

## Nitrogen fertilization and genotypes of peaches in high-density

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**Abstract-** Among the factors that affect peach productivity is the proper nutrition of plants, being nitrogen (N) one of the main nutrients for the crop. Thus, the objective of the current study was to evaluate the effect of nitrogen fertilization on macronutrient leaf contents, plant development and production of different genotypes of peach trees cultivated at high planting density, seeking to recommend the most appropriate concentration. The experiment was conducted between 2016 and 2018 using peach selections ‘Cascata 1513’ and ‘Cascata 1067’ and with nitrogen fertilization concentrations (0, 60, 120 and 180 kg ha<sup>-1</sup> of N). Pruning mass, trunk diameter, number of fruits per plant, average fruit mass, yield per plant, yield per hectare and leaf macronutrients were evaluated. The increase of N concentration increases the N content in leaves. For the conditions of this experiment the maximum production per plant was obtained for the highest dose of 180 Kg ha of N.

**Index terms:** vegetative growth, number of fruits, *Prunus persica*, leaf content.

## Adubação nitrogenada e genótipos de pessegueiros em pomar adensado

**Resumo-** Entre os fatores que afetam a produtividade dos pessegueiros, está a nutrição adequada das plantas, sendo o nitrogênio (N) um dos nutrientes primordiais para a cultura. Deste modo, o objetivo do presente trabalho foi avaliar o efeito da adubação nitrogenada de manutenção nos teores foliares de macronutrientes, no crescimento das plantas e na produção de diferentes genótipos de pessegueiros cultivados em alta densidade de plantio, buscando-se recomendar a concentração mais adequada. O experimento foi conduzido entre 2016 e 2018, com seleções avançadas de pessegueiros ‘Cascata 1513’ e ‘Cascata 1067’, e com concentrações de adubação nitrogenada (0; 60; 120 e 180 kg ha<sup>-1</sup> de N). Avaliaram-se: massa de poda, diâmetro de tronco, número de frutos por planta, massa dos frutos, produção por planta e teor de macronutrientes nas folhas. O incremento das concentrações de N aumenta o teor do N nas folhas. Para as condições deste experimento, a máxima produção por planta foi obtida para a maior dose de 180 kg ha de N.

**Termos para indexação:** crescimento vegetativo, número de frutos, *Prunus persica*, teor foliar.

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**Received:** April 03, 2020  
**Accepted:** August 26, 2020

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## Introduction

Obtaining high productivity in peach orchards is directly linked to the appropriate nutrition of plants and to the genetic material of cultivars. Among the essential nutrients for peach trees, nitrogen (N) stands out (DOLINSKI et al., 2017; TOSSELLI et al., 2019). This nutrient performs specific functions in the plants, such as amino acids and proteins formation, regulation of metabolic reactions, besides being constituent of the chloroplasts (TAIZ et al., 2017).

The responses of nitrogen fertilization in non-densified peach tree orchards have been variable compared to plant development (DOLINSKI et al., 2005; BRUNETTO et al., 2007; DELLA BRUNA; BACK, 2014). Della Bruna and Back (2014), in a study developed with Chimarrita and Aurora cultivars and using 50, 100 and 150 kg of N/ha did not verify influence on fruit setting and in the formation of vegetative buds, corroborating with Brunetto et al. (2007), which did not observe change in peach production. However, in a study conducted by Dolinski et al. (2005), in which it was used N doses in Chimarrita cv. peaches, it was verified that the reduction of nitrogen fertilization negatively affected the number of fruits and productivity in the second crop cycle.

On the other hand, the concentration of N in high dense peach orchards to satisfy its vegetative and productive growth potential is not yet defined (FERREIRA et al., 2018a). Thus, there is a need to determine the appropriate concentration of N to be applied in the orchards according to the region, soil type and planting density, besides ensuring the nutritional balance of plants and productivity.

The recommendation of nitrogen fertilization from the fertilization and liming manual for the states of Rio Grande do Sul and Santa Catarina (Soil Fertility and Chemistry Commission-CQFS – RS/SC, 2016) in peach tree production phase is based on the leaf content of the nutrient and on the expected productivity. The CQFS – RS/SC (2016) recommends the quantity between 0 to 110 kg of N/ha, according to N leaf content and the dose should be split in three times, 50% of the dose at the beginning of flowering, 25% after the fruit thinning and 25% after harvest. However, the recommendation does not consider the increase in planting density and it is presumed that the high density requires the use of higher N concentration (FERREIRA et al., 2018a).

In this context the importance of fertilization studies in peach crop is inserted, making use of inputs in a rational way, considering the environmental and economic sustainability of the crop. Therefore, the objective of this study was to evaluate the effect of nitrogen maintenance fertilization in the mineral composition of the leaves, in the vegetative growth and in the production of two peach genotypes cultivated in high planting density, seeking to recommend the most appropriate concentration.

## Material and Methods

The experiment was conducted in the 2016, 2017 and 2018 crops in the experimental area of Embrapa Temperate Climate in the municipality of Pelotas, Rio Grande do Sul (31° 40' 41.29" S and 52° 26' 22.05" W and 70m altitude). The orchard was implanted in 2012, and the plants were conducted in the *epsilon* system having as rootstock Capdeboscq. The line spacing was 5.0 m and 1.5 m among plants, totaling a density of 1,333 plants ha<sup>-1</sup>.

The region climate classification according to W. Köppen is “cfa” type - moist subtropical climate, that is, it is moist temperate with hot summers (ALVARES et al., 2013). Average temperature, precipitation and cold hours data during the experiment period were collected by Embrapa Temperate Climate automatic weather station, located in the municipality of Pelotas, RS (Figure 1A and 1B). Cold hours were calculated based on temperatures below or equal to 7.2 °C and totaled 172 hours of cold in 2016, 77 hours of cold in 2017 and 143 hours of cold in 2018.

The local soil was moderately deep with average texture in the A horizon and clay in the B horizon, classified as Yellow Red Argisol (SANTOS et al., 2006). The soil physico-chemical analyses performed before the experiment installation presented the following results: pH in water of 5.8; 17.9 mg dm<sup>-3</sup> of P; 3.4 cmol<sub>c</sub> dm<sup>-3</sup> H+Al; 155 mg dm<sup>-3</sup> of K; 1.4 cmol<sub>c</sub> dm<sup>-3</sup> of Ca; 0.6 cmol<sub>c</sub> dm<sup>-3</sup> of Mg; 26% of clay and 1.4% of organic matter, respectively. The leaf analysis of the plants before the experiment presented: 2.8% of N; 0.32% of P; 2.0% of K; 1.65% of Ca; 0.55% of Mg; 74.31 mg kg<sup>-1</sup> of Fe; 109.5 mg kg<sup>-1</sup> of Mn and 17.5 mg kg<sup>-1</sup> of Zn.

The experimental design used was randomized blocks, in a 2×4 factorial scheme (two peach selections and four nitrogen concentrations), with four replications. Each experimental unit was composed of four plants, and the two central plants were considered as useful for evaluation purposes. The genotypes used were two advanced peach selections of the Embrapa Temperate Climate such as ‘Cascata 1513’ and ‘Cascata 1067’. These selections present potential to be commercialized due to their intense red color in the epidermis, which is attractive to consumers. N concentrations used were 0, 60, 120 and 180 kg ha<sup>-1</sup>, applied on the soil surface, in the projection range of the plant canopy and without incorporation. The N source used was urea (45% of N), split in three periods, 50% of the concentration applied in full flowering in August, 30% after the thinning in September and 20% after harvest in January. All plots received equal potassium (K) and phosphorus (P) concentrations, according to the application quantities and periods recommended by CQFS – RS/SC (2016).

The following variables were analyzed in the plants during three years: green pruning mass, represented by the

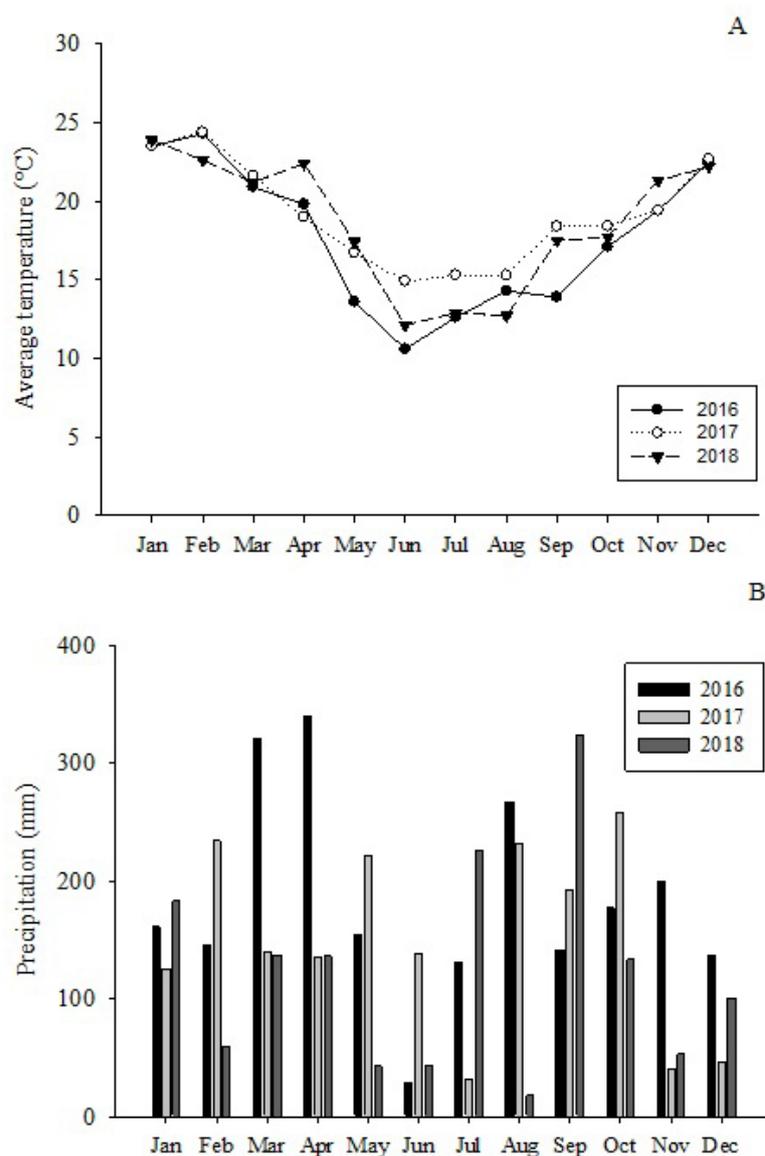
mass of the material removed from the plants during two separate pruning periods (summer pruning held in January and winter pruning held in July), expressed in grams per plant; trunk diameter, obtained from two measurements, performed with digital caliper 20 cm height above soil (mm); fruit number per plant, obtained through the fruit count in each plant in the crop (fruits plant<sup>-1</sup>); production per plant (kg plant<sup>-1</sup>); estimated production per hectare (t ha<sup>-1</sup>).

After harvesting, 20 peaches per repetition were evaluated regarding their diameter, with the aid of digital caliper and the results expressed in millimeter and the average fruit mass determined by weighing the fruits on a digital scale and the results expressed in grams (g).

During three years complete leaves (limbus + petioles) of the average part of the year branches were collected on different sides of the plants, between the 13<sup>th</sup> and the 15<sup>th</sup> weeks after full flowering. The leaves were

dried in a greenhouse at 65 °C, until reaching constant mass and grounded. Subsamples of 0.5 g were submitted to nitro-perchloric acid digestion with HClO<sub>4</sub> (1.0 mL) + HNO<sub>3</sub> (6.0 mL) at 190 °C, in digester block (CARMO et al., 2000). In the extract were determined phosphorus concentrations (P) by UV spectrophotometry (vanadate-molybdate method) and potassium (K), calcium (Ca) and magnesium (Mg) by flame atomic absorption spectrometry (AAS, Perkin Elmer AAnalyst 200, USA) and N was determined by the combustion method in TruSpec CHN-S Elementary Analyzer of LECO® brand, where N is quantified with the aid of a thermal conductivity cell (CARMO et al., 2000).

Data were submitted to variance analysis by the F test. When the effect of the quantitative factor (nitrogen fertilization concentrations) was significant, regression analysis was performed. Statistical analyses were performed with SISVAR version 5.6 (FERREIRA, 2014).



**Figure 1.** Average temperature (A) and monthly precipitation (B) of the years 2016, 2017 and 2018 for Pelotas-RS. Cascata Experimental Station, Embrapa Temperate Clima, in the municipality of Pelotas-RS.

## Results and Discussion

In the three years of study, there was no interaction between the factors (peaches genotype and the N concentrations) and nor differences among the genotypes for trunk diameter, green pruning mass and winter pruning mass. However, there was a linear increase of these parameters according to the increment of N concentrations applied in the soil (Figure 2A, 2B, 2C). These results were similar to those observed by Della Bruna & Back (2014) and Ferreira et al. (2018a), which reported that increasing N concentrations increase the vegetative growth of peach trees, because according to the increase in N concentration there was a higher amount of pruned material (DELLA BRUNA; BACK, 2014), besides increasing the trunk diameter, branches length and canopy volume (FERREIRA et al., 2018a).

The number of fruits per plant increased linearly according to the increment of N concentrations applied in the soil in 2016 and 2018 (Table 1). In 2017, the fruit number variable had interaction of the factors, and the 'Cascade 1067' Selection obtained the highest number of fruits in the concentrations of 60, 120 and 180 kg ha<sup>-1</sup> of N than the 'Cascade 1513' Selection (Table 2). For both cultivars, the number of fruits in 2017 increased with the increment of N concentrations (Table 2). According to Nava et al. (2007), the increase in the number of fruits with the increment of N concentrations, is due to the nourishment of the buds. According to these authors, the effect exerted by N in the increase of fruit setting rate is related to its role in the regulation of photosynthetic rate and carbohydrate synthesis, favoring the nutrition of the floriferous buds.

Nitrogen fertilization only changed the fruit mass in 2018 and resulted in a quadratic regression, where the largest fruit mass was estimated with the concentration of 75 kg ha<sup>-1</sup> of N (Table 3). This result is in accordance with Ferreira et al. (2018a), which found that the concentration of 70 kg ha<sup>-1</sup> of N applied via soil provided the largest fruits mass.

The production per plant increased linearly according to the increment of N concentrations in 2016 (Table 3). In 2017 and 2018 there was interaction of the studied factors, and the linear increase of production was verified according to the increasing concentrations of N applied via soil in the two peach trees selections evaluated in this study (Table 4). These results are in accordance with those of Dolinski et al. (2012) and Ferreira et al. (2018a), which also reported that increasing N concentrations resulted in a proportional increase in the production of the peach trees.

The fact that there was linear increase of production until the concentration of 180 kg ha<sup>-1</sup> of N can be related to the orchard be cultivated in high density, because it is assumed that in this condition, peach trees require higher N

concentrations. According to Ferreira et al. (2018a), in the peach trees growth phase cultivated in high density should be applied more N than the concentration recommended by CQFS – RS/SC (2016).

The results of this study indicate that high N concentrations favor the vegetative growth (Figure 2) and the increase of thieving branches was observed. Due to the greater plant vigor there can be less luminosity in the canopy and, consequently, delay in the maturation of the fruits, as well as reduction in their quality. Excess of N, besides stimulating vegetative growth, also exposes the plant to fungal diseases attacks (ROMBOLÀ et al., 2012), such as the brown rot, especially in the floral structures (SOUZA, 2005). Therefore, for the use of high N concentrations in peach trees, such as those applied in this study, requires greater removal of branches during pruning, due to these plants have large vegetative canopy, and thus an adequate relation between the vegetative and productive growth is established.

The absence of N reduced the number of fruits (Table 1 and 2) and the production per plant (Table 3 and 4) of peach orchards due to the lower productive capacity of the plant canopy, which has the lowest leaf area and, consequently, the lower photosynthetic rate. According to Leal et al. (2007), N is a component of the chlorophyll molecule necessary for photosynthesis and in the absence of this nutrient the photosynthesis is affected. Thus, the lack of energy production in plants affects the nutrient absorption and the production of carbohydrates, necessary for reproductive development.

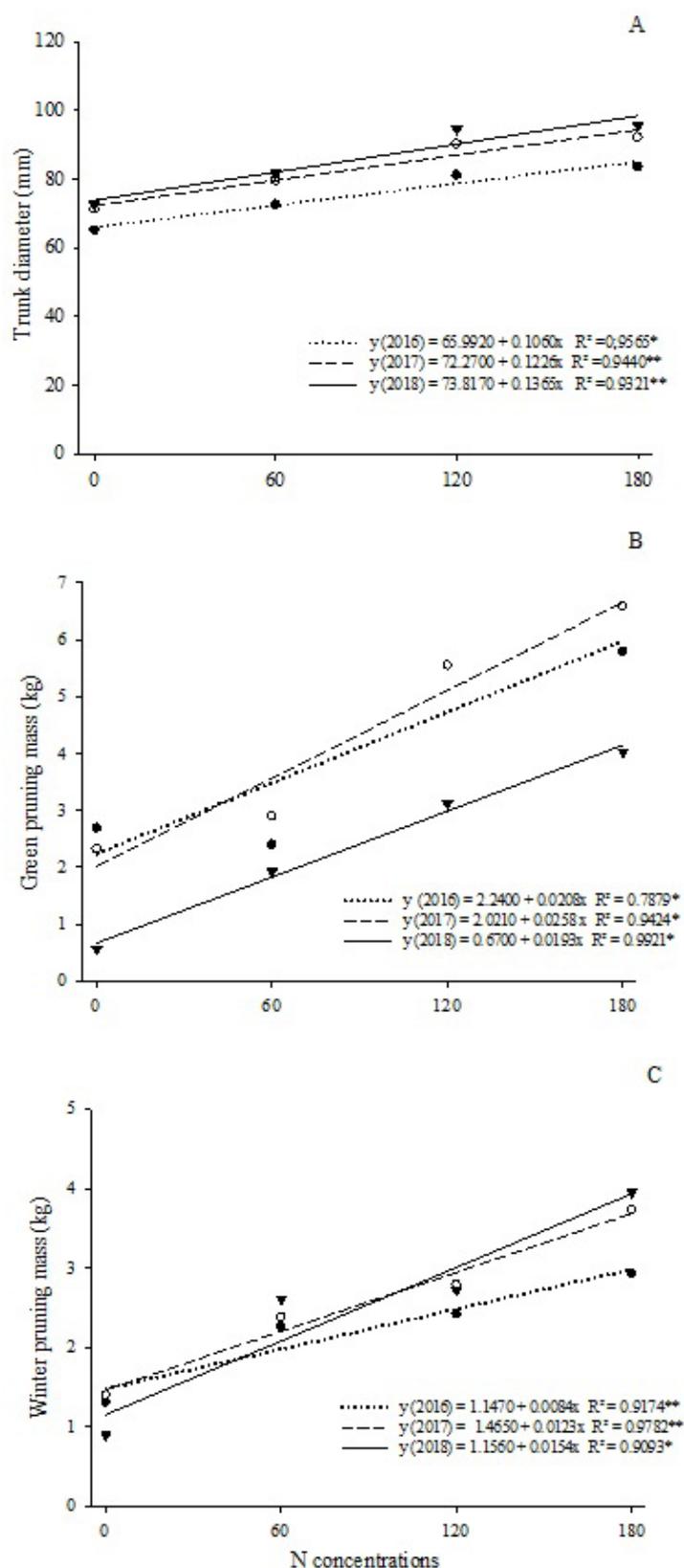
The average of three years of evaluation, a 2.92% of N content was verified in the leaves of peach trees not fertilized with N (Table 5). For this N content, the CQFS-RS/SC (2016) recommends the application of 70 kg of N ha<sup>-1</sup>, values lower than those obtained in this study in terms of productivity increment.

N leaf content increased linearly according to the increasing N concentrations applied in the soil, in the three years evaluated (Table 5). Results that corroborate with those obtained by Dolinski et al. (2005) and Brunetto et al. (2007), which verified that there was increase of N leaf content due to the increase of the concentrations applied in peach orchards. However, even for the highest N concentrations, N leaf levels remained in the range below normal (2.01 – 3.29) and normal (3.30 – 4.50%), as established by the CQSF-RS/SC (2016).

The N concentration applied in the soil did not influence the phosphorus content of peach leaves in the 2016 and 2017 harvests (Table 5), which is in agreement with that verified by Dolinski et al. (2005). However, in the third year of evaluation, the phosphorus content decreased as the concentrations of N supplied to the plants increased (Table 5). Mattos et al. (1991) reported an inverse relation between the applied N concentration and the phosphorus leaf content, possibly due to the dilution effect occurred from the largest leaf area resulting from N use.

The potassium, calcium and magnesium leaf content were not altered with the increasing N concentrations applied in the soil (Table 6). These results are in

accordance with Dolinski et al. (2005) and Ferreira et al. (2018b), which also did not observe changes in peach leaf content for potassium, calcium and magnesium, due to the increment of N concentrations applied in the soil.



**Figure 2.** Trunk diameter (A), green pruning mass (B) and winter pruning mass (C) of peach genotypes submitted to different nitrogen fertilization concentrations in the years 2016, 2017 and 2018. \*\* significant at 1% probability; \* significant at 5% probability.

**Table 1.** Number of fruits of peach genotypes submitted to different nitrogen fertilization concentrations in 2016 and 2018.

	Number of fruits per plant	
	2016	2018
Cascata 1513	143	107
Cascata 1067	155	110
F <sub>(genotype)</sub>	0.3454 <sup>ns</sup>	0.8071 <sup>ns</sup>
N concentrations (kg ha <sup>-1</sup> )		
0	114.25	69.00
60	134.75	120.00
120	158.75	98.00
180	189.25	154.00
F <sub>(concentration)</sub>	0.0019	0.0002
Linear	* (1)	* (2)
Quadratic	<sup>ns</sup>	<sup>ns</sup>
F <sub>(genotype x concentration)</sub>	0.0607 <sup>ns</sup>	0.1523 <sup>ns</sup>

<sup>ns</sup> non-significant for regression analysis; \* significant to 5% probability; <sup>(1)</sup>y = 111.90 + 0.4150x (R<sup>2</sup> = 0.9919); <sup>(2)</sup>y = 75.30 + 0.3883x (R<sup>2</sup> = 0.7031).

**Table 2.** Number of fruits per plant of peach genotypes submitted to different nitrogen fertilization concentrations in 2017.

Selection	Number of fruits per plant					
	2017					
	N concentrations (kg ha <sup>-1</sup> )				Linear	Quadratic
	0	60	120	180		
Cascata 1513	40.00	49.00	57.00	62.00	* <sup>(1)</sup>	<sup>ns</sup>
Cascata 1067	33.00	102.00	117.00	150.00	* <sup>(2)</sup>	<sup>ns</sup>
Significant <sub>(genotype)</sub>	<sup>ns</sup>	*	*	*		

<sup>ns</sup> non-significant for regression analysis; \* significant to 5% probability; <sup>(1)</sup>y = 40.90 + 0.1233x (R<sup>2</sup> = 0.9849); <sup>(2)</sup>y = 45.60 + 0.610x (R<sup>2</sup> = 0.9199).

**Table 3.** Fruit mass and production per plant of peach genotypes submitted to different nitrogen fertilization concentrations.

	Fruit mass (g)			Production per plant (kg)
	2016	2017	2018	2016
Cascata 1513	78.85 b	99.88 a	49.15 b	10.53 b
Cascata 1067	111.65 a	63.11 b	61.13 a	17.09 a
F <sub>(genotype)</sub>	0.0001**	0.0001**	0.0001**	0.0001**
N concentrations (kg ha <sup>-1</sup> )				
0	92.17	83.68	47.43	10.98
60	92.60	75.59	69.58	12.52
120	91.91	83.62	70.68	15.35
180	104.32	83.09	72.38	16.44
F <sub>(concentration)</sub>	0.0541 <sup>ns</sup>	0.5180 <sup>ns</sup>	0.0004**	0.0001
Linear	<sup>ns</sup>	<sup>ns</sup>	<sup>ns</sup>	* <sup>(2)</sup>
Quadratic	<sup>ns</sup>	<sup>ns</sup>	* <sup>(1)</sup>	<sup>ns</sup>
F <sub>(genotype x concentration)</sub>	0.3370 <sup>ns</sup>	0.9114 <sup>ns</sup>	0.1555 <sup>ns</sup>	0.1011 <sup>ns</sup>

<sup>ns</sup> non-significant for regression analysis; \* significant to 5% probability; \*\* significant to 1% probability; <sup>(1)</sup>y = 48.513 + 0.3822x - 0.0014x<sup>2</sup> (R<sup>2</sup> = 0.9437); <sup>(2)</sup>y = 10.9410 + 0.0320x (R<sup>2</sup> = 0.9731).

**Table 4.** Production per plant of peach genotypes submitted to different nitrogen fertilization concentrations in 2017 and 2018.

Production per plant (kg)						
2017						
Selection	N concentrations (kg ha <sup>-1</sup> )				Linear	Quadratic
	0	60	120	180		
Cascata 1513	3.96	4.32	5.87	6.41	*(1)	ns
Cascata 1067	1.78	5.77	7.61	9.06	*(2)	ns
Significant (genotype)	*	ns	*	*		
2018						
Selection	N concentrations (kg ha <sup>-1</sup> )				Linear	Quadratic
	0	60	120	180		
Cascata 1513	3.72	5.27	7.25	7.40	*(3)	ns
Cascata 1067	3.35	8.42	8.82	14.80	*(4)	ns
Significant (genotype)	ns	ns	*	*		

ns non-significant for regression analysis; \* significant to 5% probability; <sup>(1)</sup>y=3.805+ 0.0148x (R<sup>2</sup> = 0.9406); <sup>(2)</sup>y =2.503 + 0.0395x (R<sup>2</sup> = 0.9407); <sup>(3)</sup>y = 3.957+ 0.0217x (R<sup>2</sup> = 0.9192); <sup>(4)</sup>y = 3.635 + 0.0579x (R<sup>2</sup> = 0.9171).

**Table 5.** Nitrogen and phosphorus leaf content of peach genotypes submitted to different nitrogen fertilization concentrations in 2016, 2017 and 2018.

	Nitrogen (%)			Phosphor (%)		
	2016	2017	2018	2016	2017	2018
Cascata 1513	3.46	3.75	3.08	0.15	0.27	0.30
Cascata 1067	3.00	3.57	3.38	0.14	0.27	0.27
F (genotype)	0.1631 <sup>ns</sup>	0.0665 <sup>ns</sup>	0.0001 <sup>**</sup>	0.0008 <sup>**</sup>	0.9608 <sup>ns</sup>	0.0001 <sup>**</sup>
N concentrations (kg ha <sup>-1</sup> )						
0	2.54	3.36	2.88	0.15	0.27	0.32
60	3.06	3.67	3.26	0.14	0.27	0.28
120	2.96	3.76	3.39	0.14	0.27	0.28
180	3.23	3.85	3.40	0.14	0.28	0.26
F (concentration)	0.0037 <sup>**</sup>	0.0050 <sup>*</sup>	0.0001 <sup>**</sup>	0.1409 <sup>ns</sup>	0.9608 <sup>ns</sup>	0.0001 <sup>**</sup>
Linear	*(1)	*(2)	*(3)	ns	ns	*(4)
Quadratic	ns	ns	ns	ns	ns	ns
F (genotype x concentration)	0.6465 <sup>ns</sup>	0.0980 <sup>ns</sup>	0.3229 <sup>ns</sup>	0.8456 <sup>ns</sup>	0.9132 <sup>ns</sup>	0.0699 <sup>ns</sup>
Normal values <sup>***</sup>	3.30 - 4.50			0.15 - 0.30		

\*\*\* = values considered normal according to the CQFS (2016); ns non-significant for regression analysis; \*\* significant to 1% probability; \* significant to 5% probability; <sup>(1)</sup>y = 2.652 + 0.0033x (R<sup>2</sup> = 0.7501); <sup>(2)</sup>y = 3.426+ 0.0026x (R<sup>2</sup> = 0.8934); <sup>(3)</sup>y = 2.979+ 0.0028x (R<sup>2</sup> = 0.8028); <sup>(4)</sup>y =0.312-0.0003x (R<sup>2</sup> = 0.8526).

**Table 6.** Phosphorus, calcium and magnesium leaf content of peach genotypes submitted to different nitrogen fertilization concentrations in 2016, 2017 and 2018.

	Potassium (%)			Calcium (%)			Magnesium (%)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Cascata 1513	2.21	2.63	3.61	1.79	1.51	1.45	0.58	0.46	0.62
Cascata 1067	2.26	2.53	3.53	1.76	1.50	1.45	0.56	0.47	0.63
F <sub>(genotype)</sub>	0.46 <sup>ns</sup>	0.13 <sup>ns</sup>	0.33 <sup>ns</sup>	0.80 <sup>ns</sup>	0.96 <sup>ns</sup>	0.95 <sup>ns</sup>	0.55 <sup>ns</sup>	0.51 <sup>ns</sup>	0.65 <sup>ns</sup>
N concentration (kg ha <sup>-1</sup> )									
0	2.24	2.52	3.70	1.79	1.57	1.50	0.56	0.48	0.62
60	2.24	2.64	3.39	1.80	1.56	1.42	0.58	0.47	0.63
120	2.15	2.59	3.65	1.84	1.54	1.44	0.58	0.47	0.62
180	2.31	2.56	3.53	1.67	1.36	1.42	0.56	0.45	0.64
F <sub>(concentration)</sub>	0.47 <sup>ns</sup>	0.58 <sup>ns</sup>	0.07 <sup>ns</sup>	0.71 <sup>ns</sup>	0.35 <sup>ns</sup>	0.81 <sup>ns</sup>	0.77 <sup>ns</sup>	0.87 <sup>ns</sup>	0.81 <sup>ns</sup>
Linear	<i>ns</i>								
Quadratic	<i>ns</i>								
F <sub>(genotype x concentration)</sub>	0.76 <sup>ns</sup>	0.57 <sup>ns</sup>	0.75 <sup>ns</sup>	0.47 <sup>ns</sup>	0.76 <sup>ns</sup>	0.44 <sup>ns</sup>	0.75 <sup>ns</sup>	0.54 <sup>ns</sup>	0.47 <sup>ns</sup>
Normal values <sup>***</sup>	1.40 - 2.00			1.70 - 2.60%			0.50 - 0.80		

\*\*\* = values considered normal according to CQFS (2016); <sup>ns</sup> non-significant for regression analysis.

## Conclusions

For the conditions of this experiment there was increase in production and growth until the dose of 180 kg ha<sup>-1</sup> of N. There was linear increase, so, it was not possible to verify which was the maximum dose for the largest productivity, requiring new studies.

Nitrogen fertilization concentrations provide greater vegetative growth of peach trees cultivated in high density planting.

The nitrogen maintenance fertilization application does not change the potassium, calcium and magnesium leaf contents. In a single crop, P levels were reduced by increased N doses.

## Acknowledgments

The authors would like to thank the National Council for Scientific and Technological Development (CNPq) for granting the scholarships, EMBRAPA for support in infrastructure and logistics in carrying out this study and to Maria do Carmo Bassols Raseira for granting of the selections used in the work.

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