

Physiological quality of 'BRS' passion fruit seeds grown at different altitudes and storage environments

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Abstract

The aim of this work was to study the physiological quality of 'BRS' passion fruit seeds grown at different altitudes stored in cold chamber and in natural environment for six months. Hybrid passion fruit seeds (BRS Gigante Amarelo, BRS Sol do Cerrado and BRS Rubi do Cerrado) grown at three altitudes (104; 711; 1016 meters) in the southern region of the state of Espírito Santo were used. Germination was carried out in germitest paper rolls, placed in BOD-type germination chambers at temperature of 20-30 °C. The following parameters were analyzed: germination, germination speed index, shoot and root length and dry mass of seedlings. The experimental design used was completely randomized in a factorial scheme with split plot in time 4x(3x3) (four bimonthly analyses x three hybrids x three altitudes), with two independent storage environments and three replicates of 100 seeds. Hybrid *Passiflora edulis* f. *flavicarpa* seeds can be stored in natural environment or cold chamber. Hybrid yellow passion fruit seeds grown at altitudes of 104 and 711 meters show higher germination and vigor percentages. Hybrid 'Gigante Amarelo' seeds had lower averages for variables under study, regardless of altitude. Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages and can be stored for 180 days in natural environment or cold chamber without viability loss. *Flavicarpa* can be stored in natural environment or cold chamber. Hybrid yellow passion fruit seeds grown at altitudes of 104 and 711 meters show higher germination and vigor percentages. Hybrid 'Gigante Amarelo' seeds had lower averages for variables under study, regardless of altitude. Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages and can be stored for 180 days in natural environment or cold chamber without viability loss. *Passiflora edulis* f. *flavicarpa* can be stored in natural environment or cold chamber. Hybrid yellow passion fruit seeds grown at altitudes of 104 and 711 meters show higher germination and vigor percentages. Hybrid 'Gigante Amarelo' seeds had lower averages for variables under study, regardless of altitude. Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages and can be stored for 180 days in natural environment or cold chamber without viability loss. Hybrid 'Gigante Amarelo' seeds had lower averages for variables under study, regardless of altitude. Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages and can be stored for 180 days in natural environment or cold chamber without viability loss. Hybrid 'Gigante Amarelo' seeds had lower averages for variables under study, regardless of altitude. Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages and can be stored for 180 days in natural environment or cold chamber without viability loss.

Keywords: Germination, Hybrids, Storage, *Passiflora edulis* Sims. f. *flavicarpa* Deg.

Introduction

Passion fruit belongs to the Passifloraceae family and *Passiflora* genus, which stands out as the most economically important. Brazil is considered the center of origin for approximately 150 known species, of which 87 are endemic. It is currently the world's largest passion fruit producer, with production of 593,429 tons in an area of 41,584 hectares. The Northeastern region has been leading Brazilian production in recent years, accounting for 64.5% of production, followed by the Southeastern, Southern, Northern and Midwestern regions (Ibge, 2019).

The most suitable regions for growing passion fruit are at altitudes between 100 and 1000 m, with average temperature between 25 and 26 °C; ideal rainfall between 1,200 and 1,400 mm, well distributed throughout the year, low relative humidity and high luminosity. The plant needs at least 11 hours of light/day for floral induction to occur (Fraife Filho et al., 2010).

The crop is cultivated by small, medium and large producers in almost all regions, and can be conducted in different types of soil, but does not adapt well to places that suffer from frost or have soggy soils. However, given the growing demand from the productive sector, Embrapa maintains a passion fruit breeding program (Embrapa, 2014).

'BRS Rubi do Cerrado' hybrid, launched in 2012, was obtained based on population improvement by recurrent selection, obtaining and evaluating inter and intraspecific hybrids, is resistant to the main passion fruit diseases. 'BRS Gigante Amarelo' and 'BRS Sol do Cerrado' hybrids, launched in 2008, show high productivity, good adaptation to different edaphoclimatic conditions, high fruit quality and high pulp yield for agro-industrial purposes (Embrapa, 2012).

The quality of seeds is an important factor for the crop conduction and the storage conditions are

fundamental for the preservation of their quality. Relative humidity is related to the water content of seeds, while temperature influences the speed of biochemical processes and indirectly interferes with the water content of seeds (Carvalho & Nakagawa, 2012). However, beyond the storage period, viability responses may vary depending on the species and seed sensitivity (Hossel et al., 2016).

To obtain higher quality seeds, care should begin in the field, avoiding mechanical damage, insect attack and harvest delay (Goldfarb & Queiroga, 2013). However, the deterioration of stored seeds is unavoidable, which lose vigor, become more susceptible to stress during germination and lose ability to originate normal seedlings (Silva et al., 2014).

In view of the above, the aim of this work was to study the physiological quality of 'BRS' passion fruit seeds grown at different altitudes and stored in cold chamber and in natural environment for six months.

Material And Methods

The work was carried out at the Laboratory of Seed Analysis, Center for Agricultural Sciences and Engineering of the Federal University of Espírito Santo (CCA-E-UFES), in the municipality of Alegre-ES. Hybrid passion fruit seeds (BRS Gigante Amarelo, BRS Sol do Cerrado and BRS Rubi do Cerrado) grown at three altitudes in the southern region of the state of Espírito Santo were used (Table 1).

Seeds from ripe and freshly harvested fruits were extracted with the aid of sterilized spoon; the pulp with the slaked lime was removed with a sieve, washed under running water and kept on germitest paper in the shade until reaching 14% moisture. Subsequently, they were packed in plastic BOPP packages (bioriented polypropylene) and stored in cold chamber at temperature of 4 °C and natural laboratory environment (25 ± 2 °C), with no relative humidity control, for six months. The following parameters were measured every two months:

Seed water content - periodically determined with two replicates of 15 seeds, by the oven method at 105 ± 3 °C, for 24 hours (BRAZIL, 2009);

Germination - carried out with three replicates of 100 seeds, which were sown in germitest paper rolls moistened with distilled water at proportion of 2.5 times the mass of the dry paper, kept in BOD-type germination chamber, regulated at alternating temperature of 20-30 °C, in the absence of light. Analyses were carried out seven and 28 days after sowing, calculating the percentage of normal seedlings (Brazil, 2009), and results were expressed as germination percentage;

Germination speed index (GSI) - determined concomitantly with the germination test, being measured daily until the 28th day as the number of seeds presenting primary root protrusion equal to or greater than 2 mm (Maguire, 1962);

Shoot length - determined 28 days after sowing with the aid of millimeter ruler, by measuring the length between the stem and the apex of the last leaf of each plant in the sample and the result expressed in cm plant⁻¹;

Root length - determined 28 days after sowing with the aid of millimeter ruler, measured from the neck of the plant to the tip of the largest root and results expressed in cm plant⁻¹;

Seedling dry mass - determined 28 days after sowing, using analytical scale (0.0001 g). Seedlings were placed in Kraft paper bags, kept in convection oven at 72 °C for 72 hours (constant mass) and results expressed in mg seedling⁻¹.

The experimental design used was completely randomized, in a factorial scheme with split plot in time 4x(3x3) (four bimonthly analyses for six months of storage x three hybrids x three altitudes with two independent storage environments (natural environment and cold chamber), with three replicates of 100 seeds. For the quantitative factor, linear regression analysis was performed and for qualitative factors, the average test was performed using the Tukey method, with significance at 5% probability level. Statistical analyses were performed using the R software (R Core Team, 2021).

Results and discussion

Germination, germination speed index (GSI), shoot length (SL) and seedling dry mass (DM) did not

Table 1- Seed collection location

Data	Altitude (m)		
	104	711	1016
Latitude	20° 48' 9.93" S	20° 37' 51.91" S	20° 28' 09.40" S
Longitude	41° 24' 24.85" O	41° 36' 15.97" O	41° 43' 31.63" O
Climate (Köppen-Geiger climate classification)	Tropical - Aw	Subtropical with dry winter and hot summer - Cwa	Hot and tempered - Cwa
Average temperature (°C)	23.8	23.0	19.8
Average anual rainfall (mm)	1094	1341	1286

show significant difference in relation to the two storage environments (natural environment and cold chamber), although seedlings from seeds stored in cold chamber showed higher average root length (RL), suggesting that this is the best condition for preserving viability and maintaining vigor of hybrid 'BRS' yellow passion fruit seeds (**Table 2**). According to Smaniotto et al. (2014), the acclimatized environment (20 °C) provides better conservation of the physiological quality of seeds. However, MEZZALIRA et al. (2012) in studies with the genus

Table 2 - Anova table of yellow passion fruit BRS hybrid seeds, stored in a natural laboratory environment and cold chamber, for 180 days

Source of variation	Mean Square				
	Germination	GSI	SL	RL	DM
Treatment	251.34 ^{ns}	3.51 ^{ns}	0.54 ^{ns}	8.817 ^{ns}	0.247 ^{ns}
Residue	884.25	28.64	1.995	1.153	0.771
Environments	Mean				
Natural environment	65 a ⁽¹⁾	10.5 a	6.7 a	3.8 b	6.7 a
Cold chambre	67 a	10.8 a	6.8 a	4.2 a	6.7 a

^{ns} not significant. ⁽¹⁾ Means followed by the same lowercase letter, do not differ from each other at a 5% level, according to the F test.

Passiflora, found that storage in natural environment for a period of six months-maintained seed vigor.

The germination percentage of the three hybrids 'BRS' yellow passion fruits grown at 711 or 1016 meters, at time zero, did not present significant difference; however, hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds grown at 104 meters presented higher average germination values (**Table 3**).

Seeds grown at 104 meters did not show significant difference regardless of hybrid after 60 days of storage. However, hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and hybrid 'Sol do Cerrado' seeds grown at altitude of 711 meters showed the highest germination average values when stored for 60 days in natural laboratory environment, and hybrid

'Rubi do Cerrado' seeds grown at 1016 meters and hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds grown at 711 meters of altitude showed the highest average germination values when stored for 60 days in cold chamber. Similar behavior was observed after 120 and 180 days of cold storage. This behavior suggests that the germination of passion fruit seeds is influenced by plant genotype and the place where seeds were grown (Alexandre et al., 2004). Behavior similar to that found by Coelho et al. (2013) in seeds of *Caesalpinia ferrea* Mart. ex Tul. var. *ferrea*, in which they observed differences in the germination process depending on where the seeds were harvested.

At time zero and after 120 days of storage in natural environment, seeds from the three hybrids grown at 104 and 711 meters of altitude showed higher average germination values. However, after 60 days of storage in natural environment, the highest average germination values were observed for hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds grown at 104 meters of altitude and hybrid 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude; however, with no difference between altitudes. After 180 days of storage in natural environment, the highest average germination values were observed for hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude and for hybrid 'Rubi do Cerrado' seeds grown at 104 meters of altitude, suggesting that the origin of seeds influences their germination. According to Bauk et al. (2014), hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds stored in cold chamber, after 60 days, showed higher average germination values, when grown at 104 and 711 meters of altitude, and hybrid 'Rubi do Cerrado' seeds grown at 104 meters of altitude. After 120 and 180 days of storage in cold chamber, hybrid 'Rubi do Cerrado' and

Table 3 - Germination (%) of hybrid BRS seeds of yellow passion fruit (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in a natural environment and cold chamber for 180 days

Time (days)	Hybrids BRS	Storage environments and cultivation Altitudes (m)					
		Natural environment			Cold chamber		
		104	711	1016	104	711	1016
0	GA	97aaA ⁽¹⁾	92 aaA	27 aabB	97 aaA	92 aaA	27 aabB
	RC	90 abaA	93 aaA	21 acB	90 abaA	93 aaA	21 acB
	SC	88 baA	89 aaA	26 aaB	88 baA	89 aaA	26 aaB
60	GA	88 abas	75 bbB	33 baC	92 aaA	84 aabA	36 baB
	RC	87 aaA	71 bbB	51 aaC	93 aaA	54 bcB	51 aaB
	SC	93 aaA	90 aaA	16 cbB	96 aaA	90 aaA	28 baB
120	GA	81 bbA	76 bbA	19 bbB	95 aaA	80 bbB	20 bbC
	RC	76 bbA	68 cbA	43 abB	91 aaA	86 ababA	45 abB
	SC	89 aaA	92 aaA	5,0 ccB	93 aaA	91 aaA	8,0 cbB
180	GA	85 bbA	83 abas	21 bbB	89 aaA	52 ccB	22 bbC
	RC	74 cbA	66 bbB	43 aabC	83 abas	81 bbA	52 aaB
	SC	95 aaA	90 aaA	18 babB	90 aaA	91 aaA	11 cbB

⁽¹⁾ Means followed by the same letter, lowercase between different hybrids within each altitude and time, lowercase italicized between the same hybrid at different times, and capital letters between different locations within each hybrid and time, do not differ between si at a 5% level, by Tukey's test.

'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude, and hybrid 'Gigante Amarelo' seeds grown at 104 meters, presented the highest average germination values, with significant difference between them. Seeds grown at 104 and 711 meters of altitude, that is, grown at lower and median altitude, respectively, showed higher germination percentages, unlike what has been reported by Chen et al. (2017), in which high altitudes favor the formation of larger seeds.

Hybrid 'Gigante Amarelo' seeds grown at 1016 meters of altitude showed higher germination percentage at time zero and after 60 days of storage in natural environment and cold chamber (Figure 1A and 1B), while seeds from fruits harvested at 104 and 711 meters of altitude, at time zero (before storage) and stored in natural environment, showed higher germination

percentage. Seeds from fruits harvested at altitude of 104 meters and stored in cold chamber showed no difference in germination throughout the storage period, while seeds from fruits harvested at altitude of 711 meters showed higher germination percentages at time zero and after 60 days of storage.

Hybrid 'Rubi do Cerrado' seeds cultivated at altitude of 1016 meters showed higher germination percentage when stored for 60 and 120 days in natural environment; in cold chamber, as the storage time increased, germination percentage also increased. However, seeds grown at 104 and 711 meters of altitude and stored in natural environment showed the opposite behavior, that is, as the storage time increased, the germination percentage decreased. Only seeds grown at 104 meters and stored for 60 and 120 days in cold

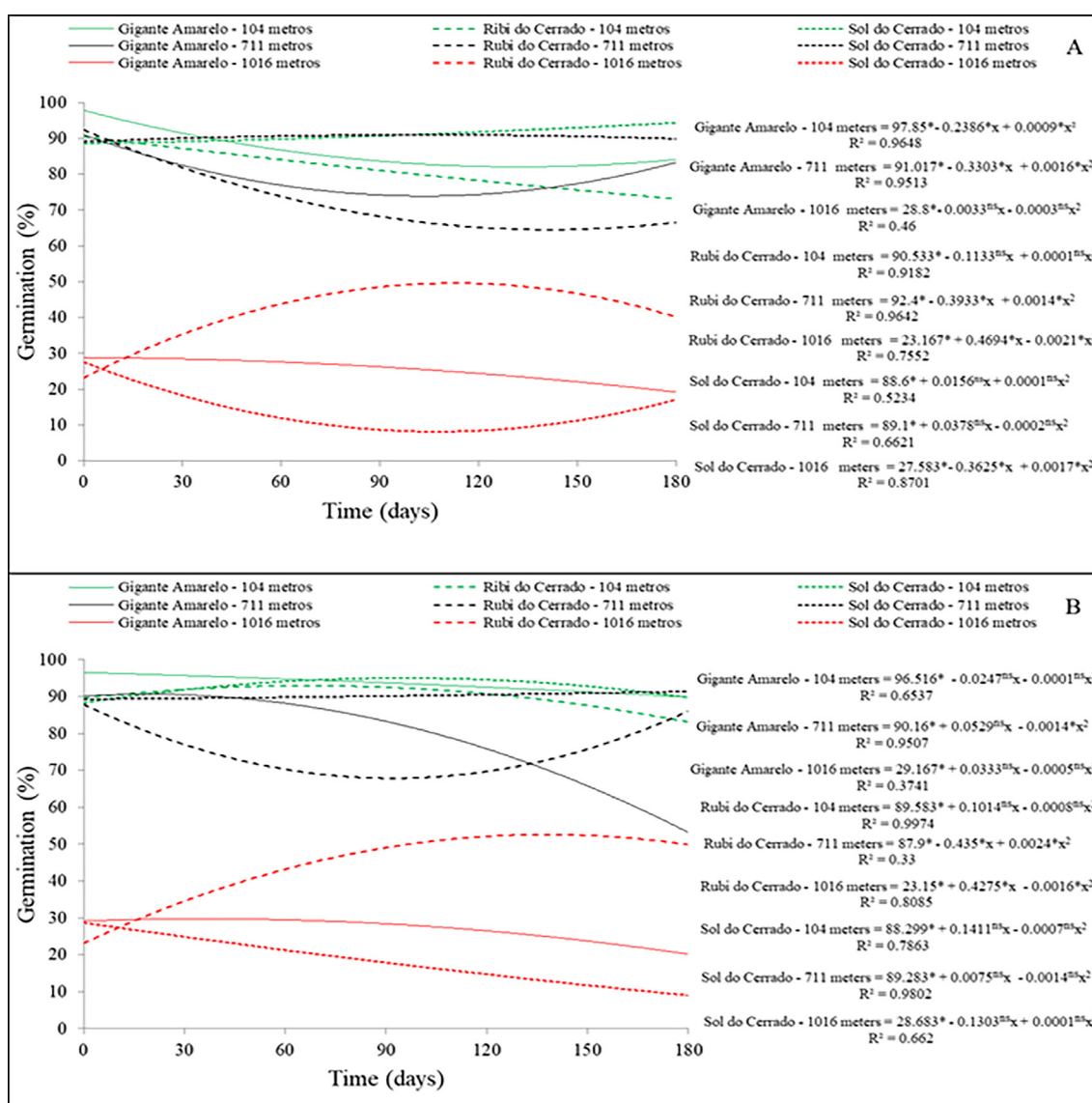


Figure 1 - Regressions obtained for germination (%), referring to the splitting of the factorial between the seeds of BRS hybrids of yellow passion fruit cultivated at different altitudes and stored in natural environments (A) and cold chamber (B). *Significant at the 5% level of probability; ^{ns} not significant. R² = coefficient of determination of the regression

chamber showed higher germination percentages. Similar behavior was observed by Carvalho et al. (2018) for *P. alata* 'BRS Mel do Cerrado' seeds, whose storage between 60 and 120 days increased the seedling emergence percentage and speed. When obtained from fruits harvested at 711 meters of altitude and stored in cold chamber, initial decrease in the germination percentage was observed, culminating in increase after 180 days of storage.

Hybrid 'Sol do Cerrado' seeds, when cultivated at 1016 meters of altitude, showed increase in seed germination percentage with increasing storage time, regardless of storage environment. However, the fruits from 104 meters of altitude, whose seeds were stored in a natural environment, and cultivated at 711 meters of altitude and the seeds stored in a natural environment and cold chamber did not differ in terms of the storage times studied, showing a reduction in the percentage of germination after 60 days only in the seeds of fruits harvested at 104 meters of altitude and stored in a cold chamber. Santos et al. (2012) observed that *Passiflora mucronata* seeds stored for one month, even when submitted to pre-germinative procedures showed low germination percentage. According to Smaniotta et al. (2014), seeds tend to lose vigor and germination during storage due to lipid peroxidation, along with high water content and temperature.

Hybrid 'Sol do Cerrado' and 'Gigante Amarelo' seeds cultivated at altitude of 1016 meters showed higher germination speed index (GSI), while hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds cultivated at altitude of 104 meters showed higher average GSI values (Table 4).

Hybrid 'Rubi do Cerrado' seeds grown at 1016 meters and hybrid 'Sol do Cerrado' seeds grown at 711 meters and stored for 60 and 120 days in natural environment showed higher average GSI values. However, no significant difference between hybrids were observed, when seeds were grown at 104 meters and stored for 60 days in natural environment, but after 120 days of storage, average GSI values were similar to those under 180 days of storage (Table 4).

Hybrid 'Rubi do Cerrado' seeds grown at 1016 meters of altitude and stored in cold chamber showed the highest average GSI values. After 60 days of storage, hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds grown at 104 meters and hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds grown at 711 meters of altitude showed higher average GSI values. After 120 days of storage, seeds grown at 104 meters of altitude did not show

significant difference in relation to the three hybrids under study; however, hybrid 'Sol do Cerrado' seeds grown at 711 meters of altitude showed higher average GSI values. After 180 days of storage, hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds grown at 104 meters, and hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds grown at 711 meters of altitude showed higher average GSI values (Table 4), suggesting that the place of growth significantly influenced seed vigor, corroborating results obtained in sugar apple seeds by Araújo Neto et al (2013).

Hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds grown at 104 and 711 meters of altitude, at time zero, presented higher average GSI values, while hybrid 'Sol do Cerrado' seeds grown at 711 meters presented the highest average GSI values. Hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds grown at 104 meters and hybrid 'Sol do Cerrado' seeds grown at 711 meters of altitude after 60 days of storage in natural environment showed higher average GSI values. Hybrid 'Gigante Amarelo' seeds with 120 and 180 days of storage in natural environment grown at 104 meters and hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude showed higher average GSI values (Table 4).

Hybrid 'Gigante Amarelo' seeds grown at 711 meters, hybrid 'Rubi do Cerrado' seeds grown at 104 meters and hybrid 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude, after 60 days of storage in cold chamber, showed higher average GSI values. After 120 days of storage in cold chamber, seeds from the three hybrids grown at 104 meters of altitude showed higher average GSI values. Hybrid 'Gigante Amarelo' seeds grown at 104 meters, hybrid 'Rubi do Cerrado' seeds grown at 711 meters and hybrid 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude showed higher average GSI values (Table 4).

Hybrid 'Gigante Amarelo' seeds grown at the three altitudes, stored in natural environment and in cold chamber, showed reduction in GSI values as storage time increased (Figure 2A and 2B).

Hybrid 'Rubi do Cerrado' seeds grown at altitude of 1016 meters and stored in natural environment showed increase in GSI values after 60 days and reduction after 120 days. However, when grown at 104 and 711 meters of altitude, GSI values decreased with the increase in storage time, and when stored in cold chamber, seeds grown at 1016 and 104 meters showed behavior similar to that of seeds stored in natural environment; however, seeds grown at 711 meters of altitude showed decrease in GSI values after 60 days, increasing after 180 days,

Table 4 - Germination speed index of BRS yellow passion fruit hybrid seeds (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in a natural environment and cold chamber for 180 days

Time (days)	Hybrids BRS	Storage environments and cultivation Altitudes (m)					
		Natural environment			Cold chamber		
		104	711	1016	104	711	1016
0	GA	15.4 abaA ⁽¹⁾	16.9 aaA	4.7 abaB	15.4abaA	16.9 aaA	4.7 aaB
0	RC	16.2 aaA	16.3 aaA	3.3 bcB	16.2 aaA	16.3 aaA	3.3 abB
0	SC	14.4 bbB	16.1 aabA	4.9 aaC	14.4 babB	16.1 aaA	4.9 aaC
60	GA	13.9 aabA	11.4 bbB	4.5 baC	12.3 bcB	14.7 abA	4.7 baC
60	RC	13.8 abA	10.6 bbcB	9.1 aaB	15.2 aaA	6.6 bcC	9.8 aaB
60	SC	15.2 aabB	17.6 aaA	2.2 cbC	16.0 aaA	15.2 aabA	4.8 baB
120	GA	13.9 babA	8.1 ccB	1.9 bbC	14.6 aabA	10.7 ccB	2.4 bbC
120	RC	11.5 ccA	11.9 bbA	5.8 abB	15.8 aaA	13.3 bbB	8.6 aaC
120	SC	16.5 aaA	17.5 aaA	0.3 ccB	15.6 aaA	16.6 aaA	0.8 bbB
180	GA	13.4 bbA	11.8 bbB	1.8 bbC	13.2 abcA	6.7 bdB	2.5 bbC
180	RC	9.7 cdA	9.9 ccA	4.9 abcB	9.3 bbB	13.9 abA	7.6 aaB
180	SC	15.0 aabA	15.4 abA	1.8 bbcB	12.9 abA	14.1 abA	1.0 bbB

⁽¹⁾ Means followed by the same letter, lowercase between different hybrids within each altitude and time, lowercase italicized between the same hybrid at different times, and capital letters between different locations within each hybrid and time, do not differ between si at a 5% level, by Tukey's test.

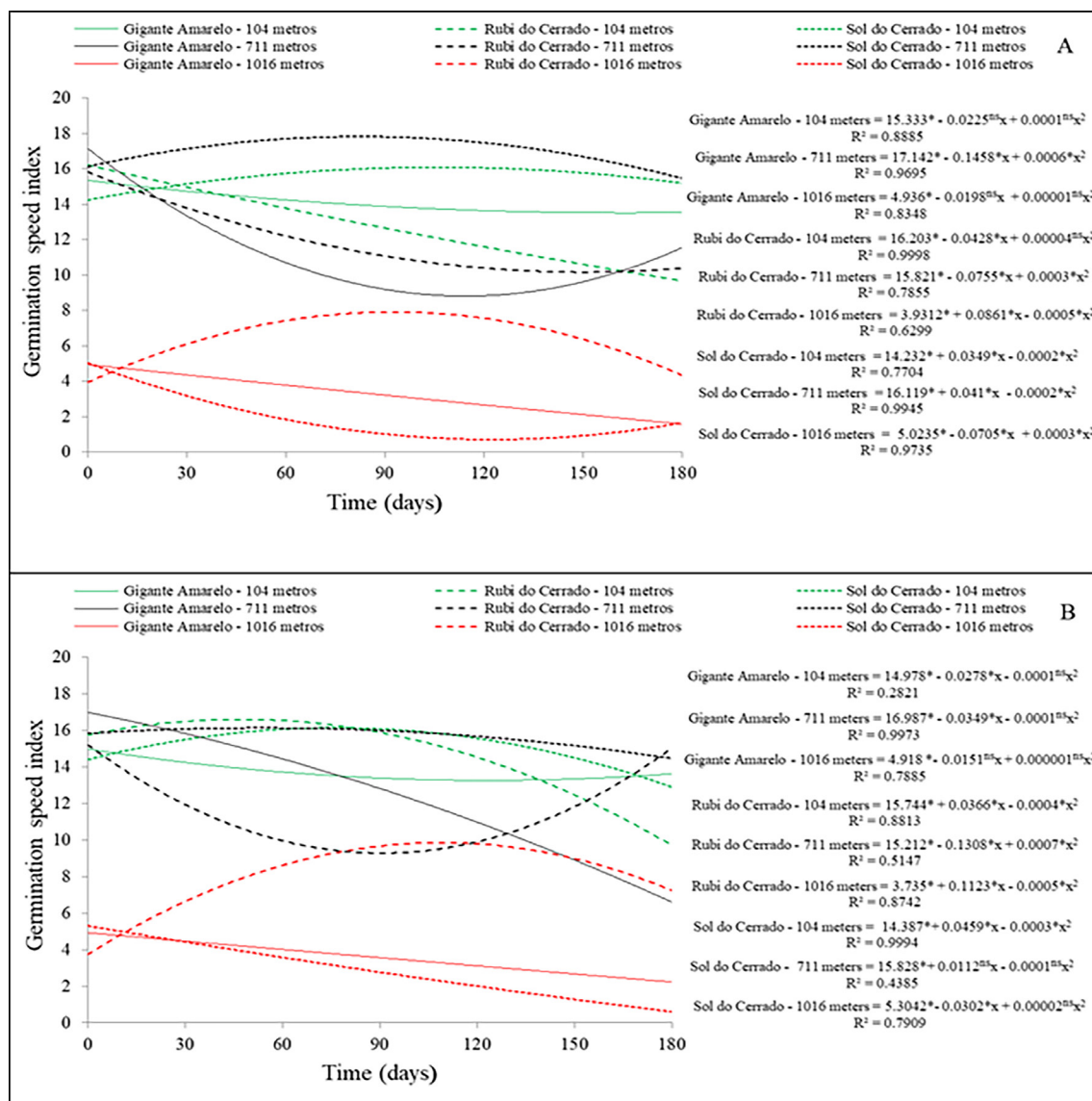


Figure 2 - Regressions obtained for the germination speed index (GVI), referring to the splitting of the factorial between the seeds of yellow passion fruit BRS hybrids cultivated at different altitudes and stored in natural (A) and cold chamber (B) environments. *Significant at the 5% level of probability; ^{ns} not significant. R² = coefficient of determination of the regression fit.

suggesting that dormancy was overcome due to the increase in seed vigor. According to Grzybowski et al. (2019), seeds from freshly harvested yellow passion fruits exhibit physical and physiological dormancy and, when stored, maintain their physiological quality for up to nine months.

Hybrid 'Sol do Cerrado' seeds stored in natural environment and cold chamber, as the days of storage increased, GSI values decreased, regardless of altitude. The decline in physiological potential over the course of the period is not restricted to the decrease in germination capacity, but this becomes slower, as well as an increase in sensitivity to environmental adversities, characterizing a decline in vigor (Marcos Filho, 2015).

The shoot length of seedlings from seeds grown at altitude of 1016 meters, not stored (time zero) and stored for 60 days in natural environment and cold chamber, did not show significant difference, regardless of hybrid. Similar behavior was observed for seedlings whose seeds came from fruits harvested at 711 meters of altitude, not stored and stored for 60 and 120 days in cold chamber, and for those grown at 104 meters, stored for 60 days in cold chamber. Seedlings derived from hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds harvested at 104 meters, not stored and stored for 60 and 180 days in natural environment showed higher average shoot length values.

However, seedlings from hybrid 'Rubi do Cerrado' seeds harvested at 1016 meters and stored for 120 days in natural environment showed higher average shoot length values. However, when stored in cold chamber, the highest averages were obtained for hybrid 'Gigante Amarelo' and 'Rubi do Cerrado' seeds (Table 5).

Hybrid 'Sol do Cerrado' seeds grown at altitude of 104 meters and stored for 120 days in natural environment and in cold chamber for 180 days showed the highest average shoot length values (Table 5).

Seedlings derived from hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds cultivated at 711 meters of altitude and stored in natural environment for 60 and 180 and in cold chamber for 180 showed higher average shoot length values, with the exception of 'Gigante Amarelo' hybrid stored for 120 days in natural environment (Table 5).

The shoot length of seedlings from hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds not stored (recently harvested), hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds stored for 60 days in natural environment and 120 and 180 days in cold chamber and hybrid 'Sol do Cerrado' seeds stored for 180 days

in natural environment showed no significant difference regardless of altitude (Table 5).

Seedlings from hybrid 'Gigante Amarelo' seeds grown at 711 and 1016 meters of altitude stored for 60 days in natural environment and cold chamber and for 120 days stored in natural environment, derived from seeds grown at 711 meters stored for 180 days in natural environment and chamber cold, and seeds grown at 1016 meters of altitude stored for 120 days in cold chamber, showed the highest average shoot length values (Table 5).

Seedlings from hybrid 'Rubi do Cerrado' seeds grown at 1016 and 104 meters of altitude at time zero, at 1016 and 711 meters stored for 120 days in natural environment and 60 days in cold chamber and at 1016 meters stored for 180 days showed the highest average shoot length values (Table 5).

Seedlings from hybrid 'Sol do Cerrado' seeds grown at 104 and 711 meters of altitude stored for 120 days in natural environment and those grown at 1016 and 711 meters stored for 60 days in cold chamber showed the highest average shoot length values (Table 5).

The shoot length of seedlings from hybrid 'Gigante Amarelo' seeds cultivated at the three altitudes and stored in natural environment and cold chamber increased after 60 days of storage, with a decrease after 120 days of storage. Similar behavior was observed for hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds, without; however, significant difference from those grown at 1016 meters of altitude and stored for 60 days in natural environment (Figure 3A and 3B).

The root length of seedlings from seeds grown at 711 and 1016 meters of altitude, not stored, did not show significant difference, regardless of hybrid under study. However, hybrid 'Gigante Amarelo' seeds grown at 104 meters of altitude presented lower average root length values (Table 6).

Seeds grown at 1016 meters stored for 60 days in natural environment and hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds stored for 120 and 180 days in natural environment and hybrid 'Rubi do Cerrado' seeds had higher average root length. However, when stored in cold chamber for 60 and 120 days, the highest average root length values were found for hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds, and with 180 days of storage for hybrid 'Rubi do Cerrado' seeds (Table 6).

Seeds grown at 104 meters with 60 days of storage in natural environment showed higher average root length values when from 'Rubi do Cerrado' and

Table 5 - Length of the aerial part (cm) of seedlings from seeds of yellow passion fruit BRS hybrids (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in natural environment and cold chamber for 180 days

Time (days)	Hybrids BRS	Storage environments and cultivation Altitudes (m)					
		Natural environment			Cold chamber		
		104	711	1016	104	711	1016
0	GA	4.7 baA ⁽¹⁾	5.1 acA	5.8 abA	4.7 babA	5.1 abA	5.8 abA
0	RC	6.1 aabAB	5.0 abB	6.4 abA	6.1 aaAB	5.0 abB	6.4 abA
0	SC	7.0 aabA	6.0 abA	6.2 abA	7.0 aaA	6.0 abA	6.2 acA
60	GA	6.0baB	8.8 aaA	8.5 aaA	6.0 aaB	7.6 aaA	8.1 aaA
60	RC	7.4 aaA	7.2 baA	7.7 aabA	6.8 aaB	7.4 aaAB	8.3 aaA
60	SC	7.2 ababA	7.5 abaA	8.5 aaA	6.9 aaB	7.4 aaAB	8.2 aaA
120	GA	6.2 baB	9.2 aaA	8.6 aaA	5.6 cabC	7.8 aaB	9.1 aaA
120	RC	6.6 babB	7.2 baAB	8.4 aaA	6.9 baA	7.8 aaA	8.0 abaA
120	SC	8.0 aaA	7.2 babAB	6.5 bbB	8.1 aaA	8.3 aaA	7.9 babA
180	GA	3.0 bbC	6.8 abA	4.5 bbB	4.4 cbB	7.1 aaA	5.1 bbB
180	RC	5.7 abB	3.7 bbC	7.8 aabA	6.0 baA	5.0 bbA	6.1 abbA
180	SC	6.2 abA	6.6 aabA	7.3 aabA	7.4 aaA	7.4 aaA	6.6 abcA

⁽¹⁾Means followed by the same letter, lowercase between different hybrids within each altitude and time, lowercase italicized between the same hybrid at different times, and capital letters between different locations within each hybrid and time, do not differ between si at a 5% level, by Tukey's test.

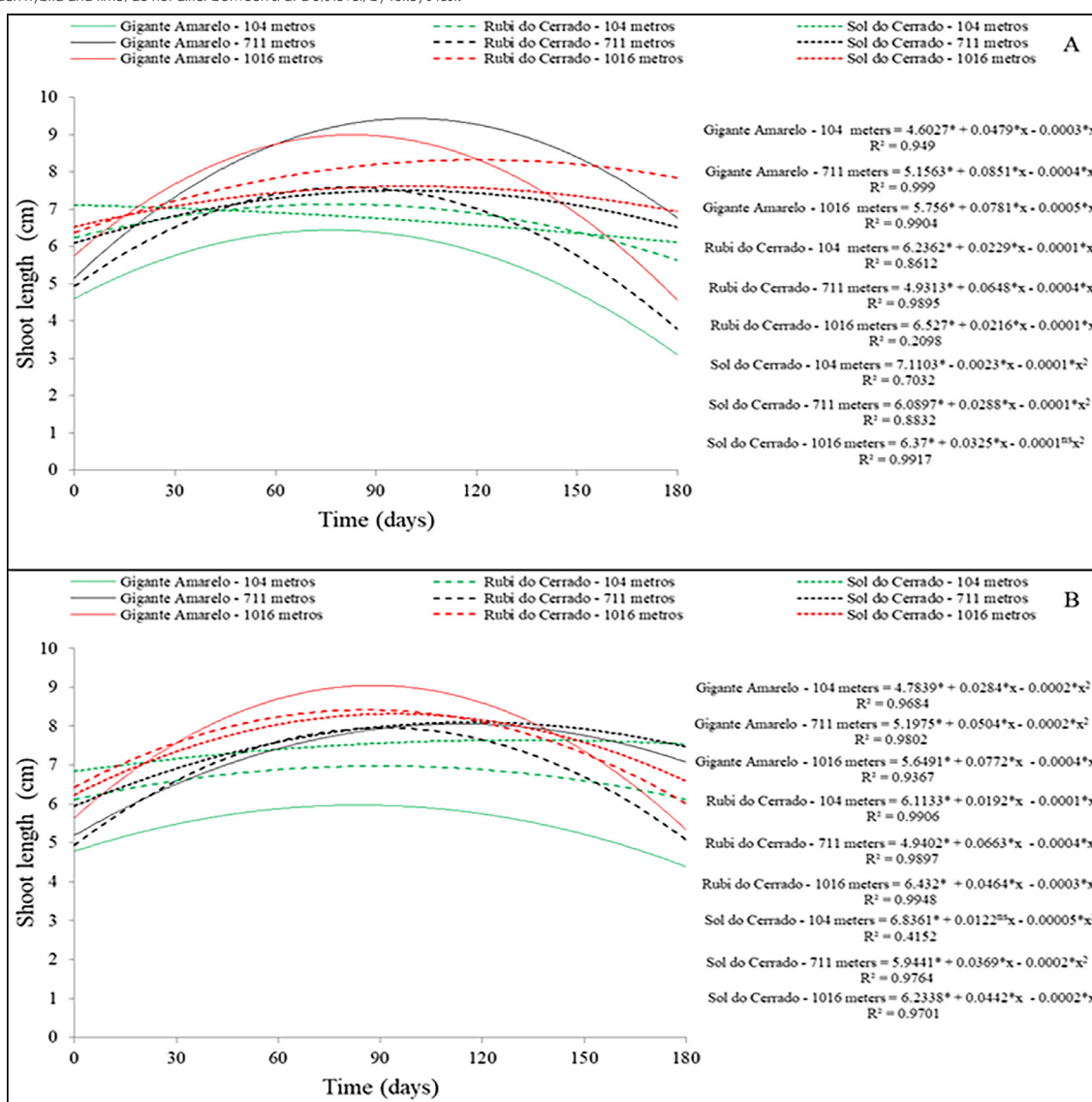


Figure 3 - Regressions obtained for the shoot length (cm), referring to the splitting of the factorial between the seeds of BRS yellow passion fruit hybrids grown at different altitudes and stored in natural (A) and cold chamber (B) environments. *Significant at the 5% level of probability; ^{ns} not significant. R² = coefficient of determination of the regression fit.

Table 6 - Root length (cm) of seedlings from BRS yellow passion fruit hybrids seeds (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in natural environment and cold chamber for 180 days

Time (days)	Hybrids BRS	Storage environments and cultivation Altitudes (m)					
		Natural environment			Cold chamber		
		104	711	1016	104	711	1016
0	GA	2.8 bbAB ⁽¹⁾	2.7 aabB	3.6 abA	2.8 bbA	2.7 abA	3.6 abA
0	RC	3.9 abA	2.7 aabB	4.0 abA	3.9 acA	2.7 aabB	4.0 acA
0	SC	4.7 aaA	2.3 acC	3.8 aabB	4.7 abA	2.3 acC	3.8 acB
60	GA	3.8 baB	4.5 baAB	5.3 aaA	4.7 aaA	4.6 aaA	4.9 baA
60	RC	5.0 aaA	3.2 caB	5.3 aaA	4.9 aabB	3.6 baC	5.9 aaA
60	SC	5.1 aaA	5.4 aaA	4.1 baB	4.4 abB	4.9 abAB	5.3 abaA
120	GA	3.1 babA	3.9 aaA	3.1 bbA	3.7 abA	4.4 aaA	3.6 bbA
120	RC	3.6 abbB	2.4 babC	5.0 aaA	4.5 abcA	2.6 bbB	4.7 abcA
120	SC	4.4 aaA	4.7 aaA	2.9 bbB	4.3 abA	4.7 abA	4.0 abcA
180	GA	2.3 cbB	4.3 aaA	2.9 bbB	3.1 bbB	4.9 baA	4.3 aabA
180	RC	4.1 babA	1.8 bbB	4.6 aabA	5.0 aaA	2.1 cbB	5.0 aabA
180	SC	5.2 aaA	3.6 abB	3.7 aabB	5.8 aaA	6.1 aaA	4.8 aabB

⁽¹⁾Means followed by the same letter, lowercase between different hybrids within each altitude and time, lowercase italicized between the same hybrid at different times, and capital letters between different locations within each hybrid and time, do not differ between si at a 5% level, by Tukey's test.

'Sol do Cerrado' hybrids; however, when stored in cold chamber for 60 and 120 days, they did not show significant difference regardless of hybrid under study. Seeds stored for 120 days in natural environment and 180 days in cold chamber showed higher average root length values when from 'Rubi do Cerrado' and 'Sol do Cerrado' hybrids; however, seeds from 'Sol do Cerrado' hybrid stored for 180 days in natural environment and cold chamber showed higher average root length values when grown at 104 meters and 711 meters of altitude, respectively (Table 6).

Seeds grown at 711 meters and stored for 60 days in natural environment, from 'Sol do Cerrado' hybrid, and stored for 120 and 180 days in natural environment and 60 and 120 days in cold chamber from 'Gigante Amarelo' and 'Sol do Cerrado' hybrids showed the highest average root length values (Table 6).

Seedlings from hybrid 'Gigante Amarelo' seeds, not stored, stored for 60 days in natural environment and 180 days in cold chamber, showed higher average root length values when grown at 711 and 1016 meters; however, when stored for 120 days in natural and cold chamber and for 60 days in cold chamber, seeds showed no significant difference regardless of altitude (Table 6).

Seedlings from hybrid 'Rubi do Cerrado' seeds grown at 104 and 1016 meters not stored, stored for 60 and 180 days in natural environment and 120 and 180 days in cold chamber, showed the highest average root length values; however, when stored for 120 days in natural environment and 60 days in cold chamber, the highest average root length values were obtained for seeds grown at 1016 meters of altitude (Table 6).

Seedlings from hybrid 'Sol do Cerrado' seeds, not stored and stored for 180 days in natural environment,

showed higher average root length values when grown at 104 meters; however, when stored for 60 and 120 days in natural environment and 180 days in cold chamber, the highest average values were obtained for seeds grown at 104 and 711 meters of altitude. Seeds stored in cold chamber for 60 days showed higher average root length values when grown at 711 and 1016 meters; when stored for 120 days, there was no significant difference regardless of altitude, suggesting that seeds can be stored for this period without reduction in their physiological quality, corroborating results obtained by Carlesso et al. (2008) (Table 6).

The root length of hybrid 'Gigante Amarelo' seeds stored in natural environment and in cold chamber grown at 104 and 1016 meters of altitude showed increase after 60 days and reduction after 120 days of storage; however, while seedlings from seeds grown at 711 meters, the average values increased over the days of storage (**Figure 4A** and **4B**). The same root length behavior was observed for hybrid 'Rubi do Cerrado' seeds when stored in natural environment, and when stored in cold chamber and for seeds grown at 104 and 1016 meters of altitude, the average increased over the days of storage, contrasting with seedlings from fruits grown at 711 meters of altitude, which showed decrease after 120 days of storage.

The root length of hybrid 'Sol do Cerrado' seeds cultivated at 104 and 1016 meters of altitude showed increase after 120 days of storage in natural environment, and when cultivated at 711 meters, values increased after time zero and reduced after 60 days of storage. When stored in cold chamber and cultivated at 711 and 1016 meters of altitude, seeds showed increase after 60 days and reduction after 120 days of storage; however,

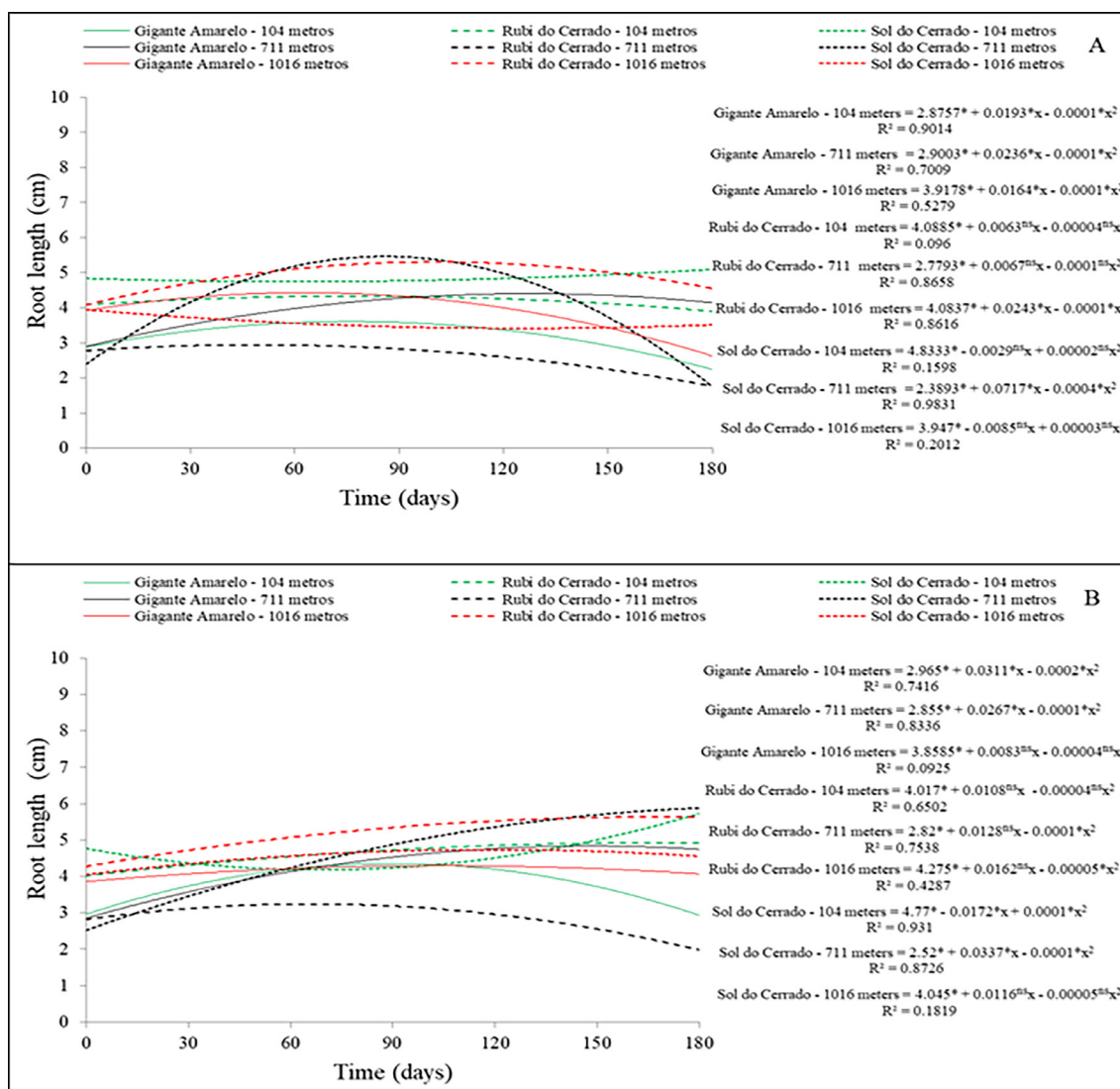


Figure 4 - Regressions obtained for root length (cm), referring to the splitting of the factorial between the seeds of BRS hybrids of yellow passion fruit cultivated at different altitudes and stored in natural (A) and cold chamber (B) environments. *Significant at the 5% level of probability; ^{ns} not significant. R² = coefficient of determination of the regression fit.

when cultivated at 104 meters, there was an increase in the average root length values after 60 days of storage, culminating in the highest average values after 180 days of storage. According to Carlesso et al. (2008), when packaged in glass and polyethylene containers, yellow passion fruit seedlings preserve their physiological quality and vigor for periods of 90 and 180 days.

According to (Table 7), no interaction between hybrids, altitudes and storage times was observed.

Seedlings from hybrid 'Rubi do Cerrado' seeds grown at 104 and 711 meters of altitude, stored in natural environment for 120 and 180 days, showed higher average dry mass values.

The dry mass of seedlings from seeds of the three hybrids under study, recently harvested, did not present significant difference in relation to altitudes they were grown (Table 8).

Table 7 - Dry mass (mg) of seedlings from seeds of yellow passion fruit BRS hybrids (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in natural environment after 180 days

Hybrids	Dry mass (mg)
Gigante Amarelo	6.6 b ⁽¹⁾
Rubi do Cerrado	6.9 a
Sol do Cerrado	6.5 b
Altitudes (m)	Dry mass (mg)
104	6.9 a
711	7.0 a
1016	6.2 b
Time (days)	Dry mass (mg)
0	5.8 c
60	6.6 b
120	7.0 a
180	7.3 a

⁽¹⁾ Means followed by the same lowercase letter in the column do not differ from each other at a 5% level, according to Tukey's test.

Table 8 - Dry mass (mg) of seedlings from BRS yellow passion fruit hybrid seeds (Gigante Amarelo, Rubi do Cerrado and Sol do Cerrado), from fruits at three altitudes (104; 711 and 1016 meters), stored in a cold chamber for 180 days

Time (days)	Hybrids BRS	Storage environments and cultivation Altitudes (m)		
		Cold chamber		
		104	711	1016
0	Gigante Amarelo	5.70 aAB ⁽¹⁾	6.13 aA	5.00 aB
0	Rubi do Cerrado	6.50 aA	6.20 aAB	5.50 aB
0	Sol do Cerrado	5.87 aAB	6.10 aA	5.13 aB
60	Gigante Amarelo	6.97 aA	6.40 bA	6.67 aA
60	Rubi do Cerrado	6.63 abB	7.73 aA	6.03 aB
60	Sol do Cerrado	5.93 bA	6.73 bA	6.30 aA
120	Gigante Amarelo	7.07 aA	7.47 aA	7.10 aA
120	Rubi do Cerrado	7.47 aAB	8.00 aA	6.70 abB
120	Sol do Cerrado	7.10 aA	7.30 aA	6.13 bB
180	Gigante Amarelo	7.63 aA	7.47 bA	6.47 bB
180	Rubi do Cerrado	8.17 aA	8.43 aA	6.73 abB
180	Sol do Cerrado	7.37 aA	7.47 bA	7.53 aA

⁽¹⁾Means followed by the same lowercase letter between the different hybrids within each altitude and time and the capital letters between the different locations within each hybrid and time, do not differ from each other at the 5% level, by Tukey's test.

Considering seed storage, seedlings from seeds of the three hybrids with 180 days of storage in cold chamber, grown at 104 meters of altitude, from 'Rubi do Cerrado' and 'Sol do Cerrado' hybrids grown at 1016 meters and from 'Rubi do Cerrado' hybrid grown at 711 meters of altitude presented the highest average dry mass values.

Seedlings from seeds of the three hybrids cultivated at 104 and 711 meters of altitude, at time zero, showed higher average dry mass values. Hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds, after 60 days of storage, showed no significant difference in relation to altitudes they were grown. However, seedlings from hybrid 'Rubi do Cerrado' seeds cultivated at 711 meters of altitude had higher average dry mass values. Seedlings from hybrid 'Gigante Amarelo' seeds stored for 120 days did not show significant difference regardless of altitude, but the average dry mass value of seedlings from hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds cultivated at 104 and 711 meters of altitude were higher.

According to (Figure 5A), seedlings derived from seeds of the three hybrids showed higher average dry mass values as the number of days of storage increased, reaching higher averages after 120 days of storage in natural environment. Regarding the three hybrids under study, seedlings from hybrid 'Rubi do Cerrado' seeds had significantly higher dry mass values than those from hybrid 'Gigante Amarelo' and 'Sol do Cerrado' seeds.

According to (Figure 5B), seedlings from hybrid 'Gigante Amarelo' seeds cultivated at 1016 meters of altitude showed increase in dry mass after 60 days of storage, and reduction after 120 days, differing from seedlings from seeds cultivated at 104 and 711 meters of altitude, which presented higher average dry mass

values with increasing storage days.

Seedlings from hybrid 'Rubi do Cerrado' and 'Sol do Cerrado' seeds cultivated at the three altitudes showed higher average dry mass values with increasing storage days. For all hybrids, seeds not submitted to storage showed lower average seedling dry mass values, a behavior similar to that observed for sugar apple seeds (Morais et al., 2014).

Conclusions

Hybrid *Passiflora edulis* Sims. f. *flavicarpa* Deg. seeds can be stored in natural environment or cold chamber.

Hybrid *Passiflora edulis* Sims. f. *flavicarpa* Deg. seeds grown at altitudes of 104 and 711 meters have higher germination and vigor percentages.

Hybrid 'Gigante Amarelo' seeds had lower average values for variables under study, regardless of altitude they were grown.

Hybrid 'Rubi do Cerrado' seeds cultivated at 1016 meters show higher germination and vigor percentages and can be stored for 180 days in natural environment or in cold chamber without viability loss.

Hybrid 'Sol do Cerrado' seeds grown at 104 and 711 meters have higher germination and vigor percentages, and can be stored for 180 days in natural environment or cold chamber without viability loss.

Thanks

The authors would like to thank the Federal University of Espírito Santo for providing facilities and equipment available for research; to the Coordination for the Improvement of Higher Education Personnel (CAPES) for the doctoral scholarship to the first author and to

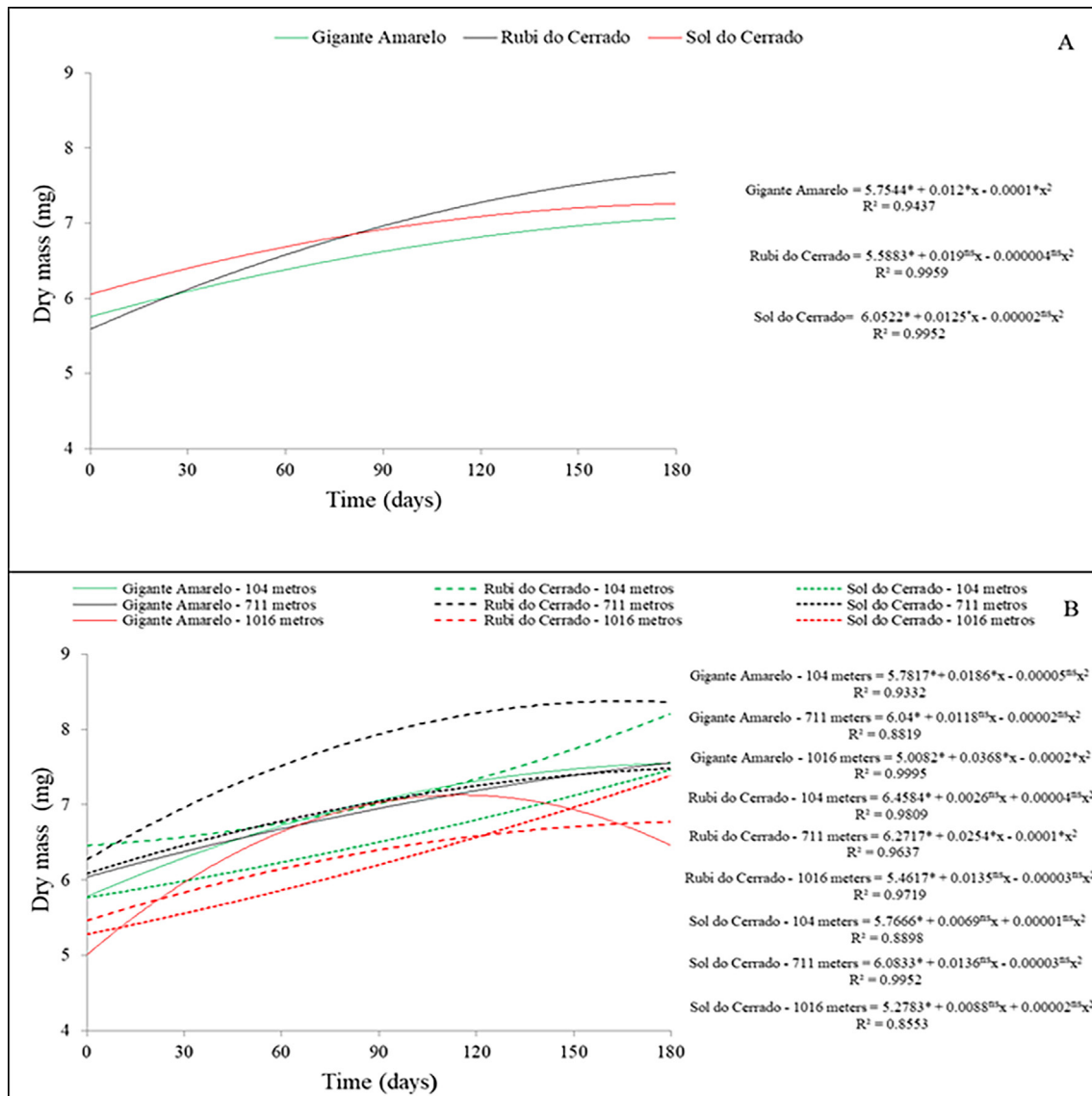


Figure 5 - Regressions obtained for dry mass (mg), referring to the splitting of the factorial between the seeds of BRS hybrids of yellow passion fruit cultivated at different altitudes and stored in natural environments (A) and cold chamber (B). *Significant at the 5% level of probability; ^{ns} not significant. R^2 = coefficient of determination of the regression fit.

the National Council for Scientific and Technological Development (CNPq), for financial support and research productivity grants to the fourth and last author, respectively; to Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES), for granting the research fee to the last author (Edital FAPES n° 19/2018 – Research fee - Process FAPES n° 82195510).

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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