Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
http://periodicos.ufersa.edu.br/index.php/sistema

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252017v30n216rc

PHOSPHATE AND POTASSIUM FERTILIZATION FOR RADISH GROWN IN A LATOSOL WITH A HIGH CONTENT OF THESE NUTRIENTS[1]

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ABSTRACT - The intensive cultivation of vegetables with frequent chemical fertilization may cause accumulation of nutrients in the soil. This, in turn, may reduce crop yields and damage the environment due to contamination of ground water and rivers. Thus, to increase the effects of P (0, 100, 200, 300 and 400 kg ha^{-1} of P_2O_5) and K (0, 60, 120, 180 and 240 kg ha^{-1} of K_2O) doses on the growth and productivity of radish cultivars (Sakata 19 and Sakata 25) in a soil with high levels of these nutrients, two experiments were conducted in randomized blocks with the factors cultivars and doses arranged in a 2 x 5 factorial design with three replications. Number of leaves per plant, leaf area, shoot and root dry mass, total and commercial productivity, percentage of cracked roots and P and K contents in the plant and in the soil were evaluated. The Sakata 19 cultivar performed better than the Sakata 25 in both experiments. The fertilization with P or K did not influence the growth and the productivity of both radish cultivars. Therefore, both cultivars of radish evaluated do not need to be fertilized with P and K when planted in a Latosol with high levels of these nutrients.

Keywords: Cultivars. Phosphorus. Potassium. Productivity. *Raphanus sativus L.*.

FERTILIZAÇÃO FOSFATADA E POTÁSSICA PARA RABANETE CULTIVADO EM LATOSSOLO COM ALTO TEOR DESSES NUTRIENTES

RESUMO - O cultivo intensivo de hortaliças com frequentes fertilizações químicas pode ocasionar acúmulo de nutrientes no solo que, por sua vez, pode reduzir a produtividade das culturas, além de prejudicar o ambiente através de contaminação de lençóis freáticos, mananciais e rios. Assim, com objetivo de avaliar o efeito de doses de P (0, 100, 200, 300 e 400 kg ha^{-1} de P_2O_5) e K (0, 60, 120, 180 e 240 kg ha^{-1} de K_2O) no crescimento e produtividade de cultivares de rabanete (Sakata 19 e Sakata 25), em solo com altos teores desses nutrientes, foram realizados dois experimentos, em delineamento de blocos ao acaso, com os fatores cultivares e doses arranjados em esquema fatorial 2 x 5, com três repetições. Foram avaliados o número de folhas por planta, área foliar, massa seca da parte aérea e da raiz, produtividade total e comercial, porcentagem de raízes rachadas e os teores de P e K na planta e no solo. A cultivar ‘Sakata 19’ apresentou melhor desempenho que a ‘Sakata 25’ nos dois experimentos. A fertilização com P ou K não influenciou o crescimento e a produtividade das cultivares de rabanete. Portanto, culturas de rabanete, com ambas cultivares avaliadas, não precisam ser fertilizadas com P e K quando implantadas em Latossolo com altos teores desses nutrientes.

Palavras-chave: Cultivares. Fósforo. Potássio. Produtividade. *Raphanus sativus* L..

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INTRODUCTION

In Brazil, the production of radish is not performed on a large scale perhaps due to the unaware of the population as it being a functional food rich in sulforaphane, a dietary isothiocyanate compound with a chemopreventive effect for cancer (FARAG; MOTAAL, 2010). However, it is a culture considered profitable, making it an interesting alternative to producers due to its short cycle, which allows the diversification of crops and increases the range of products marketed and the crop rotation process (MESQUITA et al., 2011), allowing a fast economic return (MENDOZA-CORTEZ et al., 2010).

The proper management of mineral fertilization is one of the factors that favors the success of the production of vegetables (CECÍLIO FILHO et al., 2014), a production that demands nutrients. The need for higher levels of phosphorus (P) and potassium (K) in the soil for vegetables, in relation to other cultures, encourages producers to often apply large amounts of fertilizer regardless of the levels of nutrients present in the area without monitoring the fertility of the soil before planting (CECÍLIO FILHO et al., 2015). This accumulates these nutrients in the soil, which may cause nutritional imbalance and negatively affect the plant. In the culture of radish, because of its short cycle, many cultivations are made throughout the year in the same area. It is then common to observe high levels of P and K in the soil.

The P is added to the soil in large quantities (AVALHÃES et al., 2009) due to a low efficiency of fertilization and the absorption by plants resulting from the formation of phosphorus compounds with a low solubility and a strong adsorption to the soil. Thus, this allows most nutrient to become solid (non-labile) (PAVINATO; ROSELEM, 2008). Such an event makes P one of the main limiting nutrients to crop productivity as it is part of metabolic processes such as energy transfer, protein synthesis, photosynthesis and respiration (PANDEY et al., 2015).

The K is the most required nutrient by plants, next to N, in quantitative terms (OOSTERHUIS et al., 2014), especially by vegetables that extract it from the soil in high quantities. In species that accumulate reserves (carbohydrates) in roots or tubers, the nutritional and technological quality varies according to the potassium (ZÖRB; SENBAYRAMB; PEITER, 2014). There are reports according to which high K levels in the soil negatively influence the quality of vegetables: for example, potato tubers (ZÖRB; SENBAYRAMB; PEITER, 2014) and carrot roots (ZANFIROV et al., 2012).

Radish is considered a species that demands a little quantity of nutrients (SANCHEZ; LOCKHART; PORTER, 1991; NARLOCH et al., 2002), although there are works reporting a positive response from the culture to mineral fertilization (COUTINHO NETO et al., 2010; OLIVEIRA et al., 2010). However, there are few studies on nutrition and fertilization of this culture, especially in soils with high levels of nutrients.

Moreover, the recommendation of phosphorus and potassium fertilization for radish in the state of São Paulo (TRANI et al., 1997) consists in the same levels proposed for carrot, beet, turnip and parsley crops. However, even with the similar commercial structure of these vegetables, it is believed that there is a difference in the nutrient demand because they have distinct dry mass accumulation levels and productivities and have a different physiology development.

In this context, the objective was to evaluate the effect of P and K doses on the growth and yield of radish cultivars in a soil with high levels of these nutrients.

MATERIAL AND METHODS

Two experiments were conducted in the field during April and May at the São Paulo State University, Jaboticabal, SP, at 21º15'22" S, 48º15'58" W and an altitude of 575 m. The soil of the experimental area was classified as an Eutroferric Red Latosol with a very clayey texture (EMBRAPA, 2006).

The experiment to evaluate doses of P was conducted from 04/03/2008 to 05/05/2008. During cultivation, the average maximum temperature was 27.9°C, the average minimum temperature was 17.6° C and the average temperature was 21.6°C. The accumulated rainfall was 175 mm and the average relative humidity was 82%. In the experiment with K, conducted from 04/24/2008 to 05/28/2008, the maximum, minimum and average temperatures, accumulated rainfall and average relative air humidity were 26.9, 14.4, 19.6°C, 66 mm and 74%, respectively.

In each experiment, the treatments consisted of two factors (cultivar and P or K doses). Treatments consisted of two radish cultivars (Sakata 19 and Sakata 25) and five doses of P (0, 100, 200, 300 and 400 kg ha^{-1} of P_2O_5) using triple superphosphate as a source of P, or five doses of K (0, 60, 120, 180 and 240 kg ha^{-1} of K_2O) using potassium chloride as a source of K. The radish cultivars Sakata 19 (hybrid F_1) and Sakata 25 (non-hybrid) were chosen because they are the most used by the producers in the region of Ribeirão Preto/SP. The experimental design was randomized blocks in a 2 x 5 factorial design with three replications. The area of each plot was 2.5 m^2 represented by four rows spaced 0.25 m apart and 2.5 m long. The useful area of the plot was 1 m^2 in two central lines disregarding 0.25 m at the beginning and the end of rows.

Prior to the installation of the experiments in adjacent areas, soil samples were collected from the layer 0-0.20 m. The chemical characteristics observed were pH ($CaCl_2$) = 5.5, P = 60 mg dm^{-3}, K^+ = 3.4 $mmol_c$ dm^{-3}, Ca^{2+} = 31 $mmol_c$ dm^{-3}, Mg^{2+} = 10 $mmol_c$ dm^{-3}, S = 11 mg dm^{-3}, B = 0.27 mg dm^{-3}, organic matter = 24 g dm^{-3}, CEC = 66.4 $mmol_c dm^{-3}$ and base saturation = 67%. P and K contents above 60 mg dm^{-3} and and 3.0 $mmol_c$ dm^{-3}, respectively, are considered high for radish (TRANI et al., 1997).

The soil was prepared by plowing and harrowing. A liming was performed 30 days before installing the experiments, increasing the base saturation to 80%, as recommended by Trani et al. (1997), using calcined limestone with PRNT = 126%. The sites were prepared using a rotary tiller.

The planting and cover fertilization were performed in accordance with the recommendation by Trani et al. (1997). In the P experiment, before the sowing of radish, 20 kg ha^{-1} of N (urea) and 120 kg ha^{-1} of K_2O (potassium chloride) were incorporated. Doses of P (triple superphosphate) corresponded to treatments. For coverage, 60 and 30 kg ha^{-1} of N and K_2O, respectively (TRANI et al., 1997), were applied in equal amounts at 7, 14 and 21 days after sowing (DAS) using the same sources. In the K experiment, 20 kg ha^{-1} of N (urea) and 180 kg ha^{-1} of P_2O_5 (superphosphate) were applied at sowing, as recommended by Trani et al. (1997). The amount of K (potassium chloride) at planting was 60 kg ha^{-1} of K_2O for all treatments except for the treatment without K. In order to complete the doses set forth in the treatments, the quantities of remaining K were applied in coverage, in equal amounts, at 7, 14 and 21 DAS. On the same dates, 20 kg ha^{-1} N (urea) were applied.

The sowing of radish was performed in beds spaced 0.25 m between rows. At 7 DAS, the thinning was performed by removing the excess of plants and adjusting the spacing to 0.05 m between plants. The cultural practices were performed when necessary to keep the area free of weeds, diseases and pests, providing favorable conditions for the development of the culture. Irrigation was performed daily using a spray, keeping the soil at field capacity.

The experiments evaluated the (a) number of leaves per plant (NLP): plants of the useful area were collected and leaves were counted; (b) leaf area (LA): leaf area was measured with an LICOR 3100 electronic meter; (c) shoot dry mass (SDM) and tuberous root dry mass (RDM): after determining NLP and LA, shoots and tuberous roots were washed with water and deionized water and placed in paper bags to dry in an oven with forced-air circulation at 65°C until constant mass; (d) total productivity (TP): all plant roots harvested in the useful area were weighed on a precision scale; (e) commercial productivity (CP): roots with more than 2 cm in diameter and without cracks and rots were considered commercial; (f) percentage of cracked roots (PCR): from the total number of harvested roots, the amount of roots that presented cracks were determined; (g) P content in shoots (PCS) and tuberous roots (PCRO): in the experiment evaluating P doses, the P content of shoot and root dry mass was determined, according to the method of Bataglia et al. (1983); (h) P content in the soil (PCSO): in the experiment evaluating P doses, after the collection of plants, soil samples (0-0.20 m) were collected and the P content was determined by the resin method using the method proposed by Raij and Quaggio (2001); (i) K content in shoots (KCS) and tuberous roots (KCR): in the experiment evaluating K doses, the K content in shoot and root dry mass was determined following the methods of Bataglia et al. (1983); (j) K content in the soil (KCSO): in the experiment evaluating K doses, soil samples after harvest were collected and the concentration of K was determined by the resin method (RAIJ; QUAGGIO, 2001).

The data of the variables analyzed were submitted to analysis of variance by F test ($\alpha \leq 5\%$). The means of cultivars were compared by Tukey test ($\alpha = 5\%$). For P and K doses, polynomial regression studies were conducted by choosing the significant equation with the highest coefficient of determination.

RESULTS AND DISCUSSION

Experiment 1 – Phosphorus

Radish cultivars showed differences in the production of shoot (SDM) and root (RDM) dry mass, commercial productivity (CP), percentage of cracked roots (PCR) and P content in roots (PCR) (Table 1). On the other hand, the phosphorus fertilization influenced only the P content in the soil (PCSO). Regarding NLP, LA, SDM, RDM, TP, CP, PCR, PCS and PCRO, the observed values ranged from 6.3 a 6.9; 161.2 a 191.3; 0.75 a 0.87; 1.18 a 1.29; 1.38 a 1.85; 0.56 a 0.89; 41.2 a 48.3; 0.83 a 1.58; e 0.95 a 2.11, respectively, for P doses evaluated.

Table 1. Summary of analysis of variance for growth, production and P content variables of radish cultivars submitted to different phosphorus doses.

Variation source	DF	F Test				
		NLP	LA	SDM	RDM	TP
Cultivar (C)	1	0.031^{ns}	1.067^{ns}	14.838**	4.360*	3.174^{ns}
P Doses (P)	4	1.220^{ns}	1.392^{ns}	1.095^{ns}	0.243^{ns}	1.382^{ns}
C x P	4	0.740^{ns}	2.665^{ns}	2.906^{ns}	1.451^{ns}	2.408^{ns}
Blocks	2	2.821^{ns}	9.452**	8.00**	0.517^{ns}	6.104**
Error	18	-	-	-	-	-
CV (%)	-	7.95	15.36	13.75	22.96	21.79
		Average – cultivars				
Sakata n. 19		6.65 a	172.12 a	0.716 b	1.33 a	1.79 a
Sakata n. 25		6.62 a	182.39 a	0.869 a	1.11 b	1.55 a
LSD		0.40	20.88	0.083	0.21	0.28

Variation source	DF	F Test				
		CP	PCR	PCS	PCRO	PCSO
Cultivar (C)	1	7.330*	9.330**	0.072^{ns}	6.001*	1.347^{ns}
P Doses (P)	4	0.419^{ns}	0.330^{ns}	1.053^{ns}	1.221^{ns}	3.117*
C x P	4	0.385^{ns}	0.827^{ns}	0.770^{ns}	0.439^{ns}	0.138^{ns}
Blocks	2	5.024*	2.557^{ns}	0.290^{ns}	8.757**	5.777*
Error	18	-	-	-	-	-
CV (%)	-	42.10	29.14	56.38	64.50	18.83
		Average – cultivars				
Sakata n. 19		1.147 a	37.26 b	1.233 a	1.133 b	95.533 a
Sakata n. 25		0.752 b	51.73 a	1.166 a	2.053 a	88.200 a
LSD		0.306	9.94	0.518	0.788	13.268

DF - Degrees of freedom; CV - coefficient of variation; LSD - least significant difference; NLP - number of leaves per plant; LA - Leaf area (cm^2 plant^{-1}); SDM - shoot dry mass (g plant^{-1}); RDM - tuberous root dry mass (g plant^{-1}); TP - Total Productivity (kg m^{-2}); CP - Commercial Productivity (kg m^{-2}); PCR - Percentage of cracked roots (%); PCS - P content in shoots (g kg^{-1}); PCRO - P Content in roots (g kg^{-1}); PCSO - P Content in soil (mg dm^{-3}); **, * - Significant at 1 and 5%, respectively; ^{ns} - not significant by F test at 5% probability.

The lack of influence of P doses on growth characteristics, mineral nutrition and radish productivity may possibly be explained by the high content of P present in the soil (60 mg dm^{-3}), being therefore sufficient to meet the nutritional requirements of the plants. Castellane, Ferreira and Maeda (1988) pointed out that, in general, plants grown in P-deficient soils respond well to phosphate fertilization, but usually does not respond when the availability of P in the soil is high. Cecílio Filho, Silva and Mendoza-Cortez (2013), evaluating phosphorus fertilization in cabbage grown in a soil with 93 mg dm^{-3} of P, obtained a response only for leaf dry mass, P content in leaves, accumulation P on stems and content of P in the soil. Although belonging to the radish botanical family, but with an increased demand for P, the productivity of cabbage did not increase with the increase of availability of P to plants when the soil had high levels of this nutrient.

The SDM was higher in cv. Sakata 25 (0.869 g plant^{-1}), with a statistical difference and a 25% increase compared to the value observed for the cv. Sakata 19 (Table 1). The results observed for SDM for Sakata 19 and 25 cultivars were lower than those obtained by Pedó et al. (2011) for the cultivars Cometo (1.33 g plant^{-1}) and Crimson Vip (1.19 g plant^{-1}), and by Reis, França and Cecílio Filho (2004), who obtained a SDM of 4.38, 2.63 and 1.54 g plant^{-1} for the cultivars Crimson Gigante, Comprido and Sakata 19, respectively.

Regarding RDM, there was a better performance of the radish cultivar Sakata 19, averaging 1.33 g plant^{-1}. A 20% difference was observed in relation to Sakata 25 (Table 1). It is noticed that hybrid plants (cv. Sakata 19) showed a lower growth of shoots, but a greater growth of tuberous roots, indicating that they are more efficient in using solar radiation and converting assimilates during the production of tuberous roots. Reis, França and Cecílio Filho (2004), analyzing the performance of radish cultivars in a Latosol with 98 mg dm^{-3} of P, also observed a superiority of the RDM of Sakata 19 (2.66 g plant^{-1}) in relation to the cultivars Crimson Gigante (2.10 g plant^{-1}) and Comprido (2.50 g plant^{-1}). The values are higher than those described in this work. RDM results close to those found here were reported by Pedó et al. (2011) for the cultivars Crimson Vip (1.31 g plant^{-1}) and Vermelho Redondo (1.53 g plant^{-1}).

Similar to RDM, the highest average commercial productivity (CP) of radish was obtained by Sakata 19 (1.147 kg m^{-1}), i.e., a 52% higher than the CP obtained for Sakata 25 (0.752 kg m^{-2}) (Table 1). Such observed values are directly related to the percentage of cracked roots (PCR), which are unsuitable for trade, verifying a PCR of 37.26% for Sakata 19 and 51.73% for Sakata 25. In the latter, half of the total production of radish had cracks in its tuberous roots, which explains the low CP found. The high PCR may be associated with water and temperature fluctuations in the soil caused by high temperatures and the lack of soil coverage, favoring water scarcity in the surface layer of the soil where the tuberous roots of radish are (COSTA et al., 2006). It is also noteworthy that the soil heating caused by high temperatures (> 30°C) favors the production of lignin around cells, causing cracks in the external part of radish roots (KANO; FUKUOKA, 1995).

The result found is in accordance with Sakata (2015), who reported that the cv. Sakata 19 has a greater resistance to root cracking. A similar performance was also found by Mendoza-Cortez et al. (2010) upon observing a CP of 0.95 kg m^{-2} for Sakata 19 and 0.536 kg m^{-2} for Sakata 25, obtaining 17.5 and 37.7% of PCR, respectively.

As for the P content in tuberous roots (PCRO), although no significant effects of P doses occurred, it is clear that the cv. Sakata 25 showed a higher PCRO (2.0 g kg^{-1}), while the Sakata 19 cultivar obtained 1.1 g kg^{-1} (Table 1). These values, compared to foliar P content, which is considered appropriate between 3 and 7 g kg^{-1} (TRANI; RAIJ, 1997), are below the proper range according to the authors. Considering PCRO values associated with dry plant mass, it is possible to understand in a better way whether the plant was efficient in the absorption of P from the soil and in the translocation of the element between plant parts. Considering this, a higher content of P, both in shoots and roots, was observed for Sakata 25, which had a greater leaf area, although it did not differ from Sakata 19. Thus, there was an increase in transpiration efficiency, contributing to P absorption and its translocation in the plant, which explains the results of PCRO.

Doses of P significantly influenced the nutrient content in the soil after harvest (PCSO) (Table 1). There was an increasing linear fit ($y = 76.89 + 0.074^{*}x$; $R^2 = 0.90$) with the increase in doses. Although the soil presented a high P content (60 mg dm^{-3}), the PCSO increased from 74.5 mg dm^{-3} in the control (without application of P) to 106 mg dm^{-3} when 400 kg ha^{-1} of P_2O_5 were supplied. There was an increase of 42%. Cecílio Filho, Silva and Mendoza-Cortez (2013), upon applying doses of P_2O_5 between 0 and 720 kg ha^{-1} in a soil with a high P content (93 mg dm^{-3}), found a variation of PCSO between 139 and 232 mg dm^{-3}. This same tendency was also observed by Deenik et al. (2006) upon applying phosphate fertilizers in the soil, obtaining P contents of 351 mg dm^{-3} without application of P and 530 mg dm^{-3} with the highest dose of P.

Experiment 2 – Potassium

Differences were found between the radish cultivars for growth (NLP, PLA and SDM) and production (TP, CP and PCR) variables. The K doses provided a significant effect only for PCR and KCSO. There was no significant interaction of the factors in the evaluated characteristics (Table 2).

Probably, the lack of response of radish cultivars, except for PCR, to the increase in the dose of K may be associated with its high content (3.4 $mmol_c$ dm^{-3}) in the soil (TRANI et al., 1997). This was enough to meet crop needs. The lack of response to the application of K in soils with high K contents were also found for cabbage (CORREA; CARDOSO; CLAUDIO, 2013) and lettuce (CECÍLIO FILHO et al., 2015).

The radish cultivars differed as to NLP, especially the Sakata 19, which showed 9% more leaves in relation to Sakata 25 (Table 2). This may be associated with the characteristics of each genetic material and its adaptability to environmental conditions, since the cultural management was the same for both. A similar performance was observed for PLA, confirming a higher value for Sakata 19 (228.93 cm^2 $plant^{-1}$), with a 40% difference in relation to the value found for Sakata 25 (Table 2). These results differ from those found by Reis, França and Cecílio Filho (2004), who, evaluating radish cultivars in a Latosol with a high K content (3.1 $mmol_c$ dm^{-3}), obtained NLPs of 8.0 and 8.1 leaves and an PLA of 600 and 450 cm^2 $plant^{-1}$ for the cultivars Crimson Gigante and Sakata 19, respectively.

Regarding the SDM, the cultivars were different, showing a superiority of hybrid plants (Sakata 19), with 0.981 g $plant^{-1}$, showing a 43% difference in relation to the cultivar with an open pollination (Sakata 25) (Table 2). Reis, França e Cecílio Filho (2004) reported values higher than those obtained in this work for the varieties Crimson Gigante, Comprido and Sakata 19. A similar performance was recorded by Pedó et al. (2011) studying the cultivars Cometo (1.33 g $plant^{-1}$), hybrid, and Crimson Vip (1.19 g $plant^{-1}$), not hybrid.

As for TP, Sakata 19 stood out in relation to Sakata 25, showing a superiority of 52%, i.e., a 0.65 kg difference m^{-2} between cultivars (Table 2). The same tendency was observed for commercial productivity (CP). CPs of 0.996 and 0.863 kg m^{-2} were obtained for Sakata 19 and Sakata 25 cultivars, respectively, providing a superiority of 15%. Costa et al. (2006), growing Crimson Gigante in a Red Latosol with a K content around 4.2 $mmol_c$ dm^{-3}, recorded a total and commercial productivity of 0.295 and 0.128 kg m^{-2}, respectively. Mendoza-Cortez et al. (2010) obtained similar CP results upon studying Sakata 19 (0.95 kg m^{-2}) and Sakata 25 (0.536 kg m^{-2}) in an Eutroferric Red Latosol with 2.7 $mmol_c$ dm^{-3} of K.

Table 2. Summary of analysis of variance for growth, production and K content variables of radish cultivars submitted to potassium doses.

Variation source	DF	F Test				
		NLP	LA	SDM	RDM	TP
Cultivar (C)	1	10.671**	51.918**	28.846**	2.353^{ns}	82.452**
K Doses (K)	4	0.669^{ns}	0.949^{ns}	0.933^{ns}	0.372^{ns}	1.342^{ns}
C x K	4	0.883^{ns}	0.524^{ns}	0.105^{ns}	1.476^{ns}	0.204^{ns}
Blocks	2	0.064^{ns}	6.393**	3.508**	0.993^{ns}	11.761**
Error	18	-	-	-	-	-
CV(%)		6.99	12.54	18.16	21.20	12.48
		Average – cultivars				
Sakata n.19		6.65 a	228.93 a	0.981 a	1.112 a	1.893 a
Sakata n.25		6.11 b	164.07 b	0.684 b	0.987 a	1.244 b
LSD		0.342	18.906	0.116	0.170	0.150
Variation source	DF	F Test				
		CP	KCR	KCS	KCRO	KCSO
Cultivar (C)	1	5.505*	67.866**	0.863^{ns}	0.071^{ns}	0.333^{ns}
K Doses (K)	4	1.450^{ns}	4.220*	0.077^{ns}	0.278^{ns}	5.866**
C x K	4	1.123^{ns}	2.429^{ns}	2.364^{ns}	1.643^{ns}	2.267^{ns}
Blocks	2	11.682**	3.392^{ns}	4.950*	2.115^{ns}	1.999^{ns}
Error	18	-	-	-	-	-
CV (%)		16.65	13.728	27.57	28.11	23.00
		Average – cultivars				
Sakata n.19		0.996 a	47.13 a	61.32 a	96.78 a	2.546 a
Sakata n.25		0.863 b	31.00 b	55.84 a	97.62 a	2.673 a
LSD		0.118	4.11	12.38	20.95	0.460

DF - Degrees of freedom; CV - coefficient of variation; LSD - least significant difference; NLP - number of leaves per plant; LA - Leaf area (cm^2 $plant^{-1}$); SDM - shoot dry mass (g $plant^{-1}$); RDM - tuberous root dry mass (g $plant^{-1}$); TP - Total Productivity (kg m^{-2}); CP - Commercial Productivity (kg m^{-2}); PCR - Percentage of cracked roots (%); KCS - K content in shoots (g kg^{-1}); KCRO - K content in roots (g kg^{-1}); KCSO - K content in soil (mmol $_c$ dm^{-3}); **, * - Significant at 1 and 5%, respectively; ^{ns} - not significant by F test at 5% probability.

Regarding PCR, the hybrid Sakata 19 showed 47.13% of discarded roots but still maintained a higher production than Sakata 25, which obtained a PCR of 31% (Table 2). It is also noteworthy that the PCR was influenced by potassium fertilization, demonstrating an increasing linear fit ($y = 33.94 + 0.042^{**}x$, $R^2 = 0.81$) with an increase in the dose of K. There was a variation from 34.7% to 46.36% when doses of K_2O increased from 0 to 240 kg ha^{-1}. Probably, the increase in PCR due to the increase in the K level may be related to a reduced absorption of calcium by radish. According to Cecílio Filho et al. (1998), when the K content is high in the environment, it develops a competitive inhibition interaction with Ca, negatively affecting Ca absorption by the plant. According to Cecílio Filho et al. (1998), among nutrients, calcium, when deficient, is primarily responsible for cracking radish roots. This may explain the high PCR rate observed for the hybrid Sakata 19. It was more sensitive to the low availability of calcium than the cultivar Sakata 25.

KCSO, after radish harvest, increased linearly ($y = 1.872 + 0.006222^{**}x$; $R^2 = 0.96$) due to the increase in the dose of K_2O, with an increase of 0.373 $mmol_c$ dm^{-3} for each 60 kg ha^{-1} of K_2O applied. There was a variation in KCSO from 1.916 to 3.466 $mmol_c$ dm^{-3} between the lowest and the highest dose, respectively. The soil which originally had a high content of K kept the same condition only when 240 kg ha^{-1} of K_2O was provided. Average contents were found for other doses according to Trani et al. (1997). This decrease of K in the soil may be explained by the requirement of this nutrient by radish plants (CECÍLIO FILHO et al., 1998; COUTINHO NETO et al., 2010). In this sense, the high concentration of K in the soil was sufficient to meet the demand of plants, a fact associated with the lack of response to potassium fertilization by radish.

CONCLUSIONS

In a Latosol with high P and K levels, the supply of up to 400 kg ha^{-1} of P_2O_5 and 240 kg ha^{-1} of K_2O does not increase the productivity of radish culture. It is therefore unnecessary to fertilize it with these nutrients.

The hybrid radish Sakata 19 performed better than the cultivar Sakata 25 because of its higher growth and productivity and the lower percentage of cracked roots.

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