

Nutrient solution for production and quality of strawberry grown in substrate

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ABSTRACT

Aims: This study determined a nutritive solution and evaluated the performance in the development, production and quality of strawberry cultivated in substrate.

Study design: The treatments were commercial and recommended nutritional solutions for strawberry using the methods of Castelane and Araújo (C.A.), Furlani and Fernandes Junior (F.F.J.) and the proposed solution, with seven replicates.

Place and Duration of Study: The experiment was carried out in the experimental area of the Federal Technological University of Paraná, Brazil, in the period between May and December 2014.

Methodology: Agronomic variables such as yield, number of fruits, nutrient content, physiological indicators, physical and chemical characteristics of fruits were analyzed.

Results: The proposed nutrient solution resulted in larger masses of fresh and dry matter (225.4 g plant⁻¹ and 27.5 g plant⁻¹), number of fruits (40.1) and fresh fruit mass (g plant⁻¹), in relation to the other evaluated solutions. The proposed solution resulted better physical and chemical characteristics such as soluble solids, reducing and total sugars, anthocyanins, flavonoids, phenolic compounds and ascorbic acid and the strawberry fruits presented an attractive coloration and met the quality standards for the consumer. The highest levels of nitrogen (33.7 g kg⁻¹), phosphorus (9.3 g kg⁻¹), and potassium (28.2 g kg⁻¹) in the leaf tissue were found in the proposed solution and contributed to productivity and fruit quality gains of a strawberry.

Conclusion: These results provide a nutrient base and can be adapted to other cultivars in different locations.

Keywords: *Fragaria x ananassa* Duch, nutrients; color, physical and chemical characteristics

1. INTRODUCTION

The strawberry (*Fragaria x ananassa* Duch) is one of the fruits most appreciated by consumers in different regions of the world, highlighting its color, aroma, flavor and versatility in cooking and gastronomy. For this reason, strawberries are in great demand both in the natura and industrial processings [1].

29 Strawberry fruits with better physicochemical characteristics guarantee acceptance by the
30 consumer market and increase yield in processing and industrialization. In this sense, the
31 nutritional solution concentration, together with use of processing techniques have been
32 important factors taken into account to improve the productivity and physicochemical
33 properties of the fruit [2].

34
35 Strawberry cultivation in substrate is a production technique used in several regions of Brazil
36 and around the world, allowing to obtain high production and greater ergonomics in crop
37 management [3]. The main problem faced by producers in this production system is with
38 regard to composition and management of the concentration of nutrient solution.

39
40 In the literature, [4] reported that concentrations of nutrient solution with values of electrical
41 conductivity (EC) between 1.4 and 1.8 dS m⁻¹ and up to 2.0 dS m⁻¹ [5] are proposed to
42 obtain quality and productivity of strawberry fruits, but the great difficulty with most nutrient
43 solutions is to adjust the amount of nutrients for substrate cultivation.

44
45 In this sense, the need arises for studies with nutritive solutions with determination of ionic
46 balance of nutrients and their relationship with yield and quality of strawberry fruits in
47 substrate cultivation. In this study we determined a nutrient solution for strawberry and
48 evaluated the agronomic characteristics and fruit quality. The results provide nutrient content
49 information extracted by the plants with the proposed solution, production data and
50 physiological indicators of fruit quality, which contribute to meet the demands of the
51 consumer market and make the production system more sustainable.

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54 2. MATERIAL AND METHODS

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57 2.1 Plant Material and Growing Conditions.

58 The experiment was carried out in the experimental area of the Federal Technological
59 University of Paraná, Brazil (25°42'52 "S, 53°03'94" W, 530 m altitude), in the period
60 between May and December 2014, covered with a 150-micron plastic film.

61 The seedlings of the cultivar Camino Real were purchased from a suitable nurseryman of
62 varietal quality, from Maxxi Mudas®, from Patagonia, Argentina. These were transplanted in
63 plastic pots with a capacity of 8 L in dimensions 24 × 23 cm, placed in lines, on the soil of
64 the protected environment, filled with sand of medium granulometry, being transplanted one
65 plant per pot, distributed with a density of eight plants per square meter.

66 The replenishment of nutrients was carried out daily by means of a drip irrigation system,
67 with drippers of the brand netafim®, with a spacing of 0.20 m and a flow of 3.2 L hour⁻¹, with
68 a dripper per vessel, thus maintaining the sand in the field capacity. The total fertigated
69 volume was 535.7 mm and the total irrigation time was 47.5 hours for all treatments.

70 The meteorological data (temperature, relative air humidity and solar radiation) were
71 obtained every 15 minutes using Akso® brand AK 172 dataloggers installed in
72 meteorological shelters, located in the center of the protected environment.

73 The fertilizers used to compose the evaluated nutrient solutions were potassium nitrate
74 (KNO₃), calcium nitrate Ca (NO₃)₂, monoammonium phosphate (NH₄H₂PO₄) magnesium
75 sulfate (MgSO₄). For micronutrients the amount of 25 g per 1000 L of water of the
76 commercial product Conmicros Standard® was used in all the nutrient solutions, which

presented the concentrations of B (2.0%), CuEDTA (2.0%), FeEDTA (7.9%), MnEDTA (2.0%), Mo (0.4%), and ZnEDTA (0.8%).

The nutrient solutions after addition of the nutrients presented the following values of electrical conductivity and pH: 2.0 and 6.0 mS cm⁻¹ for the commercial solution (F.F.J.) [6], 1.7 and 6.2 mS cm⁻¹ for the commercial solution (C.A.) [7], and 1.8 and 5.8 mS cm⁻¹ for the proposed solution.

In relation to the management of nutrient solutions, the fertigations were done daily, and at each application of the fertirrigation, a new solution for each treatment was prepared. Also, twice-a-week irrigations were carried out only with water to avoid salinization of the substrate. Electrical conductivity and pH were measured with conductivity and portable HI 98130 Hanna® brand portable pH meters each time the solution was prepared. pH values between 5 and 6 and electrical conductivity greater than 1.5 mS cm⁻¹ were maintained during the experiment [8].

2.2. Treatments and Experimental Design

The treatments were commercial and recommended nutritional solutions for strawberry using the methods [7] (C.A.), [6] (F.F.J.) and proposed solution, with seven replicates. The amounts of nutrients used for each solution are shown in Table 1. The calculation of the proposed solution was based on ionic nutrient balance [9].

Table 1. Quantities of nutrients used in the preparation of nutrient solutions for strawberry cultivation on substrate.

Nutrients (mg.L ⁻¹)	Commercial solution C. A.	Commercial solution F. F. J.	Proposed solution
N-NO ₃ ⁻	124.6	116.2	166.9
N-NH ₄ ⁺	5.6	5.6	31.92
P - H ₂ PO ₄ ⁻	46.5	49.6	78.12
K ⁺	195.0	234.0	182.13
Ca ⁺⁺	124.0	104.0	68.0
Mg ⁺⁺	24.60	36.0	13.7
S-SO ₄ ⁻	43.20	48.0	16.6

2.3. Evaluated Parameters

104 The content of macronutrients and micronutrients in leaf tissue was determined and four
105 leaves per plant were completely expanded in the flowering period [10].

106 During the full flowering period (120 days after transplanting [DAT]) and at 190 DAT,
107 measurements of the relative index of total chlorophyll in the abaxial and adaxial parts of the
108 last two expanded leaves of each plant were performed at 11:00 AM using the
109 chlorophyllometer model Clorofilog Falker® brand. The fresh matter mass of fruits and
110 number of fruits per plant was determined by adding all the harvests during the evaluated
111 period (fifteen harvests).

112 The average mass of fruits was obtained by dividing the fresh matter mass of fruits by the
113 number of fruits per plant. The fruits were harvested when they presented more than 75% of
114 the epidermis with pink coloration [11].

115 The fruit colour was determined in 10 fruits randomly selected from each nutrient solution,
116 using a digital colorimeter (Minolta model, Cr 200 b), where the values of luminosity ("L")
117 were determined, ranging from light to dark. The value 100 corresponds to white colour and
118 value 0 (zero), the black colour, and component "c" which expresses chroma degree of the
119 fruits, where, by the proposed classification, more colourful fruits present smaller values and
120 less colourful fruits present higher values [12].

121 The soluble solids content (SS) was obtained by direct reading in Hanna® bench
122 refractometer model HI 96801, using homogenized pulp and filtered at room temperature,
123 obtaining the values in degrees (Brix). The determination of the acidity (T.A.) was by titration
124 with 0.1N NaOH until it reaches pH 8.1. The ratio (SS/TA) was determined by dividing the
125 soluble solids content by the titratable acidity.

126 Total sugar concentrations were determined by the method described by [13] those of
127 reducing sugars were obtained by the method [14].

128 The quantification of total phenolic compounds (mg gallic acid 100g pulp⁻¹) was carried out
129 according to spectrophotometric method of Follin-Ciocauteau, proposed by [15]. The
130 ascorbic acid content (Vitamin C) was determined by standard titration method of AOAC
131 modified by [16]. Vitamin C content was calculated based on titration values of standard
132 solution of ascorbic acid and the results expressed in mg of 10 g of ascorbic acid 100 g pulp⁻¹.
133

134 In the quantification of anthocyanins and flavonoids, the procedure described by [17] was
135 used. All the physicochemical analyses were determined in a single crop, at 150 DAT, which
136 corresponded to the peak of production. A composite sample of 100 fruits per treatment was
137 used for all the analyses, taking seven subsamples of approximately 50 g each.

138 At 190 DAT, which corresponded to end of the experiment, the mass of fresh matter in a
139 precision scale (0.001 g) of all the plants of experiment was determined. After the plants
140 were placed to dry in a forced circulation air oven at 65°C until reaching constant mass to
141 determine the mass of dry matter.
142

143 2.4. Statistical Analysis

144
145 The data of experiment were submitted for analysis of variance (Test F), when the F test was
146 significant the means were compared by Tukey's test ($P=0.05$), using "SAS Studio" [18].
147
148

3. RESULTS AND DISCUSSION

During the conduction of experiment, the average temperature, relative humidity and average daily radiation was 19.2°C, 75% and 949.7kJ m⁻². The temperature conditions during the experiment were found to be within the ranges suitable for the crop. Temperatures that range between 18°C and 24°C are considered adequate for development of the crop [19].

The electrical conductivity (EC) in the solutions tested ranged from 1.5 to 2.1 dS m⁻¹, with an average of 1.8 dS m⁻¹. The mean conductivity is at the upper limit of recommended range of 1.4 to 1.8 dS m⁻¹ [6]. The pH variations of the solutions were between 5.0 and 7.0, with an average of 6.2. pH ranges between 5.5 and 6.5 are most indicated for the culture [6].

It was observed that the EC in the evaluated solutions improved fruit quality by increasing the solids content and sugars. It was found that evaluated solutions were within the recommended pH range for strawberry.

Nutrient solutions significantly influenced nutrient content in leaf tissue. The highest levels of nitrogen (33.7 g kg⁻¹), phosphorus (9.3 g kg⁻¹) and potassium (28.2 g kg⁻¹) in the leaf tissue were found in the proposed solution (Table 2). The other macronutrients did not differ significantly. For micronutrients, there were significant differences for the boron content in F.F.J. solution and higher iron and manganese contents in the proposed solution.

Table 2. Nutrient content in leaf tissue of fertigated strawberry with different nutrient solutions.

Nutrients	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
Sol. C.A.	31.1 b*	7.8 b	21.8 b	11.1 ^{ns}	6.9 ^{ns}	1.1 ^{ns}	100.5 b	5.3 ^{ns}	82.6 b	194.0 b	30.0 ^{ns}
Sol. F.F.J.	30.4 b	8.0 b	23.4 b	10.9	6.8	1.2	103.0 a	5.7	81.7 b	216.5 b	29.5
P. solution	33.7 a	9.3 a	28.2 a	10.5	7.0	1.2	98.4 b	5.5	86.5 a	222.0 a	31.6
Mean	31.7	8.4	24.5	10.8	6.9	1.2	100.6	5.5	83.6	210.8	30.4
C.V. (%)	3.9	9.2	3.3	3.1	5.6	4.3	1.2	2.3	3.5	2.6	2.2

*Means followed by the same letter in the column do not differ significantly by Tukey test, at

P=0.05.; ns: not significant; C.V.: Coefficient of variance

The macronutrients, in descending order, nitrogen (N), potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), and sulphur (S) were the nutrients extracted in greater quantity by the strawberry. The following ranges are recommended: N, 15-25g kg⁻¹; P, 2-4 g kg⁻¹; K, 20-40 g kg⁻¹; Ca, 10-25 g kg⁻¹; Mg, 6-10 g kg⁻¹; and S, 1-5 g kg⁻¹. For boron (B), iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) are 35-100, 50-300, 30-300, 5-20, and 20-50 mg kg⁻¹, respectively [20]. The contents found in the foliar tissue for the studied solutions are superior to those suitable for N and P, within the recommended range for K, Ca, Mg, B,

184 Fe, Mn, Zn, and Cu. No visual symptoms of nutritional deficiency were observed in the
185 strawberry plants during the experiment.

186
187 The proposed solution resulted in highest relative indices of total chlorophyll in the flowering
188 phase and at end of the crop cycle (Table 3). There was also a decrease in the relative
189 index of total chlorophyll in final phase of the cycle in all evaluated solutions.

190
191 The mass of the fresh and dry matter presented significant differences, being largest
192 accumulation of fresh ($225.4 \text{ g plant}^{-1}$) and dry ($27.5 \text{ g plant}^{-1}$) mass obtained in the
193 proposed solution (Table 3). The fresh mass of the proposed solution was 6.74% higher
194 than the Castelane and Araújo commercial solution.

195
196
197 **Table 3. Relative index (I.R.) of total chlorophyll phases full flowering and the end,**
198 **masses of fresh and dry matter of shoot (M.F. and M.S.) of fertigated strawberry**
199 **plants with different nutrient solutions.**

Solutions	Full Flowering	End of cycle	M.F.	M.S.
	I. R. of total	I. R. of total	(g planta ⁻¹)	(g planta ⁻¹)
	chlorophyll	chlorophyll		
Sol. C. A.	54.4 b*	50.2 b	210.2 b	21.0 b
Sol. F. F.J.	57.1 b	52.9 b	208.7 b	20.7 b
P. solution	62.2 a	59.4 a	225.4 a	27.5 a
Mean	57.9	54.17	215.0	23.1
C.V. (%)	9.3	8.4	20.4	22.0

200 *Means followed by the same letter in the column do not differ significantly by Tukey test, at
201 $P=0.05$; C.V.: Coefficient of variance

202
203 The highest relative chlorophyll index in the proposed solution is justified by higher nitrogen
204 content present in the leaf tissue. The content of chlorophyll in the leaf is used to predict
205 nutritional level of nitrogen (N) in plants, due to the fact that the amount of this pigment
206 correlates positively with the N content in the plant [21]. This relationship is attributed mainly
207 to the fact that 50% to 70% of total N of the leaves is integral with enzymes, which are
208 associated with chloroplasts [22].

209 The decrease of relative index of chlorophyll in the final phase of crop cycle can be
210 explained by the advancing age of the leaf, because in this phase, there is a decline of
211 photosynthetic capacity. The photosynthetic efficiency is linked to the amount of chlorophyll
212 and consequently, to the growth phase of the plant [23].

213
214
215 The results of mass of the fresh and dry matter obtained with the proposed solution may be
216 related to higher nutrient intake, especially the nitrogen present in the foliar tissue of the
217 proposed solution (Table 2). Plant development, productivity and strawberry fruit quality are
218 strongly influenced by nitrogen fertilization [24].

Moreover, the increase of K in the plant causes an increase in the production of photoassimilates and consequently, a greater mobilization of leaf N in the synthesis of macromolecules, which in turn are used in vegetative growth and fruit production [25].

The number of fruits per plant, average fruit mass, and fresh fruit mass were influenced by evaluated treatments, obtaining best results in the proposed solution (Table 4). There were gains of 6.1% and 7.94% in the fresh fruit mass in relation to commercial solutions F.F.J. and C.A, which can be attributed to ionic balance of the proposed solution, which met the nutritional demand of strawberry with nutrient amounts without excesses or deficiencies, contributing to fruit quality and sustainable management of fertilizers in agriculture.

For the luminosity (L) of the epidermis, the nutrient solutions evaluated did not present significant influence (Table 4). The values of luminosity of the evaluated solutions were below the value 29.24 and according to [12] indicate dark color. The dark color of strawberry fruits in the evaluated solutions is a desirable characteristic for both industry and consumers, because dark red fruits are more attractive in the eyes of consumers.

For the **colourful** component or chroma value of the epidermis, the proposed solution presented darker and more **colourful** fruits. The “C” component expresses the colourful of fruits, where values less than 24.92 have more coloration of the epidermis, values between 24.92 and 36.08 have intermediate **colouration**, and values above 36.08 have less **colouration** fruits [12]. It is of great importance that external aspect of the fruit in commercialization is mainly in natura, the proposed solution resulted in fruits being more attractive for commercialization.

Table 4. Number of fruits plant⁻¹ (N.F.P.), mean fruit mass (M.F.M), fresh fruit mass (F.F.M.), luminosity of the epidermis, **colouration of the epidermis (Chroma) of fertigated strawberry with nutritive solutions.**

Solution	N.F.P.	M.F.M.	F.F.M.	Luminosity	Chroma
		(g)	(g plant⁻¹)		
Sol. C.A.	30.3 b*	12.5 b	690.8 b	28.7 ^{ns}	35.1 a
Sol. F.F.J.	32.5 b	13.3 b	704.6 b	27.8	34.93 a
P. solution	40.1 a	15.7 a	750.4 a	26.0	32.10 b
Mean	34.3	13.83	715.3	27.8	34.0
C.V. (%)	22.4	13.7	27.8	3.81	3.87

*Means followed by the same letter in the column do not differ significantly by Tukey test, at

$P=0.05$.

^{ns} not significant, by the Tukey test, at $P=0.05$;

C.V.: Coefficient of variance

The superiority in the number of fruits and fresh fruit mass in proposed solution can be attributed to ionic balance of the solution, which favored the absorption of some ions, such as potassium (28.2 g kg^{-1}) (Table 2), which improved productivity and fruit quality [26]. The increase in mean mass of fruits, influenced by potassium present in the proposed solution, can be attributed to the important role that this nutrient plays in the translocation of photoassimilates from leaves to the fruits and the role it exerts in cell extension [25].

The number of fruits found in the proposed solution was 33.9% higher than that observed by [27], where 26.5 fruits per plant with the cultivar Camino Real in cultivation were carried out in the soil. The fresh fruit mass transformed into yield results in 60 t ha^{-1} , which is higher than the yield obtained from 9.07 and 10.55 t ha^{-1} , with the same cultivar in conventional and organic systems, respectively [28].

The proposed solution resulted in more colored fruits, with a higher content of soluble solids and of total and reducing sugars, possibly due to the higher content of potassium. Potassium is one of the nutrients most used by strawberry, considered the “element of quality” in plant nutrition, to improve physical-chemical characteristics and to increase production [10].

The titratable acidity and ratio (SS/TA) were not influenced by the evaluated nutrient solutions, the average value being $0.90 \text{ g.100 g pulp}^{-1}$ and 9.33, respectively (Table 5). It was verified that the proposed nutrient solution resulted in a higher content of soluble solids and concentration of total and reducing sugars, anthocyanins, flavonoids, phenolic compounds and ascorbic acid (Table 5).

Table 5. Soluble solids ($^{\circ}\text{Brix}$), total sugars (mg.g^{-1} fresh fruit mass), reducing sugars (mg.g^{-1} fresh fruit mass), flavonoids (mg.100 g^{-1} fresh fruit mass), anthocyanins (mg.100 g^{-1} fresh fruit mass), phenolic compounds (mg of galic acid 100 g^{-1} fresh fruit mass) and ascorbic acid (mg.100 g^{-1} pulp) of fertigated strawberry fruits with different nutrient solutions.

Solution	S. solids	T. sug.	R. sug.	Flavonoids	Anthoc.	P. comp.	Asc. acid.
Sol. C. A.	8.0 b*	8.7 b	1.1 b	3.3 b	34.0 b	75.1 b	45.1 b
Sol. F. F. J.	8.2 b	9.0 b	1.3 b	3.1 b	35.0 b	76.4 b	47.0 b
P. solution	8.9 a	10.1 a	1.9 a	4.0 a	40.4 a	80.6 a	52.5 a
Mean	8.4	9.3	1.4	3.5	36.1	77.4	48.2
C.V. (%)	8.1	7.7	19.3	17.9	20.2	10.3	12.7

*Means followed by the same letter in the column do not differ significantly by Tukey test, at $P=0.05$.

C.V.: Coefficient of variance

281 The soluble solids content in the proposed solution was 25.3% higher than the results
282 obtained by [26] of 6.65 °Brix. The minimum values of soluble solids should be higher than
283 7.0 °Brix, guaranteeing acceptable taste [11], all nutritional solutions presented values above
284 7.0 °Brix, considered acceptable for consumers.

285 In the relationship between sugar content and acidity (SS/TA) there was no statistically
286 significant difference between the evaluated solutions, with a mean value of 9.33. This value
287 meets the minimum relationship patterns for strawberry fruits of 8.75 [11]. The strawberry
288 fruits of the cultivar Camino Real presented an adequate SS/TA ratio, with degree of
289 maturation and fruit quality. The SS/TA ratio is an important parameter to determine fruit
290 maturation, and fruit taste evaluation, as well as an indicator of fruit palatability, being
291 directly linked to the preference and acceptance of the fruits by the consumer [29].

292 Commercially, the colouration of the fruits can be influenced by the anthocyanins, which
293 contributes greatly to quality evaluation, since the consumers correlate between the
294 colouration and total quality of specific products [30]. The anthocyanin content in the
295 proposed solution was higher than that reported in the literature (20.93 mg 100 g⁻¹ fresh fruit
296 mass) by [31] with the same cultivar, on different commercial substrates. According to [32]
297 the anthocyanin levels may present variations related to climatic factors, seasonality, degree
298 of maturation, nutrition and type of cultivar.

299 The results of present study indicate that fruits of the proposed solution presented an
300 attractive coloration and fruits with higher concentrations of anthocyanins, allowing greater
301 benefits to the consumer due to the antioxidant effect.

302 As the anthocyanins content may be a criterion of choice at the time of feeding, due to the
303 health benefits [31], the consumer will be eating higher anthocyanin content when
304 consuming strawberries of the Camino real proposed solution. For humans, the intake of
305 foods rich in anthocyanins, such as red fruits, is related to health benefits, as these
306 components have high antioxidant and antitumor activity, as well as acting as an anti-
307 inflammatory and preventing the formation of edemas [33].

308 The phenolic compounds and ascorbic acid contents presented significant differences for
309 the evaluated solutions. The proposed solution resulted in an increase in phenolic
310 compounds and ascorbic acid. In the literature it is reported that potassium fertilization
311 exerts a beneficial effect on vitamin C levels [34].

312 Furthermore, the phenolic contents found in this study are lower than those verified by [35]
313 with the same cultivar (174.3 mg 100 g⁻¹ pulp). Phenolic compounds are significantly
314 influenced by the genetic factors of the cultivar [36]. In addition, the "open" culture system
315 provides a higher content of phenolic compounds than the protected environment system
316 [37].

317 Another factor that possibly influenced the content of phenolic compounds was the
318 temperature. It is known that the synthesis of phenolic substances is favored by the milder
319 temperatures, especially the nocturnal ones and also the temperature variation from day to
320 night, affects pigment deposition [38]. The average temperature of 19.2 °C favored the
321 deposition of phenolic compounds, anthocyanins and flavonoids in fruits.

322 Potassium exerts influence on phenolic content, as it is related to photosynthesis and to
323 biosynthesis of starch and proteins. With the increase of K doses in the plant, the production
324 of photosynthates increases, which may increase the targeting of excess carbon fixed to the
325 pathway of shikimic acid, which is the pathway for the formation of phenolic compounds,
326 which may increase the concentration of phenolics in the plant [39].

327 The ascorbic acid (Vitamin C) in strawberry may vary according to the cultivar, stage of
328 ripening and fertilization. It is one of the most important nutritional components in fruits and
329 human food and its content can be used as an index of food quality [11]. In addition to
330 mineral nutrition, the intensity of solar radiation (949.7 kJ m^{-2}) associated with the time of
331 year (summer) contributed to the increase in ascorbic acid content. The intensity and
332 duration of fruit exposure to sunrays during growth influence the amount of ascorbic acid
333 formed is synthesized from sugars supplied by photosynthesis, which increases with the
334 highest incidence of radiation [38].

335
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361 formed is synthesized from sugars supplied by photosynthesis, which increases with the
362 highest incidence of radiation [38].

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364

365 4. CONCLUSION

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367 In this study, the proposed nutrient solution contributed to productivity gains, fruit quality and
368 comes as an option of adequate nutrient content for the strawberry, with ionic balance,
369 without excess nutrients. These results provide a nutrient base and can be adapted to other
370 cultivars in different locations.

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372

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374

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377

378

379 COMPETING INTERESTS

380

381 Authors have declared that no competing interests exist.

382

383 AUTHORS' CONTRIBUTIONS

384

385 This work was carried out in collaboration between all authors. Authors DP and AS designed
386 the study and wrote the first draft of the manuscript. Authors ICZ and DP performed the
387 experiments. Authors ICZ; DP and FK participated in fieldwork and laboratory analysis.
388 Authors ICZ and FK managed the analyses of the study. Author AS managed the literature
389 searches. All authors read and approved the final manuscript.

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