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Electrical Conductivity and Nitrogen:Potassium Ratios from Nutrigation in the Quality of Zucchini Fruits

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HIGHLIGHTS

- Electrical conductivity (EC) and N:K ratios modify zucchini fruit size.
- Organoleptic characteristics of zucchini fruits increase with EC.
- Total dry mass production of plants showed interaction between N:K ratio and EC.

Abstract: The demands of high-quality zucchini fruits by the consumer market make studies regarding the improvement of cultivation systems, such as plant nutrition and salinity tolerance. Considering the demands of the consumer market for the high quality of zucchini fruits, it is necessary studies regarding the improvement of production systems for this improvement, such as nutrition and salinity tolerance to plant. Thus, this study aimed to evaluate the zucchini fruits quality characteristics, grown in soilless, under N:K ratios, and levels of electrical conductivity of the nutrient solution. The experiment was conducted in a protected environment in pots with 8.2 dm^3 of volumetric capacity filled with commercial substrate. The trial design adopted was randomized blocks, with three replicates, in a 5x3 factorial scheme, with five levels of electrical conductivity (1.0; 2.0; 3.0; 4.0; and 5.0 dS m^{-1}) and three N:K ratios (2:1; 1:1; and 1:2), both in the nutrient solution. The application of the nutrient solution was by fertigation through drip irrigation. Throughout the experiment, variables related to fruit quality and total plant biomass production were analyzed. The increase of the electrical conductivity in the nutrient solution provided an increase in the values of fruits organoleptic properties. Regarding the nutrient solution N:K ratios, the 1:2 ratio provided larger fruits and a higher percentage of water.

Keywords: *Cucurbita pepo* L.; Fertigation Concentration; N:K Ratio; Open Hydroponics; Plant Nutrition; Salinity in Protected Cultivation; Soilless.

INTRODUCTION

Zucchini (*Cucurbita pepo* L.) is one of the main vegetables produced in the world, with acceptability and integration in the cuisine of different cultures. Its fruits are marketed immature with light green, dark green, or yellow color, depending on the cultivar. Due to its nutritional and organoleptic characteristics, the consumption of zucchini has a growing demand, accompanied by the requirement to improve the fruit quality [1-6].

In order to achieve the quality requirements for zucchini production, its production has been implemented in intensive systems, such as soilless cultivation in protected environments. In these systems, the pH and electrical conductivity control of the nutrient solution and the balance between nutrients are basic factors in crop management [7].

In productive soilless systems with nutrient solution application, the determination of electrical conductivity aims to control the nutrient concentrations and other salts. In general, plants show a yield curve-response to salinity levels, where there is an increase in this response up to a limit level, and then it exceeds the level of toxicity and development is reduced. However, in some cases of relatively high salinity (4-6 dS m^{-1}), satisfactory results regarding nutritional quality may occur [8]. Therefore, producers must reconcile their strategies to obtain good productivity and also quality.

For zucchini plant nutrition, the adequate recommendation of nitrogen (N) and potassium (K) is crucial for their good development, because they are two nutrients absorbed in higher quantities by the culture, in addition to performing essential functions [3].

Nitrogen is a basic constituent of aminoacids, nucleic acids, enzymes, and chlorophyll, and this nutrient is present in main plants' biochemical reactions. On the other hand, potassium has several physiological and metabolic functions, such as enzymatic activation, translocation of photo-assimilates, and performance in osmotic regulation, promoting water use improvements [9].

Regarding nutritional balance, it is known that nitrogen and potassium have an important interaction, witch the absorption of one element increases the demand of the other, due to their complementary physiological functions [10-11], which influence growth, development, and production of plants, and consequently the quality of the fruits.

The balance between the nitrogen and potassium (N: K ratio), modifies the growth processes and consequently the reproductive phase and the quality of the fruits, since potassium acts in the growth regulation when there is a high availability of nitrogen [12], and acts in the translocation of photoassimilates to the fruits, in the reproductive phase.

For the commercialization of zucchini, quality standards of its characteristics are required. Among the parameters analyzed at the time of purchase, consumers usually observe the physical and structural characteristics (size, shape, and color). However, the characteristics related to taste (organoleptic parameters such as soluble solids and titratable acidity) and nutritional benefits (vitamin C), are variables that provide a demand continuity and the greater consumption of zucchini.

Even though the production of zucchini is traditional over the world, soilless systems for this crop are still in implementing and expanding phase. Furthermore, there is an absence in the literature regarding the effects of the N: K ratio with levels of electrical conductivity of the nutrient solution on the quality of its fruits. The combination of these factors can demonstrate how the changes brought about by the N: K ratios in the limits of tolerance to salinity of the crop influence the fruit quality.

Given the above, the aim was to evaluate the fruit quality characteristics and the total dry mass of the zucchini plants grown in pots with the substrate (soilless) and protected environment, under N:K ratios, and electrical conductivity levels of nutrient solution.

MATERIAL AND METHODS

Experiment location and design

The experiment was carried out in a greenhouse at the Department of Biosystems Engineering of the "Luiz de Queiroz" College of Agriculture/ University of São Paulo, in Piracicaba-SP, Brazil, located at latitude -22.711207, longitude -47.629531 and altitude of 546 m. The region's climate, according to Koppen's criteria is classified as Cwa, humid tropical with hot summer and dry winter [13].

The greenhouse was located in the east-west direction and has an arched metal structure, the anti-aphid screen on the sides, and a 0.150 mm thick polyethylene cover. From the 25 days after the transplant until the end of the cycle, to avoid plants thermal stress, a thermo-reflective screen was used below the greenhouse cover arch, which blocks were about 50% of the light.

The experiment was conducted in the summer, from January 3 to March 5, 2019, in a randomized block design, with 15 treatments and three repetitions, in a 5x3 factorial scheme, with five levels of electrical conductivity (1.0; 2.0; 3.0; 4.0; and 5.0 dS m^{-1}) and three N:K ratios (2:1; 1:1; and 1:2), both in the nutrient solution, which were formulated based on the nutrient solution provided by Hoagland and Arnon [14]. Thus there were 45 experimental units in total, using plant border lines around the experiment.

Preparation and use of nutrient solution

The Hoagland and Arnon [14] nutritional solution was adopted as a reference, due to its widely use in scientific researches, as it meets nutritional needs in a basic way for different crops. The reference solution is characterized by electrical conductivity of approximately 2.7 dS m^{-1} and a N:K ratio, close to 1:1. Then, in order to adjust the nutrient solution according to the respective treatments, the concentration of nutrients was increased or diluted, to reach each level of electrical conductivity. Also, the amount of nitrogen and potassium in the solution was modified according to the treatments of the 2:1 and 1:2 N:K ratios.

The electrical conductivity and pH were monitored during the preparation, and nutrient solution application period, using a conductivity meter model DM-32 and a pH meter model DM-21, respectively, both from Digimed® (Digimed Analítica, São Paulo, Brazil). For electrical conductivity, a 10% increase or decrease in the value of each treatment was accepted, and the correction when overcoming was with water dilution or additional stock solutions aliquots. The nutrient solution pH was maintained in the range between 5.5 and 6.5, corrected with the addition of 1mol L^{-1} sodium hydroxide solution for elevation or with 1mol L^{-1} hydrochloric acid solution for reduction.

In the treatments with the N:K ratio of 1:1, the sources of macronutrients used were those recommended by Hoagland and Arnon [14], namely calcium nitrate, potassium nitrate, monopotassium phosphate, and magnesium sulfate. For the ratios of 2:1 and 1:2, ammonium nitrate and potassium chloride, respectively, were also used to increase the concentration of the nutrient until reaching the desired ratio (Table 1).

Table 1. Nutrient concentrations (mg L^{-1}) in the nutrient solutions for each treatment.

N:K	EC	N	P	K	Ca	Mg	S	Cl
2:1	1	79.97	5.30	40.46	34.31	8.27	10.91	-
	2	265.79	17.62	134.49	114.05	27.49	36.26	-
	3	451.61	29.94	228.51	193.79	46.70	61.62	-
	4	637.44	42.26	322.54	273.53	65.92	86.97	-
	5	823.26	54.58	416.57	353.27	85.14	112.32	-
1:1	1	41.52	6.10	46.57	39.49	9.52	12.56	-
	2	150.62	22.14	168.95	143.28	34.53	45.56	-
	3	259.72	38.17	291.33	247.06	59.55	78.56	-
	4	368.83	54.20	413.71	350.84	84.56	111.57	-
	5	477.93	70.24	536.09	454.63	109.58	144.57	-
1:2	1	51.90	7.63	105.71	49.37	11.90	15.70	43.07
	2	130.31	19.15	265.42	123.96	29.87	39.41	108.14
	3	208.73	30.68	425.13	198.55	47.85	63.13	173.22
	4	287.14	42.20	584.84	273.14	65.83	86.85	238.29
	5	365.56	53.72	744.56	347.73	83.80	110.57	303.36

[1] Where: N:K = nitrogen:potassium ratio; EC = electrical conductivity; N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; Cl = chlorine.

About the micronutrients, they were used in the recommendation of the original solution by Hoagland and Arnon [14] for all treatments, with the recommendations of 0.5; 0.02; 5; 0.5; 0.01; and 0.05 mg L^{-1} for boron, copper, iron, manganese, molybdenum, and zinc, using as sources boric acid, copper sulfate, Fe-EDTA solution, manganese chloride, molybdic acid and zinc sulfate, respectively.

Characterization of the substrate

The zucchini production was carried out in polyethylene pots with a volume of 0.0082 m^3, which were filled with commercial substrate AgroLink® Biogrow Fiber/Standard Compound (AgroLink®, Artur Nogueira, São Paulo, Brazil) composed mainly of composted pine acacia, composted pine bark, sphagnum peat, steamed rice husk, and coconut fiber. The chemical and physical-hidric characterizations (Table 2 and Figure 1) were performed according to Brasil [15] and Embrapa [16], respectively.

Table 2. Chemical and physical-hydric substrate characterization.

Characteristics	Values
pH ($CaCl_2$ 0,01 M)	7.5
Density (Organic Residue)	0.33 g cm^{-3}
Total Organic Matter (Combustion)	801.1 mg kg^{-1}
Organic Carbon	429.0 mg kg^{-1}
Nitrogen (N)	11.4 mg kg^{-1}
Phosphorus (P_2O_5)	2.3 mg kg^{-1}
Potassium (K_2O)	1.6 mg kg^{-1}
Calcium (Ca)	19.9 mg kg^{-1}
Magnesium (Mg)	0.9 mg kg^{-1}
Sulfur (S)	0.4 mg kg^{-1}
Ratio C/N	38,0
Boron (B)	11,0 mg kg^{-1}
Copper (Cu)	10,0 mg kg^{-1}
Iron (Fe)	5967,0 mg kg^{-1}
Manganese (Mn)	151,0 mg kg^{-1}
Zinc (Zn)	37,0 mg kg^{-1}
Sodium (Na)	444,0 mg kg^{-1}
Cation Exchange Capacity (CEC)	690.00 $mmol_c$ kg^{-1}
Water Retaining Capacity (WRC)	92.79%
Electric Conductivity (EC)	2.25 dS m^{-1}

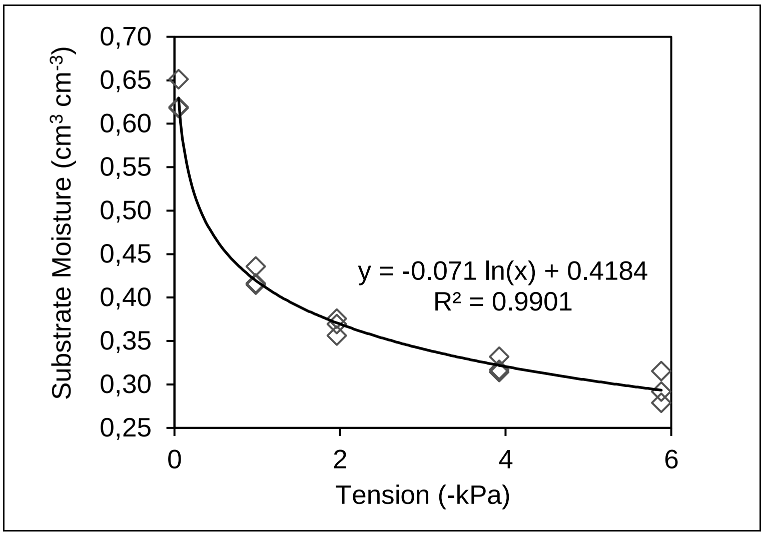

Figure 1. Substrate water retention curve as a function of tension (average of 3 samples).

Monitoring of micrometeorological variables

The monitoring of micrometeorological variables inside the greenhouse was performed by an automatic station with a data acquisition system every 15 minutes, made by Datalogger CR1000 (Campbell Scientific®, Utah, USA), with HMP45C thermohygrometer sensor (Vaissala®, Vantaa, Finland) to obtain the measurements of air temperature and relative humidity.

In addition, a LI200X silicon photodiode pyranometer sensor (LI-COR®, Lincoln, Nebraska, USA) was used to measure global solar radiation. From that, the values of the general daily means were obtained for the cycle of the zucchini, of 27.4ºC; 84.5% and 6.5 MJ m^{-2} day^{-1}, for air temperature, relative humidity, and global solar radiation, respectively.

Fertigation system and management

The fertigation system was composed by nutrient solution reservoirs (0.1 m^3) for each treatment, motor pump (Hydroblock P500 of the KSB® brand of 0.5 hp of power – KSB, Frankenthal, Germany), disc filter (120 mesh), ball registers, pressure gauge, manifold and polyvinyl chloride (PVC) accessories, return in the head, microtube and self-compensating dripper (flow of 2.6 L h^{-1}) (Figure 2).

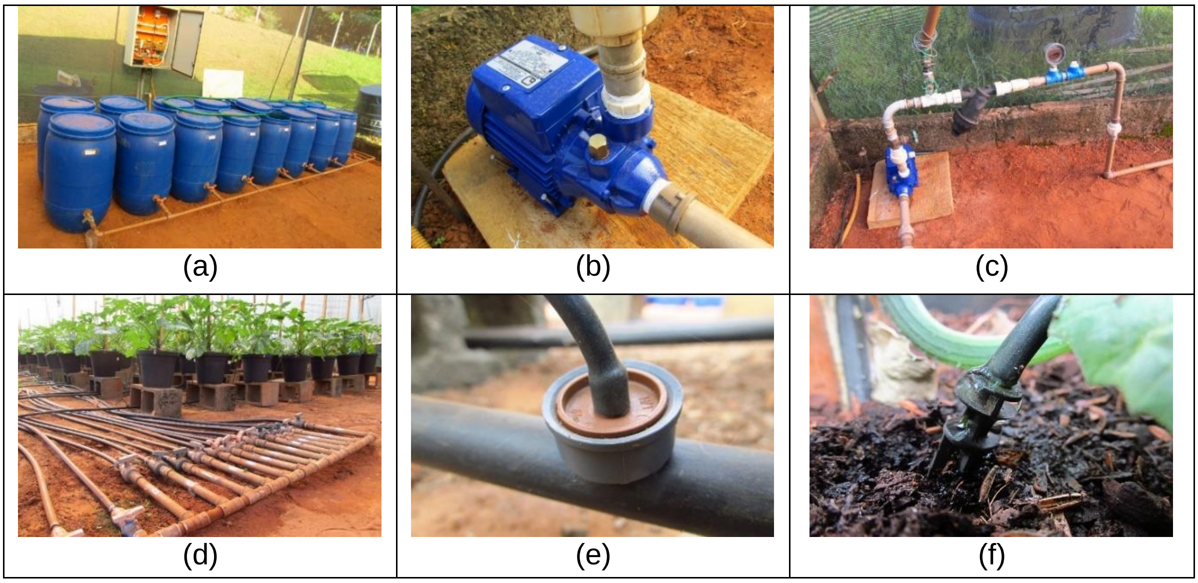

Figure 2. Set of nutrient solution reservoirs (a); Hydroblock P500 motor pump (b); motor pump and easel with a return, disc filter and pressure gauge (c); main line and the start of manifold with sphere registers (d); self-compensating dripper and microtube (e); and exit of the microtube with a drip stake (f).

The fertigation system was evaluated for uniformity indicators, using the Christiansen's Uniformity Coefficient (CUC) and Emission Uniformity (EU), which presented the values of 97.4 and 88.5%, with performance classified as excellent and good, respectively [17].

To determine the volume of nutrient solution, in fertigation, the substrate moisture monitoring was performed by gravimetry method, using a digital scale of the brand Dise® and model SF-400 (Dise, China), with an accuracy of ± 1g. Fertigation was carried out to raise the substrate moisture to about 90% of its maximum water retention capacity, with the water depths being applied separately for each treatment. Among the irrigations of each treatment, the nutrient solution of the suction pipe and main line, in the common use of all treatments, was exhausted, avoiding contamination between the solutions. The mean consumption per experimental unit of the nutrient solution during all the experiment was (22.6 ± 1.7) dm^3 $plant^{-1}$.

Implementation and conduct of the experiment

The zucchini seedlings (*Curcubita pepo* L.) cultivar Corona were produced in polyethylene trays of 128 cells, with a commercial substrate. Seedling transplantation was performed 20 days after sowing, with one plant per pot. The pots were arranged in spacing between lines of 1 m and spacing between plants of 0.5 m [18]. The plants were tutored by cuttings to avoid lodging.

Zucchini plants were fertigated with a nutrient solution, with an electrical conductivity of 1.0 dS m^{-1} and a N:K ratio of 1:1, until the differentiation of each study factor. The levels of electrical conductivity were differentiated at 12 days after transplanting the seedlings and the N:K ratios at 17 days after transplantation. From 25 days after transplantation, micrometeorological management was performed with the use of the thermoreflective screen with a blockage of approximately 50% of the light.

The first flowers open, male and female, occurred at 35 days after transplantation, and the first harvest was performed at 47 days after transplantation. Manual pollination was performed, collecting male flowers and placing their anthers in direct contact with the stigmas of female flowers. At 62 days after transplantation, the plants were cut, for the final evaluation of plants total dry mass.

Traits measured

The fruits were evaluated for quality characteristics related to the structure and organoleptic properties. The harvests were carried out twice a week when the fruits were between 18 and 20 cm in length and they were sent to the laboratory for evaluations.

As for the productive characteristics, the fresh weight of the fruits was evaluated. Regarding quality characteristics, the length of the fruits was evaluated using a graduated ruler; the transverse diameter and pulp thickness with the support of a digital caliper, in the upper, middle, and lower thirds of the fruit; the fruit percentage of water and dry mass; the total soluble solids (SS) content, determined by the use of a Bellingham + Stanley Model DR digital refractometer; total titratable acidity (TA) by titrometry; SS/TA ratio; and vitamin C by titrometry, according to methods described by Pregnolatto and Pregnolatto [19].

At the end of the cycle, zucchini plants were cut and the organs were separated for drying in a forced circulation oven at 65ºC until constant mass. After dried, the plants total dry mass (fruits + leaves + stem + roots) was evaluated, with the weighing plants vegetative and productive organs in a semi-analytical balance.

Data analysis

The data were applied to a variance analysis performed by F test, when was a significant difference between the treatments, polynomial regression was applied to the values of electrical conductivity and Tukey test for the N:K ratios of the nutrient solution. The tests were performed at a level of 5% probability in the software R (version 3.6.2).

RESULTS AND DISCUSSION

Structural quality of zucchini fruits

Regarding the quality of zucchini fruits, the variables that showed a significant difference were the fresh mass of fruits, the diameter of fruit in the lower third of fruits and the pulp thickness in the upper third of fruits (Table 3).

Table 3. Variance analysis summary, global mean and variation coefficient of structural zucchini fruits quality characteristics.

Analysis of Variance	FM	LF	DF1	DF2	DF3	PT1	PT2	PT3
EC	ns	ns	ns	ns	*	ns	ns	ns
N:K	ns	ns	ns	ns	ns	*	ns	ns
EC*N:K	**	ns	ns	ns	ns	ns	ns	ns
Global mean	248.56	19.11	41.38	27.33	59.86	13.72	7.45	10.48
cv (%)	8.74	3.88	10.11	12.99	8.50	13.87	18.01	20.32

[1] Where: FM = fresh mass of fruits (g); LF = length of fruit (cm); DF = diameter of fruit (mm); PT = pulp thickness (mm); 1 = upper third of fruits; 2 = middle third of fruits; 3 = lower third of fruits; cv = coefficient of variation; ns = not significant; ** and * significant at 0.01 and 0.05 probability levels, respectively.

About the fresh mass of fruits, the highest means (275; 264 and 271 g plant^{-1}) were observed for the values of nutrient solution electrical conductivity of 1.0; 2.9 and 2.9 dS m^{-1} (value calculated by regression model curve), and for the 2:1, 1:1 and 1:2 ratios, respectively (Figure 3a). From the treatment split, it can be observed that for electrical conductivity of 3.0 dS m^{-1}, the highest production means (289 and 267 g plant^{-1}) were obtained for the N:K ratios of the nutrient solution of 1:1 and 1:2, respectively. On the other hand, the split of the other electrical conductivity values with the N; K ratios in the nutrient solution did not provide significant differences for the fresh mass means of the fruits (Figure 3b).

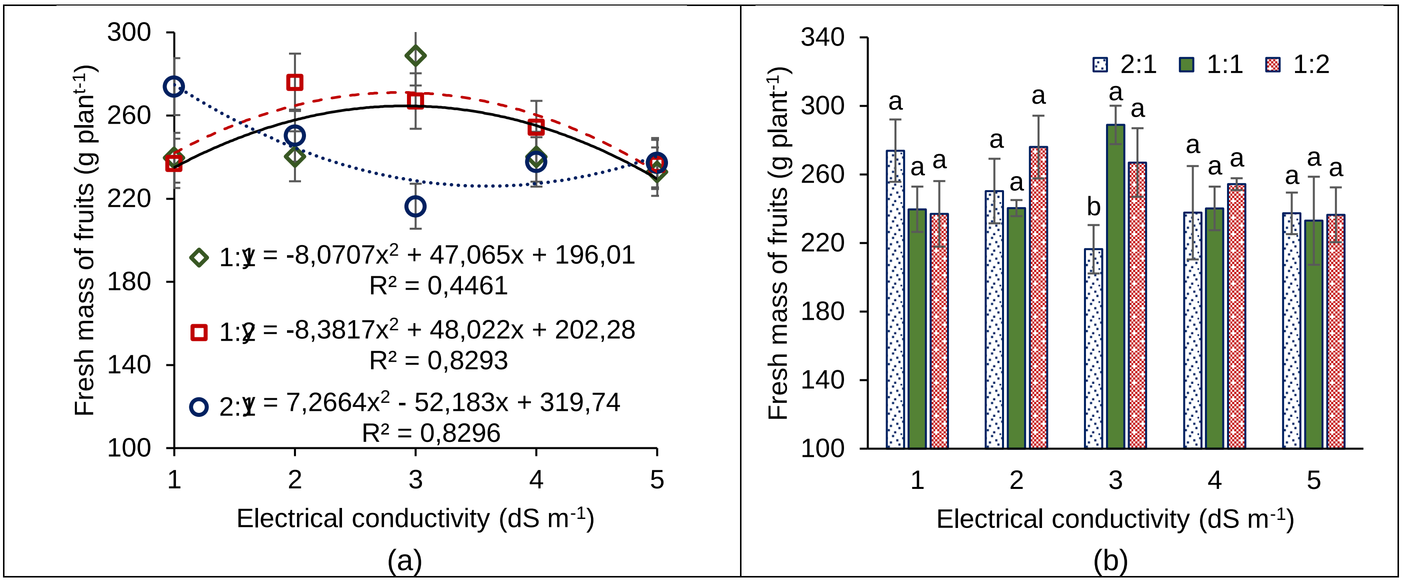

Figure 3. Fresh mass of zucchini fruits as a function of electrical conductivity (a) and N:K ratio (b) both in the nutrient solution. Where: N = nitrogen, K = potassium. Equal letters by electrical conductivity (b) do show not significant difference according to the Tukey Test at 0.05 probability level.

When considering the N:K ratio of the 2:1 in the nutrient solution, the highest zucchini fruits fresh mass production was observed in the electrical conductivity of 1.0 dS m^{-1}. Therefore, it could suggest this N:K for the nutrient solution, since the lowest electrical conductivity level in the experimental range of this treatment showed greater efficiency and economy in the use of mineral nutrients . Considering the other ratios (1:1 and 1:2), the highest production was observed at the level of 2.9 dS m^{-1} (value calculated by regression model curve), a value close to that recommended by Strassburger [20], who observed greater mass accumulation with the electrical conductivity of the 3.0 dS m^{-1} for the nutrient solution. These others indicated that zucchini has a high nutritional demand because it is a fast-growing crop and has a moderate tolerance to salinity.

The zucchini fruit length was used as a criterion for the harvest and, therefore, there was no significant difference for the factors studied; the fruits were harvested when they reached 18 to 20 cm, with the fruits global mean length being 19.11 cm, thus presenting a low coefficient of variation (3.88%) (Table 3).

For the variable zucchini fruit diameter, there was a significant difference isolated only for the electrical conductivity factor of the nutrient solution, when the diameter was measured in the lower third of the fruit. In the electrical conductivity of 2.7 dS m^{-1} (value calculated by the regression model curve), the largest diameter was estimated, with a value of 63 mm (Figures 4a and 5a). The pulp thicknesses showed isolated significance for the nutrient solution N:K ratio in the upper third of the fruit, with the 1:2 ratio being responsible for the largest thickness, equal to 15 mm (Figures 4b and 5b).

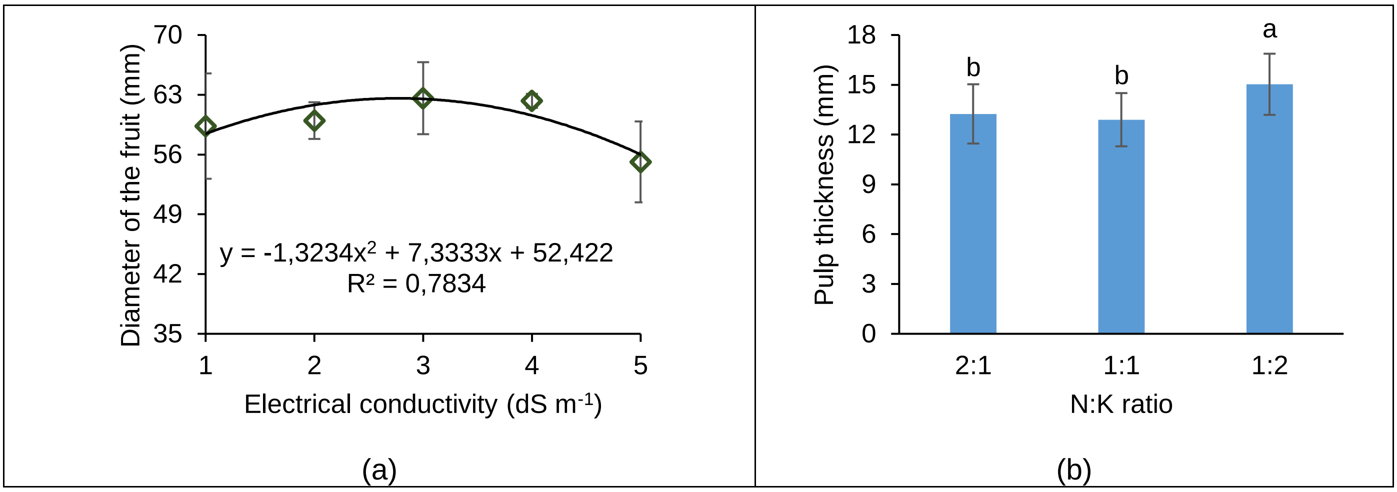

Figure 4. Diameter of the fruit in the lower third of zucchini fruits as a function of the electrical conductivity of the nutrient solution (a); and the pulp thickness in the upper third of zucchini fruits as a function of the N:K ratio in the nutrient solution (b). Where: N = nitrogen, K = potassium. Equal letters per N:K ratio do show no significant difference according to the Tukey Test at 0.05 probability level.

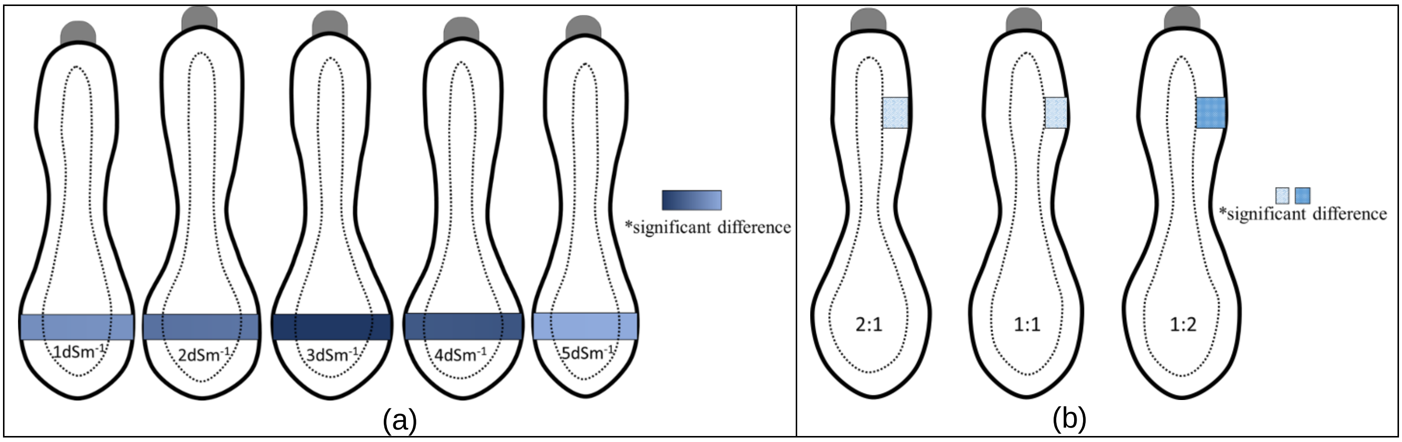

Figure 5. Representation of the dimensions of zucchini fruits as a function of the electrical conductivity of the nutrient solution, with emphasis on the fruit diameter in the lower third (a); and as a function of the N:K ratios in the nutrient solution, with emphasis on the pulp thickness of the upper third (b).

The highest fruits fresh mass (N:K 1:1 and 1:2 ratios) and the largest fruits lower diameter was observed in the fertigation using the 3 dS m^{-1} nutrient solution (Figures 3a, 4a and 5a), which demonstrates the interrelation of these variables and demonstrates also the achievement of the greatest fruits in these treatments. Therefore, the zucchini showed moderate tolerance to salinity, corroborating by previous research [8, 20-21].

The greater pulp thickness of zucchini fruit in the 1:2 ratio (Figures 4b and 5b), may be related to the plantsource-drain ratio. The reason could be the potassium participation in various crops physiological processes, such as photosynthesis, metabolism, and translocation of carbohydrates, promoting greater yield and better fruit quality [22].

Additionally, the substrate used has a high concentration of sodium (444 mg kg^{-1}), while potassium is in a lower concentration (1.6 mg kg^{-1}) (Table 2). In this way, the N:K 1:2 ratio provides a better fruit development through more favorable K:Na homeostasis. Sodium can cause toxic effects to plants, attenuated when adequate concentrations of potassium are available, which perform functions of saline resistance and ionic homeostasis [23].

Organoleptic characteristics, vitamin C of fruits and total dry mass

The organoleptic characteristics and vitamin C of the zucchini fruits showed isolated significance for the electrical conductivity values of the nutrient solution. The water and dry mass percentage of the fruits showed significant differences isolated for both study factors; the plant total dry mass showed an interaction between electrical conductivity and the N:K ratio (Table 4).

Table 4. Variance analysis summary, global mean and variation coefficient of fruit quality characteristics and total dry mass of zucchini.

Analysis of Variance	SS	TA	SS/TA	VitC	PWF	PDMF	TDM
EC	**	**	ns	**	*	*	ns
N:K	ns	ns	ns	ns	*	*	ns
EC*N:K	ns	ns	ns	ns	ns	ns	*
Global mean	4.42	0.143	31.89	21.79	94.73	5.26	68.20
cv (%)	9.66	19.58	15.08	20.13	1.22	21.97	9.37

[1] Where: SS = soluble solids (ºBrix); TA = titratable acidity (g 100 g^{-1}); VitC = Vitamin C (mg 100 g^{-1}); PWF = percentage of water in fruits (%); PDMF = percentage of dry mass in fruits (%); TDM = total dry mass of zucchini (g); cv = coefficient of variation; ns = not significant; ** and * significant at 0.01 and 0.05 probability levels, respectively.

For the total soluble solids, titratable acidity, and vitamin C in zucchini fruits, there were adjustments to linear model regression in relation to the electrical conductivity of the nutrient solution, presenting the highest values (4.8 ºBrix; 0.167 g 100 g^{-1} and 25.4 mg 100 g^{-1}) in nutrient solution of 5.0 dS m^{-1}, representing increments of 16; 29 and 29% (values calculated by the curves), respectively, when compared to 1.0 dS m^{-1} conductivity (Figure 6).

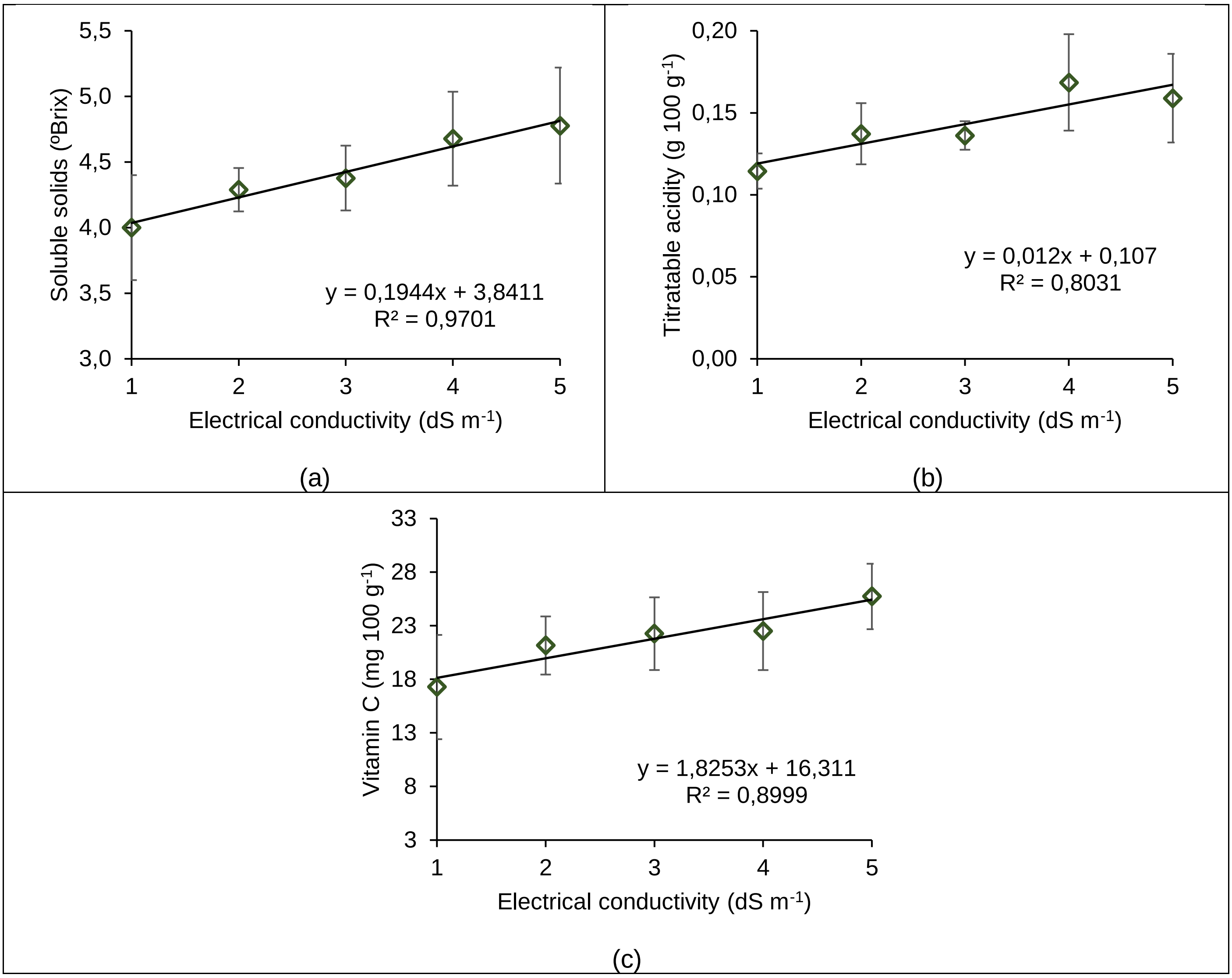

Figure 6. Soluble solids (a), titratable acidity (b) and vitamin C (c) in zucchini fruits as a function of the electrical conductivity of the nutrient solution.

The increase in the electrical conductivity of the nutrient solution from 1.0 to 5.0 dS m^{-1} led to an increase in the organoleptic quality properties and vitamin C concentration of zucchini fruits (Figure 6). Possibly, the higher nutrients availability resulted in a greater accumulation of photoassimilates in the fruits, which are related to the primary organic compounds of sugar and vitamin C synthesis [24].

Similar results are reported in previous studies, such as Liopa-Tsakalidi [8], who used two values nutrient solution electrical conductivity (2.2 and 4.4 dS m^{-1}) in the hydroponic production of zucchini Abbodanza, observed an increase in soluble solids, from 5.19 to 5.48º Brix, respectively. The authors also emphasize the importance of this variable in the preference of zucchinis for human consumption; consumers generally appreciate fruits with higher values of soluble solids.

The percentage of water in fruits and the percentage of dry mass in fruits showed isolated significance for the electrical conductivity and the N:K ratio of the nutrient solution. These two dependent variables are complementary, so that when they add up, they result in the total percentage of the fruit (100%), presenting similar responses. Regarding the electrical conductivity, while the water content is reduced with the increase in the electrical conductivity of the nutrient solution, the dry mass content is increasing (Figures 7a and 7b). For the N:K ratio, the 1:2 ratio has the highest water content and the lowest dry mass content, not differing from the 1:1 ratio (Figures 7c and 7d).

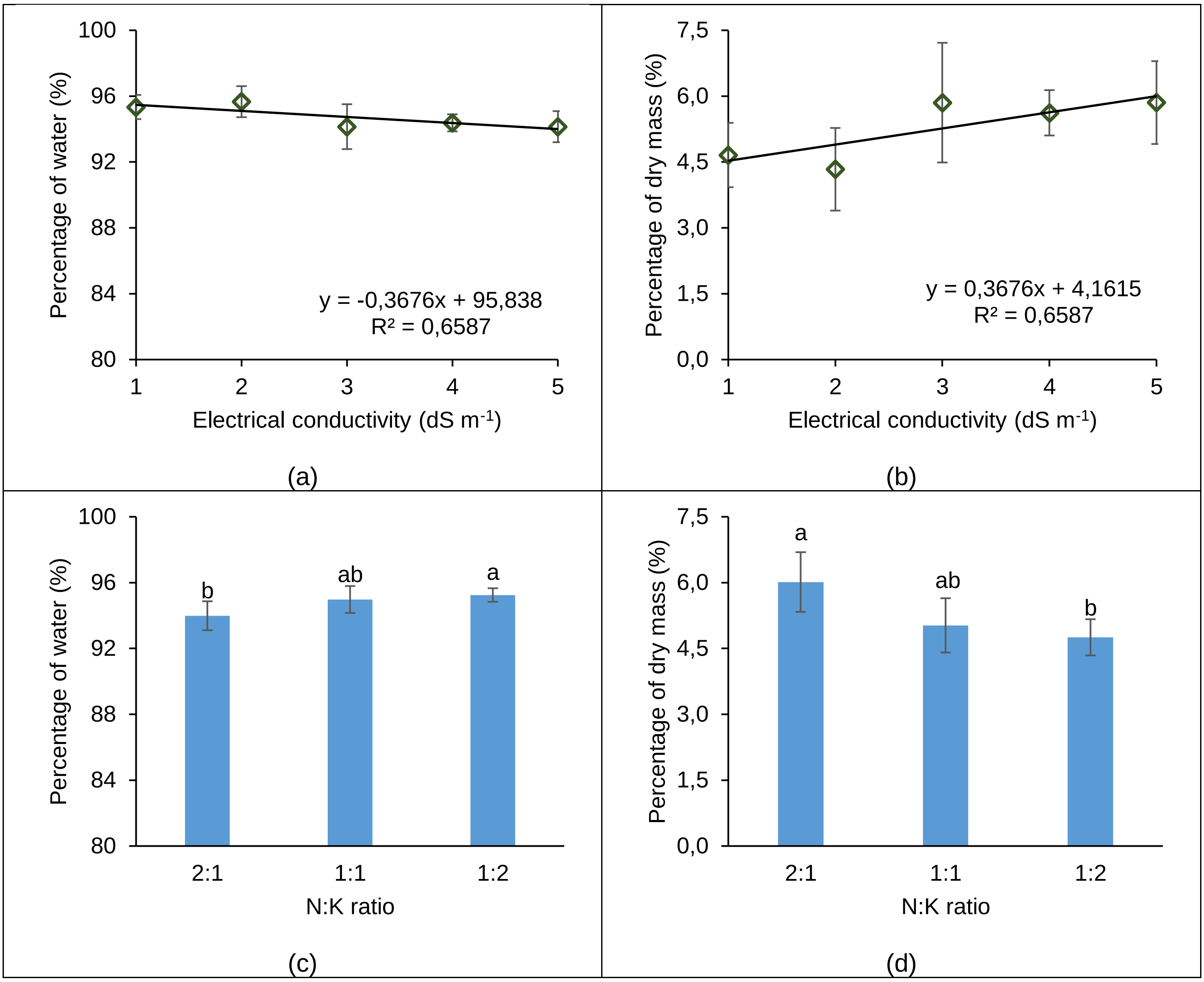

Figure 7. Percentage of water in fruits (a and c) and percentage of dry mass in fruits (b and d) of the zucchini as a function of electrical conductivity of the nutrient solution and the N:K ratio in the nutrient solution. Where: N = nitrogen; K = potassium. Equal letters per variable do not show a significant difference according to the Tukey Test at 0.05 probability level.

The increase in the percentage of dry mass with the increase in electrical conductivity is probably related to the increase in osmotic potential, which causes a reduction in the water flow to the fruits [25]. The higher water content in zucchini fruits, obtained with fertigation performed with a higher proportion of potassium in relation to other nutrients (1:2) (Figure 8b), it could be due to this nutrient is responsible for osmotic control in tissues vegetables, including fruits [9].

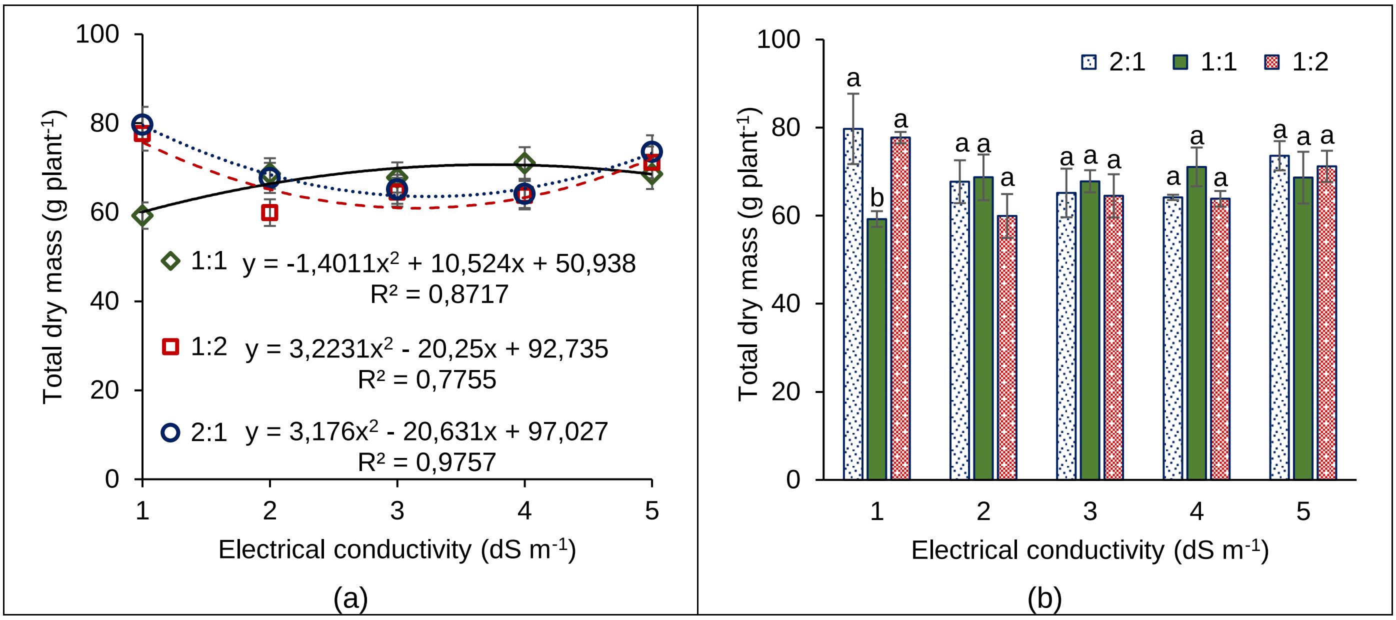

Figure 8. Total dry mass of zucchini as a function of electrical conductivity (a) and the N:K ratio (b) both in the nutrient solution. Where: N = nitrogen; K = potassium. Equal letters by splitting the electrical conductivity (b) do not show significant difference according to the Tukey Test at 0.05 probability level.

On the other hand, the total zucchini plants dry mass (fruits + leaves + stem + roots) fertigated with the N:K ratios of 2:1, 1:1 and 1:2 of the nutrient solution, presented the highest production (79.6; 70.7 and 75.7 g plant^{-1}) for the nutrient solution conductivity values of 1.0; 3.7 and 5.0 dS m^{-1} (values calculated by the curves), respectively (Figure 8a). In the split, fixing the electrical conductivity at 1.0 dS m^{-1}, higher production means (79.7 and 77.7 g plant^{-1}) were observed in the N:K ratios of the 2:1 nutrient solution and 1:2, respectively; for other values of electrical conductivities, no significant differences were observed between the other N:K ratios of the nutrient solution (Figure 8b).

Rouphael and coauthors [26] evaluated two electrical conductivity levels (2.0 and 4.1 dS m^{-1}) of the nutrient solution in zucchini production and observed a productive characteristic (roots + stem + leaves + fruits) reduction with the increase of the electrical conductivity solution. The authors found that plants submitted to higher salinity reduced evapotranspiration and a high direct correlation were found between evapotranspiration and biomass accumulation.

The evapotranspiration reduction is a consequence of the plant salinity tolerance mechanism, which resist higher salt concentrations with their exclusion and/or compartmentalization [27], increasing the osmotic potential in plant tissues, which on the other hand, decreases the flow of water in the substrate-plant-atmosphere system.

In general, concerning nutrient sources, the increase in the electrical conductivity of the nutrient solution, implies in a reduction of the nitrogen absorption and assimilation by plant, due to the competition between NO_3^- and Cl^- ions [28]. However, in zucchini plants under 2:1 treatment, no fertilizer with chloride was used, and fertilizer was added that provided NH_4^+ ions, and were more sensitive to the increase in salinity when observing the fresh mass of the fruits and the total dry mass than the other N:K ratios. In addition, for these variables in the 1:2 ratio, where chloride fertilizer was used, there were no differences with the 1:1 ratio, which had no chloride (Figures 3 and 8).

This lower tolerance to salinity, observed in zucchini plants in the N:K ratio of 2:1, could occurred due to the greater growth provided by the higher proportion of nitrogen in relation to the other nutrients, and especially to potassium witchacts in the regulation of growth [12] and osmotic regulation.

Main responses observed in fruit quality and total dry mass of zucchini

In summary, the increase in the values of the electrical conductivity in the nutrient solution, over the soilless zucchini production system, provided an increase in the organoleptic properties values. However, as for the structural characteristics of the fruits, such as fresh mass fruit and fruit diameter, larger fruits were observed in the nutrient solution fertigation with an electrical conductivity around 3 dS m^{-1} (Figure 9a).

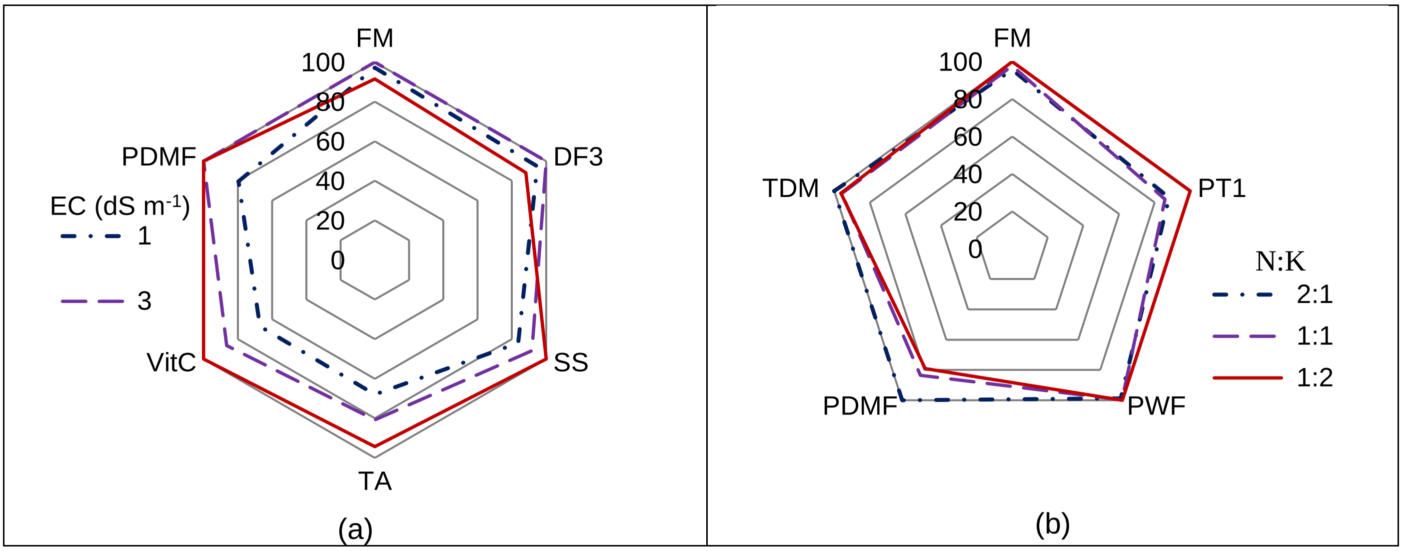

Figure 9. Representations with a summary of the significant variables of the zucchini presented in terms of relative performance (in comparison with the maximum value found) as a function of the values of electrical conductivity (a) and the N:K ratios in the nutrient solution (b). Where: FM = fresh mass of fruits (g); DF3 = diameter of fruit (mm) lower third of fruits; PT1 = pulp thickness (mm) upper third of fruits; SS = soluble solids (ºBrix); TA = titratable acidity (g 100 g^{-1}); VitC = Vitamin C (mg 100 g^{-1}); PWF = percentage of water in fruits (%); PDMF = percentage of dry mass in fruits (%); TDM = total dry mass of zucchini (g).

Regarding the N:K ratios, the use of 1:2 ratio in the nutrient solution, implied in larger fruits and higher percentage of water; while the 2:1 ratio provided a greater accumulation of a plants total dry mass and a higher percentage of the fruits dry mass (Figure 9b). According to Kalaivanan and coauthors [29], soilless cultivation has better managed nutrient availability for plants, which improves the efficiency of nutrient use when compared to soil.

CONCLUSION

The fruit quality characteristics and the total dry mass of zucchini grown in pots with the substrate in a protected environment showed different responses for the fertigation performed with N:K ratios and electrical conductivity levels in the nutrient solution.

The total soluble solids, the titratable acidity, and the vitamin C in the zucchini fruits had a value increase for the nutrient solution electrical conductivity up to 5.0 dSm^{-1}.

The fresh mass fruits of zucchini showed a significant interaction between electrical conductivity and the N:K ratio of the nutrient solution, with higher values in the 2:1 ratio and for the 1.0 dS m^{-1} level; for the other ratios (1:1 and 1:2), the highest production was observed at the level of 2.9 dS m^{-1}.

The highest total dry mass production of zucchini plants was obtained with fertigation of 2:1 - 1.0; 1:1 - 3.7; and 1:2 - 5.0 dS m^{-1} (N:K ratio - electrical conductivity).

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