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Soils and plant nutrition

Potassium fertilization and its impact on production and mineral composition of peach trees

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Abstract- This study aimed at evaluating production parameters of peach trees subject to different doses of potassium fertilization and at establishing the critical level of this nutrient in the soil and in peach tree leaves. The experiment was conducted in the 2016, 2017 and 2018 seasons in a commercial orchard located in Morro Redondo, Rio Grande do Sul state, Brazil. Peach trees of the cultivar Sensação were fertilized at the following doses: 0, 40, 80, 120 and 160 kg ha^{-1} K_2O as potassium chloride applied to the surface of the soil. In the 3-year study, production per plant, number of fruit, fruit mass and fruit diameter were evaluated while soil and leaf samples were collected to undergo chemical analyses. Potassium fertilization in peach orchards increases levels of this nutrient in the 0-20 cm soil layer. Potassium fertilization via soil increased potassium contents in peach tree leaves. Productivity of peach trees responds to superficial potassium application via soil but it does not affect mean fruit mass. The critical level between relative productivity and potassium content in the soil could not be established while the one between production and potassium content of leaves of peach trees was 2.84%.

Index Terms: *Prunus persica*; potassium; nutrition; critical level.

Adubação potássica e seu impacto na produção e composição mineral de pessegueiros

Resumo- O objetivo deste trabalho foi avaliar avaliar caracterísicas produtivas de pessegueiros submetidos a distintas doses de adubação potássica e estabelecer o nível crítico deste nutriente no solo e nas folhas de pessegueiro. O experimento foi conduzido nas safras de 2016, 2017 e 2018 em pomar comercial, localizado no município de Morro Redondo, Brasil. Os pessegueiros da cultivar Sensação foram adubados com as doses de 0; 40; 80; 120 e 160 kg ha^{-1} de K_2O, na forma de cloreto de potássio aplicado na superfície do solo. Durante os três anos, foram avaliados a produção por planta, o número de frutos, a massa dos frutos, o diâmetro dos frutos e coletadas amostras de solo e folhas para realização de análise química. A adubação potássica em pomar de pessegueiro eleva os níveis deste nutriente na camada de 0 a 20 cm do solo. A adubação potássica via solo aumentou os teores de K nas folhas de pessegueiros. A produtividade dos pessegueiros responde à aplicação superficial de potássio via solo, mas não altera a massa média dos frutos. Não foi possível estabelecer o nível crítico entre a produtividade relativa e o teor de K no solo. O nível crítico estabelecido entre a produção o teor foliar de K dos pessegueiros foi de 2,84%.

Termos para indexação: *Prunus persica*; potássio; nutrição; nível crítico.

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Introduction

Brazil produces 220 thousand ton peaches annually, mainly in both southern and southeastern regions. Even though Rio Grande do Sul (RS) is the main state in terms of production and cultivated area, its mean productivity has been considered low by comparison with other regions which also produce peaches (IBGE, 2021). Hence, the importance of knowing factors that influence low productivity to improve cultivation and production techniques.

Therefore, the search for orchard management practices, such as the right choice of crown cultivars and rootstocks (BARRETO et al., 2017), pruning (GONÇALVES et al., 2014) and balanced fertilization (FERREIRA et al., 2018), is fundamental to reach high yield. Fertilization is essential for productivity but doses must be adequate for every crop and species (AMORIM et al, 2015; FERREIRA et al., 2018).

Nitrogen (N) and potassium (K) are the mineral elements that stone fruit trees need the most; since the latter is the most exported macronutrient through fruit (ROMBOLÀ et al., 2012), it must be annually restituted to avoid soil depletion. K carries out important functions in plants, such as activation of several enzymes, participation in transport across membranes, cell expansion, photosynthesis and carbohydrate accumulation (MARSCHNER, 2011; BRUNETTO et al., 2015), which may affect production parameters of crops.

There is little information on responses of peach trees to K fertilization in Brazilian edaphoclimatic conditions. Previous studies of K fertilization applied to peach trees in Brazil involved some other factors, such as green pruning and the use of plastic throughout cultivation (TREVISAN et al., 2006) and formulations of leaf fertilizers with K (BERTOLINI et al., 2018), which make it hard to separate their effects from the real amount of K needed by plants. Therefore, this paper aimed at evaluating production parameters of peach trees subject to different doses of K fertilization and at establishing the critical level of this nutrient in the soil and in leaves.

Material and methods

The experiment was carried out in 2016, 2017 and 2018 in a commercial orchard located in Morro Redondo, in Rio Grande do Sul (RS) state, Brazil (latitude 31°31'49.3" Sand longitude 52°35'39.8"W). In the Köppen classification, the climate in the region is "cfa"- humid subtropical, i. e., humid temperate with warm summers (ALVARES et al., 2013). The soil is moderately deep with medium texture in A horizon and clayish in B horizon and has been classified into Red-yellow Argissol (SANTOS et al., 2006).

Mean temperature, precipitation and chill hours in the 3-year experiment were collected by the meteorological station at the Embrapa Clima Temperado (Cascata Experimental Station), in Pelotas, RS, Brazil (Figure 1). Calculation of chill hours was based on temperatures below or equal to 7.2 °C; they totaled 348, 198 and 378 in 2016, 2017 and 2018, respectively.

The orchard, which was implanted in 2009, consists of 'Sensação' peach trees grafted on the rootstock Capdeboscq. Vase-shaped trees at 5 m x 2 m spacing resulted in density of 1,000 plants ha^{-1}. Physicochemical analyses of the soil, which were conducted before the beginning of the experiment in the 0-20-cm layer, led to the following results: pH in water was 5.8; 3.2 cmol$_c$ dm^{-3} H+Al; CTC$_{(pH\ 7.0)}$ = 5.8; 11.3 mg dm^{-3} P (low content); 101 mg dm^{-3} K (high content); 3.7 cmmol$_c$ dm^{-3} Ca (high content); 0.9 cmol$_c$ dm^{-3} Mg (medium content); 260 g Kg^{-1}clay; and 220 g Kg^{-1} organic matter.

The experiment had a randomized block design with four replicates. Experimental units comprised four plants, but only both central plants were evaluated. K doses were 0, 40, 80, 120 and 160 kg ha^{-1} K_2O, as K chloride (60% of K). They were applied annually, close to the period of peach tree full bloom (mid-July), to the surface of the soil, with no incorporation, in the tree crown projection area. Equal doses of N and P were applied to all parcels, in agreement with recommendations issued by the CQFS - RS/SC (2016).

Variables of yield resulted from weight of fruit produced by both central plants in every parcel. Mean fruit mass was estimated by dividing total fruit mass of every plant by the number of fruit collected per plant; results were expressed as grams. The number of fruit per plant resulted from counting all fruit collected per plant. Productivity was expressed as t ha^{-1}. After harvest, twenty peaches per replicate had their diameters measured by a digital pachymeter and results were expressed as millimeters.

In the 3-year study, whole leaves (limb + petiole) were collected in the middle of current-year branches, on different sides of plants, between the 13th week and the 15th one after full bloom. Leaves were then dried in an oven, ground and had their macro- and micronutrient contents (CQFS - RS/SC, 2016) analyzed by the methodology proposed by Carmo et al. (2000). Soil was also collected in both 0-10 cm and 0-20 cm layers to determine pH in water by potentiometry and macro and micronutrient contents by the methodology proposed by Tedesco et al. (1995).

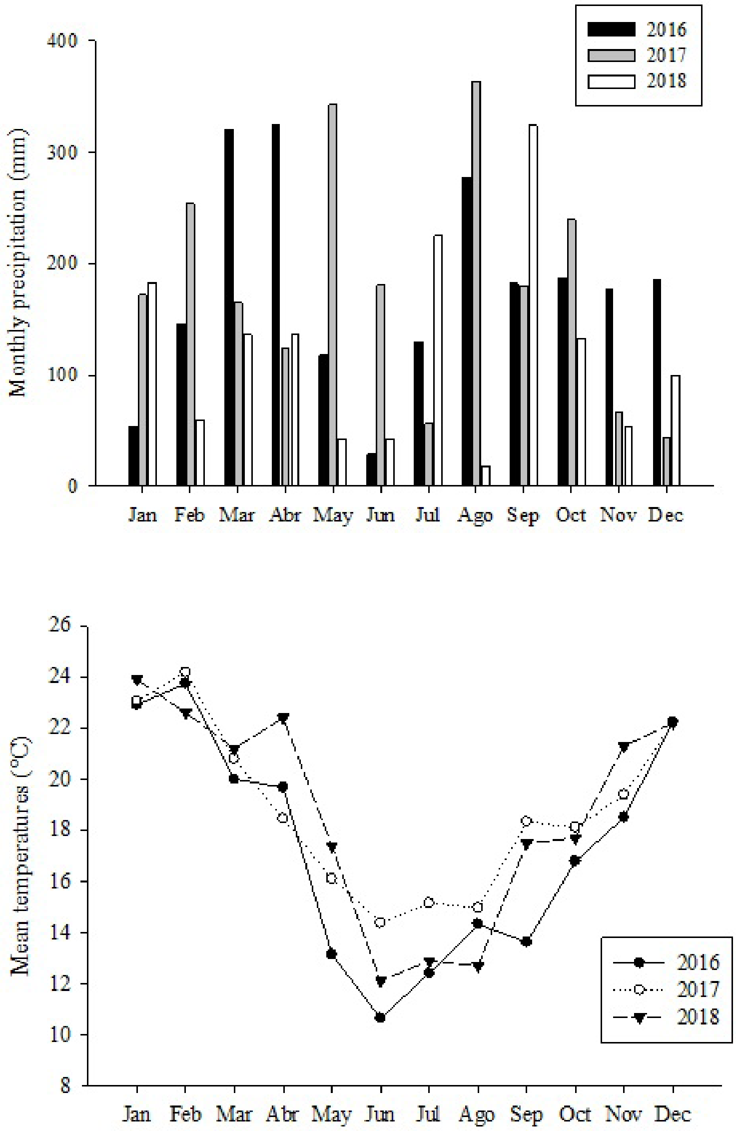

Figure 1. Monthly precipitation and mean temperatures in 2016, 2017 and 2018 in Pelotas, RS. Cascata Experimental Station, Embrapa Clima Temperado, Pelotas-RS.

Results were subject to the analysis of variance. When effects were significant, regression equations were adjusted and both linear and quadratic models were subject to the F-test ($P<0.05$) by the SISVAR 5.6 program (FERREIRA, 2014). Regarding results of leaf and soil analyses, they were correlated with each other and with productivity.

Results and Discussion

K contents available in the 0-10 cm layer increased due to the doses of K fertilization which were applied to the soil throughout the three years under evaluation (Table 1). Increase found in the superficial layer may be attributed to K application the surface of the soil, with no incorporation, and to K partial adsorption by its colloidal particles (DUARTE et al., 2013). Increase in K content in the superficial layer (0-10 cm) corroborates results found by Brunetto et al. (2015), who studied the effect of K application for three years and observed increase in K content in the superficial layer due to increase in K doses applied to pear orchards.

Table 1. Potassium content available in 0-10 cm, 10-20 cm and 0-20 cm soil layers and leaf content of 'Sensação' peach trees subject to fertilization at different potassium doses in Morro Redondo, RS, in 2016, 2017 and 2018. Embrapa Clima Temperado, Pelotas, RS, 2018.

K_2O doses (kg ha^{-1})	Soil layer (cm) 0 - 10	10 - 20	0-20	K content in leaves (%)
.	Available K content (mg dm^{-3})			
		2016		
0	124.50	104.25	114.37	2.84
40	142.00	128.50	135.75	2.83
80	171.25	141.50	156.37	2.86
120	180.50	151.50	166.00	2.85
160	196.25	176.50	186.37	2.89
CV (%)	13.90	14.08	10.88	3.54
Linear	*(1)	*(4)	*(7)	ns
Quadratic	ns	ns	ns	ns
		2017		
0	94.00	78.75	86.37	2.71
40	130.75	127.50	129.12	2.66
80	151.50	184.75	168.12	3.29
120	201.00	205.50	203.25	3.26
160	211.50	209.25	210.37	3.38
CV (%)	16.19	15.38	14.45	6.95
Linear	*(2)	* (5)	*(8)	*(10)
Quadratic	ns	ns	ns	ns
		2018		
0	98.25	86.75	92.50	1.92
40	178.00	137.25	157.62	2.06
80	152.50	135.00	143.75	2.28
120	213.50	195.75	204.62	2.15
160	218.75	208.50	213.62	2.32
CV (%)	9.21	10.88	8.88	10.13
Linear	*(3)	*(6)	*(9)	*(11)
Quadratic	ns	ns	ns	ns

[ns] non-significant for regression analysis; [*] significant at 5% probability; (1) $y = 126.50 + 0.455x$ ($R^2 = 0.9734$); (2) $y = 96.70 + 0.7631x$ ($R^2 = 0.9714$); (3) $y = 116.9 + 0.6913x$ ($R^2 = 0.7831$); (4) $y = 106.96 + 0.4188x$ ($R^2 = 0.9755$); (5) $y = 93.35 + 0.8475x$ ($R^2 = 0.9007$); (6) $y = 92.25 + 0.755x$ ($R^2 = 0.9242$); (7) $y = 99.24 + 0.4388x$ ($R^2 = 0.9714$); (8) $y = 95.02 + 0.8053x$ ($R^2 = 0.9566$); (9) $y = 104.57+ 0.7231x$ ($R^2 = 0.8658$); (10) $y = 2.67 + 0,0049x$ ($R^2 = 0.7877$); (11) $y = 1.968+ 0.0022x$ ($R^2 = 0.7422$).

There was linear increase in K contents as the number of K doses applied to both 10-20 cm and 0-20-cm layers increased in the year period (Table 1). Part of K applied to the surface of the soil, mainly at the highest doses (120 and 160 Kg ha^{-1} K_2O), migrated deeply into the soil not only due to its solubility on the surface but also because K^+ conduces electrostatic connections in the soil, which bestows it high mobility in the soil profile (ERNANI et al., 2016).

Increase in K^+ in the subsurface soil, due to its high mobility, is important since fertilizers are applied to the surface but need to reach roots to be absorbed. K^+ ions move in the soil towards roots mainly by diffusion, since the amount that reaches roots by mass flow is much lower that the absorption rate (NEVES et al., 2009; FAGERIA, 2009). Ion diffusion in the soil depends on the water content, concentration gradient of K^+ ions, pH of the soil (FAGERIA, 2009) and the buffer capacity of nutrients (NEVES et al., 2009). In both years (2016, 2017 and 2018), the nutrient was applied in mid-June, i. e., in full bloom of peach trees. There was much rainfall in the following months (Figure 1), a fact that may also have contributed to K mobility in the soil.

Superficial K application increases its levels in the 0-20 cm layer (Table 1); thus, the nutrient can be reached by a large part of the root system of peach trees. According to Freire and Magnani (2014), peach trees absorb water and nutrients mainly through their fine roots; 50% of them are found in this layer, i. e., up to 20 cm deep.

K contents of peach tree leaves did not respond to K fertilization in the first year of the study (2016) (Table 1), a fact that may have resulted from the reserve accumulated before the beginning of the experiment. In addition, low precipitation may have influenced non-absorption and displacement of K in the soil profile. However, in both following years (2017 and 2018), the more K doses applied to the soil, the more K contents of leaves increased (Table 1). It may be attributed to increase in exchangeable K in the soil after application of doses in both 0-10 cm and 0-20 cm layers (Table 1). It leads to increase in K contents in the soil solution and, consequently, in absorption by plants. K contents of leaves were classified into normal (1.40% - 2.00%) and excessive (> 2.80%), according to the CQFS-RS/SC (2016), in all treatments used in this study.

K fertilization led to increase in productivity of peach trees in the three seasons under evaluation (Table 2). Productivity exhibited quadratic behavior; the highest values were found when doses of 68, 97 and 68 kg ha^{-1} K_2O were applied in 2016, 2017 and 2018, respectively. In the 2018 season, there was drastic decrease in productivity (Table 2). There may be changes in productivity of peach trees from season to season mainly due to non uniformity of flowering and edaphoclimatic conditions throughout cultivation (BARRETO et al., 2017). Thus, in the nutritional evaluation of plants, only the first two years of the study were used; the mean K content of leaves of peach trees that had not been subject to K fertilization was 2.77%. Concerning this K content, the CQFS-RS/SC (2016) recommends the application of 36 Kg K_2O ha^{-1}, which is lower than values applied by this study to increase productivity.

Table 2. Productivity, number of fruit, mean fruit mass and fruit diameter of 'Sensação' peach trees subject to fertilization at different potassium doses in Morro Redondo, RS, in 2016, 2017 and 2018. Embrapa Clima Temperado, Pelotas, RS, 2018.

K_2O doses (kg ha^{-1})	Productivity (t ha^{-1})	Number of fruit	Mean fruit mass (g)	Mean fruit diameter (mm)
		2016		
0	24.49	285	88.34	59.23
40	29.89	277	116.24	59.69
80	28.60	283	104.00	61.79
120	24.34	259	94.34	59.89
160	23.57	250	97.99	57.80
CV (%)	10.29	20.09	7.99	2.40
Linear	ns	ns	ns	ns
Quadratic	*(1)	ns	ns	*(5)
		2017		
0	23.09	142	162.91	64.33
40	28.14	169	167.17	67.09
80	25.45	154	167.98	65.81
120	27.62	160	180.54	65.54
160	25.56	163	157.57	67.69
CV (%)	6.57	14.53	14.84	3.73
Linear	ns	ns	ns	ns
Quadratic	*(2)	ns	ns	ns
		2018		
0	6.81	58	115.01	64.70
40	7.46	72	102.43	63.38
80	13.08	102	127.78	63.12
120	5.35	44	121.81	61.64
160	6.44	46	146.31	64.57
CV (%)	23.94	15.77	16.44	3.01
Linear	ns	ns	ns	ns
Quadratic	*(3)	*(4)	ns	ns

ns non-significant for regression analysis; *significant at 5% probability;(1) $y = 25.555 + 0.0816x - 0.0006x^2$ ($R^2 = 0.5506$); (2) $y = 23.751 + 0.779x - 0.0004x^2$ ($R^2 = 0.5080$); (3) $y = 6.661 + 0.0819x - 0.0006x^2$ ($R^2 = 0.3237$); (4) $y = 58.543 + 0.6654x - 0.005x^2$ ($R^2 = 0.5061$); (5) $y = 58.912 + 0.0583x - 0.0004x^2$ ($R^2 = 0.8044$).

Considering that peach trees export 2 Kg K through their fruit (TAGLIAVINI et al., 2000), the K amount recommended by the CQFS-RS/SC (2016) is not even enough to supply the demand of fruit exportation. Since the number of fruit per plant was only influenced by K doses in the 2018 season, when the largest number of fruit was reached when 80 kg ha^{-1} K_2O was applied (Table 2). However, mean fruit mass was not affected by ascending K doses in the soil in any season under evaluation (Table 2). Results corroborate the ones found by Brunetto et al. (2015), who observed that K application in three seasons did not affect fruit mass of pears.

Fruit diameter only responded to K doses in the 2016 season; 72.9 Kg ha^{-1} K_2O was the one that led to fruit with the largest diameters (Table 2). Results of fruit diameter related to K fertilization are not always evident. Ghanem and Mimoun (2017) found that fruit diameter of 'Strival' and 'Black Star' plums did not exhibit any difference as the result of the use of K. Besides, different K doses applied on leaves, combined with water regimes, did not affect peach diameter (DBARA et al., 2016).

Even though productivity of peach trees responded to K fertilization, this variable decreased when high K doses were applied to the soil (Table 2), a fact that may be attributed to the effect of competition of K in absorption of other nutrients, such as calcium (Ca) and magnesium (Mg) (Table 3). It happens because K^+, $Ca2^+$ and Mg^{2+} compete for the same absorption sites and the cation at the highest concentration in the soil solution has preferred absorption by comparison with the others (ERNANI, 2016; BERTOLINI et al., 2018). High K doses in the soil may have led to an imbalance of the relation with other cations in the soil, thus, decreasing their absorption and productivity. However, leaf contents of N, phosphorus, copper, iron, manganese and zinc were not affected by K doses in the soil in the three years under evaluation (Table 3).

Table 3. Leaf contents of nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) of 'Sensação' peach trees after application of different K doses to the soil in 2016 e 2017. Embrapa Clima Temperado, Pelotas, RS, 2018.

K_2O doses (kg ha^{-1})	N	P	Ca	Mg	Cu	Fe	Mn	Zn
	%				mg kg^{-1}			
	2016							
0	3.11	0.17	1.85	0.54	8.50	68.25	154.00	57.00
40	3.05	0.17	1.65	0.50	8.00	72.75	155.50	59.75
80	3.16	0.17	1.71	0.47	8.00	66.00	152.50	60.50
120	2.59	0.17	1.57	0.46	7.25	68.25	154.50	58.25
160	3.07	0.17	.38	0.35	7.25	66.50	144.25	59.75
Linear	ns	ns	*(1)	*(2)	ns	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	ns	ns	ns
	2017							
0	3.37	0.35	1.82	0.52	8.75	71.00	149.25	43.75
40	3.59	0.36	1.76	0.51	9.00	72.25	149.25	43.00
80	3.54	0.36	1.75	0.47	10.00	64.50	150.25	42.50
120	3.61	0.35	1,59	0.44	8.50	71.75	162.25	42.50
160	3.36	0.36	1.52	0.48	9.25	72.75	154.50	40.25
Linear	ns	ns	*(3)	ns	ns	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	ns	ns	ns
	2018							
0	2.93	0.29	1.76	0.68	4.32	78.77	151.75	20.85
40	2.71	0.28	1.65	0.58	3.50	76.56	152.25	30.20
80	2.73	0.28	1.74	0.65	3.42	79.85	176.25	22.50
120	2.90	0.28	1.50	0.54	3.57	72.37	155.25	20.10
160	2.81	0.29	1.51	0.53	5.10	72.65	131.25	20.55
Linear	ns	ns	*(4)	*(5)	ns	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	ns	ns	ns

ns non-significant for regression analysis; *significant at 5% probability; (1) $y = 1.833 - 0.0025x$ ($R^2 = 0.8564$); (2) $y = 0.55 - 0.0011x$ ($R^2 = 0.8779$); (3) $y = 1.8415 - 0.0019x$ ($R^2 = 0.9135$); (4) $y = 1.762 - 0.0016x$ ($R^2 = 0.6963$); (5) $y = 0.664 - 0.0009x$ ($R^2 = 0.6524$).

The critical level between peach tree production and K content of leaves could be established (Figure 2). To reach 90% of maximum production, critical K value of leaves was 2.84%. According to the CQFS-RS/SC (2016), K contents of leaves above 2.80% are considered excessive in peach tree cultures and diverge from the critical level found by this study.

The relation established between relative productivity of the three seasons under evaluation and exchangeable K contents in both 0-10 cm (Figure 3A) and 10-20 cm (Figure 3B) layers did not enable to establish the critical level of the nutrient in the soil. Even though peach tree productivity was affected by K doses, there was strong change in production in the last season (Table 2), a fact that does not enable to find significant relation between relative yield and K contents in the soil, regardless of the layer under evaluation.

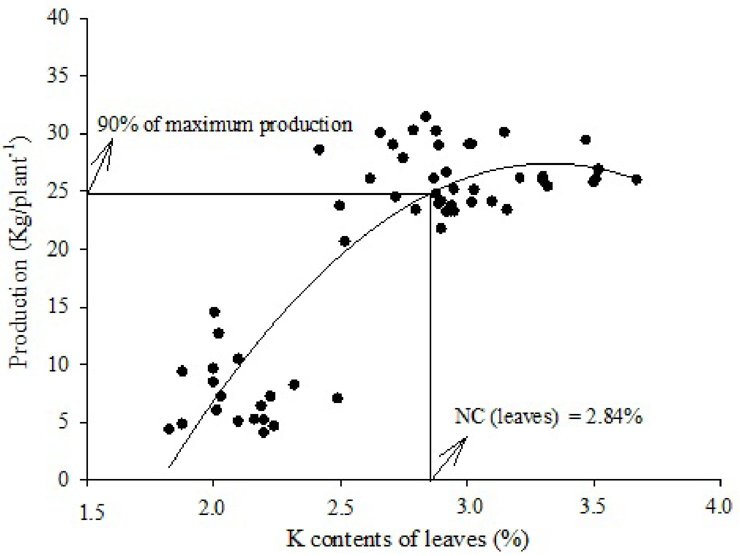

Figure 2. Relation between relative yield of ‘Sensação’ peach trees and K contents of leaves in 2016, 2017 and 2018. Embrapa Clima Temperado, Pelotas, RS, 2018.

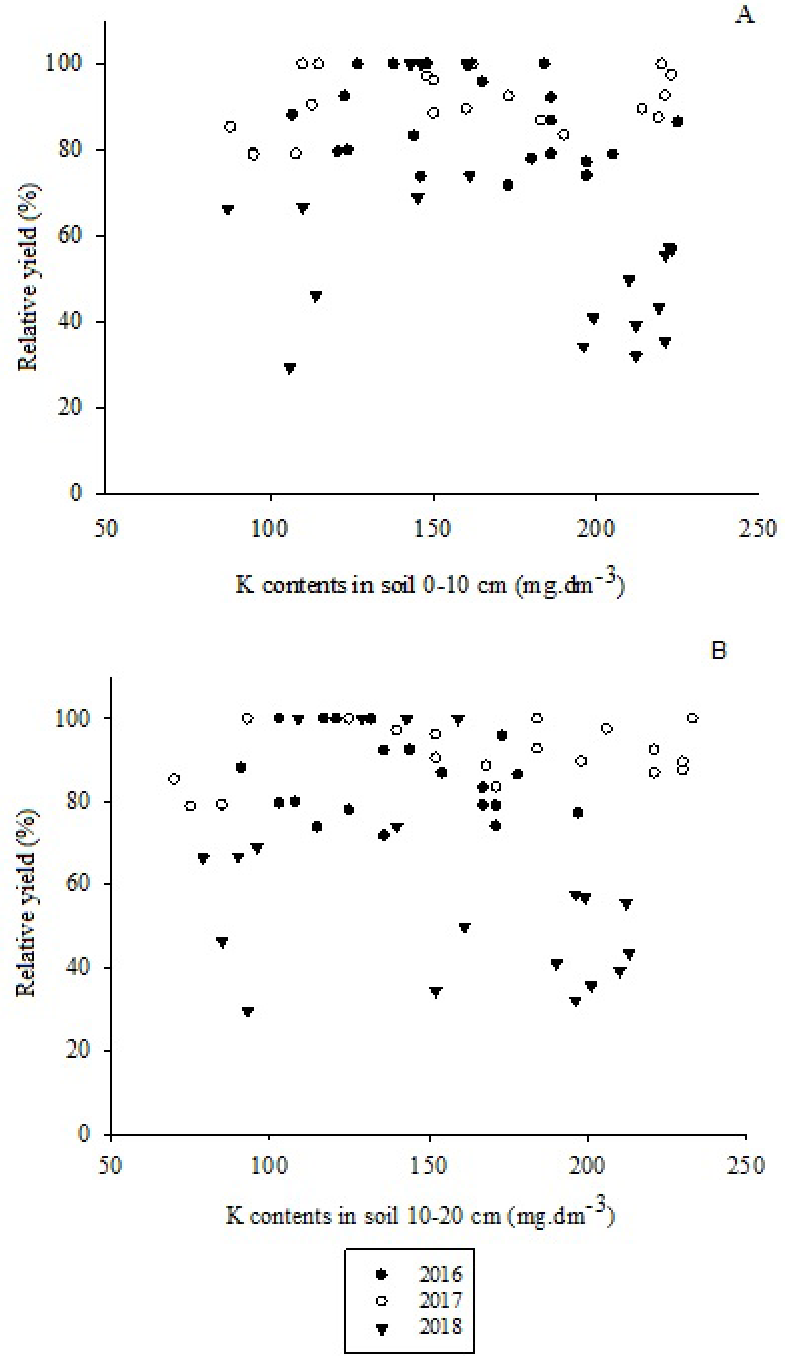

Figure 3. Relation between relative yield of 'Sensação' peach trees and K contents available in 0-10 cm (A) and 10-20 cm (B) soil layers in 2016, 2017 and 2018. Embrapa Clima Temperado, Pelotas, RS, 2018.

Conclusion

K fertilization increases K contents in the 0-20 cm soil layer and in leaves of peach trees.

Peach tree productivity responds to superficial K application and, to reach maximum productivity, annual doses should range from 68 to 97 Kg ha^{-1} K_2O.

The critical level established between production and leaf content was 2.84% of K in peach tree leaves.

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