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Organic compost and potassium top dressing fertilization on production and quality of beetroot

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Abstract

The potassium (K) in top dressing fertilization is used for beetroot production in Brazil. However, most of K studies are made with fertilization before planting, and it is not known the real need of this K top dressing after fertilization with K and organic matter before planting. So this work aimed to evaluate the production and quality of beetroot under different rates of organic compost at planting and K top dressing fertilization. The experiment was carried out in São Manuel-SP, Brazil, with ten treatments (5 x 2 factorial scheme), in a randomized blocks experimental design, with four replications. Five rates (0, 20, 40, 60 and 80 t ha^{-1}) of organic compost applied at planting, in the presence (60 kg ha^{-1} of K_2O) or absence of K top dressing fertilization were evaluated. The traits related to production evaluated were: average weight, diameter and length of roots, yield and K content in shoot and root. For the physicochemical quality of roots, pH, soluble solid content, titratable acidity, index ratio, texture, reducing, non-reducing and total sugar were evaluated. The K top dressing fertilization did not affect the production traits; however, it increases the contents of K in shoot and root and the contents of non-reducing and total sugars. The rates of the compost do not affect the quality traits, but the rate of 49 t ha^{-1} resulted in the maximum root yield estimated in 43 t ha^{-1} of roots.

Keywords: *Beta vulgaris*, organic fertilization, soluble solid content, sugars, yield.
Abbreviations: K_potassium, N_nitrogen, NRS_non reducing sugars, RS_reducing sugars, SS_soluble solid contents, TA_titratable acidity, TS_total sugars.

Introduction

The use of organic fertilizers in vegetables is of great importance, due to its effect on soil physical, chemical and biological traits (Sediyama et al., 2011). The importance becomes greater in tropical soils, where the decomposition of organic matter is intense. Little information was found in the literature consulted relating to the influence of organic fertilization on the beetroot production. Marques et al. (2010), evaluating rates (0 to 80 t ha^{-1}) of cow manure on production of beetroot, cultivar Early Wonder, obtained greatest yield values at the highest rate. Sediyama et al. (2011), using the same cultivar, verified that rates of sludge from swine wastewater (0 to 60 t ha^{-1}) did not provide any difference in the shoot and root fresh weight of beetroot. Mantovi et al. (2005) related that organic compost gave significantly lower yields than the liquid sludge because its lower N content. Besides no agreement had been found in the results, these studies were carried out with an open pollinated cultivar, and, nowadays, hybrids have been used by many growers, with no research with them in Brazilian conditions.

Grangeiro et al. (2007) verified that potassium (K) was the most exported nutrient by the beet roots, equivalent to 93.2 kg ha^{-1} of K for yield of 33 t ha^{-1}, this nutrient being accumulated more in roots than in shoot. Unlike the fertilizer recommendation for this vegetable crop, which considers the content of exchangeable K^+ present in the soil, the recommendation of K top dressing fertilization is not based on objective criteria, probably because there are no research about K in top dressing in Brazilian conditions. For example, in São Paulo, Brazil, Trani and Raij (1997) recommend applying 30-60 kg ha^{-1} of K_2O in top dressing, divided in three applications, and this recommendation is the same for any soil fertility level. Almost all organic fertilizers contain potassium in its composition, however, the concentration is low, usually between 2 and 4 %, and highly variable, mainly depending on the stage of decomposition of the waste and how they were stored. However, K in organic fertilizers is already mineralized and its availability is similar to K derived from mineral fertilizers (Ernani et al., 2007). Because of the rapid release of the K present in organic fertilizers and of the short period that beetroot remains in the field, especially when propagated by seedlings, the hypothesis that the supply of this nutrient in top dressing can be discarded on soil fertilized with mineral fertilizers and organic compost at planting had been established. Thus, this work aimed to evaluate the production and quality of beetroot depending on the rates of organic compost at planting and K top dressing fertilization.

Results and Discussion

Root production and potassium content

For the traits related to root production (yield, average weight, diameter and length of roots), both K top dressing fertilization and the interaction between the rates of organic compost and K top dressing fertilization were not significant

Table 1. Diameter, length, average weight, yield of beet roots and potassium content in shoot and root related to potassium top dressing fertilization. FCA/UNESP, São Manuel-SP, 2010.

K top dressing	Diameter (mm)	Length (mm)	Weight (g)	Yield (t ha^{-1})	Shoot K content (mg kg^{-1})	Root K content (mg kg^{-1})
Without	58.9 a	59.7 a	113 a	36.2 a	55.1 b	26.8 b
With	59.2 a	60.3 a	116 a	37.2 a	64.0 a	29.1 a
$F_{potassium}$	0.62 ^{ns}	0.18 ^{ns}	0.15 ^{ns}	3.18^{ns}	13.93**	4.8*
CV (%)	7.9	8.5	23.5	23.7	12.4	11.4

CV = coefficient of variation.
ns = not significant by F test at 5% probability.
*, ** = significant by F test at 5% and 1% probability, respectively.
Means followed by the same letter for each characteristic were not significantly different at $p \leq 0.05$ using Tukey's test.

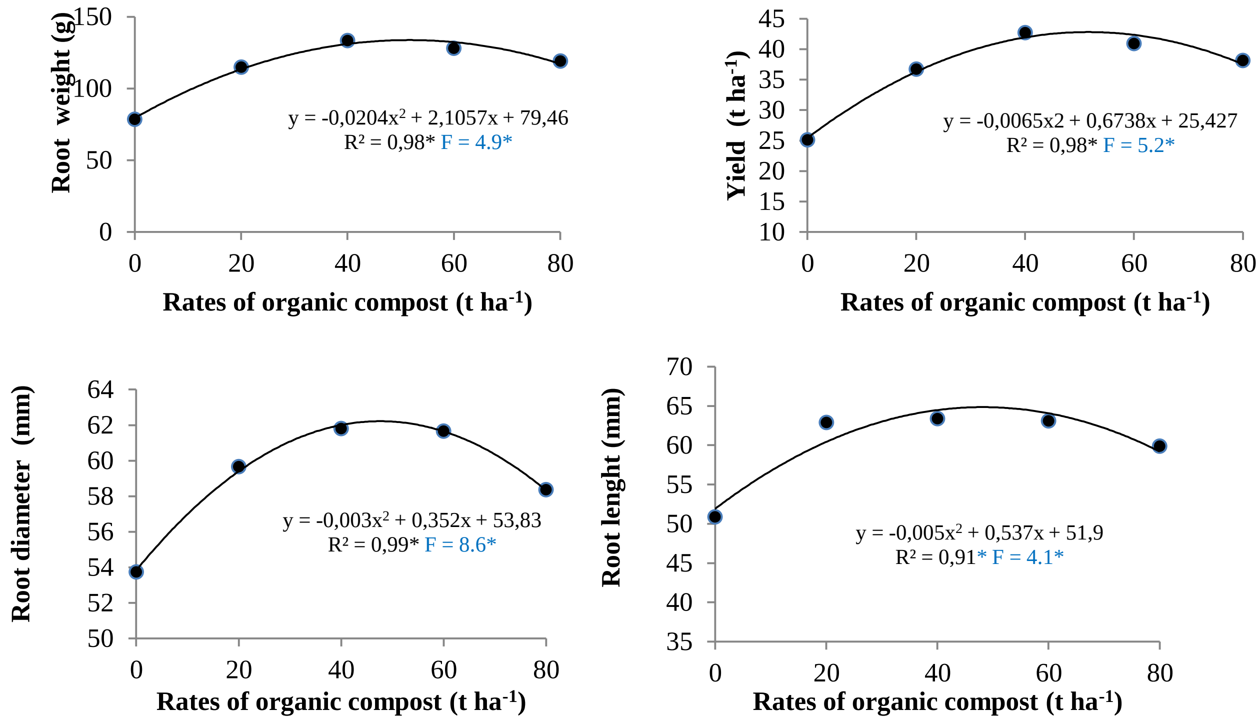

Fig 1. Average root weight, yield, diameter and length of beetroot related to the rates of organic compost. FCA/UNESP, São Manuel-SP, 2010.

by F test at 5% probability. The following averages were obtained: yield of 36.7 t ha^{-1}, average weight, diameter and length of the roots of 115 g, 59 mm and 60 mm, respectively (Table 1). Considering that K top dressing fertilization did not affect the traits related to root production, the result of this work shows that, in these conditions, beetroot does not need any K top dressing fertilization, contradicting the official recommendation for the state of São Paulo, Brazil, which recommends the application of 30 to 60 kg ha^{-1} of K_2O (Trani and Raij, 1997). In the present research, the K content in soil before the beetroot cultivation was 1.4 mmol$_c$dm^{-3}, considered low according to Trani and Raij (1997). However, after the fertilization at planting, the content raised to 4.64 mmol$_c$ dm^{-3}, considered high by the same authors and this increase could be the responsible for not obtaining response with K top dressing fertilization for the traits evaluated. So, the top dressing fertilization recommended by Trani and Raij (1997) can be unnecessary since enough potassium is provided at planting. The excess of potassium fertilization, besides being an extra cost to the producer, can result in ground water contamination by K^+ leaching. It can also cause an increase in the salinity levels in the soil and reduction of the absorption of other cations, mainly Ca^{++} and Mg^{++} (Ernani et al., 2007). The beneficial effect of K fertilization before planting on yield of sugar beet was related in many studies (Kristek et al., 1996; El-Shafai, 2000; Milford et al., 2000; Romheld and Kirkby, 2010). Abdel-Motagally and Attia (2009) related increasing in beet root fresh weight and yield the higher the K rates in a sandy calcareous soil, but they did not study the K application in top dressing. In other vegetables, many authors (Salata et al., 2011; Godoy et al., 2012, Araújo et al., 2013; Corrêa et al., 2013) found that K top dressing fertilization did not influence the production. But all these authors justified the results due to the high potassium content in soil after base fertilization, as occurred in the present research. On the other hand, Araújo et al. (2012) and Zanfirov et al. (2012) observed a increase in squash and carrot yield with K top dressing fertilization even after K fertilization before planting. For the organic compost rates, it was observed quadratic effect for all the traits related to the root production (Fig 1). The greatest root weight (134 g) was estimated at a rate of 52 t ha^{-1} of organic compost, observing a decrease in weight of beetroot after this rate, showing that organic compost in excess can be harmful to beetroot production. Maybe this effect was due to excess of K applied in the greatest organic compost rate. The total K available with 80 t ha^{-1} of organic compost was 149 kg ha^{-1} of K_2O, that is 2.5 times greater than the K applied in top dressing.

Table 2. Soluble solids content (SS), titratable acidity (TA), hydrogen potential (pH), SS/TA, texture, reducing sugars (RS), total sugars (TS) and non-reducing sugars (NRS) in the beet roots related to the rates of organic compost and potassium top dressing fertilization. FCA/UNESP, São Manuel-SP, 2010.

Organic compost (t ha^{-1})	SS (°Brix)	TA (g/100g)	pH	SS/TA	Texture (N)	RS (%)	TS (%)	NRS (%)
0	10.35 a	0.062 a	6.0 a	180 a	9.28 a	0.13 a	7.64 a	6.76 a
20	9.99 a	0.065 a	6.0 a	153 a	9.24 a	0.11 a	7.29 a	6.47 a
40	10.28 a	0.072 a	6.0 a	144 a	9.01 a	0.12 a	7.84 a	6.95 a
60	9.83 a	0.069 a	6.0 a	146 a	9.02 a	0.11 a	7.36 a	6.53 a
80	9.98 a	0.064 a	6.0 a	160 a	9.10 a	0.12 a	7.36 a	6.52 a
$F_{compost}$	0.39^{ns}	0.83^{ns}	0.80^{ns}	1.2^{ns}	0.36^{ns}	0.51^{ns}	0.68^{ns}	0.65^{ns}
K top dressing	SS (°Brix)	TA (g/100g)	pH	Ratio (SS/TA)	Texture (N)	RS (%)	TS (%)	NRS (%)
Without	9.96 a	0.066 a	6.0 a	154 a	9.14 a	0.11a	7.19 b	6.37 b
With	10.22 a	0.065 a	6.0 a	160 a	9.12 a	0.13a	7.84 a	6.93 a
$F_{potassium}$	0.74^{ns}	0.12^{ns}	0.05^{ns}	0.25^{ns}	0.01^{ns}	2.61^{ns}	6.38*	6.11*
CV (%)	9.61	17.64	1.13	23.40	6.33	27.38	10.60	10.75

CV = coefficient of variation
ns = not significant by F test at 5% probability;
* = significant by F test at 5% probability.
Means followed by the same letter for each characteristic were not significantly different at p ≤ 0.05 using Tukey's test.

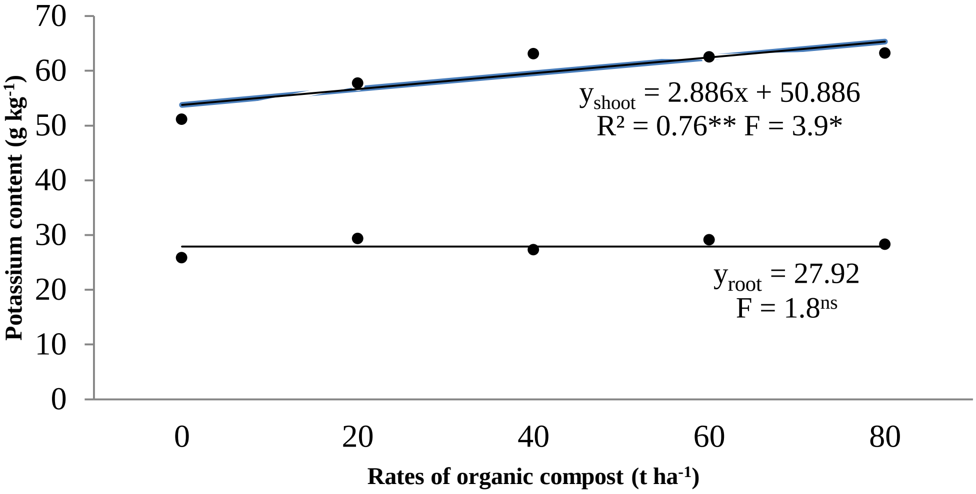

Fig 2. Potassium content (g kg^{-1} of dry matter) in shoot and root of beet plant related to the rates of organic compost. FCA/UNESP, São Manuel-SP, 2010.

The excess of K may be harmfull to Ca^{++} and Mg^{++} up take, as described by Ernani et al. (2007). Marques et al. (2010) obtained positive and linear response for average weight of commercial beet roots grown according to the rates of cow manure (0, 20, 40, 60 and 80 t ha^{-1}), with a maximum weight of 88 g. In the present research, the rates used were the same the authors mentioned above used, but the results were different. Among the possible explanations is the fact that the organic compost presents a different dynamic in soil when comparing with caw manure. Moreover, in the work of Marques et al. (2010) the fertilization at planting consisted of cow manure rates only, differing from the present research in which the soil was supplied by mineral fertilizer, too. This mineral fertilizer could have contributed to higher values for average weight of the root, and lower necessity of organic fertilizer.

For yield, the increase was observed up to the rate of 49 t ha^{-1} of organic compost, with an estimate of 43 t ha^{-1} of roots, according to quadratic equation obtained (Fig 1), and the values decreased after this rate. The values observed (maximum of 43 t ha^{-1} of roots) were higher or were close to those found by Trani et al. (2005), Carvalho and Guzzo (2008), Costa et al. (2008), Zárate et al. (2010) and Corrêa et al. (2014), who obtained maximum yield which ranged from 15 to 40 t ha^{-1}. Probably, the yield obtained in this research can be related to the obtaining a population without flaws, favorable climate to the crop, which prefers mild climate, and absence of pathogens and pests. Moreover, properly adapted hybrids generally exhibit greater uniformity and heterosis, helping reach higher yields (Maluf, 2001), considering that the most cited authors have studied the open pollinated cultivar Early Wonder. With respect to root diameter, the increases were observed up to the rate of 48 t ha^{-1} of organic compost, providing value of 62 mm, being observed, after this value, a decrease in diameter (Fig 1). The size of the beetroot is characterized by the caliber of the root, by measuring its highest diameter. In this experiment, the size of the diameters reached by the beet roots allow to classify them as Extra A or 2A (roots with diameter greater than or equal to 50 and smaller than 90mm) according to the Brazilian Program for the Modernization of Horticulture (Ceagesp, 2010). For root length, an increase up to 65 mm was verified, at the rate of 46 t ha^{-1} of organic compost (Fig 1). After this rate, the length decreased. The maximum value observed is similar to the maximum reported by Zárate et al. (2010) and Corrêa et al. (2014), which were 65 and 59 mm, respectively, and a little superior to the values reported by Zárate et al. (2008), that related maximum of 55 mm. For the four traits related to the roots (yield, average weight, diameter and length of the roots) a quadratic effect was obtained (Fig 1) and maximum values were estimated for similar rates of organic compost (46 to 52 t ha^{-1}). This fact can be explained by the direct relationship among them, after all, greater diameter and/or length determine greater root weight and, consequently, yield. The official newsletter of recommendation to the State of São Paulo, Brazil, recommends applying 30-50 t ha^{-1} of organic compost (Trani and Raij, 1997). The results of this research show that the rate (49 t ha^{-1}) in order to obtain higher roots yield are close to the maximum recommended limit. It was obtained higher K content in shoot and root in treatment with K top dressing fertilization (Table 1), because there was more K available in soil with the application of this nutrient in top dressing. But this higher K available did not result in higher yield, probably because its usual the unnecessary uptake of K by plants as described by some authors (Clough and Locascio, 1989; Araujo et al., 2012). The higher the organic compost rate, the higher the K content in shoot (Fig 2), probably because the K in the organic compost is already mineralized and its effect is similar to the application of inorganic K, as described by Ernani et al. (2007) and Magro et al. (2010). The K content in root was not affected by organic compost rate, with average of 27.9 mg de K kg^{-1} of dry matter (Fig 2). So, the shoot was the preferential place of accumulation of excess K available to plants. The K content in shoot was twice the content in root (Table 1).

Root physicochemical traits

For the traits related to the physicochemical quality of beetroot, significant differences realted to organic compost rates and K top dressing fertilization were not observed for soluble solid contents, titratable acidity, hydrogen potential (pH), SS/TA ratio and texture (Table 2). An increase of soluble solid contents in some vegetables, such as watermelon, tomato, melon and sweet pepper was reported, with the application of potassium (Cecílio Filho and Grangeiro, 2004), being this increase due to the role this nutrient plays in photosynthate translocation. The presence of this element in insufficient quantities in the soil may result in undesirable quality traits like low soluble solids content, besides reducing the photosynthetic activity. However, in this experiment, the K mineral fertilization at planting was probably enough to ensure the quality of the beet roots, considering that applying this nutrient at top dressing did not affect this trait. Researches on other vegetables showed that K top dressing application did not affect the soluble solids content, as it was verified for edible pea (Salata et al., 2011) and cauliflower (Godoy et al., 2012). In these latest two studies, besides the soluble solids content, other traits, such as titratable acidity and pH, were not affected by K fertilization, as found in this research.

In relation to organic compost application, Marques et al. (2010) observed that the soluble solids content, pH and firmness of the roots were not influenced by cow manure application in rates ranging from 0 to 80 t ha^{-1}. These authors obtained SS values from 10.26 to 11.10 ºBrix, similar to the values in this research (9.83 to 10.35 ºBrix) (Table 2). The same authors verified, differently from this experiment, increasing values of titratable acidity with an increase of rates of manure. According to Chitarra and Chitarra (2005), potassium fertilization increases the ascorbic acid content, which led the authors to relate the increase in titratable acidity with the addition of potassium in the treatments. However, for the rates of organic compost in this experiment and for the K top dressing application, the titratable acidity was not affected (Table 2), probably because K mineral fertilization at planting was enough to obtain high ascorbic acid content in beet root. The absence of significant effect, in the treatments for soluble solids (SS) content and titratable acidity (TA) traits, helps explain the absence of effect for the ratio between both, SS and TA (Table 2). The SS/TA ratio is one of the best methods to evaluate flavor, being more representative than the isolated measurement of the soluble solids or acidity, providing good estimate of the equilibrium between both composts (Chitarra and Chitarra, 2005). For some vegetables, the ratio which provides the best flavor was already determined. In the case of beetroot, this information had not been found in literature. In this work, the values ranged from 144 to 180. The K application did not influence the reducing sugars (RS). However, superior values for total sugars (TS) and non reducing sugars (NRS) were obtained with K top dressing fertilization (Table 2). Potassium is responsible for translocation of sugar in plants (Kumar et al., 2007; Abdel-Motagally and Attia, 2009), which can explain these increases in the beet roots, which are storage structures. Other authors (El-Shafai, 2000; Milford et al., 2000; Abdel-Motagally and Attia, 2009) also related increasing in total sugars with K fertilizing in sugar beet. However, the sugars were not influenced by the rates of compost (Table 2). Mantovi et al. (2005) related that sugars concentrations were not affect by organic compost in comparation to inorganic fertilization. According to some authors (Chitarra and Chitarra, 2005; Aquino et al., 2006), soluble solids offer a good estimation of sugar content in plant tissue, which is an important qualitative characteristic for the beetroot. In fact, soluble solids constitute all the dissolved substances in water and, since the sugars are the most abundant constituent, it is common to associate that the higher soluble solids contents, the higher sugar content (Chitarra and Chitarra, 2005). But it was observed that not always it is true and it is recommended that all evaluations must be made to conclude about sugars content. It was observed that organic compost fertilization is important to increase beet root production, but it did not affect physicochemical traits of the roots. On the other hand, potassium in top dressing fertilization did not affect yield and most of physicochemical traits, probably because the potassium fertilization made before planting increased potassium levels in the soil to high values. But, potassium top dressing fertilization increased total and non-reducing sugars of roots and K content in shoot and root.

Materials and Methods

Locality and soil characterization

The experiment was carried out at the São Manuel Experimental Farm, located in the municipality of São Manuel, São Paulo State University (FCA/UNESP), Botucatu Campus. The geographical coordinates of the site are 22°46' S, 48°34' W, and it has an average altitude of 750 m. The predominant climate of the region of São Manuel, according to Köppen climate classification, based on meteorological observations, is type Cfa (umid subtropical, mesothermal) (Cunha and Martins, 2009). During the experimental period, the average daily temperature varied from 15 ^{o}C to 27 ^{o}C. The soil in which the research was installed is a Dystrophic Red Latosol, according to Embrapa (2006) classification. It is a sandy soil, with about 836, 116 and 48 g kg^{-1} of sand, silt and clay, respectively. The chemical analysis (0-20cm depth), made after liming, showed: $pH_{(CaCl2)}$ = 6.3; organic matter = 10 g dm^{-3}; $H^{+} + Al^{3+}$ = 13 $mmol_c$ dm^{-3}; K^{+} = 1.4 $mmol_c$ dm^{-3};

P_{resin} = 22 g dm^{-3}; Ca^{2+} = 36 $mmol_c$ dm^{-3}; Mg^{2+} = 15 $mmol_c$ dm^{-3}; SB = 52 $mmol_c$ dm^{-3}; CTC = 65 $mmol_c$ dm^{-3} and V = 80%. Based on Trani and Raij (1997), the potassium content of the soil was classified as very low.

Treatments and experimental design

The experimental design was a randomized complete block, with ten treatments (5 x 2 factorial scheme), with four replications and 64 plants per plot in the field. Five rates of organic compost (0, 20, 40, 60 and 80 t ha^{-1} in wet base) applied at planting were evaluated in the presence (60 kg ha^{-1} of K_2O) or absence of K top dressing fertilization. The compost was applied before planting, in the total area of the seedbed and incorporated till 20 cm depth. The average rate of organic compost recommended by Trani and Raij (1997) for beetroot is 40 t ha^{-1} and it was studied rates ranging from half to twice the rate recommended, besides a control treatment without compost application. For the treatments receiving K top dressing fertilization, the highest rate recommended for beetroot by the authors mentioned (60 kg ha^{-1} of K_2O) was used as reference.

The organic compost Provaso® was used and its chemical analysis showed values of MO; N; P_2O_5; K_2O; Ca; Mg and S, expressed in % of dry matter, respectively: 41; 0.72; 0.39; 0.30; 2.70; 0.30 and 0.19. The moisture of the compost was 37.9%. Each 10 t ha^{-1} of organic compost corresponds to the application of 18.6 kg ha^{-1} of K_2O. The total potassium applied in soil considering only the highest rate (80 t ha^{-1}) of organic compost was 149 kg ha^{-1} of K_2O.

The fertilization at planting consisted of rates of organic compost used in the treatments, in addition to the provision for N, P_2O_5 and K_2O, using formulated 8-28-16, which was supplemented with magnesium thermophosphate to complete phosphorus requirements suggested by Trani and Raij (1997). The total amount of N, P_2O_5 and K_2O applied before planting as inorganic fertilizer were 20, 360 and 180 kg ha^{-1}, respectively. In the top dressing fertilization, 60 kg ha^{-1} of K_2O were provided only for K fertilization treatments, divided into three times, every 14 days after transplanting, and, for all treatments, it was applied N (90 kg ha^{-1} of N) too, in same dates. The sources of K and N were KCl and urea, respectively. The hybrid Boro was used. Sowing was performed in expanded polystyrene trays of 288 cells, containing substrate for vegetable seedling production. Seedlings were transplanted on August 30, 2010, for seedbeds with 1.20 m width, a total of four rows in the longitudinal direction, spaced 0.250 m between rows and 0.125 m between plants. Sprinkler irrigation was carried out, on average, three times a week. Controlling pests and diseases was not necessary.

Traits measured

Manual harvesting was held on October 10, 2010 (60 days after transplanting), when 90% of the plants showed roots with diameter superior to 5.0 cm, following the criterion adopted by Horta et al. (2001). In a sample of six central plants of each plot, the following traits were evaluated in the field: average weight of root, with values expressed in grams; yield: obtained transforming the data of the average weight of the root to t ha^{-1}, considering the plant population (320.000 plants ha^{-1}); diameter and length of the roots: obtained using a digital caliper, with the values expressed in mm.

For the determination of K content in shoot and root, two plants per plot were washed in distilled water, and, after this, each sample (root or shoot) were put in a kiln (60 ^oC) to obtain dry matter that was evaluated to K content, according to methodology described by Malavolta et al. (1997).

In a sample of two roots per plot, the following traits related to the physicochemical quality of beetroot were evaluated: pH: was measured through the aqueous extract, in potentiometer Micronal model B-221, according to the rules of Instituto Adolfo Lutz, published in Brasil (2005); titratable acidity: determined according to the norms of Instituto Adolfo Lutz, published in Brasil (2005), with results expressed in grams of oxalic acid per 100 g of pulp; soluble solids: the roots were crushed and then the reading of soluble solids was performed using refraction, through digital refractometer Atago, according to the recommendation of the AOAC (2005), and results being expressed in ^{o}Brix; maturation index ratio: obtained through the relation between soluble solids (SS) and titratable acidity (TA), where ratio = SS/TA; determination of reducing, non-reducing and total sugars: determined by method described by Somogyi (1937), adapted by Nelson (1944), and results being expressed in percentage.

Statistical analysis

Data were subjected to analysis of variance (ANOVA, F test) at 5% and regression for organic compost rates. In case of quadratic effect, the highest values were estimated by software according to the equation. For the K top dressing fertilization data were compared by Tukey test (5%). Analyses were performed using Sisvar software.

Conclusions

The application of the organic compost increases root production, but it does not affect the physicochemical quality of the beetroots.

The K top dressing fertilization (60 kg ha^{-1} of K_2O) does not affect the production traits; however, it increases the contents of non-reducing and total sugars and K content in shoot and root.

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