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Characterization of Fruits in Contrasting Environments and Germination of Tamarillo Seeds at Different Temperatures

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Abstract

Tamarillo (*Solanum betaceum* Cav. Syn *Cyphomandra betacea* Cav.) Sendt is a small tree native to the subtropical Andean region of South America from Colombia to Chile, popularly known as arboreal tomato, belonging to the family Solanaceae. The objective of this study was to evaluate the physicochemical characteristics of fruits and the germination of tamarillo (*Solanum betaceum*) seeds produced in the *Caparaó*-ES and MG regions. The following procedures were performed: Fruit and peel biometrics; fruit weight; pulp and peel weight; thousand-seed weight, pulp and peel yield and fruit dry mass. In the physicochemical analysis, the following parameters were determined: pH; soluble solids; titratable acidity and *ratio*. For the analysis of the physiological quality of the seeds, different temperatures (20˚C; 25˚C; 30˚C and 20˚C - 30˚C) were evaluated in the presence and absence of light and the following was determined: Seed moisture content; germination; germination speed index; germination mean time; shoot length; root and total seedling dry mass. Tamarillo in the region of *Caparaó*-ES presents greater chemical characteristics of the fruits, germination and vigor, and in the region of *Caparaó*-MG presents greater physical characteristics of the fruits. Tamarillo can germinate both in the presence and absence of light, although in the presence of light, it presents greater vigor.

Keywords

Solanum betaceum, Temperatures, Brightness and Biometric

1. Introduction

Tamarillo (*Solanum betaceum* Cav. Syn *Cyphomandra betacea* Cav.) Sendt is a small Solanaceous tree, native to the subtropical Andean region of South America from Colombia to Chile [1], known as arboreal tomato [2].

Tamarillo fruits present a consistent, juicy, sweet-acid flavored pulp with natural or processed consumption. The fruits are ovoid berries, with long peduncles and exocarp glabro, and the color may be red, orange or yellow [3]. When mature, the fruits present high nutritional value, with relatively high levels of proteins, some vitamins and minerals. In the present study, it was found that the high levels of carbohydrates and caloric value [4] and components with important antioxidant, therapeutic and preventive properties [5] [6].

Fruit biometry provides information on the conservation and exploitation of resources of economic value. Also, it detects genetic variability within populations of the same species, and the relationships between this variability and environmental factors, as well as breeding programs [7].

Tamarillo is propagated usually by seminiferous, however uneven germination may occur [8]. The process begins with water absorption in the seed and ends with the beginning of the embryonic axis elongation, which can be identified by radicle protrusion of the embryo. Temperature is one of the main factors that influence seed germination by controlling the intensity and speed of this process [9].

The studies of tamarillo in Brazil are scarce. Therefore, the objective of this study was to evaluate the physical and chemical characteristics and the germination of tamarillo (*Solanum betaceum*) seeds from different regions.

2. Material and Methods

The experiment was developed at the Laboratory of Seed Analysis (LAS) at the campus Center of Agricultural Sciences and Engineering of the Federal University of Espírito Santo (CCAE-UFES), in Alegre-ES. Seeds of 60 mature tamarillo fruits (*Solanum betaceum* Cav. Syn *Cyphomandra betacea* Cav.) Sendt were collected from mother plants with an average height of 3.0 m in the region of Caparaó-ES, municipality of Divino de São Lourenço, ES (L1) 20˚35'54.93"S, 41˚44'19.43"W and 700 m altitude, and also collected from mother plants in the municipality of Caparaó-MG (L2) 20˚32'15.24"S, 41˚53'18.90"W and 831 m altitude.

The climate of Divino de São Lourenço-ES is humid subtropical (Köppen-Geiger climatic classification: Cwa) with rainfall around 1700 mm annually [10]. The climate of Caparaó-MG is the humid subtropical (Köppen-Geiger climatic classification: Cwa) with rainfall around 1345 mm per year.

The collection of tamarillo seeds from the two regions Caparaó Espírito Santo (ES) and Minas Gerais (MG) show similar characteristics of climatological data and relief, but are two Brazilian states.

The fruits biometric evaluations were: longitudinal and transverse diameter;

peel thickness was measured using a digital caliper (Zaas precision-6G-150 mm); fruit weight; pulp and peel weight; thousand-seed weight using an analytical balance (0.0001 g), pulp and peel yield and fruit dry mass on an analytical balance (0.0001 g), after drying in a convection oven at 72˚C for 72 hours, in Kraft paper bags and the results were expressed in grams.

For the physico-chemical analyzes, the following determinations are performed: pH by the potentiometric method using a digital pH meter; soluble solids content (SS) by direct reading in digital refractometer and expressed in ˚Brix [11]; titratable acidity (TA), according to the Adolfo Lutz Institute [12] evaluated by neutralization titration with 10 mL of pure juice diluted in 90 mL of distilled water and titrated with 0.1 N NaOH solution until the juice reached pH 8.1 and the *ratio* ratio between the soluble solid and the titratable acidity.

Seeds harvested from ripe fruit were extracted with a sterilized spoon, removing the pulp in a sieve under running water. Then the seeds containing the mucilage were washed and placed on germitest type paper in the shade to dry.

The experiment was conducted in a subdivided plot, with four replicates of 25 seeds, in a 2 × 5 × 2 factorial scheme [two lots × four temperatures (three constants: 20, 25, 30 and one alternate 20˚C - 30˚C) × absence and presence of light for 12 hours)].

The tests to evaluate the physiological quality of the seeds were:

Seed moisture content—was determined in a greenhouse at 105˚C ± 3˚C for 24 hours, according to the Rules for Seed Analysis [13] instructions, using two replicates for each treatment, with approximately 2.0 g of seeds and the results were expressed as percentage on wet basis.

Germination—it was conducted four replicates of 25 seeds for each treatment, seeded in Petri dishes with a germitest paper, moistened with distilled water in the proportion of 2.5 times the mass of the dry paper, which were kept in a germination chamber BOD, with specific temperatures (constant of 20˚C, 25˚C, 30˚C and alternating of 20˚C - 30˚C), under a 12-hour photoperiod. The evaluations were held up to 35 days after sowing, computing the percentage of normal seedlings [13], and the results were expressed as germination percentage.

Germination speed index was determined together with the germination test, and the number of seeds that had primary root protrusion equal to or greater than 2 mm was computed daily according to the methodology described by Maguire [14], being done up to the 35 day after sowing;

Shoot length—was determined 35 days after sowing, using a millimeter ruler, by measuring the length between the stem and the apex of the last leaf of each sample and the result were expressed in plant^{-1} cm;

Root length—was determined 35 days after sowing, using a millimeter ruler, by measuring the length between the stem and the tip of the largest root of each sample and the result were expressed in plant^{-1} cm;

Total seedling fresh and dry mass was determined 35 days after sowing, in an analytical balance (0.0001 g). After the fresh mass was obtained, the seedlings

were packed in Kraft paper bags, kept in a convection oven at 72˚C for 72 hours. Subsequently, the samples were stored in a desiccator with silica gel beads and then weighed, and the results were expressed in seedling^{-1} mg.

The data were submitted to the residue normality test and the analysis of variance, and when the F value was significant at 5% level, the means were compared using the Tukey test. For all analyzes, the R statistical program was used by the ExpDes package [15].

3. Results and Discussion

Table 1 presents the physical characterization data of tamarillo fruits, in which all variables evaluated (transverse diameter, endocarp, fruit weight, pulp and peel weight, thousand-seed weigh, pulp and peel yield and fruit dry mass), except for the longitudinal diameter, fruits from the region of Caparaó-MG (L2) presented higher values than those harvested in the region of Caparaó-ES (L1). The differences observed may be due to climatic and edaphic influences, in which the environment may be favorable to the certain characteristic that would not manifest in different places [16].

The morphometric data showed variations in all the variables analyzed, and the tamarillo fruits from the region of Caparaó-ES (L1) showed higher value only in longitudinal diameter (52.10 mm), in relation to the fruits of Caparaó-MG region (L2), which presented a value of 51.30 mm, while the values obtained in the other morphometric variables were significantly higher in the fruits from Caparaó-MG. These results were similar to those found by Guilherme *et al.* [17] studying the biometry of tamarillo, whose values were 54.8 ± 4.0 mm and 34.6 ± 2.4 mm in length (peduncle apex) and diameter, respectively.

Thousand-seed weight (5.34 g) L2 results indicates seed quality, as well as generating information to calculate the sowing density of a given crop. According to Delouche [18], the fruit and seed sizes can be used as indicators of the physiological maturation of the species, which may result in higher values of dry mass, germination and seed vigor in larger fruits when compared to smaller fruits. However, the fruit and seed size and mass can vary between and among individuals of the same species, between fruits and seeds of the same individual

Table 1. Physical characteristics of the fruits of the tamarillo (*Solanum betaceum*) matrices harvested in the Caparaó - ES (L1) e MG (L2)[(1)].

Region	LD (mm)	TD (mm)	E (mm)	PW (mg)	PPW (mg)	TSW (g)	PPY (%)	DMF (mg)
L1	52.1 a	34.8 b	4.7 b	37.95 b	32.66 b	4.85 b	86.06 b	4.42 b
L2	51.3 b	41.7 a	4.9 a	46.60 a	45.04 a	5.34 a	96.65 a	5.76 a
CV (%)	0.11	1.07	1.20	0.01	0.01	0.01	0.01	0.01

[(1)]Means followed by different letters in the columns differ by the Tukey test, at the 5% level of significance. LD = longitudinal diameter, TD = transverse diameter, E = endocarp, PW = fruit weight, PPW = pulp and peel weight, TSW = thousand seed weight, PPY = pulp and peel yield, DMF = dry mass of the fruit.

and between production cycles [19]. Peach seeds with higher values of length, width and thickness presented a higher germination rate and more vigorous plants [20]. Pulp and peel yield was 96.65% for the fruits harvested from the mother plants in Caparaó-MG (L2), differing from the values obtained from fruits harvested from the mother plants in Caparaó-ES (L1), which was 86.06%, values higher than those found by Guilherme *et al.* [17] in a fruit mesocarp harvested in Ponta Grossa-PR, which was 83.3% and *Eugenia calycina* fruits, whose pulp yield was 59.1% [21]. This yield is a key factor to be considered in the choice of the ideal raw material by the food industry and high pulp content is one of the most desirable characteristics in the commercialization of fresh fruits [22].

Table 2 shows the correlation data of the physical characteristics of tamarillo fruits. It was verified that there was a negative correlation of the longitudinal diameter with the variables: transverse diameter, endocarp, fruit weight, pulp and peel weight, thousand-seed weight, pulp and peel yield and fruit dry mass, suggesting that the longitudinal diameter is not suitable for analyzing the physical characteristics of the fruit of this species.

For the other biometric variables, a positive correlation was observed, in which they were statistically significant, except for the correlation of the transverse diameter × endocarp.

Twenty correlation coefficients (0.99) were observed for the variables, in which the value of one variable is directly proportional to the value of the other.

Considering the physico-chemical characterization of tamarillo pulp (**Table 3**), fruits from the region of Caparaó-ES (L1) had higher values of pH, soluble solids (SS) and *ratio*, in relation to fruits from the region of Caparaó-MG (L2). However, for the titratable acidity (TA) there was no significant difference for the two regions. The pH of the fruit pulp from Caparaó-ES (L1) was 4.26, being considered slightly acid and soluble solids content (12 ˚Brix), which is related to

Table 2. Correlation for the biometric variables of the fruits of the tamarillo matrices (*Solanum betaceum*) harvested in the region of Caparaó - ES e MG.

Variables	LD	TD	E	PW	PPW	TSW	PPY	DMF
LD	-	−0.98**	−0.88*	−0.99**	−0.99**	−0.99**	−0.99**	−0.99**
TD		-	0.80^{ns}	0.99**	0.99**	0.99**	0.99**	0.99**
E			-	0.82*	0.82*	0.82*	0.82*	0.82*
PW				-	0.99**	0.99**	0.99**	0.99**
PPW					-	0.99**	0.99**	0.99**
TSW						-	0.99**	0.99**
PPY							-	0.99**
DMF								-

^{ns}not significant; **, *significant at the 1% and 5% probability level by the F test, respectively. LD = longitudinal diameter, TD = transverse diameter, E = endocarp, PW = fruit weight, PPW = pulp and peel weight, TSW = thousand seed weight, PPY = pulp and peel yield, DMF = dry mass of the fruit.

Table 3. Chemical characteristics of the fruits of the tamarillo (*Solanum betaceum*) matrices harvested in the Caparaó - ES (L1) e MG (L2)[(1)].

Region	pH	SS (˚Brix)	TA (%)	*Ratio*
L1	4.26 a	12 a	0.88 a	13.64 a
L2	3.96 b	10 b	0.87 a	11.49 b
CV (%)	0.87	0.01	1.04	1.02

[(1)]Means followed by different letters in the columns differ by the Tukey test, at the 5% level of significance. SS = soluble solids; TA = titratable acidity; *ratio* = reason between soluble solids and titratable acidity.

the fruit flavor, including sugars and acids and when mature they present uniformity in relation to the solutes [17]. In the fruits harvested in the region of Caparaó-MG (L2) these values were lower (pH = 3.96-acid and SS-10, respectively). Expressive values of soluble solids are important in the food industry and for natural consumption, because it has a higher yield during processing [23]. The characteristics of ˚Brix and pH are responsible for the sweet and slightly acid flavor of the tamarillo fruit pulp. According to Hoffmann [24], low acid foods have pH = 4.5, and pH is of fundamental importance in the limiting the different microorganisms capable of developing in foods, since below this value there is the development of *Clostridium botulinum* and pathogenic bacteria.

The correlation between the physical and chemical characteristics of tamarillo fruits (**Table 4**) showed that there was no statistical difference in the correlation between pH × TA (0.79), SS × TA (0.74) and TA × *ratio* (0.67). However, the correlation between pH and SS (0.98) was significant, which means that the increase in pH is proportional to the increase of soluble solids and the correlation between pH × *ratio* (0.96) and SS × ratio (0.99) is high.

Tamarillo (L1) seeds presented 7.08% of water content and L2 7.20%, a variation of approximately 0.12% between the regions, which is considered low for the analysis of physiological quality of the seeds, suggesting that it didn't interfere with the analysis results. **Figure 1** shows the germination results, germination speed index and germination mean time of tamarillo seeds. The germination percentage of the seeds from the L1 region in the presence of light was higher at temperatures of 30˚C and 20˚C - 30˚C; while in the absence of light the highest germination percentage was observed at the temperature of 20˚C - 30˚C. However, the seeds of the L2 region presented a higher germination percentage in the presence of light, under temperatures of 25˚C and 30˚C whereas in the absence of light. A higher percentage was obtained in the alternating temperature of 20˚C - 30˚C, suggesting that in both presence and absence of light, the best temperature for germinating was the alternating temperature of 20˚C - 30˚C, corroborating with Baskin and Baskin [25] that observed the need of light for some species is strongly influenced by temperature. This behavior disagrees with the expected results because the seeds of the *Solanum betaceum* species are positive photoblastic and present latency of photo [26].

Considering the seed vigor analysis, the tests conducted: germination speed

Table 4. Correlation for the chemical characteristics of the fruits of the tamarillo (*Solanum betaceum*) matrices harvested in the region de Caparaó, ES e MG.

Variables	pH	SS	TA	*Ratio*
pH	-	0.98**	0.79^{ns}	0.96**
SS		-	0.74^{ns}	0.99**
TA			-	0.67^{ns}
Ratio				-

^{ns}not significant; **, *significant at the 1% and 5% probability level by the F test, respectively. SS = soluble solids; TA = titratable acidity; *ratio* = reason between soluble solids and titratable acidity.

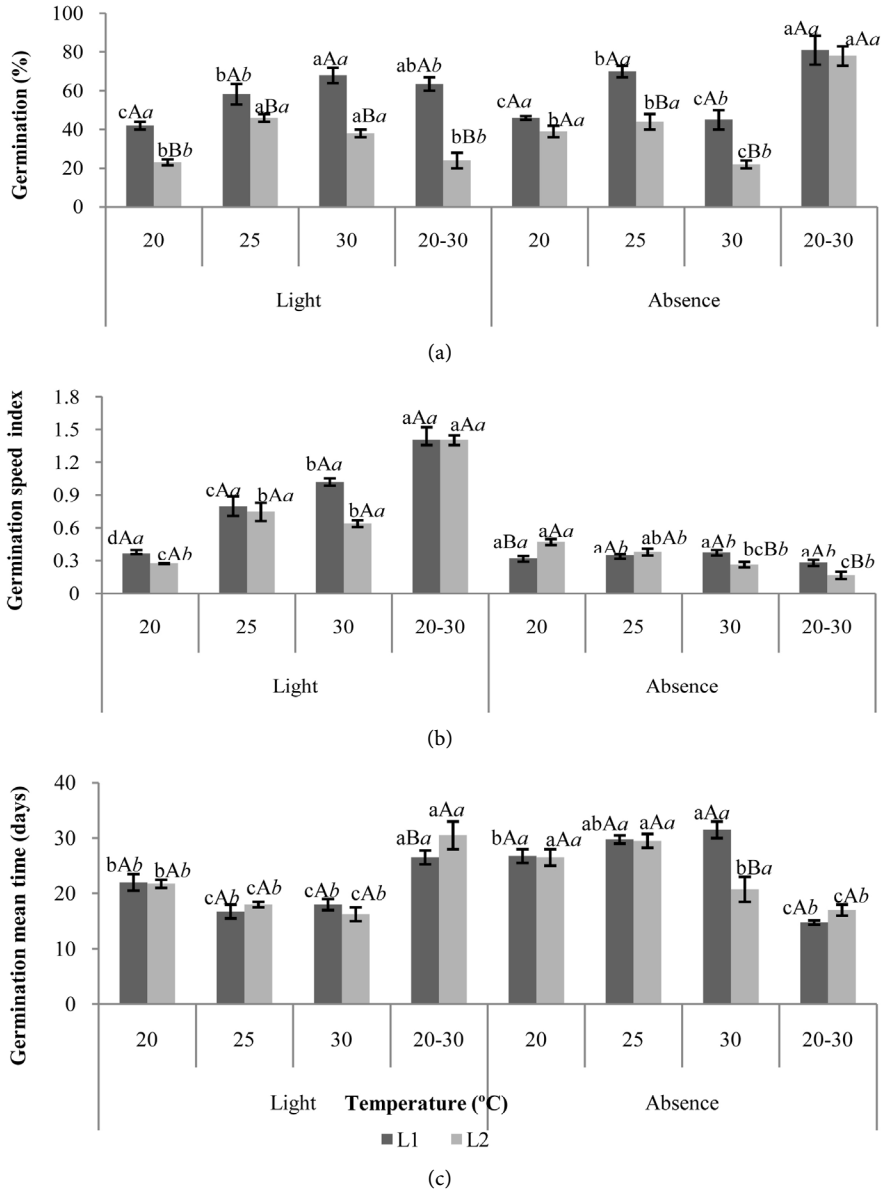

Figure 1. Germination (a), germination speed index (b) and germination mean time (c) of tamarillo (*Solanum betaceum*) seeds harvested in Caparaó - ES (L1) and MG (L2) at different temperatures and light regimes. Means followed by the same letter, lowercase between the temperatures and uppercase for batches and italics for light, do not differ at the 5% level by the Tukey test.

index (GSI) and germination mean time (GMT), the behavior was similar to the germination test, with temperatures of 25˚C and 30˚C for the seeds in the presence of light and the alternating temperature of 20˚C - 30˚C in the absence of light, regardless of the seeds origin. Baskin and Baskin [25] reported differences in the germination speed between seeds of different populations of one species. The mean germination time presented homogeneity between the regions, which shows that there was no significant differences between them. Also, the light positively influenced a higher uniformity at all temperatures, except for the alternating temperature of 20˚C - 30˚C. Several authors have pointed out that the optimum temperature for total germination is different from the optimum for seed germination speed. Carvalho and Nakagawa [27] affirm that at higher temperatures, the water absorption rate and the chemical reactions are higher, and the seeds germinate quickly.

Considering the post-seminal development (**Figure 2**), the tamarillo seedlings of Caparaó-ES region (L1) presented a larger shoot length (3.72 cm), root (1.73 cm) and total dry mass (5.23 mg) when the seeds were submitted to the alternating temperature of 20˚C - 30˚C, in the presence of light and in relation to L2. In majority of the interactions, L1 presented greater vigor in relation to L2, whereas tamarillo in the presence of light presented high vigor compared to the absence of light. Similar behavior was observed by Bastiani *et al.* [28], in rice grass seeds. Mendes and Carvalho [29] found that basil seeds had a higher dry mass when submitted to the presence of white light.

4. Conclusions

The biometric and physicochemical evaluations of tamarillo fruits present high variation, indicating genetic potential for germplasm conservation and for seed harvesting.

There is variability between the analyzed characteristics according to where the tamarillo fruits were harvested. The tamarillo in the region of Caparaó-ES presents greater chemical characteristics of the fruits, germination and vigor and in the region of Caparaó-MG presented greater physical characteristics of the fruits.

The germination of tamarillo seeds in the presence of light should be conducted at constant temperatures of 25˚C and 30˚C and in the absence of light at alternating temperature of 20˚C - 30˚C. Tamarillo can germinate both in the presence and absence of light, although it presents greater vigor in the presence of light.

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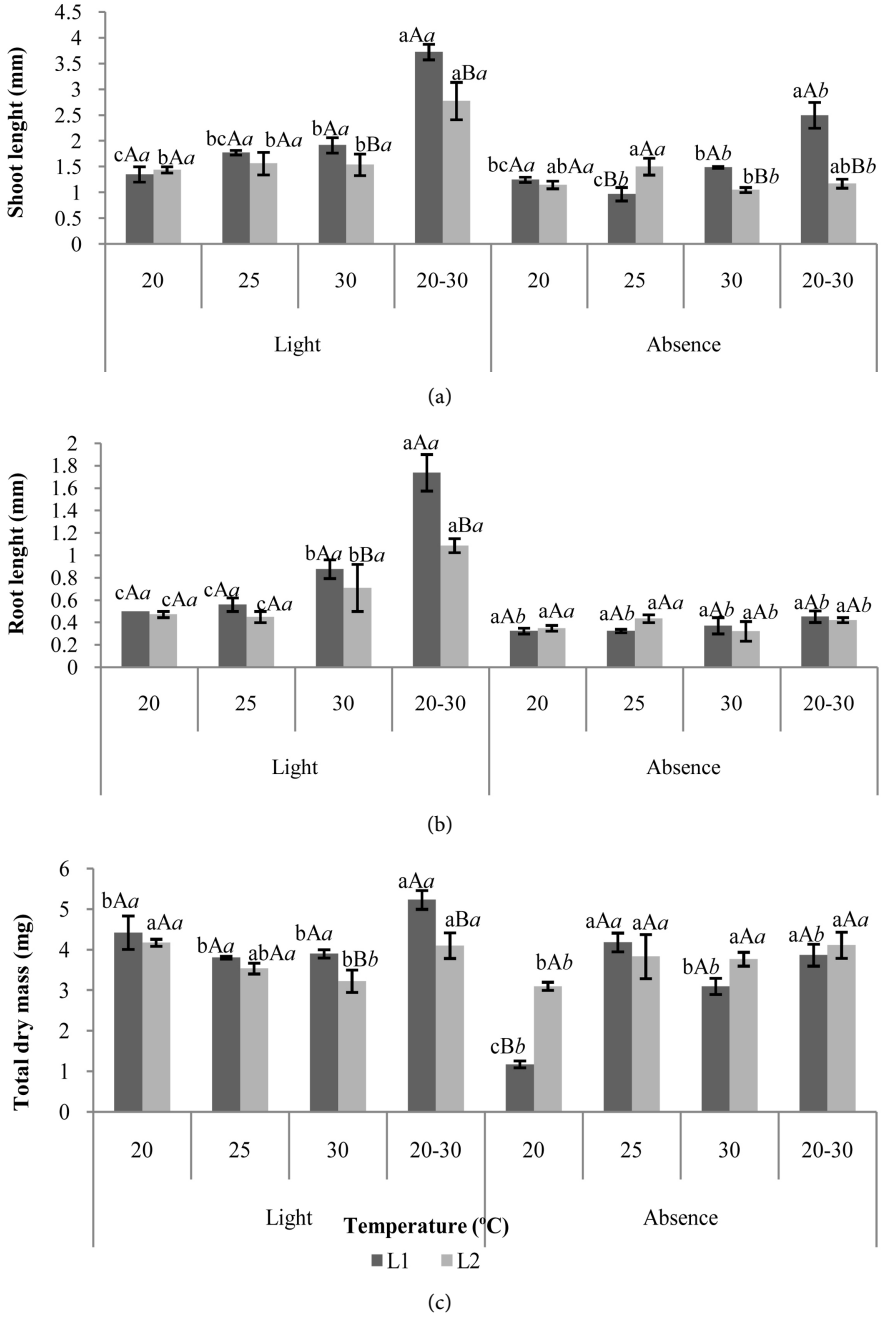

Figure 2. Shoot length (a), root (b), total dry mass (c) of tamarillo (*Solanum betaceum*) seedlings harvested in the region of Caparaó, ES (L1) and MG (L2), at different temperatures and light regimes. Means followed by the same letter, lowercase between the temperatures and uppercase for batches and italics for light, do not differ at the 5% level by the Tukey test.

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