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Agronomic characterization of strawberry cultivars in substrate during the late planting period in an organic production system

Caracterização agronômica de cultivares de morangueiro em substrato em período de plantio tardio em sistema orgânico de produção

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RESUMO

O cultivo de morangueiro em substrato, está em ascensão, dessa forma, muitos aspectos relacionados com o manejo tem se modificado entre esses está a época de plantio do morangueiro. Dessa forma, objetivo dessa pesquisa foi caracterizar agronomicamente cultivares de morangueiro em substrato em período de plantio tardio em sistema orgânico de produção. As cultivares avaliadas foram ALPINA10 e CAV 56.9 (neutros aos dias) e CAV 107.7 e CAV 107.12 (curtos aos dias). Utilizou-se um delineamento experimental em parcelas subdivididas, com três repetições para cada genótipo. As avaliações incluíram aspectos fenológicos, características das plantas e produção. As plantas da cultivar ALPINA10 apresentam comportamento tardio em todos os aspectos fenológicos avaliados, A ALPINA10 apresentou maior crescimento vegetativo e produtivo em comparação a CAV 56.9. Já a CAV 107.12 apresentou um crescimento mais robusto do que a CAV 107.7. Para as condições de plantio tardio a cultivar de dia neutro ALPINA 10 e de dia curto CAV 107.12 apresentaram maior crescimento vegetativo e produção. Entretanto, devido o período de plantio os valores para todas as cultivares pesquisadas são inferiores não sendo indicado o plantio tardio.

PALAVRAS-CHAVE: *Fragaria x ananassa* Duch; ALPINA10; CAV 56.9; CAV 107.12; CAV 107.7.

ABSTRACT

The cultivation of strawberries in substrate is on the rise, and as a result, many aspects related to management have been modified, including the planting season for strawberries. Therefore, the objective of this research was to agronomically characterize strawberry cultivars in substrate during the late planting period in an organic production system. The evaluated cultivars were ALPINA10 and CAV 56.9 (day-neutral) and CAV 107.7 and CAV 107.12 (short-day). An experimental design was used in split plots, with three replications for each genotype. Evaluations included phenological aspects, plant characteristics, and production. Plants of the ALPINA10 cultivar exhibited late behavior in all evaluated phenological aspects. ALPINA10 showed greater vegetative and productive growth compared to CAV 56.9. On the other hand, CAV 107.12 exhibited more robust growth than CAV 107.7. For late planting conditions, the day-neutral cultivar ALPINA 10 and the short-day cultivar CAV 107.12 showed greater vegetative growth and production. However, due to the planting period, the values for all researched cultivars are lower, indicating that late planting is not recommended.

KEYWORDS: *Fragaria x ananassa* Duch; ALPINA10; CAV 56.9; CAV 107.12; CAV 107.7.

INTRODUCTION

With strawberry production (*Fragaria × ananassa* Duch.) attractive to producers, research into new cultivars is essential to verify the performance of these materials in different environmental conditions in Brazil (SAMPIETRO et al. 2023). These evaluations are also an important tool for advising growers on which strawberry cultivar is suitable for their growing region (WURZ et al. 2021). It's worth noting that these strawberry cultivars are classified based on photoperiod and temperature. Short-day plants are those that flower best during periods with shorter days and temperatures below 15°C, typically in autumn and winter.

Neutral-day cultivars, on the other hand, are not affected by day length for flowering, but rather by temperature, with the ideal being not to exceed 28°C (DIEL et al. 2022, SAMTANI et al. 2019).

Among the new technologies that have encouraged an increase in strawberry cultivation area and production in recent years is soilless substrate cultivation, also known as semi-hydroponic farming (VALMORBIDA et al. 2022). This type of cultivation is generally done in a protected environment, using fertigation and substrate planting systems (OLIVEIRA et al. 2017). In recent years there has been a migration from the in-ground to the out-of-ground system, with 70% of the strawberry production area in the state of Rio Grande do Sul alone being out-of-ground (COCCO et al. 2020). This migration is attributed to the benefits of soilless cultivation, such as eliminating crop rotation, improved ergonomics, reduced disease incidence, earlier harvest times, and increased yield per area (LIZ et al. 2020).

With soilless cultivation in substrate, the planting season, previously determined by cultivar requirements and local soil and climate conditions, has become secondary for many farmers (PEREIRA 2009, SAUSEN et al. 2020). Other factors, such as the setup of the protected environment and the source of seedlings, have become important in determining the planting schedule. This is because 60% of the seedlings come from international nurseries, which often face delivery delays due to logistical issues. Moreover, challenges in acquiring materials for constructing protected environments, combined with some producers' lack of planning, contribute to delayed planting (SCHIAVON et al. 2021a). It should be noted that the strawberry planting season in Brazil is as follows, for short-day cultivars during the months of March to May (SCHMITT et al. 2012, MENDONÇA et al. 2012). For day-neutral materials, planting takes place in June or July (COSTA et al. 2014, ANTUNES et al. 2014).

Another production system that is growing in strawberry cultivation is organic (FIEDLER et al. 2020). This production system aims to reduce the use of chemical inputs, thereby lowering costs and environmental impact, while producing high-quality fruit (KIRINUS et al. 2018). Moreover, there is a growing trend among consumers seeking healthier food options produced without pesticides. Thus, the production measures of the organic system for strawberries have come into play, attracting the interest of consumers and farmers who are looking for health, profitability and the preservation of environmental factors (LEITE et al. 2013).

Strawberry planting time affects the growth and development of the plants (BHATIA et al. 2017, PALOMBINI et al. 2023). Because environmental factors such as temperature, light intensity, photoperiod, humidity and others influence flower induction, the production and number of flowers and fruits as well as their quality and production (RAHMAN et al. 2014). Therefore, research aimed at understanding the consequences of late strawberry planting is essential for the development of this crop in various environments and conditions. Therefore, this study aims to agronomically characterize strawberry cultivars grown in substrate during a late planting period under an organic production system.

MATERIALS AND METHODS

The experiment was conducted at the experimental horticulture area of the Federal University of Southern Frontier (UFFS), located at BR 158, Km 405 (Rural Zone), Laranjeiras do Sul - PR, at coordinates 25°24'28" S 52°24'58" W and an altitude of approximately 840 meters. The Köppen-Geiger climate classification of 1948 places Laranjeiras do Sul in the temperate climate type (Cfb), with average annual temperatures of between 18 and 19 ºC and rainfall of between 1800 and 2000 mm.year^{-1} (CAVIGLIONE et al. 2000).

The experiment was conducted from August 2022 to May 2023, with minimum and maximum temperatures of 9.48 and 30.13 °C, respectively, and a total precipitation of 2403.81 mm (Figure 1) (UFFS 2023).

Four strawberry cultivars were used for the experiment, sourced from the Center for Agroveterinary Sciences (CAV) at the Santa Catarina State University (UDESC). The cultivars used were two short-day varieties called ALPINA10 and CAV 56.9, and two day-neutral varieties identified as CAV 107.7 and CAV 107.12. These materials were given to the Federal University of the Southern Frontier to be used in experiments in the soil and climate conditions of the municipality of Laranjeiras do Sul/PR. The materials were grown in a soilless system using substrate in gutter containers and managed under an organic production system.

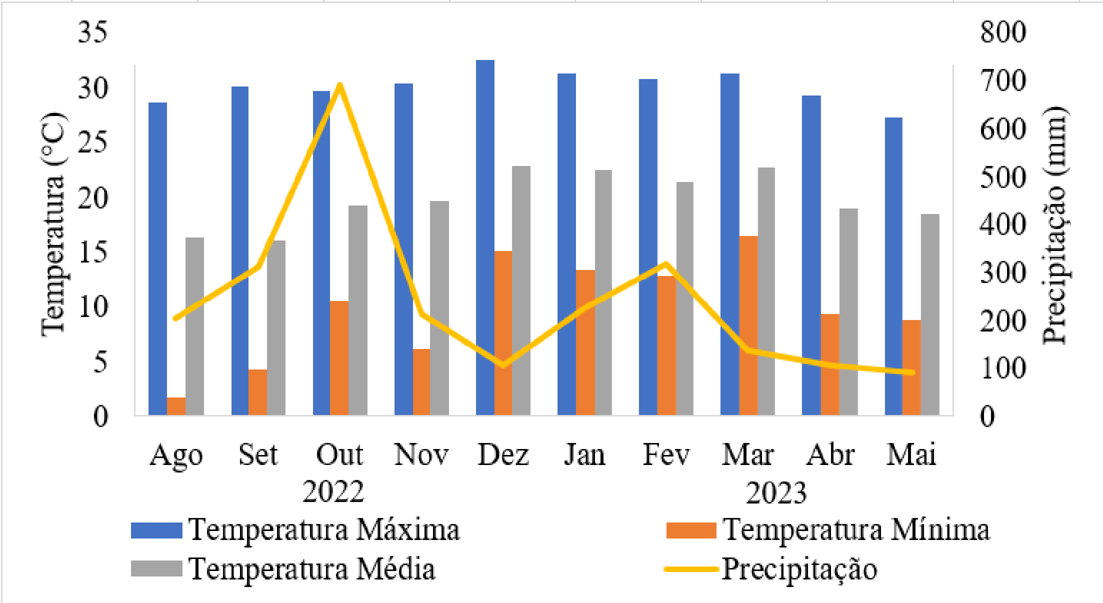

Figure 1. Average rainfall (mm), minimum, average and maximum air temperatures (°C) in the evaluation months of August to December 2022 and January to May 2023, Laranjeiras do Sul-PR. Data obtained from the climate station at UFFS - Laranjeiras do Sul-PR

The experimental design for each pair of cultivars was randomized in split plots, with the main plots representing the cultivars and the subplots representing the evaluation months (August, September, October, November, December, January, February, March, April, and May). For each cultivar, three replications were used, each consisting of 18 plants. The protected environment used for both genotype groups was a greenhouse-type structure measuring 2.5 m in height, 8.0 m in width, and 50.0 m in length.

The container used in the soilless cultivation system was commercial gutters made from recycled carton packaging material, called Calhapak type W (6.00 m long, 0.30 m wide at the top, 0.13 m wide at the base, and 0.20 m high). The gutters were arranged on benches 0.90 m high, with each bench having two gutters spaced 0.40 m apart.

The substrate used was adapted from that recommended by MAZON (2019) for organic strawberry cultivation in soilless substrate systems. This consisted of 31.80% sifted soil, 8.07% vermiculite, 24.84% organic poultry litter compost, 34.78% Tecnomax commercial substrate (class F), composed of vermiculture, pine/eucalyptus bark, ash, coconut fiber, and rice hulls, with 0.49% limestone added. After filling the gutters with substrate, they were covered with black and white plastic mulch film (20 microns thick), with the white side facing up.

The seedlings were planted on August 9, 2022, marking the beginning of the first growing cycle. The plant spacing used was 0.20m.

Drip irrigation was automated, generally set to run three times a day with four-minute pulses. On the hottest days, due to rising temperatures, a fourth irrigation was implemented throughout the day. During the spring and summer seasons, when temperatures were higher and humidity lower, a sprinkler system was installed at the base of the benches, which activates along with the irrigation system.

Fertilization was carried out through a non-recirculating fertigation system. The inputs used were organic farming-approved products, such as biofertilizers, sugarcane molasses, and bokashi compost. The electrical conductivity was kept between 1.1 and 1.2 $dS.cm^{-1}$ during the vegetative growth phase and between 1.5 and 1.8 $dS.cm^{-1}$ during the reproductive phase (ANTUNES et al. 2016). Fertilization was carried out four times a week, depending on weather conditions and plant requirements.

As a control measure for phytophagous insects and plant pathogens, plant protection sprays were applied weekly, such as horsetail (*Equisetum fluviatile* L.) solution at 1%, milk solution at 1%, wheat flour solution at 1%, garlic (*Allium sativum* L.) solution at 1%, among other preparations. Commercial adhesive traps for yellow and blue insects were placed on the benches, with four traps per bench. To repel pest insects and attract natural enemies, repellent and attractive plants such as rue (*Ruta graveolens* L.), chives (*Allium* *schoenoprasum* L.), and lavender (*Lavandula latifolia* Mill.) were planted along the edges of the gutters.

In February, severe pruning of short-day plants was carried out in the second half of the month, while day-neutral plants were pruned in the first half of March. Drastic pruning was carried out based on the recommendations of VIGNOLO et al. (2018).

The evaluations conducted on the plants were divided into phenological assessments, plant characterization, and productivity aspects. Phenological assessments were based on the methodology of ANTUNES et al. (2006). This was considered the beginning of flowering when at least 50% of the plants had an open flower. From this point, the start dates of the parameters were determined, expressed in days for the occurrence of each one: from transplanting to the beginning of flowering (T-F), from the beginning of flowering to the start of harvest (BFSH), from transplanting to the start of harvest (T-SH), and from the beginning of transplanting to the start of stolon emission (T-SS).

Plant characterization assessments were conducted monthly. For short-day genotypes, due to severe pruning, evaluations were not carried out in February. For day-neutral materials, assessments were not done in March. The following factors were evaluated: number of leaves and crowns; plant diameter in millimeters, measured at the base of the plant at substrate level using a digital caliper, considering all crowns; and total chlorophyll content, determined using a Falker Clorofilog CFL 1030 chlorophyll meter on two leaves per plant, with results expressed in FCI (Falker Chlorophyll Index).

The analyses of productive aspects were conducted weekly, examining the number of fruits per plant and fresh fruit mass, which was determined using a digital scale, with results expressed in grams.

The data obtained were subjected to analysis of variance and the differences between means were compared using Tukey's test at a 5% probability level. The evaluations were carried out using the Sisvar 5.6 program (FERREIRA 2011).

RESULTS AND DISCUSSION

For the two day-neutral cultivars studied, it was found that the plants of the cv. ALPINA10, were later for all the phenological aspects evaluated (Table 1). This was observed for both short-day cultivars, where plants from the CAV 107.7 material require more days to begin flowering, produce harvestable fruits, and emit stolons.

The findings of this study regarding phenological parameters associated with the day-neutral genotype ALPINA10 contradict those reported by SAMPIETRO et al. (2023). These authors, working with a day-neutral genotype called CREA FRF 114.01, transplanted during the recommended period for cultivation (June) in soilless culture using substrate in Laranjeiras do Sul, Paraná, with the use of gutters, observed fewer days required to reach each phenological stage. According to these authors, it took 52.08 days for T-F and 59.66 days for T-SS.

When observing the plants derived from the two short-day materials (ALPINA10 and CAV 56.9), it was found that the number of days to reach each phenological stage differs from those identified by MORITZ et al. (2021) in a study carried out in Laranjeiras do Sul/PR. According to these authors, the short-day genotype CREA FRF LAM01, transplanted in May (appropriate planting period), required 103.66 days to start flowering and 32.23 days to begin harvesting, as the suitable planting time provided favorable conditions for plant growth and development.

Table 1. Number of days from transplanting to flowering onset (T-FO), flowering onset to harvest onset (FO-HO), transplanting to harvest onset (T-HO), and transplanting to stolon emergence onset (T-SE) for day-neutral cultivars (ALPINA10 and CAV 56.9) and short-day cultivars (CAV 107.7 and CAV 107.12).

Genotype	T-IF	IF-IC	T-IC	T-IE
ALPINA10	69 a	20 a	89 a	78 a
CAV 56.9	45 b	16 b	61 b	61 b
CV(%)	18,34	10,1	29,3	19
CAV 107.7	44 ns	20 ns	64 ns	73 a
CAV 107.12	42 ns	18 ns	60 ns	62 b
CV(%)	45,68	16,7	20,3	12,4

Averages followed by equal letters do not differ according to Tukey's test at the 5% probability level. *ns not significant.

To begin stolon formation SCHIAVON et al. (2021b) analyzing the day-neutral cultivar Aromas and the short-day cultivar Camarosa, both transplanted at the appropriate time (June for day-neutral and May for short-day) in soilless cultivation in the Pelotas/RS region, identified a greater number of days to initiate stolon emission when compared to the results of this study. These authors observed 223.50 days for the Aromas cultivar and 248.56 days for the Camarosa cultivar.

The results obtained in this study for cultivars ALPINA10 and CAV 56.9 were not within the expected range for the crop, according to ANTUNES et al. (2006), COCCO et al. (2015) Generally, after transplanting, strawberry plants require 20 to 45 days to begin flowering, 45 to 60 days to start producing fruit, and 150 to 210 days to begin producing runners.

For plants to reach each phenological stage, various factors exert influence, such as cultivar/genotype, planting location, and climatic factors, with temperature being particularly significant (ZEIST et al. 2019, BUENO et al. 2002). According to COSTA et al. (2017), temperature has a significant impact on the various phenological stages (leaf development, flowering, fruiting, stolon formation, senescence, and abscission) of strawberry plants. The duration of the vegetative and reproductive periods, as well as the timing of phenological stages, are directly linked to temperature. 2013). These exhibit substantial interannual variability, particularly regarding the timing of transplantation, directly affecting the start and end of the growth period, which corresponds to the period of greatest activity in carbon, water, and nutrient cycling (LOVAISA et al. 2015).

As temperatures rise and days grow longer, short-day strawberry plants produce fewer fruits and more runners (CECATTO et al.). (2013). For day-neutral plants, temperature is the key factor, with high temperatures preventing flowering but promoting vegetative growth. For both short-day and neutral-day plants, the maximum temperatures for flower differentiation are between 21° and 27 °C (OTTO et al. 2009). Long days with approximately 16 hours of light and temperatures around 24°C are required for stolon formation (HEIDE 1977, GUTTRIDGE 1985, RISSEL & NAVATEL 1997).

In this study, the materials were transplanted late, in August, a period when temperatures begin to rise in the study area. Despite this, these factors did not promote early flowering or harvest. However, there was a shorter productive period, as the plants soon began producing runners.

For the evaluations related to plant characterization, there was a statistical interaction between the day-neutral cultivars and the nine months of assessment (Table 2). For these materials, the number of crowns was not statistically significant.

For each evaluation month, the day-neutral cultivar ALPINA10 exhibited plants with a higher number of leaves, diameter, and total chlorophyll. The number of crowns was not significant, but from the second month of evaluation (September 2022) to the seventh month (February 2023), it was also higher compared to the CAV 56.9 cultivar.

Table 2. Number of leaves and crowns, plant diameter (mm), total chlorophyll (CCI), number of fruits per plant, and yield per plant (g) of day-neutral cultivars (ALPINA10 and CAV 56.9) during the nine-month evaluation period.

Months/Years	Number of leaves		Number of crowns		Plant diameter (mm)		Total chlorophyll (IFC)	
2022/ 2023	ALPINA 10	CAV 56.9	ALPINA 10	CAV 56.9	ALPINA 10	CAV 56.9	ALPINA 10	CAV 56.9
Aug	4.40 eA	4.20 eA	1*n.s	1 *n.s.	13.08 gA	9.27 gB	38.40 cA	28.70 cB
Set	28.45 dA	15.44 dB	3	2	19.27 fA	12.44 fB	44.59 bA	38.35 bB
Out	39.44 cA	20.44 cB	3	2	28.10 eA	19.34 eB	48.11 bA	40.24 aA
Nov	52.30 bA	38.20 bB	4	2	35.50 dA	27.98 dB	53.20 aA	44.24 aB
Dec	59.30 aA	44.66 aB	4	3	42.40 cA	39.30 cB	37.20 cA	27.40 cB
Jan	62.10 aA	48.20 aB	5	3	67.30 bA	55.20 bB	37.80 cA	27.50 cB
Feb	62.20 aA	48.50 aB	6	4	74.50 aA	60.40 aB	37.90 cA	27.40 cB
Apr	22.90 dA	15.50 dB	3	3	35.60 dA	30.20 cdA	42.50 bA	34.20 bB
May	32.40 cA	24.10 cB	3	3	46.70 cA	40.20 cA	45.10 bA	37.90 bB
CV(%)	24,59		47,90		16,70		17,34	

Averages followed by the same letters do not differ according to Tukey's test at a 5% probability level, lowercase letters in the column, uppercase letters in the row. Note Drastic pruning carried out in March 2023.

Evaluating the day-neutral cultivar Seascape grown in soil under an organic production system in the Chapecó region of Santa Catarina, VERONA et al. (2007) observed a leaf number of 19.61 leaves per plant. These values are similar to those observed in this study for the CAV 56.9 cultivar, with average values of 28.80 leaves, but differ from those obtained for the ALPINA10 material, which had an average of 40.37 leaves.

The strawberry plant continuously renews its leaves throughout its life cycle, with varying rates depending on the cultivar/genotype. Generally speaking, strawberry leaves have a short lifespan of about two months. Due to this characteristic, the strawberry plant exhibits simultaneous leaf production and senescence throughout much of its productive cycle. 2007).

Regarding the results obtained in this study for plant diameter, they differ from those reported by RICHTER et al. (2017) in the municipality of Lages/SC. These researchers, studying day-neutral cultivars San Andreas, Albion, and Capitola grown in soilless substrate and transplanted at the appropriate planting time, obtained plant diameter values of 29.0, 35.4, and 29.0 mm, respectively. These results surpass those of the study for the ALPINA10 cultivar in the first three months of evaluation, while for the CAV 56.9 material, the diameter values identified by the aforementioned researchers are higher in the initial four months of assessment.

Plant diameter, in the case of strawberry plants characterized by the diameter of the crowns, is an important factor in plant growth and development because it is where the reserve substances that act during vegetative growth are stored (SAMPIETRO et al. 2023). In this study, the initial plant diameter observed in the first month of evaluation (August 2023), which corresponds to the planting period, complies with the standards set by Brazilian legislation in Normative Instruction No. 28, dated September 18, 2012, for both day-neutral cultivars assessed. According to this legislation, the minimum diameter for strawberry seedlings is 5 mm. According to COCCO et al. (2011) Strawberry plants should have a diameter greater than 8mm during their production cycle to be considered vigorous. Thus, based on this information, both evaluated day-neutral cultivars exhibited desirable diameter values.

As for the number of crowns FRANCO et al. (2017) in a study conducted in the Laranjeiras do Sul region of Paraná, evaluating the day-neutral San Andreas cultivar transplanted in March, researchers found that in August and September, nearly all plants had more than four crowns, with crown production remaining relatively stable during these winter months. These findings differ from those obtained in this study, likely due to the planting season.

The crown of the strawberry has a conductive tissue, located on the periphery and spiraling in both directions and joining the leaf. Over time, the crown ages and can generate eight to ten new lateral crowns (BORTOLOZZO et al. 2007). Therefore, the average crown values in this experiment for day-neutral materials differ from what a strawberry plant can typically produce.

For the two evaluated day-neutral cultivars (ALPINA10 and CAV 56.9), an increase in leaf number, crown number, and plant diameter was observed over the evaluation months until the drastic pruning was performed in March 2023. However, for both cultivars evaluated, leaf production stabilized in January and February 2023. Leaf production only resumed increasing after severe pruning, which led to rapid growth of new foliage. There was also a decrease in the number of crowns after severe pruning, as excess crowns are removed during this process.

The production stabilization of leaves observed in this experiment may be related to the onset of a new reproductive phase, where a transformation occurs in the apical meristem, causing the plant to produce flower components in its buds instead of vegetative organs (ANTUNES et al. 2016). As a result, these factors stabilize, allowing the plant to expend energy on reproduction rather than vegetative growth.

Strawberry plants exhibit enhanced vegetative growth (leaves, diameter, and crowns in this experiment) under high temperature conditions (≥ 28 °C) (OTTO et al. 2009) and longer hours of light, which was provided under the conditions of this study for the neutral-day genotypes. It should be noted that this vegetative growth is beneficial, as it leads to more leaves on the crop, increasing the amount of assimilates produced and stored, thus enhancing photosynthetic production (RICHTER et al. 2019).

Strawberry plants with a higher number of crowns also indicate this vegetative vigor, which in this experiment, for the ALPINA10 material, may have been favored by environmental conditions. It is worth noting that the crown is the central component from which leaves, inflorescences, and new crowns develop, so factors that promote the formation of new crowns directly or indirectly benefit the formation of other organs (TORRES-QUEZADA et al. 2015). According to SAVINI et al. (2005), the number of crowns can be used as an indicator of plant yield, since each crown can be a potential zone for floral initiation.

For each evaluation month, the day-neutral cultivar ALPINA10 produced plants with higher chlorophyll content. An increase in chlorophyll content was observed in both neutral-day materials as the evaluation months progressed until November 2023. This month shows the highest chlorophyll levels for both cultivars. For both the ALPINA10 and CAV 56.9 cultivars, the evaluation months of December, January, and February resulted in the lowest measured chlorophyll levels.

PALENCIA et al (2016). observed chlorophyll values similar to those found in this study in an experiment with strawberry cultivation carried out in Spain and in an off-ground system. These authors obtained average chlorophyll indices of 39.52, results similar to those observed in the evaluation months of December, January, February, and March for the ALPINA10 cultivar and in December for the CAV 56.9 material.

The higher total chlorophyll content observed in the day-neutral cultivar, ALPINA10, may explain the greater vegetative growth achieved in plants of this variety. This is because the chlorophyll content in leaves reflects the amount of nitrogen absorbed by the plant (SANTOS & CASTILHO 2015), consequently being related to its growth as well as the productivity that the crop will exhibit (LEONARDO et al. 2013).

The decrease in total chlorophyll levels for ALPINA10 and CAV 56.9 cultivars during the peak vegetative growth period (December, January, and February 2023) may be associated with leaf characteristics. This is because plant leaves are adaptive, changing their structure and composition in response to their environment's light conditions, which can degrade chlorophyll and proteins within them. In high-light environments, plants activate protective mechanisms to reduce light absorption through two processes: photoinhibition and photooxidation (STREIT et al. 2005). Therefore, as light transmission increased during the evaluation periods of December, January, and February, a reduction in chlorophyll content was observed in this experiment.

It was observed that after severe pruning, both evaluated day-neutral cultivars regrew successfully. The ALPINA10 cultivar showed similar monthly performance after pruning compared to its performance before this practice. In other words, with more leaves, larger crowns, greater diameter, and higher chlorophyll content compared to CAV 56.9. A rapid vegetative regrowth following severe pruning was observed by BACKES et al. (2020). These authors, working with the day-neutral cultivar San Andreas in a soilless system, observed rapid plant growth after pruning.

For each evaluation month with a harvest, the plants with the highest fruit count and yield were obtained from the ALPINA10 cultivar (Table 3).

Table 3. Fruit per plant and yield per plant (g) of the day-neutral strawberry cultivars (ALPINA10 and CAV 56.9) evaluated during the nine months of the experiment.

Months	Number of fruits per plant		Production per plant (g)	
2022/2023	ALPINA10	CAV 56.9	ALPINA10	CAV 56.9
Aug	0.00 eA	0.00 eA	0.00 fA	0.00 fA
Set	0.00 eA	0.00 eA	0.00 fA	0.00 fA
Out	4.00 dA	3.00 cA	50.20 dA	40.10 dB
Nov	18.10 bA	15.20 bA	199.50 bA	159.00 bB
Dec	28.40 aA	21.40 aA	230.50 aA	200.10 aB
Jan	18.10 bA	13.10 bA	143.10 cA	123.10 cB
Feb	13.20 bA	11.10 bA	130.10 cA	115.45 cB
Apr	5.00 cA	3.00 dB	44.50 eA	40.00 dA
May	8.00 cA	5.00 cB	59.96 dA	30.10 eB
Total	82,80	83,30	788,9	776,86
CV (%)	18,30		24,28	

Averages followed by the same letters do not differ according to Tukey's test at a 5% probability level, lowercase letters in the column, uppercase letters in the row.

Regarding the number of fruits per plant, the values in this study are lower than those observed by GUIMARÃES et al. (2015), in a study carried out in the municipality of Datas/MG, using the neutral-day cultivar Aromas. These authors obtained an average of 42.31 fruits per plant, with the experimental period running from March to November. Thus, the lower fruit yield observed in this experiment for both day-neutral cultivars may be attributed to late planting. According to ANTUNES et al. (2006), for strawberry plants to flower and bear fruit, various physiological processes are necessary, involving chemical and physical changes in the buds through stimuli detected by the leaves, transforming the apex of the vegetative and reproductive stem system. This differentiation depends on genetic and environmental factors, with environmental factors such as day length and temperature being variables that affect the occurrence of flowering.

ROSA et al. (2013), analyzing different transplanting periods for the Araza cultivar (day-neutral) in the Santa Maria/RS region, obtained varying yields depending on the transplanting month. These authors found that the most productive plants were transplanted in April, yielding an average of 546.8 g per plant, while plants transplanted in June were the least productive, averaging 121.7 grams per plant. Thus, it is evident that the transplanting period affects production.

For both neutral-day materials evaluated, December was the month with the highest production. It should be noted that November and December 2022 had the highest temperatures, which theoretically hinders strawberry flowering and fruit formation. As a result, production occurred during warmer months of the year, which can be attributed to the characteristics of strawberry plants that typically reach peak production five months after transplanting (ANTUNES et al. 2016). For producers, peak production occurring during periods of greater production difficulty can be advantageous. Because marketing values are defined by supply and demand, so having fruit at a time of lower supply can lead to higher sales values (SILVA et al. 2017). However, production volume during this period may be low.

Regarding the total production during this experiment's nine-month cycle, the values are higher than those identified by BRANDT et al. In a 2022 study conducted on seven day-neutral genotypes transplanted during the recommended growing season. These authors observed total production values ranging from 162 to 298 grams per plant over a five-month cycle in the Alfenas-MG region. It's worth noting that the total yield of strawberry plants in an organic production system during one production cycle (10 months) ranges from about 700 grams to 1.0 kg per plant, depending on the cultivar (ANTUNES et al. 2016, ANTUNES et al. 2017, BERNARDI 2007).

In this experiment, it is believed that the greater vegetative growth of the day-neutral ALPINA10 material led to higher fruit production compared to CAV 56.9. However, delayed planting hurt overall production figures. According to RICHTER et al. (2017), when plants are affected by environmental conditions, they divert their photosynthetic products towards survival rather than fruit production, resulting in a reduction in the size and quantity of fruits produced by the plant.

For each evaluation month, the short-day cultivar CAV 107.12 exhibited plants with a higher number of leaves, diameter, and total chlorophyll (Table 4). The number of crowns was not significant, with values being equal for both genetic materials evaluated in August (2022), March, and April (2023).

Table 4. Number of leaves and crowns, plant diameter (mm), total chlorophyll (CCI), number of fruits per plant, and yield per plant (g) of short-day cultivars (CAV 107.7 and CAV 107.12) during the nine-month experimental evaluation period.

Months /Years	Number of leaves		Number of crowns		Plant diameter (mm)		Total chlorophyll (IFC)	
2022/ 2023	CAV 107.7	CAV 107.12	CAV 107.7	CAV 107.12	CAV 107.7	CAV 107.12	CAV 107.7	CAV 107.12
Aug	3.90 eA	4.10 fA	1*ns	1*ns	12.10 gB	14.50 fA	39.50 bB	41.20 bA
Set	10.44 dB	15.45 eA	2	2	18.62 eB	25.10 eA	45.56 abB	49.20 aA
Out	18.30 dB	20.80 dA	2	3	19.34 eB	28.10 eA	49.60 aA	50.23 aA
Nov	23.40 cB	29.10 dA	3	4	35.90 dB	45.24 cA	44.24 aB	53.20 aA
Dec	25.90 cB	31.10 cA	3	5	44.80 cA	39.33 dB	33.65 bB	38.20 cA
Jan	35.80 bB	58.10 aA	3	5	60.45 aB	70.00 aA	28.10 cB	32.10 cA
Mar	25.10 cB	39.20 bA	3	3	40.10 cB	50.20 cA	33.89 bB	38.31 cA
Apr	44.30 aB	55.67 aA	4	4	56.70 bB	65.70 bA	39.10 bA	39.00 cA
May	54.78aB	67.23aA	4	6	60.00 aB	70.00 aA	48.00aA	49.00aA
CV (%)	23,10		46,70		17,44		11,45	

Averages followed by the same letters do not differ according to Tukey's test at a 5% probability level, lowercase letters in the column, uppercase letters in the row. Note Drastic pruning carried out in February 2023.

Both genotypes CAV 107.7 and CAV 107.12 show increased vegetative growth (number of leaves, plant diameter, and total chlorophyll) over the evaluation months until January 2023. After severe pruning in February 2023, both short-day cultivars resumed vegetative growth with monthly increases. The cultivar CAV 107.12 continued to outperform CAV 107.7 during the evaluation months of March, April, and May 2023.

This study found that for both cultivars, during the evaluation months with shorter days (March, April, and May 2023), the number of leaves, plant diameter, and total chlorophyll showed greater monthly increases compared to the other months evaluated. According to ASSIS & CANESIN (2015), short-day strawberry plants thrive in cool temperatures (16-22°C) and shorter daylight hours. Thus, in this study, when environmental conditions led to shorter days and lower temperatures, they favored the growth of these materials. According to RAHMAN (2014), planting later than the recommended period for the crop results in fewer leaves and crowns, as climate conditions become less favorable for their growth and development.

The number of crowns was not significant at the 5% significance level, as also observed by TREVISAN et al. (2017) in a study conducted in Laranjeiras do Sul, Paraná, using substrate cultivation with slabs and the short-day cultivar Milsei-Tudla planted in April. In a study conducted by MENZEL & SMITH (2012) in Nambour, Australia, using the short-day cultivar Festival planted at different times (late March, mid-April, and late April), they observed crown numbers of 6.9, 4.1, and 3.3 per plant, respectively. These authors noted that the later the planting was carried out, the fewer crowns were produced, which differs from the results obtained in this study.

Analyzing whether crown diameter TORRES-QUEZADA et al. (2015), using the short-day cultivars Florida Radiance, WinterStar™ and Strawberry Festival, obtained plant diameter values of 21, 21, and 22 centimeters six weeks after transplanting, and 36, 36, and 39 cm eighteen weeks after transplanting, respectively. These results were similar to those shown by short-day plants in November and December in this experiment. According to these authors, crown diameter influences initial and total fruit yield, with a larger plant diameter being desirable for strawberry plants. This diameter includes the crowns, which, as stated by BECKER et al. (2019), are responsible for accumulating plant carbohydrate reserves, so the larger the diameter of these crowns, the greater the capacity to accumulate reserves and consequently the higher the plant's productive potential.

For chlorophyll values VIGNOLO et al. (2011) analyzing the short-day cultivars Camarosa and Camino Real transplanted at the appropriate time, which is in May, obtained chlorophyll indices of 44.3 and 47.6 respectively, average levels similar to those observed for the cultivar, CAV 107.12. Light is one of the most crucial factors for proper plant development, with its intensity, wavelength, and photoperiod being essential in regulating various processes in plant tissues. Light also affects processes such as plant growth, photosynthesis, and specifically for strawberry plants, their fruit production (BECKER et al. 2019).

Based on the chlorophyll data in this study, it appears that higher levels are observed during months with shorter days, while longer days correspond to a decrease in chlorophyll content. According to STREIT et al. (2005) plants adapt to their light environment, adjusting their photosynthetic system to use available light more efficiently. This adaptation influences the plant's growth.

After severe pruning, there was a reduction in plant diameter of approximately 66%. This reduction is caused by the removal of excess crowns and leaves, as well as the plants' consumption of reserves. After leaves are removed when pruning is carried out, in order for the plant to grow again, it needs to consume the carbohydrates that are in its reserve organs, which have been stored until then, but which will be used for its growth (BACKES et al. 2020). For chlorophyll levels, however, the opposite trend was observed, with an increase following severe pruning.

According to ROSA et al. (2014), plants suffer from inadequate radiation for their species, so lack or excess of light can be considered an abiotic stress factor. This affects the plant's efficiency in distributing photosynthetic products to all its organs and in adjusting its morphophysiological variables to acquire primary resources efficiently. Thus, it is believed that inadequate radiation for short-day materials may have influenced chlorophyll-related factors.

For the months when harvesting occurred, the short-day cultivar CAV 107.12 showed the highest number of fruits and yield per plant (Table 5).

The highest fruit yield per plant was recorded in November 2022 for both short-day cultivars under evaluation. It is believed that this may have been caused by an accumulation of plant reserves, since according to ANTUNES et al. According to breeding programs in 2020, strawberry genotypes that rapidly accumulate reserves are prioritized to achieve early production. It is important to note that the peak production of short-day strawberry plants planted at the right time is in September and October (ALMEIDA et al. 2009). The short-day strawberry plants in this experiment showed peak production later than expected for this type of material.

Table 5. Number of fruits per plant and yield per plant (g) of the short-day strawberry cultivars (CAV 107.7 and CAV 107.12) evaluated during the nine months of the experiment.

Months	Number of fruits per plant		Production per plant (g)	
2022/2023	CAV 107.7	CAV 107.12	CAV 107.7	CAV 107.12
Aug	0.00 eA	0.00 eA	0.00 gA	0.00 gA
Set	0.00 eA	0.00 eA	0.00 gA	0.00 gA
Out	2.00 dB	3.00 dA	20.34 fB	31.45 eA
Nov	13.20 aB	14.30 aA	70.34 dB	96.54 cA
Dec	9.00 bB	11.10 bA	98.20 bB	110.20baA
Jan	8.00 bB	12.20 bA	84.30 cB	109.10 bA
Mar	2.00 dB	3.00 dA	25.00 fB	29.00 fA
Apr	4.00 cB	5.00 cA	38.10 eB	51.90 dA
May	10.00 bB	12.00 bA	110.00 aB	130.12aA
Total	48,20	60,60	446,28	559,21
CV (%)	24,56		21,10	

Averages followed by the same letters do not differ according to Tukey's test at a 5% probability level, lowercase letters in the column, uppercase letters in the row.

Strawberry plants with higher fruit yields compared to those observed in this study, for short-day genotypes, were obtained by WURZ et al. (2021) in a study carried out on the northern plateau of Santa Catarina. These authors, using the short-day cultivars Jônica and Pircinque in a May planting in soil cultivation under high tunnels, observed values of 35.5 and 39.7 fruits per plant, respectively.

PEREIRA et al. (2013) also found that the strawberry planting season affects fruit production per plant in short-day cultivars. These authors, using the short-day cultivars Camarosa, Festival, and Oso Grande in Bom Repouso, Minas Gerais, found that plants transplanted in August produced fewer fruits, with yields of 4.44 fruits per plant for "Camarosa," 8.75 fruits for "Festival," and 16.24 fruits per plant for Oso Grande.

As for the production per plant during the cycle (nine months), the values obtained in this research were 446.28 grams for CAV 107.7 and 559.21 grams for CAV 107.12. These values are considered low, as a 150 m^2 greenhouse with 2000 plants would yield a total production of 49.58 kg for CAV 107.7 and 62.13 kg for CAV 107.12. According to ROSA et al. (2013) for short-day cultivars, early planting is generally beneficial for

Brazil's soil and climate conditions. According to these authors, delaying planting by about three months reduces yield per plant by over 200 grams.

The highest yield per plant for both cultivars was achieved before pruning in December 2022 (98.20g for CAV 107.7 and 110.20g for CAV 107.12) and after severe pruning in May 2023 (110.00g for CAV 107.7 and 130.12g for CAV 107.12). According to LIZ et al. (2020) the decrease in production for short-day cultivars is associated with rising temperatures and radiation incidence. Although peak production may vary depending on the genetic characteristics of each cultivar and the climate conditions of each year, it is greatly influenced by the planting date of the seedlings. Moreover, the longer the period under unfavorable conditions, the lower the average fruit weight at harvest, due to increased plant stress.

When observing neutral-day cultivars and short-day varieties in this late planting situation, it is evident that plants from neutral-day materials exhibited greater vegetative growth and fruit production compared to those from short-day varieties. However, short-day cultivars exhibited earlier phenological development. The growth of strawberry plants and fruit production are greatly influenced by micrometeorological factors and management practices. As a result, strawberry cultivars vary based on regional adaptation, meaning that a cultivar that thrives in one area may not perform as well in another location with different environmental conditions (UENO 2004).

CONCLUSION

Para as condições de plantio tardio a cultivar de dia neutro ALPINA 10 e de dia curto CAV 107.12 apresentaram maior crescimento vegetativo e produção. Entretanto, devido o período de plantio os valores para todas as cultivares pesquisadas são inferiores não sendo indicado o plantio tardio.

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