaves). The dried and weighed subsamples were then ground to determine the nutrient content according to methods described by Malavolta et al. (1997). The ratio between the dry matter productions of roots and of leaves was calculated.

The nutrient extraction values were obtained by the sum of the amounts of nutrients allocated to the roots and to the leaves. These amounts were obtained by the product of the dry matter yield and the nutrient contents in the respective parts of the plants. Export was considered as the amount of nutrients allocated to the roots.

The data of each experiment were subjected to analysis of variance. When an effect of treatment was detected, the mean values were clustered by the Scott-Knott criterion at 5 %. The software Sisvar, version 5.3 was used for statistical analyses (Ferreira, 2011).

RESULTS AND DISCUSSION

The greatest overall mean of total and commercial yield occurred in cropping under summer conditions. In transition cropping (summer-winter), both the summer and the winter cultivars had lower total and commercial yields than in the first experiment (Table 2). This occurred due to the greater difficulty of adapting the best cultivar to a growing condition that has climate characteristics of winter and summer simultaneously, which may increase the incidence of diseases and physiological disturbances (Luz et al., 2009a).

In the three experiments, there were differences in the total and commercial yields of the cultivars (Table 2). The greatest total yield was not always associated with the greatest commercial yield. In the experiment in the summer crop (experiment 1), for example, the cultivar AF 2335 was in the group that had the greatest total yield; however, it exhibited less commercial yield than the cultivars Juliana, Marli, Poliana, and Verano. In the experiments set up in the summer - winter transition season (experiments 2 and 3), the number of cultivars that had greater total and commercial yield was less. Among the summer cultivars (experiment 2), the Nativa cultivar stands out, and among the winter cultivars (experiment 3), the cultivars Belgrado and Hana stand out.

The bigger difference between total and commercial yield of some cultivars may be explained by greater discard of roots due to defects such as cracks, the occurrence of galls, and green shoulder. Under high temperature conditions, these defects may occur to a greater degree and affect the commercial quality of carrot (Paulus et al., 2012). The smaller number of cultivars with greater commercial yield in the summer-winter transition crop (experiments 2 and 3) may be explained by the growing conditions, sometimes summer, sometimes winter, which impedes better adaptation of the cultivar to the environmental conditions of this growing season.

The mean dry matter content in the roots of the cultivars of the three experiments ranged from 8.6 to 10.3 % (Table 2). There was no effect of the cultivars on the dry matter contents in the roots only in the summer-winter transition crop with the summer cultivars (experiment 2). In the summer crop (experiment 1), the greatest dry matter contents in the roots were of the cultivars AF 2335, Bruna, Carandaí, and Juliana. In the summer-winter transitions crop season with winter cultivars (experiment 3), the greatest dry matter contents in the roots were in Maestro and Romance. The variation in dry matter contents in the roots is similar to that observed in other studies (Smolen and Sady, 2009; Figueiredo Neto et al., 2010). Knowledge of the dry matter content of the cultivar is used in estimation of dry matter yield based on total or commercial yield of the roots. This estimate is necessary for calculation of the amounts of nutrients accumulated and exported by the roots.

The mean value of the ratio between the dry matter of the roots and of the leaves ranged from 2.0 to 2.4, and in all the experiments exhibited differences among cultivars (Table 2). The greatest ratio was of the cultivar AF 2335 in the summer crop season (experiment 1), of the cultivars Juliana and Sigma (experiment 2), and of the cultivars Baltimore and Romance (experiment 3). The summer cultivars like Amanda, Bruna, Carandaí, Diana, Nativa, and Poliana exhibited the lowest ratios between root dry matter and shoot dry matter. In addition to the factor of the cultivar, this ratio is affected by climatic conditions, especially temperature. Greater temperatures reduce this ratio, i.e., there is greater allocation of photoassimilates in the leaves to the detriment of the roots (Hussain et al., 2008).

The ratio between root dry matter and leaf dry matter may be important in the estimate of nutrient uptake by carrot because, based on root dry matter production (more easily quantifiable), leaf yield may be estimated. The yields of roots and leaves, together with the respective nutrient contents, are determining factors for uptake and export of nutrients, which must be known for efficient fertilizer management (Oliveira et al., 2005; Santos et al., 2008).

For most of the nutrients, the cultivars differed in regard to the contents in the roots and leaves and the extraction and export of most of the

Table 2. Total yield (TY) and commercial yield (CY) of roots, root dry matter (RDM) and leaf dry matter (LDM), root dry matter content (RDMC), and ratio of root dry matter and leaf dry matter (RDM/LDM) in summer carrot cultivars in summer cropping (Experiment 1), and in summer and winter cultivars in summer-winter transition cropping (Experiments 2 and 3)

Cultivar	TY	CY	RDM	LDM	RDMC	RDM/ LDM
	t ha^{-1}				%	
	Exp. 1 – Summer cultivars in summer cropping					
AF 2031	66.3 b	57.3 b	5.9 b	3.1 b	8.9 b	1.9 b
AF 2335	76.8 a	62.2 b	7.9 a	3.1 b	10.4 a	2.6 a
Amanda	69.7 a	58.6 b	6.5 b	3.4 b	9.4 b	1.9 b
Bruna	60.2 b	49.4 c	6.3 b	3.4 b	10.4 a	1.9 b
Carandaí	59.2 b	43.9 c	6.3 b	3.8 a	10.5 a	1.6 c
Juliana	75.2 a	72.9 a	7.3 a	3.2 b	10.0 a	2.2 b
Marli	74.8 a	66.9 a	7.1 a	3.4 b	9.5 b	2.1 b
Poliana	75.6 a	66.5 a	7.3 a	3.8 a	9.7 b	1.9 b
Suprema	65.6 b	58.6 b	6.5 b	3.2 b	9.8 b	1.9 b
Verano	72.1 a	67.7 a	7.1 a	3.2 b	9.8 b	2.1 b
Mean	69.5	60.2	6.9	3.4	9.8	2.0
F	4.35**	7.02**	3.8**	2.36*	6.60**	9.1**
CV (%)	8.9	11.1	9.6	10.5	3.9	8.6
	Exp. 2 – Summer cultivars in summer-winter transition cropping					
AF 2031	58.2 b	48.1 c	5.1 a	2.6 a	8.6 a	2.0 c
Amanda	53.7 b	45.4 d	4.7 b	2.4 b	8.5 a	1.9 c
Bruna	60.8 a	56.8 b	5.1 a	2.6 b	8.5 a	2.0 c
Carandaí	49.1 c	42.9 d	4.5 b	2.6 a	9.1 a	1.7 c
Diana	60.8 a	55.6 b	5.5 a	2.2 b	8.7 a	2.4 b
Juliana	62.3 a	58.2 b	5.5 a	2.0 c	8.7 a	2.7 a
Marli	63.9 a	52.3 c	5.5 a	2.4 b	8.7 a	2.3 b
Nativa	63.9 a	63.7 a	5.1 a	2.6 a	7.9 a	1.9 c
Poliana	58.6 b	48.5 c	5.5 a	2.8 a	9.2 a	2.0 c
Sigma	38.1 d	26.2 e	3.2 c	1.2 d	8.2 a	2.5 a
Suprema	53.1 b	42.6 d	4.5 b	2.0 c	8.3 a	2.2 b
Verano	55.8 b	50.1 c	4.7 b	2.0 c	8.5 a	2.2 b
Mean	56.6	49.3	4.9	2.2	8.6	2.2
F	8.48**	24.01**	7.92**	15.56**	3.10^{ns}	9.60**
CV (%)	8.9	8.0	9.6	9.1	4.9	8.9
	Exp. 3 – Winter cultivars in summer-winter transition cropping					
Baltimore	47.9 d	44.6 b	4.9 c	1.4 c	10.2 b	3.4 a
Belgrado	73.6 a	59.7 a	7.7 a	2.9 a	10.3 b	2.6 c
Concerto	46.7 d	42.7 c	4.7 c	1.6 c	9.9 b	3.2 b
Excelso	55.5 c	52.8 b	5.7 b	2.1 b	10.4 b	2.8 b
Forto	54.5 c	41.4 c	5.6 b	2.6 a	10.3 b	2.2 c
Hana	65.9 b	56.6 a	6.1 b	2.4 a	8.6 c	2.4 c
Invicta	42.7 d	39.9 c	4.4 c	2.1 b	10.5 b	2.0 c
Maestro	53.4 c	48.9 b	5.9 b	2.9 a	11.0 a	2.0 c
Nayarit	56.1 c	49.9 b	5.7 b	2.1 b	10.6 b	2.9 b
Romance	43.9 d	40.0 c	5.0 c	1.4 c	11.7 a	3.6 a
Soprano	52.2 c	49.3 b	5.2 b	2.6 a	10.3 b	2.1 c
Mean	53.8	47.9	5.6	2.3	10.3	2.4
F	17.43**	8.45**	9.65**	11.87**	9.45**	9.91**
CV (%)	8.3	9.7	10.2	14.5	4.8	13.2

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

nutrients (Tables 3 at 8). In general, the cultivars Juliana, Marli, Poliana, and Verano in the summer and transition crops had lower nutrient contents in the leaves and in the roots (Tables 3 and 5). The lower content is an indication that these cultivars accumulated more dry matter per nutrient unit taken up. This behavior is interesting for yield and, in fact, in the summer crop, these cultivars were highest yielding. In a similar manner, the winter cultivars in the transitions crop that had the lowest nutrient contents in leaves and in roots, Belgrado and Hana, were the highest yielding (Table 7). An exception was the K content in the leaves of the Belgrado cultivar, which was among the highest values found. The contents of Ca, Mg, K, and Zn are similar to those obtained by Nicolle et al. (2004) in various carrot cultivars with orangish colored roots in the south of France.

The contrasting nutrient contents among the cultivars associated with the different yields resulted in differences between the cultivars in regard to extraction and export of most of the nutrients (Tables 4, 6, and 8). Thus, it is necessary to consider the particular aspects of cultivars and of cropping systems on nutrient contents so as to obtain a better estimate of their extractions and exports for a balance between the applied and required amounts of nutrients. The amounts of K exported by the cultivars Juliana, Marli, and Verano in the summer crop (Table 4) and by the Nativa cultivar in the transition crop (Table 6) stand out, which went beyond 300 kg ha^{-1} of K. In the experiment with winter cultivars in the

Table 3. Nutrient contents in the roots and leaves of summer carrot cultivars sown in the summer crop season (Experiment 1)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg^{-1}						mg kg^{-1}				
	Root content										
AF 2031	22.1	5.6 a	58.5 a	0.89 a	1.19 a	1.05 b	37.3 a	2.1 a	322 a	1.8 b	13.9
AF 2335	21.8	5.1 b	43.0 b	0.86 a	1.17 a	1.27 a	33.4 a	2.1 a	181 b	2.4 a	13.9
Amanda	19.1	4.8 b	41.1 b	0.84 a	1.05 a	1.06 b	35.1 a	2.2 a	321 a	2.1 b	13.8
Bruna	24.3	4.7 b	40.4 b	0.89 a	0.90 b	0.96 b	34.9 a	2.0 a	254 b	2.4 a	12.2
Carandaí	23.0	4.4 b	44.4 b	0.95 a	1.10 a	1.29 a	32.9 a	2.1 a	209 b	2.8 a	17.6
Juliana	20.2	5.1 b	41.3 b	0.68 b	1.07 a	1.20 a	24.1 c	2.1 a	177 b	2.4 a	13.9
Marli	22.6	4.9 b	46.1 b	0.69 b	1.07 a	1.14 a	29.7 b	2.1 a	235 b	1.9 b	13.6
Poliana	20.8	5.5 a	45.0 b	0.93 a	0.92 b	0.99 b	32.5 a	1.6 b	244 b	2.2 a	12.0
Suprema	21.6	4.8 b	43.4 b	0.92 a	0.84 b	0.97 b	30.4 b	1.3 b	215 b	1.9 b	12.2
Verano	21.3	4.9 b	46.5 b	0.95 a	1.03 a	0.82 b	36.5 a	2.1 a	194 b	1.8 b	12.0
Mean	21.7	5.0	44.9	0.86	1.06	1.07	32.7	1.9	235	2.2	13.5
F	1.73^{ns}	2.87^{*}	4.09^{**}	4.97^{**}	5.53^{**}	2.65^{*}	4.24^{**}	2.41^{*}	2.65^{*}	3.35^{**}	2.15^{ns}
CV (%)	10.3	8.4	11.4	10.3	11.4	16.9	11.5	17.3	27.2	16.2	16.7
	Leaf content										
AF 2031	16.3 a	1.15 a	49.6	40.6	1.83 a	1.45 b	53.9 a	83.9 b	2,313 b	9.3 b	24.9 b
AF 2335	13.7 b	0.86 c	45.3	41.6	1.43 b	2.28 a	42.7 b	109.3 a	1,867 b	8.6 b	24.6 b
Amanda	15.7 a	0.76 d	45.2	39.5	1.49 b	1.73 b	46.1 b	94.3 b	2,068 b	8.9 b	25.8 b
Bruna	14.4 b	0.99 b	45.7	36.6	1.49 b	1.85 b	47.3 b	136.1 a	1,622 b	7.6 b	26.2 b
Carandaí	17.2 a	1.15 a	47.1	42.3	1.57 b	2.22 a	31.8 d	127.1 a	3,852 a	12.2 a	27.5 b
Juliana	13.6 b	0.76 d	43.4	37.9	1.36 b	1.82 b	47.0 b	90.6 b	1,930 b	6.7 b	25.4 b
Marli	14.7 b	0.86 c	47.7	38.7	1.66 a	2.23 a	48.1 b	118.4 a	1,640 b	8.0 b	30.5 a
Poliana	15.4 a	1.05 b	40.9	47.2	1.89 a	2.30 a	42.4 b	99.1 b	2,251 b	8.4 b	26.2 b
Suprema	14.4 b	0.92 c	38.8	42.7	1.70 a	1.60 b	44.4 b	118.1 a	2,562 b	12.5 a	31.4 a
Verano	14.7 b	0.92 c	49.7	43.2	1.46 b	2.28 a	39.6 c	114.8 a	1,707 b	10.8 a	23.6 b
Mean	15.0	0.94	45.3	41.0	1.59	1.98	44.3	109.2	2,181	9.3	26.6
F	2.59^{*}	9.54^{**}	2.09^{ns}	0.90^{ns}	4.34^{**}	3.35^{**}	11.25^{**}	3.86^{**}	3.48^{**}	4.09^{**}	2.36^{**}
CV (%)	9.5	9.8	10.8	15.8	10.7	17.8	7.9	15.7	32.6	20.4	12.4

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ns: not significant.

Table 4. Nutrient extraction and export by summer carrot cultivars sown in the summer crop season (Experiment 1)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	kg ha^{-1}						g ha^{-1}				
	Nutrient extraction (accumulation of nutrients in the leaves + roots)										
AF 2031	181.9	36.7 b	495.6	130.9	12.8	10.7 b	386.8	261.0 c	9,087 b	38.7 b	157.2
AF 2335	215.8	43.0 a	482.8	134.7	13.8	17.0 a	397.9	353.3 c	7,233 b	45.6 b	186.8
Amanda	179.1	34.0 b	425.3	141.0	11.9	13.0 b	394.7	337.3 c	9,253 b	43.8 b	178.9
Bruna	200.0	32.6 b	405.4	126.4	10.5	12.2 b	377.6	468.0 a	7,010 b	40.3 b	163.7
Carandaí	210.7	31.8 b	461.1	172.4	13.0	16.8 a	329.8	508.7 a	16,670 a	65.6 a	217.8
Juliana	195.9	40.7 a	452.2	129.9	12.6	15.2 a	335.7	327.0 c	7,602 b	40.7 b	189.0
Marli	210.5	38.1 a	490.1	137.8	13.4	15.2 a	375.6	417.0 b	7,354 b	41.1 b	201.8
Poliana	213.3	44.2 a	486.0	185.2	14.0	16.0 a	397.7	381.9 b	10,209 b	47.4 b	186.8
Suprema	184.8	33.6 b	403.4	142.8	10.9	11.3 b	338.0	390.2 b	9,561 b	52.9 b	179.7
Verano	199.0	38.1 a	495.2	151.9	14.0	13.4 b	389.2	399.1 b	7,172 b	49.2 b	165.5
Mean	199.2	37.3	459.7	145.3	12.8	14.2	371.8	384.3	9,115	46.4	182.7
F	1.02^{ns}	3.09*	2.19^{ns}	2.06^{ns}	2.24^{ns}	3.82**	1.87^{ns}	6.00**	4.18**	3.92**	2.15^{ns}
CV (%)	13.5	13.3	10.8	18.6	12.4	16.5	10.5	15.1	31.1	17.5	13.6
	Export (accumulation of nutrients in the roots)										
AF 2031	113.6 b	28.6 b	298.7 a	4.7 b	6.1 b	5.5 b	190.2 a	10.3 b	1,677	9.3 b	82.5 b
AF 2335	140.0 a	32.6 a	276.3 a	5.7 a	7.5 a	8.1 a	214.6 a	13.2 a	1,169	15.2 a	110.8 a
Amanda	105.6 b	26.5 b	226.3 b	4.7 b	5.9 b	5.9 b	194.9 a	12.2 a	1,783	11.3 b	90.4 b
Bruna	124.6 b	24.1 b	207.3 b	4.7 b	4.7 b	4.9 b	179.5 a	10.3 b	1.317	12.0 b	76.2 b
Carandaí	106.0 b	20.3 b	206.0 b	4.5 b	5.1 b	5.9 b	112.1 a	9.5 b	974	13.0 b	109.6 a
Juliana	146.3 a	37.1 a	300.5 a	4.9 b	7.9 a	8.9 a	176.5 a	15.0 a	1,272	17.6 a	104.5 a
Marli	143.6 a	31.6 a	293.6 a	4.5 b	6.9 a	7.3 a	188.8 a	13.0 a	1,459	12.0 b	96.6 a
Poliana	136.3 a	35.4 a	291.5 a	6.1 a	6.1 b	6.5 b	209.1 a	10.3 b	1,570	14.2 a	88.3 b
Suprema	122.2 b	27.2 b	245.2 b	5.3 a	4.9 b	5.5 b	172.0 a	7.5 b	1,207	11.0 b	77.2 b
Verano	141.1 a	32.8 a	308.2 a	6.3 a	8.7 a	5.5 b	240.9 a	13.6 a	1,276	12.0 b	85.9 b
Mean	128.0	29.6	265.2	5.1	6.3	6.5	191.9	11.5	1,331	12.8	92.2
F	2.40*	4.54**	4.03**	2.98*	4.83**	2.95*	2.59*	3.55**	1.44^{ns}	4.16**	2.41*
CV (%)	15.8	16.6	15.1	15.9	19.4	23.5	16.1	20.9	30.3	18.2	17.8

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

transition crop, the extractions and exports were less than in the other crops (Table 8). The lower extractions and exports of most of the nutrients by the cultivars Concerto, Forto, and Invicta stand out. The lower extractions of these cultivars are associated both with the lower contents in the leaves and in the roots (Table 7), as well as with the lower yields (Table 2).

The extraction of N and K for most of the cultivars in the three experiments went beyond the amounts applied through fertilizers. Thus, there was the contribution of soil nutrients to obtain the yields observed, without which there would have been nutritional limitation to yield. Nevertheless, exports were less than the amounts applied through fertilizer. In the nutrient balance, it is necessary to consider

Table 5. Nutrient contents in the roots and leaves of summer carrot cultivars sown in the summer-winter transition crop season (Experiment 2)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg^{-1}						mg kg^{-1}				
					Root content						
AF 2031	19.8 a	3.8 c	52.2 b	4.3 b	0.89 c	1.11 a	37.0	2.1	248 b	3.2 c	16.9 a
Amanda	20.4 a	3.8 c	60.6 a	4.5 b	0.84 c	0.86 b	36.5	1.9	260 b	3.0 c	13.4 c
Bruna	18.9 a	3.6 c	51.0 b	4.0 b	0.82 c	1.08 a	39.7	2.3	254 b	3.8 b	16.4 a
Carandaí	19.8 a	4.1 b	53.8 b	5.2 a	1.00 b	1.07 a	36.4	2.0	305 b	3.9 b	18.8 a
Diana	17.2 a	4.2 b	47.6 c	4.9 a	0.90 c	1.05 a	40.9	1.9	234 b	4.9 a	17.6 a
Juliana	18.1 a	3.2 d	54.2 b	4.2 b	0.98 b	0.87 b	37.5	1.8	291 b	3.7 b	14.4 b
Marli	19.8 a	4.2 b	58.1 a	4.0 b	0.96 b	0.82 b	37.0	1.7	217 b	3.6 b	15.4 b
Nativa	19.7 a	3.0 d	61.4 a	4.7 a	1.21 a	0.89 b	34.3	1.7	249 b	3.5 c	12.9 c
Poliana	17.9 a	3.6 c	42.5 c	3.9 b	0.67 d	1.11 a	33.3	2.0	269 b	3.1 c	15.5 b
Sigma	21.0 a	3.3 d	54.0 b	5.1 a	1.05 b	0.87 b	35.3	2.1	426 a	2.7 c	13.6 c
Suprema	18.8 a	4.5 a	59.2 a	4.5 b	0.98 b	0.91 b	35.8	1.8	226 b	3.4 c	16.7 a
Verano	22.2 a	4.9 a	53.6 b	4.8 a	1.19 a	0.97 b	37.5	1.7	263 b	2.9 c	16.9 a
Mean	19.5	3.8	54.0	4.5	0.96	0.97	36.8	1.9	270	3.5	15.7
F	2.21**	9.57**	8.42**	3.23**	10.08**	3.83**	1.77^{ns}	1.53^{ns}	3.33**	9.65**	7.33**
CV (%)	9.6	9.3	6.9	11.0	9.9	11.4	8.6	15.4	22.4	10.5	8.7
					Leaf content						
AF 2031	17.6	0.97 a	40.8 b	34.2 b	1.5 b	2.5 b	37.0 b	3.1 a	3,776	18.1 b	51.8 b
Amanda	17.4	0.85 b	42.2 b	34.0 b	1.6 b	2.2 b	34.4 b	2.1 c	2,169	14.1 c	64.2 a
Bruna	17.6	1.00 a	40.5 b	36.3 b	1.5 b	2.7 a	40.4 a	2.3 b	3,810	19.1 b	58.0 b
Carandaí	17.6	0.94 a	50.3 a	39.5 a	1.5 b	2.3 b	36.4 b	1.9 c	3,199	15.4 c	53.3 b
Diana	17.6	1.00a	54.0 a	36.7 b	1.6 b	2.4 b	40.9 a	1.9 c	3,293	16.5 c	57.4 b
Juliana	18.0	0.89 b	45.2 b	35.2 b	1.7 b	2.1 b	30.9 c	2.3 b	5,146	17.4 b	71.9 a
Marli	17.6	1.02 a	38.9 b	34.6 b	1.5 b	3.2 a	38.9 a	3.1 a	3,731	21.4 a	57.8 b
Nativa	16.0	0.81 b	52.6 a	31.5 b	1.6 b	2.1 b	42.7 a	2.5 b	3,221	12.2 c	64.9 a
Poliana	17.6	0.91 b	40.8 b	39.0 a	1.7 a	2.3 b	34.5 b	2.6 b	3,911	17.3 b	57.2 b
Sigma	18.6	0.85 b	55.2 a	35.1 b	1.8 a	1.9 b	37.0 b	3.1 a	3,511	18.2 b	76.9 a
Suprema	17.6	0.87 b	41.6 b	40.9 a	1.8 a	2.9 a	35.8 b	2.3 b	3,981	18.4 b	59.6 b
Verano	18.0	0.85 b	48.8 a	39.0 a	1.9 a	2.8 a	38.5 a	2.8 a	4,171	22.8 a	68.9 a
Mean	17.6	0.91	45.9	36.3	1.6	2.4	37.3	2.5	3,660	17.6	61.8
F	1.86^{ns}	2.56*	6.61**	4.80**	5.99**	5.15**	6.10**	6.61**	1.82^{ns}	4.10**	4.50**
CV (%)	5.0	9.8	10.0	7.0	6.4	13.5	7.1	14.1	28.5	16.3	11.6

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

both the total amounts taken up (roots and leaves), as well as exports (roots). Meeting the requirements of uptake allows the effect of nutritional limitation on yield to be minimized, while the application of at least the exports allows maintenance of soil fertility.

In the case of N, low levels of this nutrient in the soil may lead to reduction in organic matter in the soil. Costa et al. (2008) observed that the lowest contents of organic matter were observed in the soil under pasture without N fertilization. A suitable N

Table 6. Nutrient extraction and export by summer carrot cultivars sown in the summer-winter transition crop season (Experiment 2)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	kg ha^{-1}						g ha^{-1}				
	Nutrient extraction (accumulation of nutrients in the leaves + roots)										
AF 2031	144.4 a	21.3 b	365.2 b	109.1 b	8.3 b	12.0 a	280.5 a	18.4 a	10,935	62.5 a	217.6 a
Amanda	135.5 a	19.1 b	380.0 b	107.9 b	7.7 b	9.3 b	251.1 a	13.6 b	6,477	48.3 b	218.2 a
Bruna	142.2 a	21.3 b	365.3 b	112.5 b	8.1 b	12.2 a	306.8 a	17.4 a	11,034	67.9 a	231.0 a
Carandaí	135.3 a	20.9 b	376.0 b	128.2 a	8.5 b	11.0 a	259.2 a	13.8 b	10,110	59.0 a	227.7 a
Diana	132.6 a	24.5 a	378.9 b	111.3 b	8.5 b	11.1 a	312.1 a	14.2 b	9,000	63.7 a	226.5 a
Juliana	134.2 a	19.1 b	385.7 b	94.3 b	8.7 b	9.1 b	266.9 a	14.4 b	12,235	56.4 a	224.7 a
Marli	151.5 a	26.0 a	415.0 a	103.2 b	8.7 b	12.0 a	295.0 a	16.8 a	9,960	70.4 a	221.7 a
Nativa	142.6 a	17.2 c	451.8 a	109.3 b	10.3 a	10.1 b	289.0 a	15.4 a	9,996	50.5 b	241.3 a
Poliana	145.8 a	22.1 b	342.3 b	128.0 a	8.3 b	12.4 a	275.2 a	17.8 a	12,026	64.1 a	239.9 a
Sigma	89.4 c	11.4 d	241.1 c	61.7 c	5.7 c	5.3 c	158.4 c	10.3 b	5,916	32.2 c	142.8 b
Suprema	117.0 b	21.5 b	341.3 b	100.2 b	7.7 b	9.7 b	227.7 b	12.6 b	8,956	51.5 b	191.4 a
Verano	143.2 a	24.9 a	354.9 b	103.0 b	9.5 a	10.3 b	258.2 a	13.8 b	9,826	61.0 a	222.5 a
Mean	134.5	20.7	366.5	105.3	8.3	10.3	265.1	15.0	9,706	57.4	217.0
F	5.73**	9.29**	6.77**	11.49**	11.10**	9.35**	8.05**	5.21**	2.05^{ns}	6.28**	4.45**
CV (%)	10.4	12.4	10.5	9.6	8.2	12.6	11.0	13.9	27.8	14.5	11.6
	Export (accumulation of nutrients in the roots)										
AF 2031	81.9 b	15.6 b	216.0 b	17.6 c	3.6 c	4.7 a	132.4 b	8.5 a	1,026 a	13.2 c	85.0 a
Amanda	78.5 b	14.4 b	234.2 b	17.0 c	3.2 c	3.2 b	141.1 b	7.3 b	990 a	11.6 c	60.8 b
Bruna	91.5 a	17.4 b	246.0 b	19.3 b	3.8 c	5.3 a	191.8 a	10.7 a	1,221 a	18.2 b	84.2 a
Carandaí	77.9 b	16.0 b	212.3 b	20.5 b	3.8 c	4.3 a	143.2 b	7.7 b	1,225 a	15.4 b	84.6 a
Diana	84.2 b	20.3 a	231.4 b	24.0 a	4.5 b	5.1 a	198.9 a	8.9 a	1,134 a	23.5 a	93.1 a
Juliana	91.9 a	16.2 b	274.4 a	21.3 b	4.9 b	4.5 a	189.2 a	9.1 a	1,472 a	19.1 b	77.7 a
Marli	90.4 a	19.3 a	265.3 a	18.0 c	4.5 b	3.9 a	168.3 a	7.5 b	979 a	16.6 b	86.0 a
Nativa	98.8 a	15.0 b	308.0 a	23.7 a	5.9 a	4.5 a	172.2 a	8.5 a	1,233 a	17.4 b	64.7 b
Poliana	79.7 b	16.2 b	189.0 b	17.4 c	3.0 d	5.1 a	147.6 b	8.9 a	1,182 a	13.6 c	85.6 a
Sigma	45.2 d	7.1 c	116.2 c	10.9 d	2.2 e	1.8 c	75.8 d	4.5 c	919 a	5.9 d	42.2 c
Suprema	66.1 c	15.8 b	206.7 b	15.8 c	3.4 c	3.2 b	125.3 c	6.3 b	789 a	12.0 c	73.6 a
Verano	94.9 a	20.9 a	229.2 b	20.5 b	5.1 b	4.0 a	159.6 b	7.1 b	1,128 a	12.6 c	80.3 a
Mean	81.7	16.2	227.3	18.9	4.1	4.0	155.5	7.9	1,107	15.0	76.3
F	7.66**	15.97**	12.64**	8.48**	17.92**	9.00**	12.18**	7.22**	2.13*	18.73**	10.66**
CV (%)	12.9	10.9	11.8	12.9	12.0	15.4	12.4	14.9	22.3	13.9	11.3

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

supply may contribute to reducing degradation of organic matter or even increase it and, that way, maintain or improve the physical, chemical, and biological properties of the soil that interact with organic matter.

Mean extraction of P in the experiments ranged from 20.7 to 37.3 kg ha^{-1} and, in all cases, was influenced by the cultivar (Table 4, 6, and 8). This is equivalent to extraction of 47 to 85 kg ha^{-1} of P_2O_5. The amount taken up is considerably less than that

Table 7. Nutrient contents in the roots and leaves of winter carrot cultivars sown in the summer-winter transition crop season (Experiment 3)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg^{-1}						mg kg^{-1}				
	Root content										
Baltimore	16.9 b	4.5 b	47.1 c	0.67 c	0.84 c	1.08 b	30.6 c	2.04	273	5.9 a	15.6 c
Belgrado	9.0 c	4.4 b	41.3 d	0.67 c	0.96 c	0.88 c	29.0 c	2.81	280	2.9 c	15.9 c
Concerto	11.6 c	4.3 b	51.5 b	1.22 a	1.76 a	0.87 c	36.9 a	2.99	449	4.0 b	18.3 b
Excelso	12.5 c	5.1 a	44.2 c	0.68 c	1.18 b	1.05 b	29.6 c	3.51	385	4.5 b	22.5 a
Forto	11.3 c	3.7 c	38.9 d	1.06 b	1.18 b	1.03 b	28.8 c	2.43	405	4.4 b	18.4 b
Hana	18.3 b	3.5 c	41.7 d	0.73 c	0.86 c	1.23 a	26.2 d	2.09	372	4.1 b	14.6 c
Invicta	10.5 c	4.6 b	45.6 c	0.77 c	0.91 c	0.76 c	29.4 c	1.89	322	1.9 d	13.1 c
Maestro	21.4 a	4.2 b	48.6 b	0.70 c	1.16 b	1.25 a	27.6 c	2.56	310	3.1 c	18.9 b
Nayarit	10.4 c	4.1 c	46.8 c	0.73 c	0.89 c	1.05 b	32.7 b	2.33	353	3.5 c	14.3 c
Romance	16.7 b	4.3 b	52.5 b	0.65 c	1.11 b	0.97 c	28.3 c	2.65	229	3.3 c	16.4 c
Soprano	11.2 c	4.9 a	57.4 a	0.75 c	1.14 b	1.04 b	24.2 d	2.87	319	2.8 c	16.3 c
Mean	13.6	4.3	46.9	0.78	1.09	1.01	29.4	2.56	336	3.7	16.7
F	17.34^{**}	5.96^{**}	12.46^{**}	18.96^{**}	19.62^{**}	4.86^{**}	8.47^{**}	2.14^{ns}	2.09^{ns}	17.15^{**}	5.36^{**}
CV (%)	14.2	8.8	6.6	10.7	10.7	13.1	7.8	25.4	26.5	14.1	13.6
	Leaf content										
Baltimore	23.7 b	1.03 a	57.7 a	23.2 d	1.5 c	2.7 b	45.9 a	29.6 b	2,400 b	26.5 b	66.9 b
Belgrado	14.8 d	0.95 b	57.7 a	34.7 b	1.6 c	2.7 b	39.1 b	29.8 b	1,938 b	18.4 c	62.5 b
Concerto	17.8 c	1.05 a	55.2 b	43.8 a	2.4 a	2.4 b	42.8 b	26.1 b	3,614 a	16.6 d	66.4 b
Excelso	28.0 a	1.09 a	53.1 b	34.9 b	1.2 d	2.5 b	39.6 b	29.5 b	2,158 b	20.0 c	64.6 b
Forto	15.4 d	1.10 a	51.2 b	37.5 b	1.9 b	3.3 a	40.7 b	36.7 a	3,607 a	41.3 a	74.7 a
Hana	6.3 e	0.86 b	45.9 c	34.2 b	1.9 b	2.6 b	40.8 b	27.4 b	2,411 b	20.1 c	58.7 c
Invicta	13.9 d	1.02 a	40.9 d	33.2 b	1.9 b	3.5 a	44.1 a	30.5 b	1,845 b	14.7 d	53.3 c
Maestro	25.3 b	0.82 b	48.9 c	31.3 c	2.2 a	2.6 b	48.5 a	29.6 b	1,698 b	13.3 d	51.2 c
Nayarit	15.1 d	0.98 b	56.7 a	30.6 c	2.0 b	2.7 b	40.2 b	28.1 b	2,794 a	18.5 c	63.1 b
Romance	6.4 e	0.90 b	52.0 b	34.2 b	1.9 b	3.2 a	48.4 a	36.1 a	2,139 b	22.8 b	76.5 a
Soprano	25.1 b	0.96 b	61.5 a	38.1 b	2.5 a	2.2 b	41.9 b	24.3 b	1,390 b	12.6 d	53.9 c
Mean	80.29^{**}	3.42^{**}	10.50^{**}	10.00^{**}	13.84^{**}	3.33^{**}	4.29^{**}	2.16^{*}	$2,900^{*}$	26.78^{**}	4.73^{**}
F	17.4	0.98	52.8	34.2	1.9	2.8	42.9	29.8	2,363	20.4	62.9
CV (%)	9.5	10.3	6.9	9.5	11.2	16.0	7.6	17.1	35.9	15.2	12.1

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

applied. This suggests that soil fertility in terms of P will increase after cropping.

Regardless of the crop season and the cultivar, the nutrient most taken up and exported was K, followed by N. It should be noted that Ca is the third element most taken up and only the fourth or sixth most exported, according to the cultivar. In contrast, Mg is the sixth most taken up and, nevertheless, for many cultivars, more exported than Ca. The cultivars Juliana, Marli, and Verano in the summer crop and Nativa and Conserto in the transition crop were those that showed the greatest exports of Mg. Thus, the correct choice of limestone or the use of additional sources of Mg is necessary for maintenance of the Ca:Mg ratio in the soil. Peixoto (2011) also found greater relative export of Mg in relation to Ca in the carrot cultivar Forto under cropping conditions in the Alto Paranaiba region (MG).

Table 8. Nutrient extraction and export by winter carrot cultivars sown in the summer-winter transition crop season (Experiment 3)

Cultivar	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	kg ha^{-1}						g ha^{-1}				
	Nutrient extraction (accumulation of nutrients in the leaves + roots)										
Baltimore	118.2 b	23.1 c	313.7 d	37.8 c	6.3 c	9.0 c	214.3 d	52.9 b	4,748 b	66.2 b	169.9 d
Belgrado	114.9 b	35.9 a	494.8 a	115.1 a	12.2 a	15.3 a	341.8 a	115.6 a	8,271 a	79.4 b	315.6 a
Concerto	82.5 c	21.4 c	328.4 d	77.5 b	12.0 a	8.0 c	240.3 d	56.9 b	8,129 a	45.6 c	193.4 d
Excelso	129.2 b	32.0 b	366.3 c	77.1 b	9.4 b	11.3 b	254.0 c	81.5 b	6,734 b	67.5 b	265.1 b
Forto	102.4 c	23.7 c	348.0 c	102.4 a	11.5 a	13.9 a	264.3 c	105.7 a	11,491 a	129.7 a	291.1 a
Hana	121.0 b	22.1 c	349.6 c	88.4 a	9.6 b	13.4 a	250.4 c	79.6 b	8,026 a	72.9 b	227.5 c
Invicta	76.6 c	22.6 c	293.2 d	77.8 b	8.2 b	11.1 b	227.4 d	77.1 b	5,670 b	40.6 c	174.1 d
Maestro	198.5 a	27.3 c	427.4 b	93.8 a	13.2 a	14.8 a	302.2 b	100.6 a	6,752 b	56.8 c	259.2 b
Nayarit	91.4 c	26.1 c	390.7 c	65.5 b	9.2 b	11.7 b	274.2 c	69.6 b	7,568 a	57.8 c	210.5 c
Romance	94.7 c	23.5 c	344.2 c	52.4 c	8.3 b	9.6 c	215.0 d	65.1 b	4,239 b	49.8 c	193.8 d
Soprano	124.8 b	29.3 b	468.5 a	102.4 a	12.7 a	11.3 b	237.6 d	78.5 b	5,317 b	47.5 c	226.2 c
Mean	114.2	26.1	375.0	81.0	10.3	11.8	256.4	80.3	6,995	82.3	229.6
F	14.80^{**}	8.79^{**}	13.14^{**}	8.89^{**}	10.11^{**}	8.48^{**}	10.01^{**}	5.76^{**}	3.06^{**}	32.69^{**}	18.73^{**}
CV (%)	15.2	11.9	9.4	19.0	13.6	13.8	9.5	20.6	33.4	13.3	9.6
	Export (accumulation of nutrients in the roots)										
Baltimore	77.6 b	20.0 b	213.4 b	3.1 d	3.8 d	4.9 b	137.2 b	8.0 b	1,252	26.5 a	74.3 c
Belgrado	55.2 c	26.6 a	255.8 a	4.2 b	5.9 b	5.2 b	179.1 a	16.7 a	1,720	17.2 b	118.6 a
Concerto	48.6 c	17.9 b	216.9 b	5.0 a	7.3 a	3.7 d	155.1 a	12.5 b	1,900	16.9 b	84.4 c
Excelso	69.1 c	28.2 a	243.2 a	3.8 c	6.4 b	5.7 b	163.3 a	19.1 a	2,112	24.7 a	131.1 a
Forto	47.9 c	15.8 b	165.0 b	4.5 b	5.0 c	4.3 c	122.2 b	10.3 b	1,736	18.8 b	102.9 b
Hana	89.5 b	17.1 b	202.7 b	3.5 c	4.2 d	5.9 a	128.2 b	10.1 b	1,821	19.8 b	82.9 c
Invicta	44.2 c	19.1 b	191.0 b	3.1 d	3.8 d	3.1 d	123.8 b	9.2 b	1,367	8.0 c	58.7 d
Maestro	115.1 a	22.8 a	262.2 a	3.8 c	6.3 b	6.8 a	148.5 a	13.9 a	1,638	16.7 b	111.1 b
Nayarit	55.2 c	21.6 b	248.8 a	3.8 c	4.7 c	5.6 b	173.7 a	12.4 b	1,842	18.6 b	84.8 c
Romance	78.0 b	20.2 b	245.8 a	3.0 d	5.2 c	4.5 c	132.1 b	12.4 b	1,071	15.7 b	84.1 c
Soprano	56.7 c	25.2 a	291.4 a	3.8 c	5.7 b	5.2 b	122.6 b	14.4 a	1,624	14.3 b	87.9 c
Mean	67.0	21.4	230.5	3.8	5.4	5.0	144.1	12.7	1,645	17.9	92.8
F	11.48^{**}	8.08^{**}	5.89^{**}	6.70^{**}	9.13^{**}	10.83^{**}	4.44^{**}	4.51^{**}	1.69^{ns}	12.75^{**}	10.83^{**}
CV (%)	19.0	13.1	13.0	12.6	14.4	12.5	13.8	24.8	28.5	15.6	13.8

The mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %. ** and *: significant at 1 and 5 %, respectively. ^{ns}: not significant.

The micronutrients most taken up and exported were Fe and B, and the least taken up and exported was Cu. The magnitudes of uptake and export of Zn and Mn varied with the crop and the cultivars. It should be noted that Fe has content and uptake similar to that of some macronutrients. This must be observed with caution because it may be linked to contamination of the samples with Fe from the soil.

CONCLUSIONS

The crop season and the cultivars influence the yield and the nutrient contents in the leaves and roots of the carrot crop, and the extraction and export of nutrients by the carrot crop.

Studies are necessary to quantify the efficiency of nutrient recovery by carrot cultivars, which, associated with nutrient uptake and soil fertility, allow estimation of the need for fertilizers.

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REFERENCES

Centro de Estudos Avançados em Economia Aplicada - CEPEA. Laboratório de Informação [internet]. São Paulo; 2010 [accessed on Dec.13, 2013]. Available at: http://www.cepea.esalq.usp.br/rrs.php>.

Costa KAP, Faquim V, Oliveira IP, Rodrigues C, Severiano EC. Doses e fontes de nitrogênio em pastagem de capim-marandu. I - Alterações nas características químicas do solo. R Bras Ci Solo. 2008;32:1591-9.

Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Sistemas de Produção: Cenoura [internet]. Brasília, DF; 2010 [accessed on Dec. 13, 2013]. Available at: http://www.cnph.embrapa.br.

Ferreira, D.F. Sisvar: A computer statistical analysis system. Ci Agrotec. 2011;35:1039-42.

Figueiredo Neto A, Oliveira SB, Lima MS, Amorim M, Figueiredo RMC. Efeito do composto orgânico nas características físico-químicas de cenoura "Brasília". R Bras Prod Agroind. 2010;12:61-6.

Hussain SI, Hadley P, Pearson S. A validated mechanistic model of carrot (*Daucus carota* L.) growth. Sci Hortic. 2008;117:26-31.

Luz JMQ, Silva JJA, Teixeira MSSC, Silva ADM, Severino GM, Melo B. Desempenho de cultivares de cenoura no verão e outono-inverno em Uberlândia-MG. Hortic Bras. 2009a.;27:96-9.

Luz JMQ, Zorzal Filho A, Rodrigues WL, Rodrigues CR, Queiroz AA. Adubação de cobertura com nitrogênio, potássio e cálcio na produção comercial de cenoura. Hortic Bras. 2009b;27:543-8.

Malavolta E, Vitti GC, Oliveira SA. Avaliação do estado nutricional das plantas. Princípios e aplicações. Piracicaba: Universidade de São Paulo; 1997.

Mesquita Filho MV, Souza AF, Silva HR. Nível crítico de boro em cenoura cultivada em um solo sob cerrado. Hortic Bras. 2005;23:68-71.

Nicolle C, Simon G, Rock E, Amouroux P, Rémésy C. Genetic variability influences carotenoid, vitamin, phenolic, and mineral content in white, yellow, purple, orange, and dark-orange carrot cultivars. J Am Soc Hortic Sci. 2004;129:523-9.

Oliveira CD, Braz LT, Banzatto DA. Adaptabilidade e estabilidade fenotípica de cultivares de cenoura. Hortic Bras. 2008;26:88-92.

Oliveira FHT, Novais RF, Alvarez V VH, Cantarutti RB. Desenvolvimento de um sistema para recomendação de adubação para a cultura da bananeira. R Bras Ci Solo. 2005;29:131-43.

Paulus D, Moura CA, Santin A, Dalhem AR, Nava GA, Ramos CEP. Produção e aceitabilidade de cenoura sob cultivo orgânico no inverno e no verão. Hortic Bras. 2012;30:446-52.

Peixoto FC. Acúmulo de macronutrientes em cenoura "Forto" [dissertação]. Jaboticabal: Universidade Estadual Paulista "Júlio de Mesquita Filho", 2011.

Santos FC, Neves JCL, Novais RF, Alvarez V VH, Sediyama CS. Modelagem da recomendação de corretivos e fertilizantes para a cultura da soja. R Bras Ci Solo. 2008;32:1661-74.

Sharma KD, Karki S, Thakur NS, Attri S. Chemical composition, functional properties and processing of carrot - a review. J Food Sci Technol. 2012;49:22-32.

Singh DP, Beloy J, McInerney JK, Day L. Impact of boron, calcium and genetic factors on vitamin C, carotenoids, phenolic acids, anthocyanins and antioxidant capacity of carrots (*Daucus carota* L.). Food Chem. 2012;132:1161-70.

Smolen S, Sady W. The effect of various nitrogen fertilization and foliar nutrition regimes on the concentrations of nitrates, ammonium ions, dry matter and N-total in carrot (*Daucus carota* L.) roots. Sci Hortic. 2009;119:219-31.

Zumbado RF, Soto CM. Rendimiento de 12 híbridos comerciales de zanahoria (*Daucus carota* L.) en el campo y en la planta de empaque. Agron Mesoam. 2010;21:167-76.