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SOIL WATER TENSIONS AND POTASSIUM FERTILIZATION IN CHERRY TOMATO CULTIVATION

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1 ABSTRACT

The aimed to evaluate the accumulated water consumption, growth characteristics, chlorophyll index, soil pH and the productive characteristics of cherry tomatoes cultivated in pots under soil water tensions and potassium doses in a protected environment. The experiment was carried out in a greenhouse in pots of 12 dm^3 soil, in a dystrophic Oxisol. The experimental design was in randomized blocks in a 5^2 fractioned factorial arrangement, with five water availabilities in the soil (4, 14, 24, 34 and 44 kPa) and five potassium doses (0, 125, 250, 375 and 500 mg dm^{-3}) with four blocks. The accumulated water consumption indicates that the greatest water restrictions growing and development were for soil water tensions of 44 and 34 kPa. The soil water tension in the around 22 kPa provided greater growth in the flowering stage. The potassium fertilization in the dose of 500 mg dm^{-1} were observed the largest masses of roots, leaves and stems. The highest dry mass of cherry tomato fruits occurs in the soil water tension of 28 kPa and in the potassium dose of 284 mg dm^{-3}. Deficiency and excess potassium in the soil reduced fruit production, as well as the deficit and excess water in the soil.

Keywords: Diviner 2000, *Lycopersicon esculentum* Mill, oxisol, protected environment, soil water.

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TENSÕES DE ÁGUA NO SOLO E ADUBAÇÃO POTÁSSICA NO CULTIVO DE TOMATE DE CEREJA

2 RESUMO

Objetivou-se avaliar o consumo de água acumulado, características de crescimento, índice de clorofila, pH do solo e características produtivas do tomate cereja cultivado em vasos sob tensões de água e doses de potássio em ambiente protegido. O experimento foi conduzido em casa de vegetação em vasos de 12 dm^3 com Latossolo Vermelho. O delineamento experimental foi em blocos casualizados em esquema fatorial 5^2 fracionado, com cinco disponibilidades hídricas (4, 14, 24, 34 e 44 kPa) e cinco doses de potássio (0, 125, 250, 375 e 500 mg dm^{-3}),

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com quatro repetições. O consumo de água acumulado apontou maiores restrições de crescimento e desenvolvimento nas tensões de água no solo de 44 e 34 kPa. A tensão de água no solo próximo de 22 kPa proporcionou maior crescimento na fase de floração. Na dose de potássio de 500 mg dm^{-1} foram observadas as maiores massas secas de raízes, folhas e caule. A maior massa seca dos frutos ocorreu na tensão de água no solo de 28 kPa e na adubação potássica de 284 mg dm^{-3}. A deficiência e o excesso de potássio no solo reduziram a produção de frutos, assim como o déficit e o excesso de água no solo.

Palavras-chave: Diviner 2000, *Lycopersicon Esculentum* Mill, Latossolo Vermelho, ambiente protegido, água no solo

3 INTRODUCTION

Due to the extent of the cultivated area, tomato (*Lycopersicon esculentum* Mill.) is considered the most important vegetable all over the world, marketed fresh or processed, possessing the first form, greater demand for quality (COYAGO-CRUZ et al., 2019; LE et al., 2018; MACHADO et al., 2018). In this sense, cherry tomato stands out among the groups of tomato, due to its striking sensory characteristics and best prices in the consumer market (ROCHA et al., 2009).

To ensure the satisfactory productivity producers, the management of the crop should be concerned with several factors that are involved in the production system, which influence growth, development and production (LIMA et al., 2020), such as soil water tension and potassium fertilization.

Water is essential for the plants and their deficit, depending on the severity and duration, beyond the growth stage, affect development and production (KHAPTE et al., 2019). Soil water tension indicates the hydric availability, which when in excess or deficit, to the tomato plant, reduces the growth rate, with lower biomass of the aerial part and roots, decreasing the potential of crop yield. The reduction may occur due to damage induced by the stress, in the biosynthesis or increased of chlorophyll, which compromises carbon assimilation and the production of photoassimilates (AGHAIE et al., 2018).

In turn, the adequate management of potassium fertilization is crucial for the adequate plants' development. Potassium is an essential nutrient for the higher plants and is also the nutrient extracted in larger quantities by tomato plants, acting in osmotic regulation, in the control of the opening and closing of the stomata, in the photoassimilates translocation and giving greater resistance to pests and diseases. However, enzyme activation stands out, on the part of these enzymatic systems, to be part of the photosynthesis and respiration processes (ERNANI et al., 2007; TAIZ; ZEIGER, 2013).

In this sense, soil water tension and potassium fertilization have an important relationship. The functions of potassium in controlling the osmotic potential of cells, the absorption and retention of water in the cells, the opening and closing of the stomata, maintaining the cellular turgor, even when the cell expansion occurs, which promote the proper water use (KRAUSS, 2005).

However, if the recommendations close to the ideal of soil water tension and potassium dose are not used, tomato plants can present different negative responses. In the works of Candido et al. (2015), Santana et al. (2010) and Zhang et al. (2016) they verified that the excess or deficit of water availability hinders the growth, development and production of tomato plants. Moreover, for potassium fertilization, Kanai et al.

(2011) and Melo (2014) observed that the deficiency or excess in the doses of potassium reduces the growth, development and production of tomato plants.

The monitoring of development conditions is a key strategy for changes in management during cultivation, to ensure the desired production (MORAES et al., 2018). For example, the soil pH and chlorophyll index of the tomato plants diagnostic leaves can be evaluated. Soil pH is closely related to nutrient availability, and through monitoring it can be observed how nutrient absorption by plants is occurring (MALAVOLTA, 2006). The chlorophyll index can be obtained by using chlorophyll meters, a non-destructive method, which allows evaluating the state nutritional of plants (FONTES; ARAÚJO, 2006).

In view of the above, the objective was to evaluate the accumulated water consumption, growth characteristics, chlorophyll index, soil pH and the productive characteristics of cherry tomatoes cultivated in pots under soil water tensions and potassium doses in a protected environment.

4 MATERIAL AND METHODS

4.1 Localization, weather conditions and design of experiments

The experiment was carried out in a greenhouse, located in Rondonópolis-MT, Brazil, situate at latitude 16°27'51"S, longitude 54°34'50"W and altitude of 284 m. The experiment was conducted from 2016 February to July.

The greenhouse is oriented in a North-South direction, with an arched metallic structure with a covering polyethylene film (thickness) with adiabatic cooling. Climate types (Köppen) of occurrence in the region is classified as Aw with dry winter. Where the average weather conditions inside the greenhouse were temperature of 27.7 °C, relative humidity of 72.6% and global solar radiation of 3.98 MJ m^{-2} day^{-1}.

The experimental design was randomized with blocks, with five water tensions in the potting mix (soil) (4, 14, 24, 34 and 44 kPa) and five potassium doses (0, 125, 250, 375 and 500 mg dm^{-3}), with 5^2 fractioned factorial arrangement planned based on the adapted central compound of Littell e Mott (1975), totalling 13 treatments (4-0; 4-250; 4-500; 14-125; 14-375; 24-0; 24-250; 24-500; 34-125; 34-375; 44-0; 44-250; 44-500) (kPa - mg dm^{-3}), with four replications.

4.2 Soil characteristics and fertilizations

The soil used was classified as dystrophic Oxisol (EMBRAPA, 2013), collected in a Cerrado area at a depth of 0.0-0.2 m. The soil was sifted into a 2 mm mesh for chemical and granulometric characterization (Table 1) (EMBRAPA, 1997) and 4 mm before of liming and accommodation in pots.

Table 1. Chemical and granulometric characterization of layer 0.0-0.2 m of the dystrophic Oxisol.

pH ($CaCl_2$)	P	K	Ca	Mg	Al	H	SB	CEC	V	O.M.	Sand	Silt	Clay
	mg dm^{-3}		---------- $cmol_c$ dm^{-3} ---------						%	mg dm^{-3}	------ g kg^{-1} ------		
4.0	1.4	23	0.4	0.2	0.8	5.4	0.7	6.8	9.7	27.1	423	133	444

P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Al = Aluminum; H = Hydrogen; CEC = Cation exchange capacity at pH 7.0; V = Base Saturation; O.M. = Organic matter.
Source: Authors.

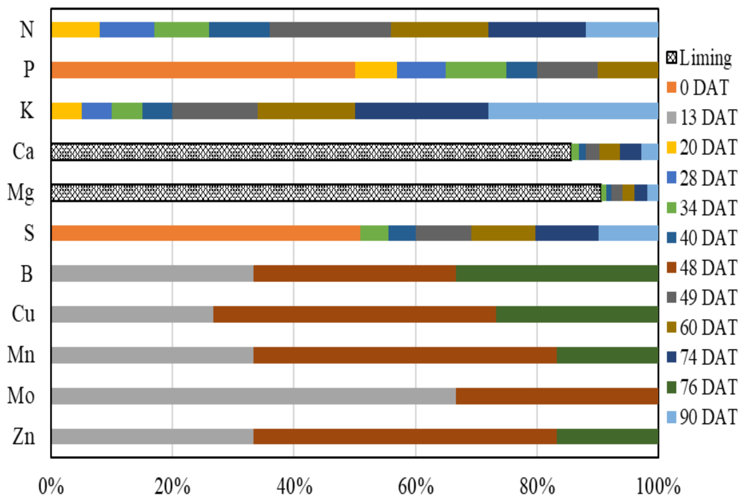
Macro and micronutrients fertilization were adjusted following the recommendations of Alvarenga (2013) (Table 2). Considering that the volume of soil explored by the roots was restricted by the pot, the fertilizer applications were divided (Figure 1) to avoid possible salinization risks by fertilization, and the recommendations were also balanced among the nutrients using different sources.

Table 2. Recommendation and sources for fertilization with macro and micronutrients.

	Recommendation (mg dm^{-3})				
Macronutrients	N [C,D,G]	P [A,C]	Ca [B,E,G]	Mg [B,F]	S [A,F]
	200	387	1400	795	220.8
Micronutrients	B [H]	Cu [I]	Mn [J]	Mo [K]	Zn [L]
	1.5	1.5	3.0	0.3	3.0

Sources used: A – Simple superphosphate incorporated into the soil at the time of transplanting; B – Dolomitic limestone applied to liming; C – Monoamonic phosphate (P.A.); D – Urea; E – Calcium chloride (P.A.); F – Magnesium sulfate (P.A.); G – Calcium nitrate; H – Boric acid (P.A.); I – Copper sulfate; J – Manganese sulfate; K - Molybdenum acid; L – Zinc sulfate.
Source: Authors.

Figure 1. Recommendation instalments of fertilizations with macro and micronutrients for cherry tomato. DAT – Days After Transplanting.



Source: Authors.

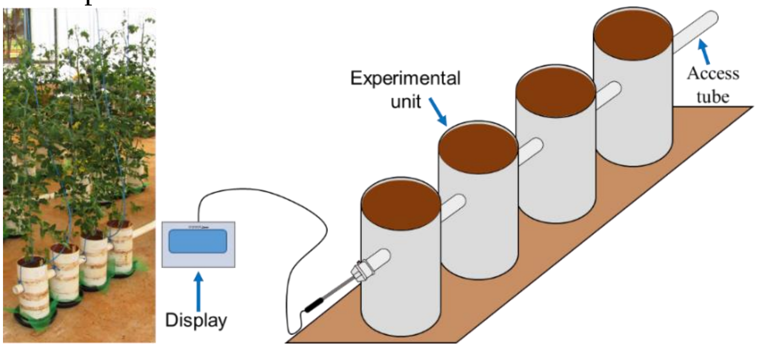
4.3 Pots composed and water management

The soil water tension was determined by an indirect method, with the capacitance probe Diviner 2000®, a sensor Frequency Domain Reflectometry (FDR) principle for soil moisture measurement. Several researches demonstrate the reliability of the sensor (SOUZA et al., 2013; PROVENZANO et al., 2015; SILVA et al., 2018). The assembly of the experimental units and the calibration equations and water stress relationship in soil with soil moisture are detailed below.

The experimental units were made with PVC tubes 20 cm diameter and 40 cm height, which accommodated 12 dm^3 soil per pot. At the 25 cm height was made holes of 5 cm diameter with a saw cup tool, for installation of the access tube that allows the monitoring of soil moisture with the capacitance probe Diviner 2000®.

The access tubes were installed in the horizontal direction with four pots per tube for the use of the Diviner 2000® probe, as used by Pereira et al. (2016). Considering that the readings were performed every 0.1 m, the pots diameter was 0.2 m, the space between the pots was 0.1 m, each profile had four usual readings in the centre of each pot (Figure 2).

Figure 2. Set of experimental units and representation of soil moisture monitoring with capacitance probe.



Source: Authors.

A previous calibration was performed to determine the water tension ratio in the soil with the volumetric moisture and the volumetric moisture ratio of the capacitance probe and with the standard volumetric moisture, the procedures are described in the paper Silva et al. (2018).

Through calibration it was obtained the ratio of water tension in the soil with the standard volumetric moisture (Equation 1) (R^2 = 0.97), which was used to determine soil volumetric moisture according to soil water tension for each treatment.

$$\theta = 0.5994.T^{-0.418} \qquad (1)$$

Wwhere: θ = soil volumetric moisture obtained by the standard method (cm^3 cm^{-3}); T = water tension in the soil (kPa).

In the experiment, monitoring of soil moisture for irrigation was performed daily with the capacitance probe. The volumetric moisture for the determination of the lamina per experimental unit (pot) was obtained by the relation between the volumetric moisture of the capacitance probe and the standard volumetric moisture (Equation 2) (R^2= 97.3).

$$\theta = 1.0737.\theta_{Diviner2000} - 0.006 \qquad (2)$$

Where: θ = soil volumetric moisture obtained by the standard method (cm^3 cm^{-3}); θDiviner2000 = volumetric moisture of the capacitance probe Diviner 2000® (cm^3 cm^{-3}).

Based on the soil volumetric moisture (standard) and the soil volume in the pot, the necessary blade was calculated (Equation 3) to achieve the desired volumetric moisture (Table 3), according to the treatment of soil water tension. Irrigation management was carried out daily and each pot individually. The accumulated blade of daily water consumption throughout the crop cycle was used as the variable water consumption by tomato plants.

$$W = (\theta_{Trat} - \theta_{Current}).12000 \qquad (3)$$

Where: W = Water volume (cm3); θ_{Trat} = moisture for the desired treatments (cm^3 cm^{-3}) (Table 3); $\theta_{Current}$ = volumetric moisture current (cm^3 cm^{-3}); 12000 – volume of soil in cubic centimeters.

Table 3. Soil moisture as a function of each treatment of soil water tension (Equation 1).

Soil tension (kPa)	4	14	24	34	44
θ (cm^3 cm^{-3})	0.3357	0.1989	0.1589	0.1373	0.1232

4.4 Semiautomated irrigation system

The irrigation system was by drip irrigation with semiautomated irrigation control. The system components were a reservoir with a volume of 1 m^3 with hydraulic buoy, 0.5 hp motor pump, 120 mesh disc filter, ball registers, manometer, PVC (Polyvinyl Chloride) pipes and fittings, solenoid valves, relief valves in head and at the end of the lines, pressure regulator, microtube and 4 L h^{-1} self-compensating dripper.

Solenoid valve actuation was performed by serial relay modules controlled by a RoboCORE® BlackBoard arduino board. The program used by the controller had its architecture developed in the environment of the arduino platform. The computer interface for communication with the controller software, was developed for the input of the flow data of each dripper, the water volume to be applied by experimental unit (each pot) and the start time of irrigation. For communication security, in the event of any electrical current failure, the computer interface resubmits the programming sequence to the controller every second.

4.5 Plant material and growing conditions

The tomato seedlings were produced in styrofoam trays with commercial substrate and vermiculite in the proportion 1:1, where a seed was sown per cell of tomato BRS ‘Iracema’ cultivar. Transplanting was performed with one seedling per pot, when they presented three to four definitive leaves. It is a basic experiment for preliminary studies of the relationship between soil water tension and potassium fertilization, however, productive systems can be established with soil cultivation and containers such as the experiment, in order to have greater control over the use of nutrient water and also to avoid possible contamination of the water table with the leaching of salts.

Seven days after transplanting, treatments were separated according to soil water tensions. The plants were conducted with wire and a single stem about two meters high in relation to the plant's neck, with the elimination of side shoots (MARIM et al., 2005; VIOL et al., 2017).

The accumulated water consumption was measured by experimental unit and presented with the daily mean by water tension in the soil. Plant height, stem diameter, number of leaves and the chlorophyll index at 30, 60 and 110 days after transplanting were evaluated. The fruits were harvested periodically according to maturation, which occurred in the period of the 62 to 110 days after transplanting (DAT), and by means of the summation, it was determined the dry mass of fruits produced along the crop cycle. At the end of the crop cycle, the soil pH, dry mass and root volume, stem dry mass and leaf dry mass were evaluated.

4.6 Traits measured

The accumulated water consumption was measured by experimental unit and presented with the daily mean by water tension in the soil. Plant height, stem diameter, number of leaves and the

chlorophyll index at 30, 60 and 110 days after transplanting were evaluated. The fruits were harvested periodically according to maturation, which occurred in the period of the 62 to 110 days after transplanting (DAT), and by means of the summation, it was determined the dry mass of fruits produced along the crop cycle. At the end of the crop cycle, the soil pH, dry mass and root volume, stem dry mass and leaf dry mass were evaluated.

The plant height was determined with a tape measure from the soil surface to the shoot apical meristem, the stem diameter was determined one centimeter above the ground with an analog caliper, the number of leaves by counting and the chlorophyll index was measured with a chlorophyll meter (SPAD Minolta, China).

Roots were washed in running water on sieves with 2 mm mesh. The root volume was obtained by the volume variation after submerging them in a graduated test tube with a defined volume of water. The biomasses variables were determined after drying in forced-circulation kiln to 65 °C until they reached constant mass to measure them on a semi-analytical balance.

4.7 Data analysis

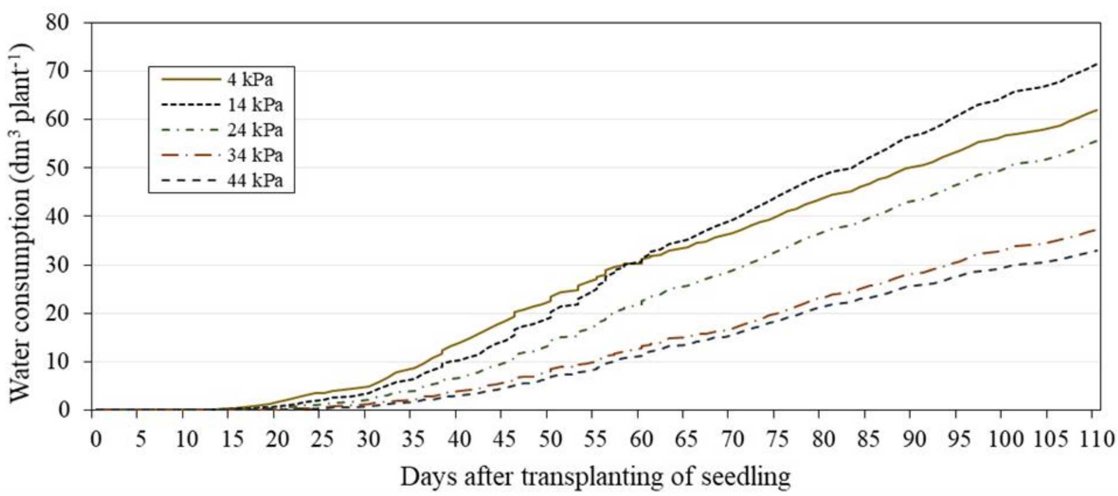
Data were submitted to analysis of variance by the F test at 5% probability, and when the interaction was significant, a response surface study was performed, or the linear and quadratic regression model was adjusted when there was significance by factor, with the Statistical Analysis System version 8.2.

5 RESULTS AND DISCUSSION

5.1 Water consumption in cherry tomato cultivation

The accumulated water consumption of cherry tomato BRS 'Iracema' for each soil water tension demonstrated a higher water consumption with the treatment 4 kPa, until 60 days after transplanting, where it is surpassed by the consumption of the plants kept under the water tension in the soil of 14 kPa, until the end of the crop cycle (Figure 3).

Figure 3. Accumulated water consumption of cherry tomato BRS Iracema under soil water tensions of the soil (kPa).



Source: Authors.

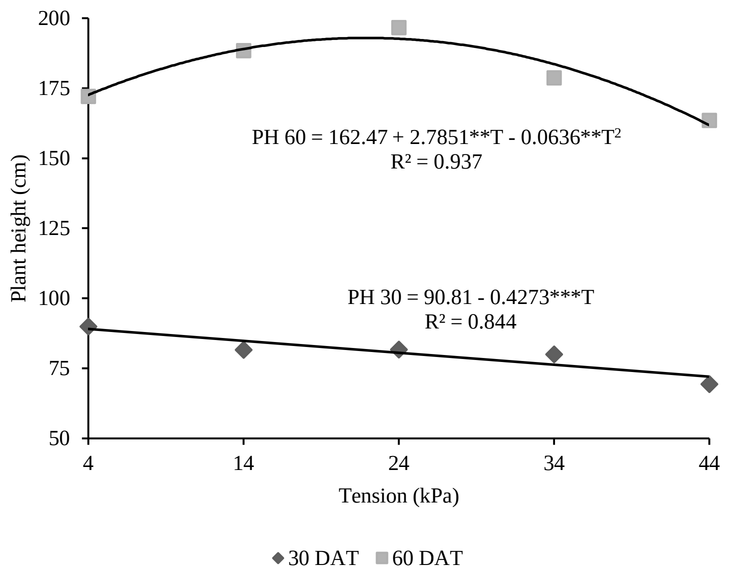
With the accumulated water consumption observed that there are differences in water availability, which indicates the highest water restrictions for soil water stresses of 44 and 34 kPa (Figure 3), where the lowest evapotranspiration occurred, of water to maintain their respective levels of water tensions in the soil.

At 30 days after transplanting, it was observed that the highest growth occurred with the lowest water tension in the soil (4 kPa). According to Taiz and Zeiger (2013), under water excess conditions there is an increase in the induction of stretching and cell division stimulated by the action of gibberellins, however, it causes the increase in the consumption of plant carbohydrate reserves, which subsequently reduces growth, as observed at 60 days after transplanting, where the lowest water tension in the soil (4 kPa) had a lower plant height than in the soil water tension of 22 kPa. In this sense, under water deficit conditions, there is possibly a reduction in growth due to the lower action of gibberellins, justifying the lower plant height in the treatment with soil water tension of 44 kPa, at 30 and 60 days after transplanting.

5.2 Plant height, stem diameter and leaf number of cherry tomato

Cherry tomato plant height, in the assessments at 30 and 60 days after transplanting, showed significant differences to the soil water tension, with adjustment to linear and quadratic regression model, respectively. According to the estimated polynomial model, the highest plant height (193 cm) in the evaluation at 60 days after transplanting was obtained with a soil water tension of 22 kPa (Figure 4). At 110 days after transplanting, plant height was not significant for soil water tensions and potassium doses due to plant height restriction to two meters.

Figure 4. Plant height in cherry tomato BRS Iracema under soil water tensions of the soil at 30 and 60 days after transplanting of seedling. PH – Plant height; T – Soil water tension. ** and *** significant to 1 and 0.1%, respectively.

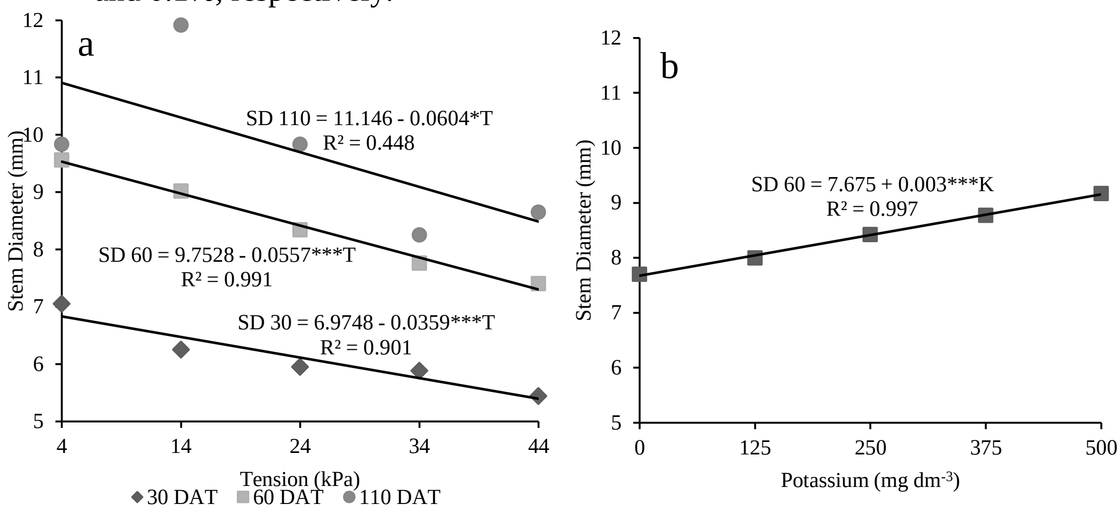


Source: Authors.

Macêdo and Alvarenga (2005) worked with the hybrid tomato plant ‘Bonus F1’ with irrigation blades and potassium fertigation and observed that the height of plants showed significant difference for water blades, with increased growth of water blades. Santana et al. (2010) worked with water blades in the cultivation of hybrid tomato 'Andrea' in a dystroferric Oxisol, observed similar behavior to the evaluation at 60 DAT of the present study, the water excess and deficit of 190 and 70% soil replenishment, respectively, promoted the lowest plant heights. Bogale et al. (2016) worked with two tomato cultivars on peat and sand substrate (1:1) under water deficit conditions (50% total lamina) and observed reduction of plant height with the decrease of water tension in the soil.

For stem diameter, there was a significant difference for water availability at 30, 60 and 110 DAT and potassium doses at 60 days after transplanting. There was adjustment to the decreasing regression linear model in all assessments for water availability and increasing for potassium doses at 60 DAT (Figures 5).

Figure 5. Stem diameter of cherry tomato plants BRS Iracema under soil water tensions (a) and potassium doses (b) at 30, 60 and 110 days after transplanting of seedling (DAT). SD – stem diameter; T – Soil water tension; K – Potassium. * and *** significant at 5 and 0.1%, respectively.



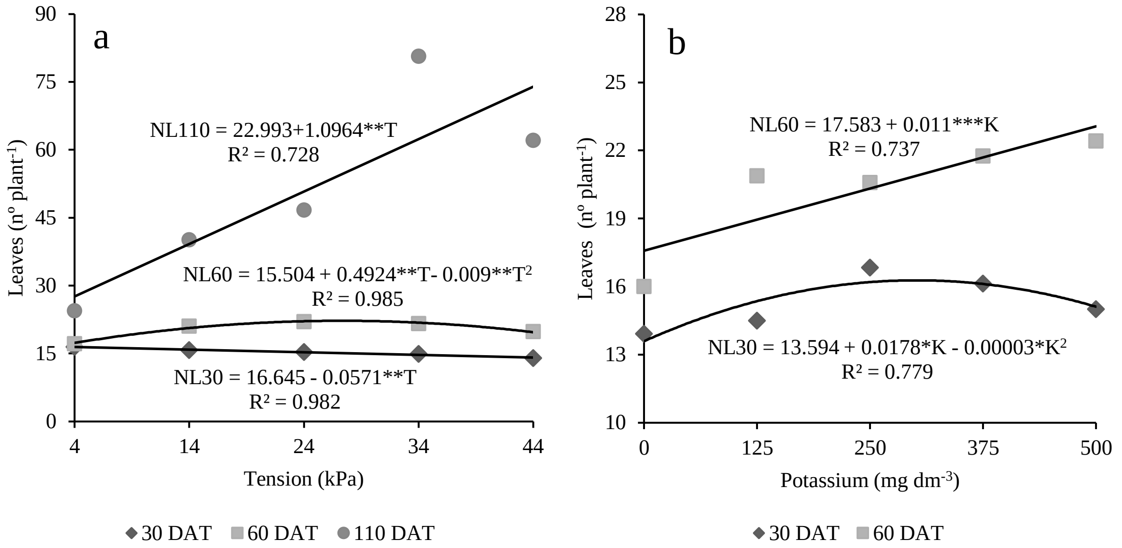
Source: Authors.

Regarding water tension in the soil, the results corroborate Candido et al. (2015) who observed the reduction of tomato stem diameter with the reduction of the water slide. Regarding potassium doses, stem diameter results are concordant with Kanai et al. (2011), who observed a reduction in the diameter of tomato plants under conditions of potassium deficiency.

The well-developed stem reflects in the other plant structures by sustaining the photosynthetic and reproductive organs appropriately to perform their functions, besides maintaining the conductive vessel systems, which enable the source-drain communication, for example (WINTER, 1986). Thus, larger stem diameter is related to the larger set of conducting vessels and the ability to sustain higher mechanical loads.

The number of leaves showed significance for soil water tensions at 30, 60 and 110 DAT and for potassium doses at 30 and 60 DAT. At 30 DAT, the availabilities presented adjustment to linear regression model, with a reduction in the number of leaves of 14% with the increase of the soil tension up to the limit of the experimental interval (44 kPa). At 60 DAT, the largest number of leaves (22) was observed in the soil water tension of 27 kPa. In turn, at 110 DAT, there was an adjustment to linear regression model in relation to water availability, with the highest number of leaves (71) under the tension of 44 kPa (Figure 6a).

Figure 6. Number of leaves of cherry tomato plants BRS Iracema under soil water tensions (a) and potassium doses (b) at 30, 60 and 110 days after transplanting of seedling (DAT). NL – Number of leaves; T – Soil water tension; K – Potassium. *, ** and *** significant to 5; 1 and 0.1%, respectively.



Source: Authors.

Regarding the evaluation at 30 DAT, the results found for the behaviour of the plants corroborate with the results observed by Morales et al. (2015), who observed a reduction in the tomato plant number of leaves with the reduction of soil water tension. However, the results of the evaluation at 110 days after transplanting do not corroborate with the other assessments. Possibly the reduction of soil water tension promoted the shortening of internodes from flowering and fruiting stages, since the main drains became the fruits. With the reduction of internodes, the plants increased the number of leaves until they reached the limit of the stoning system.

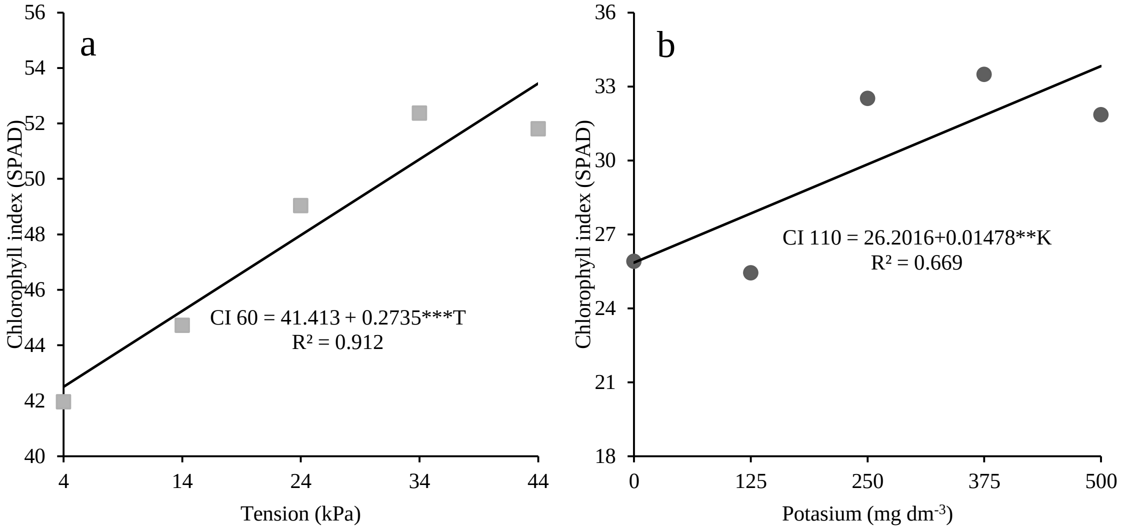
For potassium doses at 30 DAT, the number of leaves presented an adjustment to the quadratic regression model, with the highest number of leaves (17) in the dose of 297 mg dm^{-3}. At 60 DAT, the linear regression model was adjusted, where the highest number of leaves was observed in the highest potassium doses (Figure 6b).

The increase in number of leaves due to the increase in potassium fertilization showed similar behaviour to the chlorophyll index and leaf dry mass, demonstrating that the increase in potassium doses allows a greater photosynthetic capacity reflecting in higher production of photoassimilates, which caused the increase of the productive components of the tomato crop.

5.3 Chlorophyll index and soil pH in cherry tomato cultivation

For the chlorophyll index there was a significant difference for soil water tensions at 60 DAT and for potassium doses at 110 DAT. In both cases, there was an adjustment to a linear regression model, increasing with the increase of the levels of each factor (Figures 7 a and b).

Figure 7. Chlorophyll index of cherry tomato plants BRS Iracema under soil water tensions at 60 days after transplanting of seedling (a) and potassium doses at 110 days after transplanting (b). CI – Chlorophyll index; T – Soil water tension; K – Potassium. ** and *** significant to 1 and 0.1%, respectively.



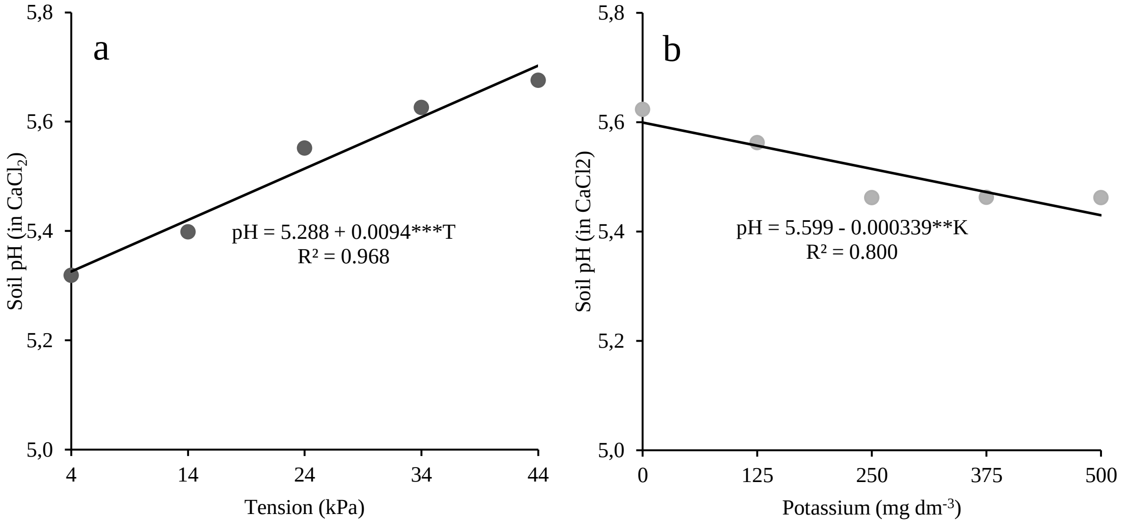
Source: Authors.

The results corroborate Ahmad et al. (2014), who observed for different cultivars of Brassica juncea under potassium deficiency reduction of up to 44% in total chlorophyll concentration in leaves, which cause a decrease in photosynthetic activity, reducing the production of photoassimilates and consequently in the productive characteristics of tomato plants.

Fontes and Araújo (2006) observed the viability of using the chlorophyll index measured by SPAD chlorophyll meter as a tool to evaluate the nutritional requirement and recommend the use of this non-destructive methodology.

For soil pH, there was an significance for water tensions and potassium doses. For the soil water tensions there was adjustment to linear regression model. The tension of 44 kPa presented the highest soil pH (5.7), while the tension 4 kPa the smallest (5.3) (Figure 8a). Potassium doses were adjusted to a linear regression model, with the reduction in pH values with an increase of potassium doses, in both assessments. In the absence of potassium fertilization, pH value (5.5) was higher than the value (5.3) in potassium dose of 500 mg dm^{-3} (Figure 8b).

Figure 8. Soil pH in cultivation of cherry tomato plants BRS Iracema under soil water tensions (a) and potassium doses (b) at 110 days after transplanting of seedling in dystrophic Oxisol. T – Soil water tension. ** and *** significant to 1 and 0.1%, respectively.



Source: Authors.

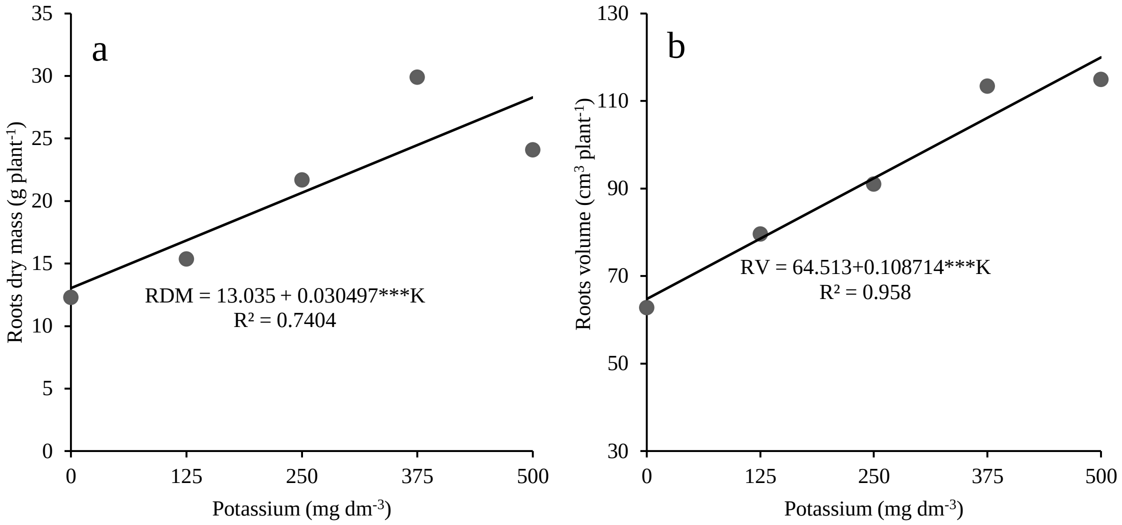
Soil pH was reduced by the higher water availability due to the inverse behaviour of the dry mass of the aerial part and roots, which indicates that there was a greater absorption of nutrients, which occurs by the release of protons (H^+) to the external environment by the roots, which contributes to reducing the pH (MALAVOLTA, 2006).

The increase of soil acidity as a function of potassium doses may be related to the nutrient absorption process, due to the release of protons (H^+) to the external medium that occurs when potassium is absorbed by the roots (MALAVOLTA, 2006). Therefore, the greater availability of potassium may have stimulated its greater uptake by the roots.

5.4 Productive characteristics of cherry tomato

Considering the root system, its dry mass and volume presented significant difference for potassium doses. There was an adjustment to the linear regression model, with the highest production (28.3 g plant^{-1} and 119 cm^3 plant^{-1}) of roots with the potassium dose of 500 mg dm-^{3}, obtaining an increment of 54% when compared to the absence of potassium fertilization, for both dry mass and root volume (Figure 9).

Figure 9. Dry mass (a) and roots volume (b) of cherry tomato plants BRS Iracema under potassium levels in a dystrophic Oxisol. RDM – Root dry mass; K – Potassium; RV – Roots volume. *** Significant to 0.1%.



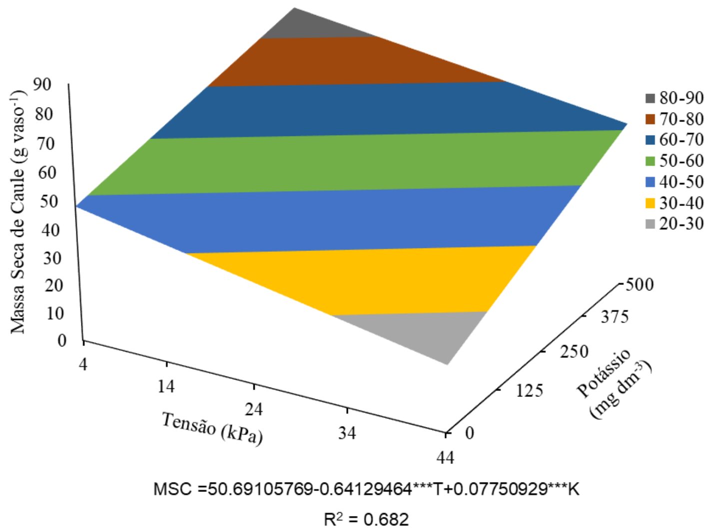
Source: Authors.

The results correlate with Melo et al. (2014) who observed an increase in the roots dry mass of tomato with the increase of potassium levels in the nutrient solution in hydroponic system, and with Kanai et al. (2011), who observed reduction of the root mass of tomato plants in a situation of potassium deficiency.

According to Winter (1986) the well-developed root system confers to plant greater absorption of water and nutrients capacity, allowing an increase in the productive components of the plant. Therefore, with the increase of potassium fertilization there is a higher roots volume of tomato, representing a greater capacity to support the aerial part allowing and enabling a higher production.

Stem dry mass showed significant interaction between the soil water tension and potassium doses. According to the model, the water tension in the soil of 4 kPa combined with the potassium dose of 500 mg dm^{-3} provided the highest stem dry mass (87 g $plant^{-1}$), obtaining an increment of 74% when compared with the combination of 44 kPa and absence of potassium fertilization (Figure 10).

Figure 10. Dry stem mass of cherry tomato plants BRS Iracema under soil water tension and potassium doses in a dystrophic Oxisol. SDM - Stem dry mass; T – Soil water tension; K – Potassium. *** significant to 0.1%.



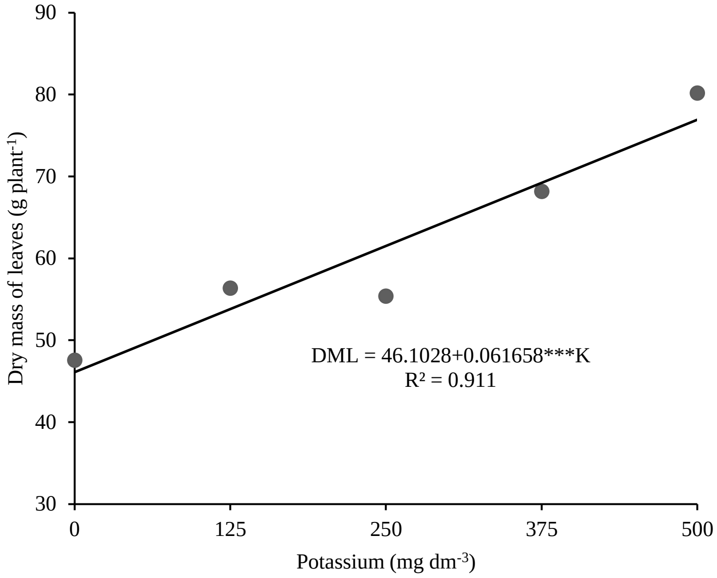
Source: Authors.

Regarding soil water tensions, a correlation was observed by Zhang et al. (2016) who observed for the tomato under different water blades, the increase of the stem dry mass with the increase of the water slide, and with Bowles et al. (2016), with tomato in deficit condition, that observed a reduction of stem dry mass.

According to Winter (1986), the stem is important because it sustains the photosynthetic and reproductive organs and the conductive vessels, which are responsible for the exchange of water, mineral nutrients and photoassimilates between these structures and the roots.

Leaves dry mass was significant different according to potassium doses. There was an adjustment to a linear regression model, with the highest production of leaves (77 g plant^{-1}) at the potassium dose of 500 mg dm^{-3}, with an increment of 40% in relation to the absence of potassium fertilization (Figure 11). Melo et al. (2014) observed an increase in the dry mass of tomato leaves with the increase of potassium levels in the nutrient solution in hydroponic system. Kanai et al. (2011) observed reduction of leaf mass of tomato plants under conditions of potassium deficiency.

Figure 11. Dry mass of leaves of cherry tomato plants BRS Iracema under potassium levels in a dystrophic Oxisol. DML – Dry mass of leaves; K – Potassium. ***significant to 0.1%.

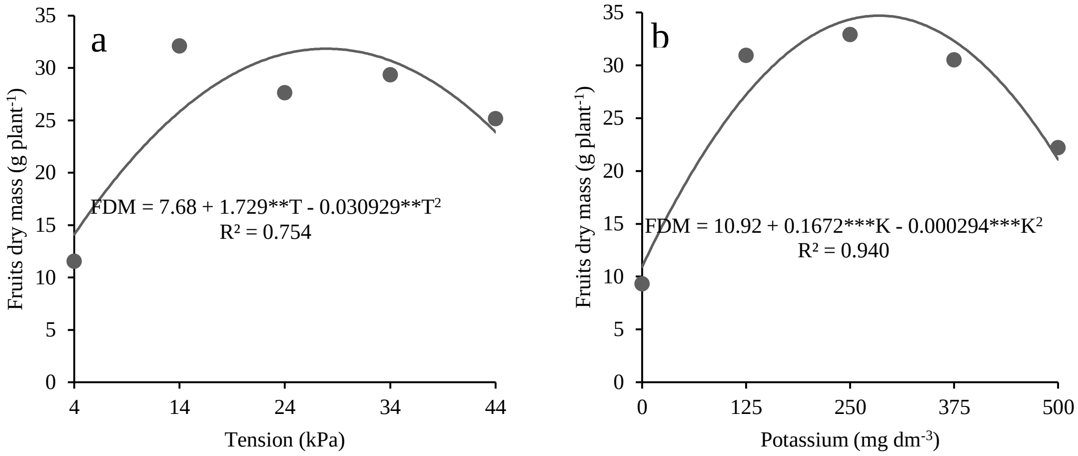


Source: Authors.

Potassium fertilization absence reduces the production of leaves due to physiological changes that are influenced by potassium. According to Sung et al. (2015), who evaluated the initial development of tomato under potassium deficiency, its functions of synthesis, conversion and allocation of metabolites is compromised, with a reduction of carbohydrates, aminoacids and organic acids in the leaves, reducing biomass accumulation.

Cherry tomato fruits dry mass showed an significance for the soil water tensions and potassium doses, both with adjustment to the quadratic regression model. The highest fruit yield (31.8 g plant^{-1}) was observed in the soil water tension of 28 kPa, with an increment of 31% when compared with 4 kPa (Figure 12a).

Figure 12. Fruits dry mass of cherry tomato plants BRS Iracema under potassium levels in a dystrophic Oxisol. DMF – Fruits dry mass of; T – Soil water tension; K – Potassium. ** and *** significant to 1 and 0.1%, respectively.



Source: Authors.

In relation to fruit production, Santana et al. (2010) and Zhang et al. (2016) observed for tomato plant under water different blades, a similar behaviour to the present study, where the water stress, due to excess or deficit, reduced the productive potential. Corroborating also with Bogale et al. (2016), Bowles et al. (2016), Candido et al. (2015) and Kuşçu et al. (2014), who worked with tomato in a water deficit condition and observed that there was a reduction in fruit mass.

For potassium fertilization, the highest fruits dry mass (34.7 g plant^{-1}) was observed with the potassium dose of 284 mg dm^{-3}, obtaining an increment of 54% in relation to the absence of potassium fertilization (Figure 12b). Fontes et al. (2000), worked with potassium fertigation in the Santa Clara group, and observed increases in productivity up to the potassium dose of 198 kg ha^{-1}.

The increment of the fruit mass with the increase in potassium fertilization may be related to the functions of photoassimilates transport with the aid of potassium. Mengel and Viro (1974) observed in tomato plants the positive effect of potassium on the transport of sugars, aminoacids and organic anions from the leaves and stem to the fruits. These results are aligned with the work of Hassan et al. (2016) that defend the importance of balanced tomato nutrition for growth, biomass production and fruit production.

The yield (fruits dry mass) for not increasing up to the maximum potassium dose, such as the production of roots, stems and leaves, suggests that a nutritional imbalance may occur in relation to the other nutrients, resulting in a reduction in the translocation of the photoassimilates to the fruits. Potassium has an antagonistic relationship with some other nutrients, such as calcium and magnesium, with the excess of potassium fertilization favoring the translocation of potassium to the fruits (MALAVOLTA, 2006; LI et al., 2018; DAOUD et al., 2020).

Regarding the soil water tension, the higher fruit production at the tension of 22 kPa (Figure 12a), justifies the increase in constant water consumption in treatments 14 and 24 kPa, from 60 days after emergence (Figure 3). The process of water absorption by the plants is accompanied by the absorption of nutrients, in the soil the nutrients approach the roots through the mass or diffusion flow and in the plant the upward flow is used to transport the nutrients to the aerial parts and the fruits (REICHARDT; TIMM, 2012).

6 CONCLUSION

The growth characteristics, chlorophyll index, soil pH and productive characteristics of cherry tomato cultivated in pots with dystrophic Oxisol under protected environment are influenced by soil water tension and potassium fertilization.

The accumulated water consumption indicates that the greatest water restrictions growing and development were for soil water tensions of 44 and 34 kPa.

For the growth of the cherry tomato the highest water availability favours in greater initial development, yet water tension in the soil near 22 kPa provided greater growth (plant height) close to 60 DAT.

For potassium fertilization, there was a higher growth with the use of higher potassium doses. Leaves and roots dry mass and the root volume showed increments of 40 to 54% with the increase of potassium fertilization up to the potassium dose of 500 mg dm^{-3}.

There was a relationship between soil water tension and potassium doses for the stem dry mass with the highest production in the combination of 4 KPa and 500 mg dm^{-3} of potassium.

The highest cherry tomato fruits dry mass occurs in the soil water tension of 28 kPa and potassium dose of 284 mg dm^{-3}. Deficiency and excess potassium in the soil reduced fruit production, as well as the deficit and excess water in the soil.

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