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Esverdeamento pós-colheita de tubérculos de batata: efeito de época de plantio e cultivar

Greening of potato tubers after harvest: effect of planting date and cultivar

Enverdecimento poscosecha de tubérculos de papa: efecto de la época de siembra e cultivar

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Resumo

As diferentes épocas de plantio da batata na região Sul do Brasil possuem fatores climáticos distintos que afetam a produtividade e a qualidade dos tubérculos produzidos. O objetivo deste trabalho foi testar o efeito de épocas de plantio e de cultivares de batata no esverdeamento de tubérculos em pós-colheita. Os tratamentos consistiram de três épocas de plantio (outubro, dezembro e fevereiro) e três cultivares de batata (Ágata, BRS Clara e BRS F63 Camila). Observou-se que os tubérculos colhidos em fevereiro foram menos suscetíveis ao esverdeamento inicial, provavelmente devido à maior maturidade fisiológica dos tubérculos produzidos nessa época. Tubérculos da cv. BRS Clara tiveram menor esverdeamento que tubérculos das demais cultivares. Além das condições de luz, a cultivar e a temperatura do ar no armazenamento também são fatores importantes que afetam as taxas de esverdeamento. Deve-se ter cuidado com esses fatores para evitar perdas de tubérculos por esverdeamento.

Palavras-chave: Armazenamento; Época de colheita; *Solanum tuberosum* L.; Variedade.

Abstract

The different potato planting dates in southern Brazil have different climatic factors that affect the yield and quality of the tubers produced. The objective of this work was to test the effect of planting date and potato cultivars on the postharvest greening of tubers. The treatments consisted of three planting dates (October, December, and February) and three potato cultivars (Agata, BRS Clara, and BRS F63 Camila). It was observed that the tubers harvested in February were less susceptible to greening, probably due to the higher physiological maturity of the tubers produced in this planting date. Tubers of cv. BRS Clara had lower greening than the tubers of the other cultivars. In addition to the light conditions, the cultivar and storage air temperature are also important factors that affect greening rates. Care must be taken with these factors to avoid losses of tubers by greening.

Keywords: Harvest date, *Solanum tuberosum* L., Storage, Variety.

Resumen

Las diferentes épocas de siembra de la papa em la región sur de Brasil tienen distinctos factores climáticos que afectan la productividad y la calidad de los tubérculos producidos. El objetivo de este trabajo fue evaluar el efecto de las épocas de siembra y de los cultivares de papa em el enverdecimiento de los tubérculos en poscosecha. Los tratamentos consistieron em três épocas de siembra (octubre, diciembre y febrero) y três cultivares de papa (Ágata, BRS Clara y BRS F63 Camila). Se observó que los tubérculos cosechados em febrero eran menos susceptibles al esverdecimiento inicial, probablemente debido a la mayor madurez fisiológica de los tubérculos producidos en ese momento. Tubérculos de la cv. BRS Clara tuvo menos enverdecimiento que los tubérculos de otros cultivares. Además de las condiciones de luz, el cultivar y la temperatura del aire em el almacenamiento también son factores importantes que afectan las tasas de esverdecimiento. Se debe tener cuidado com estos factores para evitar la pérdida de tubérculos por esverdecimiento.

Palabras clave: Almacenamiento, Época de cosecha, *Solanum tuberosum* L., Variedade.

1. Introduction

Potato tubers (*Solanum tuberosum* L.) develop green pigmentation in their periderm, called "greening" when exposed to light. This greening occurs due to the transformation of amyloplasts into chloroplasts and may occur in tubers already harvested or during their development in the field (Ali, 1993; Zhu et al., 1984). Exposure time, light quality and intensity, air temperature, and cultivars are factors that contribute to turning potato tubers green in post-harvest (Mekapogu et al., 2016; Tanios et al., 2018). Exposure to light also induces the synthesis of glycoalkaloids in the tubers, especially solanine (Haase, 2010). When in high concentrations, solanine gives the tubers a bitter taste and can cause food poisoning when ingested in large quantities (De et al., 1988). In addition, greening is one of the main post-harvest problems leading to loss of market value and the disposal of potato tubers (Olsen et al., 2018).

Studies conducted abroad show that immature tubers exposed to light are more prone to greening than mature tubers (Tanios et al., 2018). This degree of greening is also dependent on the cultivar and the environment in which it is grown, as greening rates are influenced by the physiological state of the tuber at harvest and at the time of exposure to light (Yamaguchi et al., 1960). The greening of the post-harvest tubers can be affected not only by cultivar and exposure to light but also by the storage time and physiological age of the tubers (Griffiths et al., 1994).

Most of the studies of potato tuber greening conducted in Brazil compare the performance of potato genotypes (Brune & Melo, 2001; Castro et al., 1982; Eschemback et al., 2014; Evangelista et al., 2011; Feltran et al., 2004; Fernandes et al., 2011; Spoladore et al., 1983). Some of these studies also studied the methodology for greening measurement (Brune & Melo, 2001; Feltran et al., 2004). Costa et al. (2017), in one of the rare national studies on the effect of management on the greening of potato tubers, concluded that succession with Tanzania grass under no-till resulted in a lower incidence of the greening of tubers in the field when compared to succession with corn under conventional tillage.

Potato planting date results in varying climatic conditions that consequently affect the characteristics of the tubers that are produced. The primary planting season is the spring planting, characterized by the growing from August to December, and the autumn planting, cultivated from February to June (Pereira & Daniels, 2003). These planting dates have distinct environmental factors that directly influence the physiology of the plants and affect the development of the tubers (Eschemback et al., 2019), which may limit the yield potential and quality of the tubers produced. There is little work done in Brazil quantifying the effect of the planting date and cultivar on the greening of potato tuber.

The objective of this study was to test the effect of planting date and cultivars on post-harvest greening of potato tuber.

2. Material and Methods

This study used both field and laboratory researches (Pereira et al., 2018). The nature of the work was quantitative.

2.1 Field experiment

The experiments were conducted at the Midwestern Parana State University, UNICENTRO, in Guarapuava, PR (25° 23' 04" S and 51° 29' 36' 'W), in the crop season 2015/16. The soil is classified as Latossolo Bruno distrófico (Embrapa, 2018).

The treatments consisted of three planting dates (October, December, and February) and three potato cultivars (Ágata, BRS Clara, and BRS F63 Camila). The experimental design was done in completely randomized blocks in a split-plot scheme, with the planting date being allocated to the plot, and the cultivars in the subplots, with three repetitions. The experiments, in the three planting dates, were implanted in the same area. Each subplot measured 8.0 x 4.5 m and was composed of 10 rows, with 18 plants each, spaced 0.80 m between the rows and 0.25 m between plants. The useful area of the plot was 14.4 m^2 (72 plants).

The seed-tubers of the three cultivars were type III (30 and 40 mm), being standardized regarding physiological age, sprouting, and phytosanitary quality. They were kept in cold storage at 4 °C in the dark until approximately 40 days before planting in all planting dates.

Soil preparation took place one month before the planting of the crop, being performed conventionally with desiccation, one subsoiling, and two harrowings. A light harrowing with a subsequent furrowing was performed in the area for each planting date. The compound fertilizer NPK 04-14-08 was manually distributed in the total area at 4 t ha^{-1} (Queiroz et al., 2013) directly in the furrow before planting the seed-tubers.

The hilling was performed mechanically, approximately 15 days after plant emergence (DAE), for all plating dates (approximately 35 days after planting). Phytosanitary management followed the technical recommendations for the crop in the region (Pereira & Daniels, 2003). No irrigation system was used.

Rainfall and air temperature (maximum, average, and minimum) data during the experiment period were obtained from the Sistema Meteorológico do Paraná (SIMEPAR) (Simepar, 2020), whose meteorological station was located about 100 m from the site where the field experiment was conducted.

Plant emergence was defined when 75% of the plant emerged. It was done by counting the number of plants per plot at intervals of 2 to 3 days. The senescence accounted for when 75% of the plants turned yellow. The growth period was determined as the interval between emergence and the senescence of the plants.

At 15, 30, 45, and 60 DAE, stages of tuber initiation, flowering, maximum shoot growth, and tuber bulking, respectively, the number of initiated tubers of 4 plants per plot in the 4 central rows was quantified. Initiated tubers were those twice the diameter of the stolon but less than 1 cm in diameter.

2.2 Laboratory measurements

The tubers of 12 plants per plot were collected. Three plants from each row were collected manually from the four central rows after senescence, and the tubers were harvested, and divided into two categories: total tuber and marketable tuber (tubers > 45 mm diameter).

For evaluation of the post-harvest greening of the tubers, we adapted the methodology used by Tanios et al. (2020). It was randomly selected three marketable tubers (between 160 and 180 g) from each subplot at each planting date. These tubers were washed and exposed for 35 days under constant fluorescent light on the laboratory bench. The light intensity was measured with a luximeter on the bench where the tubers were placed. These measurements were done at four points on the bench and ranged from 413 to 547 lux.

The greening intensity assessments were performed after 7, 14, 21, 28, and 35 days of tuber exposure to light. The quantification of greening was performed by scoring each plot of three tubers according to the scale: score 1 (complete absence of greening), 3 (low greening), 5 (medium greening), 7 (strong greening) and 9 (very strong greening) according to the methodology proposed by Brune & Melo (2001). The experimental design of the laboratory experiment was completely randomized, with three repetitions, being the experimental unit formed by a tuber.

2.3 Statistical analysis

The Shapiro-Wilk test of normality was applied, and the data referring to the values of the greening notes went through the square root transformation. The analysis of variance (ANOVA) and Tukey's mean comparison test ($p < 0.05$) were performed. When there was a significant interaction of the data, the result of the interaction was presented as a figure.

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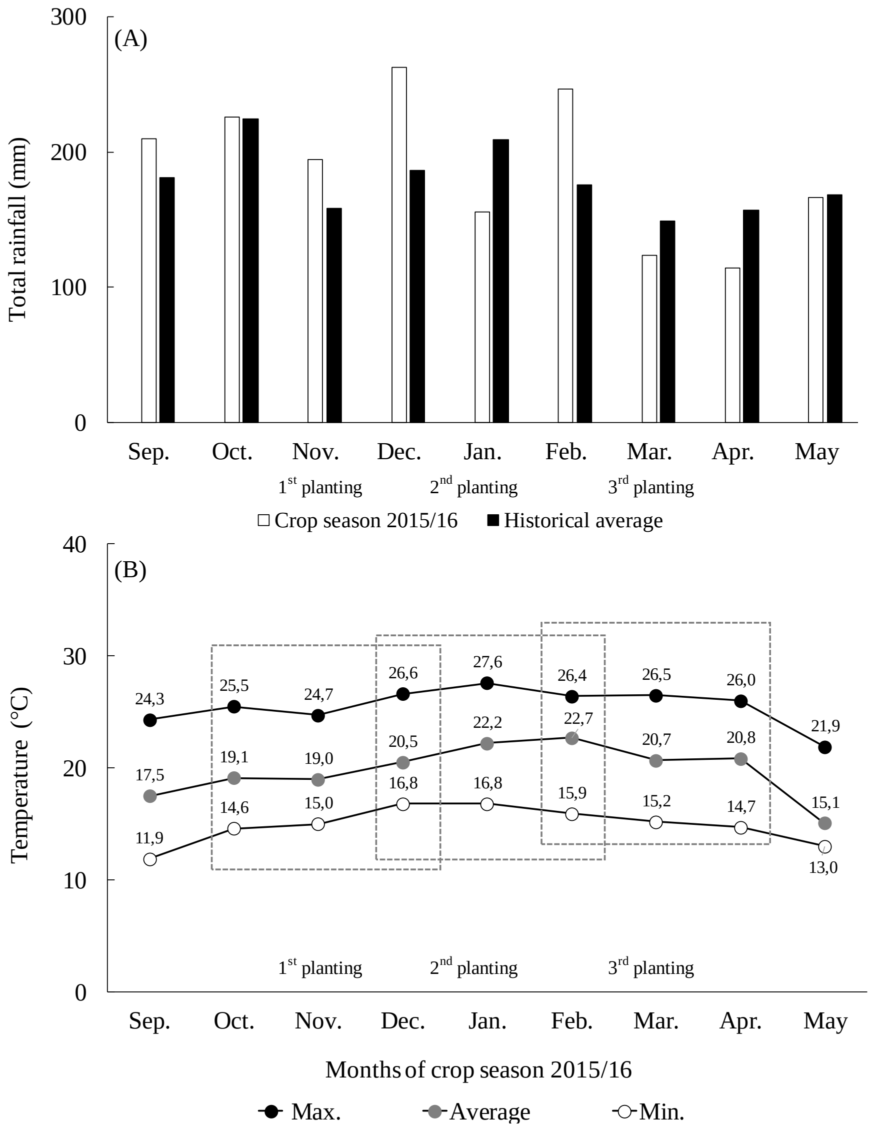
3. Results and Discussion

It was observed that in the crop season 2015/16, there was a total rainfall of 1,632 mm (Figure 1A). In the third planting date, there was lower rainfall (484 mm) compared to the first (642) and second (629) planting dates. In March and April, we observed the lowest rainfall, which is lower than the historical average for these months. In the first planting date, an average air temperature of 19.1 °C was observed at the time of planting, while in the second planting date, an increase in air temperature was observed in the first planting date: 20.5 °C (Figure 1B). In the third planting date, the increase in temperature was even higher, with an average temperature of 22.7 °C at the time of planting.

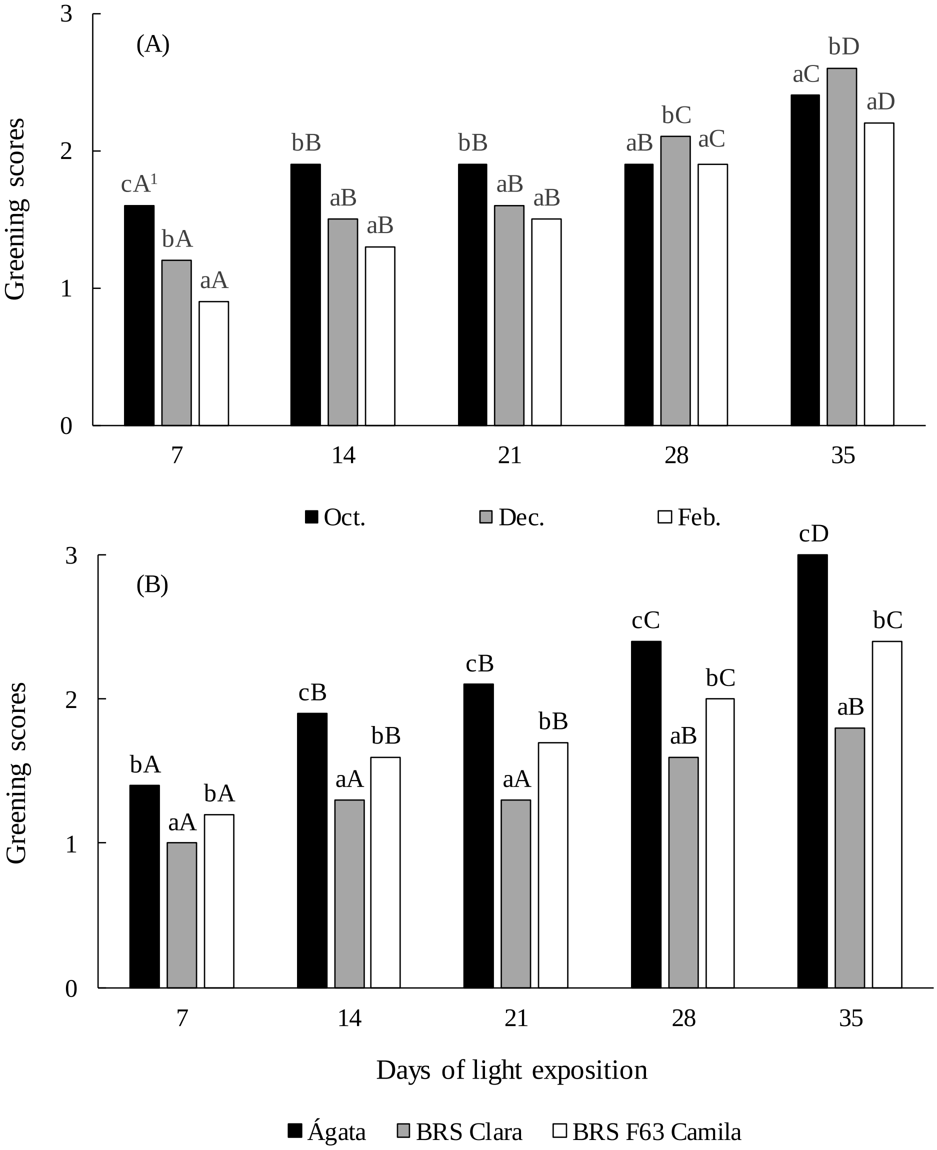
Figure 1. Total rainfall (mm) (A) and air temperature (°C) (B), for the planting dates and tuber greening in the crop season 2015/16.



Source: Simepar (2020). Historical average: 1986~2015.

We did not observe significant interactions among planting date, cultivar, and day of light exposition for greening scores (Figure 2). However, significant interaction for greening was observed between planting date and days of light exposure, and between cultivar and days of exposure.

Figure 2. Greening scores of tubers harvested from plants planted in different dates (A) from different cultivars (B), submitted to days of the light exposition.



Anova significance:
Planting date (P): **; Cultivar (C): **; Days of light exposition (D): **; PxC: ns;
PxD: **; **CxD: ****; PxCxD: ns

Scores: 1 (no greening at all), 3 (slight greening), 5 (middle greening), 7 (strong greening), and 9 (very strong greening).
[1]Means followed by the same lower-case letters in each day of the light exposition, and capital letters in each cultivar do not differ significantly by the Tukey test ($p<0.05$).

The tubers harvested in the third planting date had slower greening than those harvested in the first and second planting dates, especially at the beginning of light exposure (Figure 2A). In addition, the tubers produced at all three planting dates started to turn green as they were kept under the light. Similar results were observed in other studies, reporting that the tubers show constant greening with the advancement in light exposure time, and that greening begins on the first day of post-harvest light exposure when the amyloplasts already begin to turn into chloroplasts (Brune & Melo, 2001; Evangelista et al., 2011; Grunenfelder et al., 2006). Our data shows that planting date affected tuber greening and cultivars had different greening depending on the planting date.

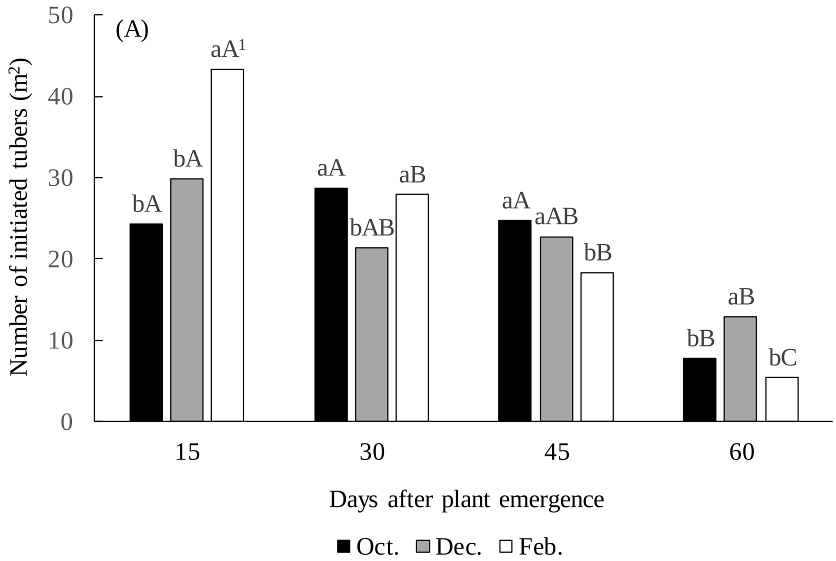
It was found that tubers harvested in winter and early spring were more susceptible to greening than those harvested in late spring and autumn (Yamaguchi et al., 1960). This fact seems to be related to the immaturity of the skin of the tubers harvested in winter and in spring, which comprises the first and second planting dates of the present work, compared to those tubers harvested in the fall, which comprises the third planting date, tubers with well-developed skin. The greening occurs due to the synthesis of chlorophyll in the cortex, tissue of the parenchyma situated below the periderm of the tubers (Tanios et al., 2018). Well-developed skin in tubers harvested in autumn (higher air temperature period), can serve as a physical barrier to light, decreasing the incidence and synthesis of chlorophyll below the periderm.

The effect of the maturity of the tubers at harvest, and the quality of the skin on the incidence of greening, has still been inconsistent (Tanios et al., 2018). If this is the case, the time of drying of the stems and the length of the storage period become additional factors, besides light and air temperature, which influence the post-harvest greening rates of the tubers (Bamberg et al., 2015). Early desiccation may result in faster greening of the tubers due to a reduction in the growth period and the maturity of the tubers' skin.

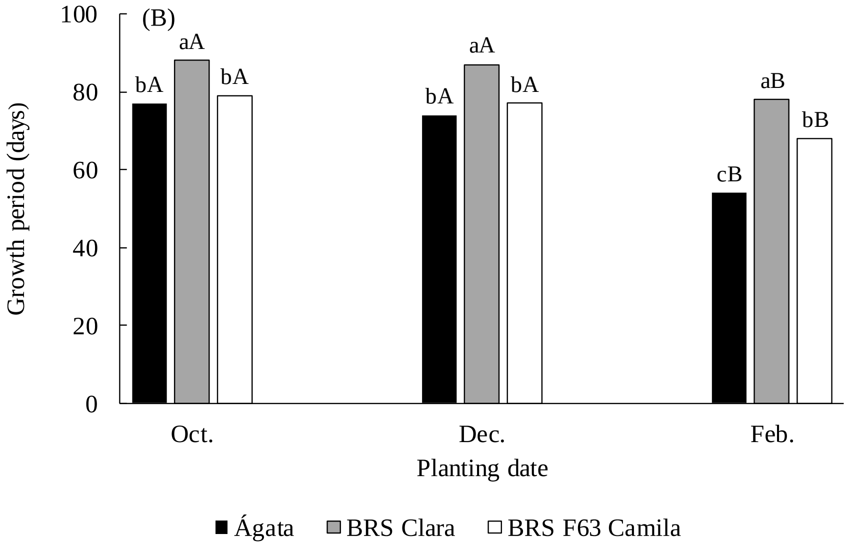
Tubers of cultivar BRS Clara were more tolerant against greening, with a significant difference already in the first week of light exposure (Figure 2B). The ‘Agata’ and ‘BRS F63 Camilla’ tubers were more susceptible to greening at 7 days of light exposure, and from the second week (14 days) on, the ‘Agata’ tubers had a higher increase in greening than the other cultivars. From 14 days of light exposure, the tubers of ‘BRS F63 Camila’ had intermediate greening. This difference in tolerance to greening among cultivars is in line with other studies that report a difference in the intensity of greening of tubers when exposed to the same light conditions, and that variations are depending on the cultivar (Brune & Melo, 2001; Castro et al., 1982; Eschemback et al., 2014; Evangelista et al., 2011; Feltran et al., 2004; Fernandes et al., 2011; Grunenfelder et al., 2006; Spoladore et al., 1983).

It was observed that there was an interaction between DAE and the planting date for the number of initiated tubers (Figure 3A).

Figure 3. Number of initiated tubers at four days from plant emergence (A) and the number of days from plant emergence until plant senescence (growth period, B) of plants planted on three different dates.



Anova significance:
Planting date (P): **; Days after plant emergence (D): **; **PxD: **.**



Anova significance:
Planting date (P): **; Cultivar (C): *; **PxC: ****.

[1]Means followed by the same lower-case letters at each days after plant emergence (A) or each planting dates (B), and capital letters in each planting dates (A) or in each cultivar (B) do not differ significantly by the Tukey test ($p<0.05$).

At 15 DAE, the plants of the third planting date produced more tubers compared to the first and second planting dates. At 30 DAE plants in the first and third planting dates produced the same number of tubers, the number of initiated tubers being higher than in the second planting date. However, at 45 and 60 DAE plants in the third planting date had the lowest number of initiated tubers, differing from plants in the first and second planting dates. Plants of the third planting date anticipated the formation of tubers, probably because the temperature was higher at the beginning of the third planting date compared with the first and second planting dates (Figure 1B). High temperatures may also have favored the physiological maturity of the tubers and the firmness of the periderm, as at harvest, these tubers (third planting) were physiologically more mature than those which started later (first and second planting). Indeed, Tanios et al. (2020) concluded that greening was strongly related with an increase of suberin in the potato tuber periderm. Morris et al. (1989) and Thomas (1982) showed that potato tuber periderm occurs most rapidly at 25 °C. Therefore, it can be inferred that the higher temperature that occurred in the third planting date favored the suberin production of the tubers produced in the third planting date and resulted in lower greening of these tubers.

Cultivar Agata, in the third planting date, had the shortest growth period, BRS Clara the longest, and BRS F63 Camila had an intermediate growth period (Figure 3B). The longer growth period was observed for ‘BRS Clara’, in all planting dates, compared to ‘BRS F63 Camila’ and ‘Agata’. The growth period of the cultivars may have influenced the variation in the susceptibility of the tubers to greening. The longer growth period of cultivar BRS Clara may have contributed to better periderm maturity and thus lower sensitivity to greening after harvest. Indeed, Tanios et al. (2020) concluded that resistance to greening was related to increased suberin in the periderm, and this increase in suberin was related to tuber maturity.

The greening of the tubers appears to be related to their physiological maturity, precisely, the suberin production in the periderm. This production, in turn, appears to be maximum at 25 °C, a factor that can be modified by the planting date.

4. Final Considerations

The tubers from February planting and cultivar BRS Clara were less susceptible to greening, probably due to their higher physiological maturity. In addition to light conditions, the cultivar and air temperature in storage are also important factors affecting greening rates. Therefore, greater care should be taken with these factors to avoid losses of tubers by post-harvest greening.

There are still many unclear points about potato tuber greening that deserves detailed studies: e. g., how crop-husbandry like rate of fertilization, especially nitrogen, and planting distance, affect tuber greening. Also, it is important to know why different cultivars have different greening patterns. This information will be useful for potato breeders to launch new cultivars with greening resistance.

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