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Analysis of growth, nutrient uptake and production of three virus-free garlic cultivars

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Abstract

Garlic cultivars in southern Brazil are virus-free, however, the rate of nutrient absorption and plant growth is unknown. The objective of this work was to determine the growth curve, production and nutrient uptake of three virus-free garlic cultivars. The experiment was conducted in Fraiburgo, SC state, in a randomized complete block design, with four replicates. The treatments were arranjed in a factorial 3 x 10 scheme with parcel subdivided in time. The three cultivars (Ito, Caçador and Quitéria) were distributed in the parcels and ten collects (14, 28, 42, 56, 70, 84, 98, 112, 126 and 140 days after planting) were the subparcel. The plant height, number of leaves, leaf area and extraction of N, P, K, Ca, Mg, Zn, Fe and Cu were determined. The three cultivars present differences in their growth curve and accumulation of nutrients. Nutrient extraction and dry mass accumulation are highly intensified after the plants differentiation into cloves. The maximum accumulation of all nutrients and the bulbs and total dry mass of plants occur at harvest. The nutrients absorption follows the sequence: K>N>Ca>P>Mg>Fe>Zn>Cu.

Keywords: *Allium sativum*, nutrients accumulation, nutritional requirement

Introduction

Brazil produces around 65% of the garlic needed to supply the domestic market, which in 2022 was 181 thousand tons (IBGE, 2024). The state of Santa Catarina has the largest area of noble garlic in the South of Brazil, with 1,580 hectares planted in the 2021/22 season crop, representing 8.1% of national production (Epagri/Cepa, 2024). In the state, the municipalities in the Central-West region, Curitibanos, Frei Rogério and Fraiburgo concentrate the largest number of garlic farmers.

From 2008 onwards, the adoption in SC of cultivars that underwent meristem cultivation to eliminate viruses intensified, which currently represent around 95% of the garlic cultivated in the state. These cultivars present significant increases in vegetative vigor, yield and bulb quality compared to cultivars multiplied conventionally (Mueller et al., 2005). Results obtained by Resende et al., (1999), showed that cultivars virus-free provided an increase of 99.8, 109.5 and 36.9% in production, average bulb weight and number of cloves per bulb, respectively, compared to conventional garlic. The increase in yield for virus-free cultivars in relation to conventional cultivars is 27.7; 22.0; 16.4 and 27.5%, respectively for Quitéria, Caçador, Chonan and Jonas (Mueller et al., 2005).

With the consolidation of the use of noble virus-free garlic cultivars, there is a need to define appropriate nutrient application times to more accurately meet the nutritional requirements of the cultivars throughout the growth cycle. For this, it is important to know the growth analysis and nutrient absorption process of the crop under field conditions (Andrioli et al., 2008). These analyzes help in the fertilization program, mainly in the quantity of different nutrients that must be applied in the different physiological stages of the crop, avoiding nutritional imbalances due to the supply of nutrients in under or overestimated fertilizations. More precise nutritional

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management could even reduce production costs and make cultivation viable on agricultural properties in southern Brazil (Hahn et al., 2024).

The analysis of growth and nutrient accumulation in the environmental conditions of southern Brazil must be studied for different cultivars, mainly considering the length of the pre-bulbification and bulbification periods of each cultivar as a function of the photoperiod and temperature of the growing region, soil type, water availability. Additionally, the contribution of different organs to growth and nutrient absorption must be identified (Cochavi et al. 2020).

There are no research studies available on the growth analysis and nutrient absorption rate of the main virus-free noble garlic cultivars for the conditions of Southern Brazil. The information currently available is from cultivars cropped in Brazilian Cerrado (Andrioli et al., 2008). In view of this, technical/scientific investigations are needed to better understand the nutritional needs and indication of fertilizer management of virus-free cultivars in Southern Brazil.

The objective of the present work was to determine the growth curve, yield and nutrient absorption rate of virus-free garlic cultivars grown in Santa Catarina.

Materials and Methods

The experiment was conducted from May to November in a commercial farm of municipality of Fraiburgo, SC. The climate of the region according to the Köppen classification is Cfb. The experimental area is classified as Typic Hapludox (Soil Survey Staff, 2014) or Nitossolo Bruno Distrófico (Santos et al., 2018) and presents the following characteristics in the 0-20 cm layer: clay 57%, pH H2O (1:1) 5.1.0 mg, P (Meh1) K (Mehlich-1) 367 mg dm^{-3}; MO 5.9 %; Ca 10.6 cmolc dm^{-3}; Mg 2.3 cmolc dm^{-3}; CTC 18.2 cmolc dm^{-3}; S 35 mg dm^{-3}; Zn 2.7 mg dm^{-3}; Cu 6.1 mg dm^{-3}; B 1.2 mg dm^{-3} and Mn 28 mg dm^{-3}.

The three virus-free cultivars account for about 70% of the cultivation area of SC and are distinguished by cycle hair: Ito - early cycle, Caçador- semi-early cycle and Quitéria - late cycle. Bulbs of 3th generation after viral elimination were used, which were subjected to vernalization in a cold chamber with an average temperature of 4 °C, for a period of 20 days. Afterwards, the bulbs of the size 2 (barely 10 x 20 mm) were selected for planting, on May 26th.

The experimental units consisted of a 6.0 m long bed. The plants in the beds were arranged in a double row, with an internal double row spacing of 0.12 m and spacing between double rows of 0.38 m and 0.10 m between plants. The spacing between the external lines of the beds was 0.5 m. The entire plot was considered a useful area for collecting plants. The plot was divided into ten collections (evaluation period). Until the 4th collection, nine plants were sampled per plot and, afterwards, five plants were collected.

The differentiation of plants into cloves occurred at different times for each cultivar: cv. Caçador at 79 DAP, cv. Ito at 75 DAP and cv. Quitéria at 82 DAP. Evidence of plant differentiation was considered when 50% of the plants presented small circular spots, the size of a grain of rice, close to the central axis of the bulb (Lopez□Bellido et al., 2016).

The evaluations carried out were plant height, leaf area, number of leaves, dry mass and accumulation of macronutrients N, P, K, Ca, Mg and micronutrients Fe, Zn and Cu. The determination of mineral content in the leaves, pseudo stems and bulbs of plants was carried out according to the methodology of Tedesco et al. (1995). At 140 DAP, plants were harvested from the plots to determine commercial yield.

For production data, analysis of variance was used with subsequent Tukey test (5% significance). For leaf area and number of leaves data, a segmented straight line model was used. To describe the behavior of nutrient accumulation and plant height, the Logistic and Gompertz models were used, whose expressions are presented below:

Logistic model $y = \frac{\beta 1}{1 + e^{\left(\frac{\beta 2 - x}{\beta 3}\right)}}$ (1)

Gompertz model $y = \beta 1\ e^{(-\beta 2 \beta x 3)}$ (2)

To compare the models, the Akaike information criterion (AIC) was used, with the model with the lowest AIC value being considered more appropriate. Diagnostic analysis was carried out to check possible trends or lack of adjustment of the models used. All analyzes were performed using the R environment (R Development Core Team, 2022).

Results and Discussion

The three cultivars Ito, Caçador and Quitéria were distinct for all growth variables and for nutrient accumulation (**Figures 1** and **2**). The model segmented straight lines had the best adjusted for the analysis of leaf area (LA) (Figure 1a) and number of leaves (NF) (Figure 1b). However, the logistic model presented a better fit to describe plant height (Figure 1c). Cvs. Caçador and Quitéria reached maximum LA at 104 and 105 DAP, respectively, while cv. Ito reached maximum LA at 112 DAP (Figure 1a). The maximum LA values were 632.1; 570.7 and 627.7 cm² $plant^{-1}$ for cvs. Caçador, Ito and Quitéria,

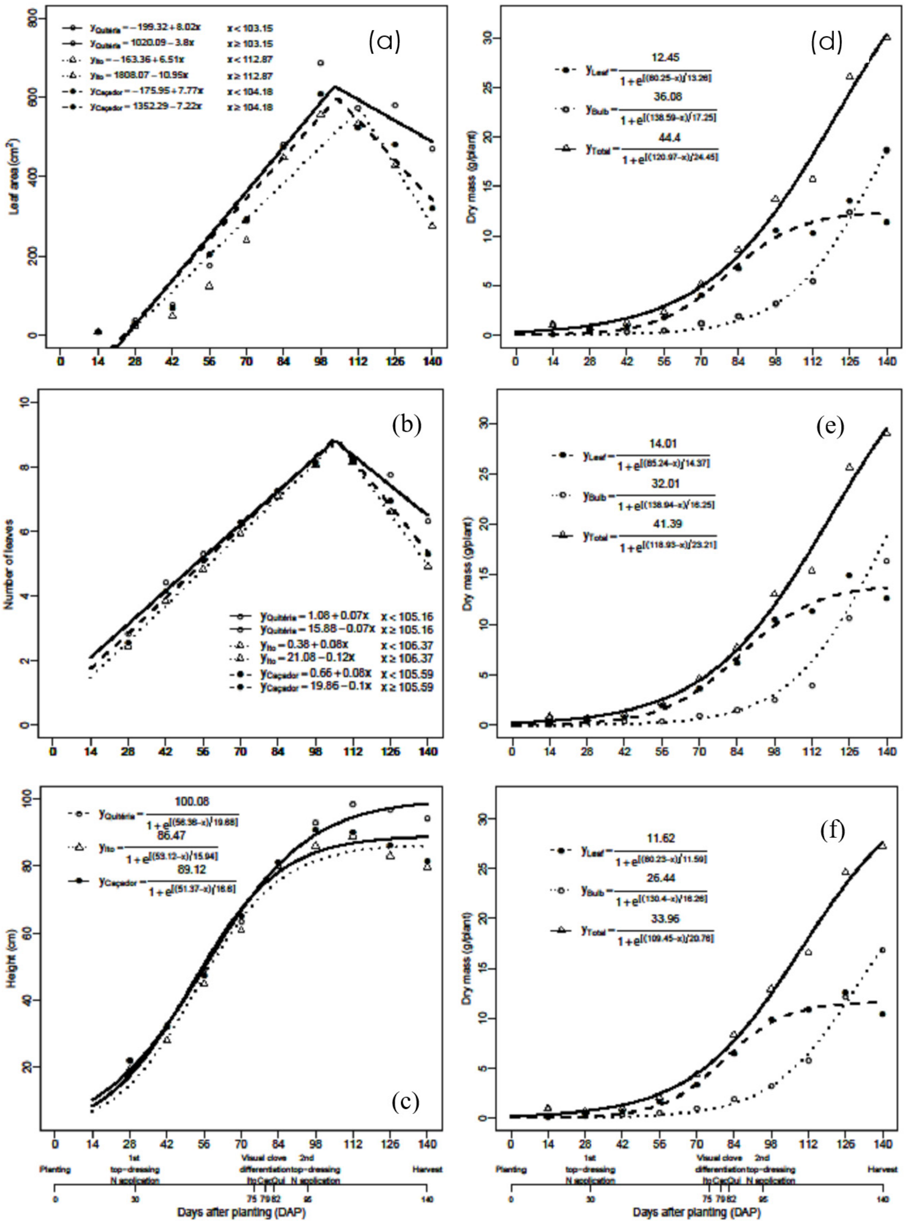

Figure 1. Leaf area (a), number of leaves (b), height (c) and accumulation of dry mass in plants (leaf, bulb and total) of three garlic cultivars, (d) cv. Caçador, (e) cv. Ito, (f) cv. Quiteria.

respectively. A leaf senescence and linear reduction occurred after maximum LA until plant harvest, at 140 DAP. Quitéria cultivar showed the highest LA at harvest, with 488 cm² plant^{-1}, while cv. Ito had a lower LA of 275 cm^2 plant^{-1}, which corresponds to 43% of the LA of the cv. Quiteria. In an experiment in Minas Gerais, Brazilian southeast, Resende et al. (1999) observed the highest LA of garlic from cv. Gigante Roxão at 110 DAP, after which it progressively decreased.

The maximum NF ranged from 8.2 to 8.3 leaves for the three cvs and occurred between 105 and 106 DAP (Figure 1b), which corresponds close to the maximum LA and after the differentiation of the plants into cloves (75, 79 and 82 DAP for the cvs. Caçador, Ito and Quitéria, respectively) and after the application of N in top dressing (90 DAP). The cv. Quitéria had the highest NF at harvest (6.08), in relation to cv. Caçador (5.86) and cv. Ito (4.28). Despite the difference in NF and LA between the three cvs., all were harvested at 140 DAP. Similar to LA and NF, plant height (Figure 1c) was also higher for cv. Quitéria, obtaining 98.7 cm when harvested, compared to 86.1 cm for cv. Ito and 88.4 cm of cv. Caçador.

The model that best suited to describe the accumulation of dry mass for the three cultivars was the logistic model. Total dry mass accumulation was reduced until mid-cycle (70 DAP) in the three cultivars (Figures 1d, 1e and 1f). During this period, plants accumulated approximately 16% of the total dry mass, with an average daily accumulation rate of approximately 0.07 g plant^{-1}. After this period, there was a rapid development of the

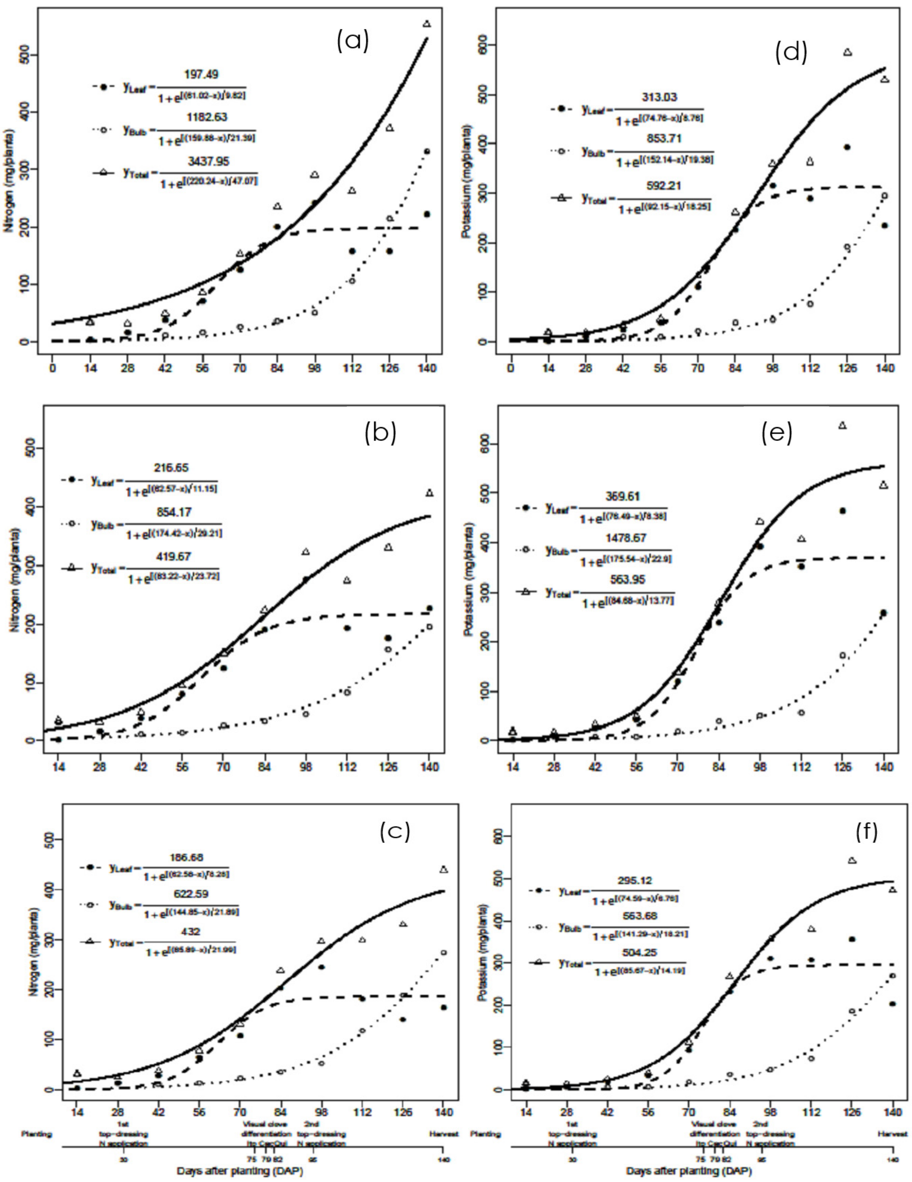

Figure 2. Accumulation of nitrogen (N) and potassium (K) in plants (leaf, bulb and total) of three garlic cultivars, (a, b) cv. Caçador, (c, d) cv. Quitéria and (e, f) cv. Ito.

plants, with a significant increase in dry mass and an average daily rate of approximately 0.34 g plant^{-1}.

The 50% of the maximum plants dry mass accumulation occurred after the period of plant into cloves differentiation at 102, 105 and 106 DAP, with 13.3, 15.2 and 14.7 g plant^{-1} in cvs. Caçador, Ito and Quitéria, respectively. These data show that the entire plant accumulates on average 50% of the maximum accumulated in the last 38, 35 and 34 days of the cycle for the cultivars Caçador, Ito and Quitéria, respectively. At harvest, the total accumulated dry mass was very similar for all cvs., 30.4; 27.6 and 29.5 g plant^{-1}, respectively for Caçador, Ito and Quitéria.

The accumulation of 50% of the maximum leaves dry mass of cvs. Caçador (Figure 2a) and Ito (Figure 2b) occurred at 80 DAP, very close to cv. Quitéria (Figure 2c) which reached 50% at 85 DAP. In bulbs, 50% of the maximum accumulated occurred at 120, 119 and 122 DAP for cvs. Caçador, Ito and Quitéria, respectively, representing 10.0; 8.8 and 8.4 g plant-^{1}, respectively, with an average increase in this period of 0.09; 0.09 and 0.07 g plant^{-1} day^{-1}. Considering the plants harvest at 140 DAP, there is an intense increase in the bulbs dry mass in the last 20 days of plant growth (on average, 0.49, 0.39 and 0.45 g plant^{-1} day^{-1}, respectively for cvs. Caçador, Ito and Quitéria) and a halt in the leaves dry mass, indicating the translocation of photoassimilates and other organic and inorganic compounds from the aerial part to the bulb.

Andreoli et al. (2008), in work conducted with cv. Roxo Pérola de Caçador, observed similar behavior to the present study, with a predominance of accumulation of leaves dry mass during 75 DAP. After and until the end of the cycle, the accumulation of bulbs dry mass predominated. Using the same cultivar, Souza et al. (2011), found that the accumulation of bulbs dry mass intensifies only around 50 DAP, with the maximum accumulated observed at harvest, at 130 DAP. Similar results were obtained by Resende et al. (1999), in a study comparing growth and production between garlic from tissue culture and conventional multiplication. The authors found that the accumulation of dry mass in the aerial part and root system of plants was reduced until 70 DAP, intensifying thereafter and reaching its maximum at 110 DAP, for both forms of multiplication. Significant differences in the accumulation of nutrients between the multiplication forms were verified only in the phase that coincided with the maximum development of the aerial part and the bulb. Plants multiplied conventionally showing a greater requirement for N in relation to K than plants from tissue culture.

The bulbs dry mass at harvest represented 65% of the total dry mass accumulated by the entire plant for cv. Caçador. Lower values were obtained with the cultivars Ito and Quitéria with 62 and 56%, respectively. This behaviour is due to the harvest is carried out when the plants still have four to six green leaves, completing the bulb maturation through the curing process in the shed. It is also noteworthy an increase in bulbs dry mass of 88% for cvs. Caçador and Ito, while for cv. Quitéria the increase was 91% after applying N fertilization in top dressing (at 90 DAP).

The accumulation of N (Figure 2a, 2c and 2e), K (Figure 2b, 2d and 2f) P, Ca and Mg and Cu, Zn and Fe (**Table 1**) in the leaves, bulbs and whole plant of the three cultivars accompanied the dry mass accumulation in different parts of the plant. Thus, nutrient accumulation was slow until the first half of the plant cycle (up to 70 DAP, corresponding to the beginning of plant differentiation) and intensifying until the harvest.

The exponential model presented the best fit to explain the nutrient accumulation rate. On the other hand, logistical model was the best model for P and Fe in the bulbs of all cultivars, Mg in the bulbs of cv. Quitéria, Cu in the bulbs of cv. Caçador and Quitéria and Zn of cvs. Ito and Caçador.

K was the nutrient most extracted by garlic plants. For a stand of 370,000 plants ha^{-1} and a commercial yield of 12.7; 11.0 and 15.2 t ha^{-1}, respectively for cvs. Caçador, Ito and Quitéria, we estimated an extraction of 552.1; 493.2 and 552.1 mg plant^{-1} at 140 DAP, respectively. This equates to an extraction of 204.2; 182.5 and 204.2 kg ha^{-1} of K and 246.0; 219.9 and 246.0 kg ha^{-1} of K_2O, respectively, for these cultivars. N was the second nutrient most accumulated by garlic plants, estimated at 334.7; 398.0 and 384.6 mg plant^{-1} at 140 DAP for the cultivars Caçador, Ito and Quitéria respectively, which is equivalent to an extraction of 195.7; 147.3 and 142.3 kg ha^{-1} of N, respectively. Andrioli et al. (2008) and Souza et al. (2011), observed higher absorptions of N, followed by K, in cv. Pérola de Caçador purple garlic. A significantly greater absorption of K observed in the present work may be due to the "luxury" consumption of the element, which is also observed in studies with other crops (Wang et al., 2023; Sidhu et al. 2024). It is noteworthy that the levels of K available in the soil were interpreted as very high and 300 kg ha^{-1} of K_2O was also applied during planting, which may have promoted high absorption of K by the plants.

Of the total N accumulated by the plant until harvest, 37, 47 and 56%, were allocated to the leaves and 63, 70 and 52% in the bulbs, respectively for cvs. Caçador, Ito and Quitéria. Before bulbification, plants accumulated only 31, 41 and 53% of total N, respectively for cvs. Caçador, Ito and Quitéria. The N accumulation peak showed differences between cultivars. For cv. Caçador, the maximum N absorption in the entire plant occurred at 140 DAP (9.4 mg plant^{-1} day^{-1}) coinciding with the maximum N absorption by the bulb (11.1 mg plant^{-1} day^{-1}). In cv. Ito the maximum N absorption in the entire plant occurred in the period of 82 to 91 DAP (4.9 mg plant^{-1} day^{-1}) and the maximum in the bulb was at harvest (7.0 mg plant^{-1} day^{-1}). Similar behavior was observed in cv. Quiteria, with maximum N accumulation in the entire plant in the period from 78 to 89 DAP (4.4 mg plant^{-1} day^{-1}) and in the bulb at harvest (5.2 mg plant^{-1} day^{-1}). Understand the rate of N absorption in garlic cultivars is of great importance as this is the element that most affects the commercial yield of garlic (Hahn et al., 2020).

Following K and N, there is the following decreasing sequence of nutrients extracted by garlic plants: Ca, P, Mg, Fe, Zn and Cu (Table 1). The total amounts of nutrients extracted, considering a population of 370,000 plants ha^{-1} and a commercial yield of 12.7 t ha^{-1} for cv. Caçador were: 113.7; 73.4; 19.1; 0.5; 0.33 and 0.049 kg ha^{-1} for Ca, P, Mg, Fe, Zn and Cu, respectively. For cv. Ito and a commercial yield of 11.0 t ha^{-1} were 105.6; 66.2; 18.9; 0.46; 0.31 and 0.045 kg ha^{-1} for Ca, P, Mg, Fe, Zn and Cu, respectively. Finally, for cv. Quitéria and a commercial yield of 15.2 t ha^{-1}, were 113.7; 73.4; 20.7; 0.5; 0.33 and 0.050 kg ha^{-1} for Ca, P, Mg, Fe, Zn and Cu, respectively. These quantities are significantly greater than those determined by Souza et al. (2011). In that study, the following average nutrient extraction by

Table 1. Accumulation of macronutrients (mg plant^{-1}) and micronutrients (µg plant^{-1}) in plants (leaves, bulb and total) of three garlic cultivars.

Nutrient	Cultivar	Parts of the plant	50% of the maximum accumulated (mg plant^{-1})	Days after planting	Maximum accumulated	Equation	R^2
Phosphorus	Caçador	Leaves	38.0	85	76.4	y = 77.3/{1+e [(85.4−x)/12.4]}	0.96
		Bulb	61.5	129	119.8	y = 4.4+0.015(1.07x)	0.98
		Total	99.4	115	198.4	y = 1775.3/{1+e [(208.9−x)/ 33.2]}	0.97
	Ito	Leaves	34.3	83	69.50	y = 69.7/{1+e [(83.2−x) /9.8]}	0.97
		Bulb	57.8	129	111.8	y = 3.85+0.02(1.07x)	099
		Total	90.7	113	178.7	y = 580.3/{1+e [(164.9−x) /30.81]}	0.97
	Quitéria	Leaves	43.9	89	88.4	y = 90.6/{1+e [(89.8−x)/ 13.7]}	0.94
		Bulb	55.6	129	109.3	y = 4.03+0.01(1.07x)	0.98
		Total	99.4	115	198.4	y = 940.3/{1+e [(182.9−x)/ 31.2]}	0.96
Calcium	Caçador	Leaves	80.5	93	160.0	y = 172.3/{1+e [(95.3−x) /17.4]}	0.84
		Bulb	75.6	110	152.6	y = 252.4/{1+e [(130.0−x) /23.6]}	0.94
		Total	153.7	100	307.4	y = 361.7/{1+e [(106.0−x)/ 19.7]}	0.92
	Ito	Leaves	72.6	90	143.5	y = 148.3/{1+e [(90.6−x)/ 14.9]}	0.85
		Bulb	66.6	104	134.5	y = 160.2/{1+e [(110.2−x) /18.1]}	0.94
		Total	137.7	96	274.5	y = 296.3/{1+e [(98.3−x) /16.4]}	0.91
	Quitéria	Leaves	92.9	95	186.9	y = 203.0/{1+e [(97.9−x) /17.2]}	0.84
		Bulb	65.9	110	131.9	y = 205.4/{1+e [(126.9−x)/ 22.5]}	0.84
		Total	153.6	100	307.8	y = 365.0/{1+e [(106.0−x)/ 18.8]}	0.88
Magnesium	Caçador	Leaves	12.3	86	33.9	y = 35.7/{1+e [(87.2−x) /18.2]}	0.88
		Bulb	9.1	119	18.3	y = 38.8/{1+e [(142.1−x) /19.6]}	0.74
		Total	26.1	98	51.7	y = 65.0/{1+e [(107.5−x) /24.0]}	0.88
	Ito	Leaves	16.0	82	31.5	y = 32.2/{1+e [(82.1−x)/ 14.8]}	0.92
		Bulb	10.1	120	20.2	y = 46.0/{1+e [(144.6−x) /19.5]}	0.67
		Total	26.0	97	51.2	y = 62.1/{1+e [(104.5−x)/ 22.9]}	0.88
	Quitéria	Leaves	20.4	89	41.0	y = 44.0/{1+e [(91.7−x) /18.4]}	0.86
		Bulb	6.0	117	11.9	y = 0.19(1.03x)	0.50
		Total	25.1	97	55.9	y = 65.5/{1+e [(102.7−x)/ 21.2]}	0.83
Iron	Caçador	Leaves	459.3	65	910.2	y = 927.6/{1+e [(65.4−x) /18.8]}	053
		Bulb	338.7	118	674.3	y = 113.3+1.1(1.05x)	0.67
		Total	683.0	73	1339.8	y = 1474.5/{1+e [(75.9−x)/ 25.4]}	0.67
	Ito	Leaves	414.2	66	822.6	y = 833.4/{1+e [(66.2−x)/ 17.1]}	0.54
		Bulb	283.1	117	559.7	y = 94.2+1.9(1.04x)	077
		Total	628.4	76	1255.8	y = 1324.5/{1+e [(75.3−x) /22.3]}	0.67
	Quitéria	Leaves	562.7	72	1119.3	y = 1160.4/{1+e [(73.2−x)/ 20.2]}	0.57
		Bulb	253.9	119	509.0	y = 111.0+0.43(1.05x)	0.74
		Total	695.7	73	1364.8	y = 1667.8/{1+e [(81.0−x)/ 26.33]}	0.67
Cooper	Caçador	Leaves	32.6	78	66.0	y = 66.4/{1+e [(78.4−x)/ 12.1]}	0.73
		Bulb	36.2	115	72.1	y =1.5(1.03x)	0.72
		Total	66.6	93	134.7	y = 144.1/{1+e [(95.5−x) /16.7]}	0.77
	Ito	Leaves	51.1	78	60.5	y = 60.6/{1+e [(77.5−x)/ 9.9]}	0.74
		Bulb	33.3	91	66.4	y = 67.0/{1+e [(106.2−x)/ 10.4]}	0.85
		Total	60.7	90	122.8	y = 126.5/{1+e [(91.1−x)/ 14.0]}	0.80
	Quitéria	Leaves	39.2	84	76.6	y = 77.5/{1+e [(83.7−x) /12.7]}	0.67
		Bulb	29.2	114	58.3	y = 1.4(1.03x)	0.76
		Total	66.6	93	134.7	y = 135.6/{1+e [(93.5−x) /14.6]}	0.75
Zinc	Caçador	Leaves	256.2	93	500.9	y =506.4/{1+e [(92.8−x)/ 10.5]}	0.68
		Bulb	237.3	119	478.9	y = 4.4(1.03x)	0.94
		Total	453.2	100	891.3	y = 916.0/{1+e [(100.2−x)/ 11.1]}	0.88
	Ito	Leaves	249.4	93	498.2	y =501.4/{1+e [(93.1−x)/ 9.3]}	0.73
		Bulb	176.0	117	347.3	y = 5.54(1.03x)	0.92
		Total	414.6	73	828.6	y = 873.9/{1+e [(99.0−x)/ 9.9]}	0.89
	Quitéria	Leaves	305.2	96	585.9	y = 589.4/{1+e [(95.4−x)/ 8.7]}	0.65
		Bulb	224.6	83	389.8	y = 389.8/{1+e [(111.2−x) /11.2]}	0.74
		Total	453.4	100	891.3	y = 934.2/{1+e [(99.8−x) /8.89]}	0.80

garlic plants of the Roxo Pérola de Caçador cultivar (kg ha^{-1}) was found: N=179.25, P=19.95, K=103.54, Ca=46.84, Mg=6.98, S=31.73; and (g ha^{-1}) B=156.42, Cu=90.10, Fe=654.78, Mn=76.67 and Zn=138.66. Andrioli et al. (2008), in studies carried out with the same cultivar, observed an even lower accumulation of macronutrients (kg ha^{-1}) of 62.4 N, 12.1 P, 61.0 K, 27.6 Ca, 6.0 Mg and 10.3 S. However, the harvest was carried out at 105 DAP, 35 days before the harvest carried out in our present study.

P was the nutrient accumulated later, as 50% of the total accumulated after 113 DAP for cv. Ito and 115 DAP for cvs. Caçador and Quitéria was observed. (Table

1). We also highlight that more than 50% of the P in the bulbs is accumulated in the last 11 days before harvest. N (61.7%), P (59.3%) and K (51.9%) were the nutrients allocated in greatest quantities in the bulbs; Mg (32.0%) was the nutrient that showed the greatest accumulation in the leaves.

Commercial bulb yield was higher for cv. Quitéria (15.2 t ha^{-1}), followed by cv. Caçador (12.7 t ha^{-1}), and the lowest yield was obtained with cv. Ito (11.0 t ha^{-1}). The highest yield of cv. Quitéria can be attributed to the greater number of bulbs from the largest commercial classes, with 62.8 and 29.3% of bulbs from classes 6 (47 to 56 mm) and above 7 (>56 mm), respectively. For cv. Caçador, 60.7 and 23.4% and cv. Ito 54.7 and 13.9% of the bulbs are found in these two larger caliber classes. Even though cv. Quiteria. did not stand out in the dry mass and nutrients accumulation, a greater LA, NF and plant height may explain the higher yields.

Conclusions

The cultivars virus-free Ito, Caçador and Quitéria present differences in their growth and nutrient accumulation.

Nutrient extraction and dry mass accumulation are highly intensified after the plants differentiation into cloves. The maximum accumulation of all nutrients and the bulbs and total dry mass of plants occur at harvest.

The nutrients absorption follows the sequence: K>N>Ca>P>Mg>Fe>Zn>Cu.

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